Chapter 1 Interdisciplinarity: reconfigurations of the Social and Natural Sciences

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The idea of discipline opens up a nexus of meaning. Disciplines discipline disciples.[1] A commitment to a discipline is a way of ensuring that certain disciplinary methods and concepts are used rigorously and that undisciplined and undisciplinary objects, methods and concepts are ruled out. By contrast, ideas of interdisciplinarity imply a variety of boundary transgressions, in which the disciplinary and disciplining rules, trainings and subjectivities given by existing knowledge corpuses are put aside. In this introduction we interrogate the current preoccupation with interdisciplinarity and transdisciplinarity, in particular the ascendance in recent years of a particular discourse on interdisciplinarity where it is associated with a more generalised transformation in the relations between science, technology and society. We are therefore less concerned with interdisciplinarity in general than with the contemporary formation of interdisciplinarity: how it has come to be seen as a solution to a series of current problems, in particular the relations between science and society, the development of accountability, and the need to foster innovation in the knowledge economy. The present situation, we will suggest, can be understood as a problematisation:[2] the question of whether a given knowledge practice is too disciplinary, or interdisciplinary, or not disciplinary enough has become an issue and an object of enquiry for governments, funding agencies and researchers.

An influential manifestation of this problematisation was the publication by Helga Nowotny, Peter Scott and Michael Gibbons of *Rethinking Science: Knowledge and the Public in an Age of Uncertainty* in 2001. The book took as its focus the evolving institutionalization of knowledge in the guise of science and research policy, research funding and evaluation, and the nature of the university. Nowotny and her collaborators suggested that the concern with interdisciplinarity is part of a shift from what they call Mode-1 science to Mode-2 knowledge production (Gibbons et al 1994, Nowotny et al 2001, Nowotny 2003, Strathern 2004b). The latter was said to include: 1) the growth of transdisciplinary research which, unlike interdisciplinary research, is not derived from pre-existing disciplines; 2) the development of novel forms of quality control which undermine disciplinary forms of evaluation; 3) the displacement of a 'culture of autonomy of science' by a 'culture of accountability'; 4) the growing importance of the 'context of application' as a site for research; and 5) a growing diversity of sites at which knowledge is produced. In a subsequent online forum on interdisciplinarity Nowotny reiterated these views: 'We introduced the idea of Mode-2 in order to bring in a new way of thinking about science, which is often described in strictly disciplinary terms. We identified some attributes of the new mode of knowledge production, which we think are empirically evident, and argued that, all together, they are integral or coherent enough to constitute something of a new form of production of knowledge' (Nowotny nd: 2).[3] Other commentators broadly concur with this account, and we return later to consider the significance of the distinction

between transdisciplinarity and interdisciplinarity. Leading figures in the Interdisciplinary Studies Project at Harvard University, for example, note that there is a 're-emerging awareness of interdisciplinarity as a pervasive form of knowledge production' (Mansilla and Gardner nd: 1); while a major report on 'facilitating interdisciplinary research' sponsored by the US National Academies[4] claims that 'as a mode of discovery and education, [interdisciplinary research] has delivered much already and promises more – sustainable environment, healthier and more prosperous lives, new discoveries and technologies to inspire young minds, and deeper understanding of our place in space and time' (National Academies 2005: 1).

This collection therefore responds to the emergence and prominence of the contemporary discourse on interdisciplinarity. It has its origins in a research programme, 'Interdisciplinarity and Society: A Critical Comparative Study', which, given the considerable claims, took its initial impetus from the paucity of empirical studies of how interdisciplinarity unfolds in practice. The programme encompassed ethnographic studies of interdisciplinary fields that cut across the boundaries between the natural sciences and engineering, on the one hand, and the social sciences, humanities and arts, on the other. It is these kinds of interdisciplinary research that are understood to have the greatest significance in the transition to a new mode of knowledge production, auguring closer relations between science and society (Strathern 2004a). The programme had two main empirical components. First, studies undertaken by Andrew Barry, Georgina Born and Gisa Weszkalnys of three salient and contrasting interdisciplinary fields identified by an internet-based mapping survey: environmental and climate change research (Weszkalnys and Barry, this volume); ethnography in the IT industry (this introduction);[5] and art-science (Born and Barry 2010, Born and Barry, this volume). We carried out ten case studies of interdisciplinary institutions and initiatives and the practices they supported, in different national settings, across the three fields[6] - institutions chosen because they were understood to be influential in or symptomatic of the respective fields (Born 2010a: 19-20).[7] The second component was an ethnographic study carried out by Elena Khlinovskaya Rockhill in dialogue with Marilyn Strathern of an institution, the Cambridge Genetics Knowledge Park, created to implement an experiment in collaboration between the biosciences and studies of the Ethical, Legal and Social Implications of research (or ELSI) (Strathern 2004c, 2006, 2011, Khlinovskaya Rockhill 2007, Strathern and Khlinovskaya Rockhill, this volume). A conference held at the completion of the programme brought together colleagues working on adjacent research questions, and led to initial publications by the editors of this volume (Barry, Born and Weszkalnys 2008, Born and Barry 2010).[8] After the conference we invited a number of participants as well as scholars who responded to our initial publications to contribute to this collection. The book thus emerges from iterative dialogues between a loose 'community of critics' (Strathern 2006) concerned in distinctive

ways with the problematisation of the disciplines. At the heart of our concerns is the question of the articulation between contemporary programmatic statements and practices of interdisciplinarity and the reconfiguration of the relations between the social and natural sciences.

Two inflections of the discourse on interdisciplinarity are particularly apparent. The first portrays interdisciplinarity as offering new techniques for accountability, or even as itself an index of knowledge practices that are accountable to society (Strathern 2004b, Doubleday 2007). The second lays emphasis on the capacity of interdisciplinarity to assist in forging closer relations between scientific research and the requirements of the economy through fostering innovation (Mirowski and Mirjam Sent 2002). In contrast, disciplinarity tends to be associated with a defence of academic autonomy. Assertions of a link between interdisciplinarity and accountable science responsive to user needs can be found in the US Gulbenkian Commission's report on the restructuring of the social sciences (Wallerstein 1996), and the 2000 report of the German Science Council (Wissenschaftsrat 2000). In the UK, an influential paper by HM Treasury argued that interdisciplinarity should lie at the heart of the government's research strategy: 'In order to maintain the UK's world-class university system, the [g]overnment is keen to ensure that excellent research of all types is rewarded, including user-focused and interdisciplinary research' (HM Treasury 2006). For the British Treasury, by releasing research from the restrictions of disciplinary boundaries (Weingart and Stehr 2000: 270), interdisciplinarity enables research to be more readily connected to the needs of industrial users and market demands (Nowotny 2005).

In interrogating the contemporary preoccupation with interdisciplinarity, it is important to avoid two temptations. The first temptation is to imagine that interdisciplinarity is historically novel - that in the past knowledge production has primarily taken place within autonomous and unified disciplines, and that it no longer does so (Galison and Stump 1996, *Social Epistemology* 1995, Weingart and Stehr 2000, Weingart 2010, Schaffer, this volume). Without doubt, knowledge production has always occurred in a variety of institutional sites and geographically dispersed assemblages, not only in the scientific laboratory or the apparently enclosed space of the humanist's study (Livingstone 2003, Osborne 2004). Moreover, the evolution of disciplines has often occurred in the form of what would now be identified as interdisciplinary phases. Even an apparently 'pure' discipline such as astronomy has been transformed historically through the development of practices and methods that might now be considered interdisciplinary (Schaffer 1996, 2007). In other cases what were once interdisciplines may themselves become progressively established as distinct disciplines (Fuller 2002, Jasanoff, this volume). If the appearance of what is now called interdisciplinarity is a historical constant, then, what is novel is the contemporary sense that greater interdisciplinarity is a necessary

response to intensifying demands that research should become more integrated than before with society and the economy.[9] Interdisciplinarity has come to be at once a governmental demand, a reflexive orientation within the academy, and an object of knowledge.[10]

Second, and relatedly, there is a temptation to read the contemporary concern with interdisciplinarity too politically in the conventional sense of the term: to view it entirely as an emanation from current governmental preoccupations with accountability, the knowledge economy or innovation, or as driven by commercial imperatives. Here, in other words, the temptation is to unify interdisciplinarity excessively. Others have rightly pointed to the force of these dynamics, as noted above (eg Mirowski and Mirjam Sent 2002, Nowotny 2005). Yet it is critical to recognize that these developments co-exist with, and may reinforce the importance of, a series other dynamics. One of the arguments that we will propose is that the current burgeoning of varieties of interdisciplinarity has not led straightforwardly to a reduction in the autonomy of research. As we shall argue, interdisciplinarity is equally associated with the development of fields, initiatives and sites in which new types of autonomy are created and defended against a reduction of research to the imperatives of accountability or innovation. Interdisciplinarity is certainly a key term in present efforts to transform the relations between research, economy and society, and the promotion of interdisciplinarity has come to be central to the government of research (cf Power 1996, Barry 2001). Yet despite this, we want to suggest that interdisciplinarity may on occasion generate knowledge practices and forms, and may have effects, that cannot be understood merely as instrumental or as a response to broader political demands, social or economic transformations. In short, autonomy can be associated as much with interdisciplinary as with disciplinary research.

In light of these temptations, the starting point of our research programme was a dissatisfaction with the teleological account of interdisciplinarity in much of the literature. Certainly, the notion that we are witnessing a progressive decline in the significance of disciplines as institutions of knowledge production has been highly influential. Indeed, during our research we found that the narrative of 'Mode-2' was not only echoed in assessments of research policy and practice (eg Becker 2003, Century 1999), but that it had become performative: folded into the research institutions and practices that we were studying, and even offered by some interviewees as a kind of 'local' framework of understanding (Weszkalnys and Barry, this volume). Rather than accept this framing, we strove to get a sense of the multiplicity of interdisciplinary forms and their diverse histories, to interrogate the unity of interdisciplinarity – fostered through a series of apparently interrelated or mimetic initiatives, analyses and claims[11] – but also to grasp its heterogeneity, evident not only in the proliferation of a variety of interdisciplinary fields, institutions, practices and experiments, but in the

specificity of their trajectories (Weszkalnys and Barry, this volume, Pickering, this volume, Greco, this volume, Born and Barry, this volume). Following Foucault's injunction, we do not take interdisciplinarity or transdisciplinarity to be a sign of 'culture in its totality' or an indicator of a generalized transformation in science and society, but a particular configuration of programmatic statements, interventions and practices (Foucault 1972: 159). Nor do we imagine that this configuration emanates from a specific source or series of authors (ibid.: 205), or that it could be analysed simply as a discourse of science policy that bears little relation to the conduct of research. Given this approach to the analysis of interdisciplinarity, we confronted a series of problems: how can we give any coherence to interdisciplinarity if it takes such specific forms, and what other unities might be revealed that are not immediately apparent? If the claim that there is a discontinuity in the mode of production of knowledge has been influential, what other 'differences, relations, gaps, shifts, independences, autonomies' might be occluded by such a claim (ibid.: 191)? Is it possible to map some of the diverse ways in which interdisciplinarity is invoked, promoted and contested, and the extent to which analyses of interdisciplinarity have been performative (cf MacKenzie et al 2007)? How might one understand interdisciplinarity less as a unity and more as a field of differences, a multiplicity?

Critics have rightly argued that dominant accounts of interdisciplinarity have often understood its value in largely instrumental terms, terms that may inhibit rather than foster novelty. In these circumstances, rather than interdisciplinarity, what may be required is a certain degree of antidisciplinarity (Pickering 1995)[12] or indiscipline (Rancière 2006, cf. Guattari 1992, Althusser 1990). At the same time, others maintain that it is the disciplines that continue to sustain intellectual change through their capacity both to foster productive forms of internal disagreement and dissent (Strathern 2006) and to generate new ways of interrogating an exteriority (Osborne, this volume). We do not disagree with these arguments. Our pronounced skepticism about the value of interdisciplinarity 'in general' is matched only by incredulity towards any claim for the infallible intellectual and creative vitality of the established disciplines. Nonetheless, in what follows we argue that interdisciplinary research has the potential to be inventive. By this we mean two things. First, the notion of invention points to the openness of the contemporary historical situation. An invention can be understood as the introduction of a form of novelty within a specific domain, one that cannot be explained away as the consequence of pre-existing factors or forces, and that serves to protend or open up the space of future possibilities (Barry 2001, 2005a, Born 2005b, 2010b, Connolly 2011). As we shall suggest, while the call for greater interdisciplinarity today is often understood in terms of the needs of society or stakeholders or the demands of the economy, interdisciplinary research can lead to forms of novelty that cannot be assumed to follow from

governmental demands nor from any given historical tendency. Novelty, of course, can also be anti-inventive in so far as it closes down rather than opens up the space of possibilities. Indeed we have argued elsewhere that it is possible to identify 'defensive innovation' when anti-invention, or the creation of stasis and avoidance of significant change, becomes a deliberate or indirect aim of cultural, artistic, technological, industrial or political strategy (Barry 2001: 212, Born 1995: 325-7). Our second argument is that in order for inventiveness not only to open up possibilities but to bring about an event, it is necessary for it to be recognised and taken up by others (Feltham and Clemens 2003: 27, Stengers 1997, Tarde 2001). Invention should not be understood as a moment in time, but as a process. But while the anticipation or protention of the future by those engaged in invention may lead to the recognition, reception and development of this inventiveness by others, this is not inevitable; invention is a fragile and contested quality and some inventive works fail to be recognized (Born 2005b: 20-4). In referring to the question of invention, then, we highlight a critical issue in relation to the chapters that follow. Rather than describe the formation of a new mode of production of knowledge, our interest is in heightening awareness of what is potentially inventive, or anti-inventive, in the emergence of interdisciplinarity in particular eras and fields.

The chapters in this volume do not provide a unified account of interdisciplinarity, nor do their authors necessarily agree with the analyses advanced in this introduction. However, despite the differences between them, all of the authors gathered together in this collection insist on the need to attend to the specificity and the history of the disciplines and interdisciplines that they interrogate, rather than assume that there has been a generalised movement from a disciplinary to an interdisciplinary or transdisciplinary mode of knowledge production. The volume develops a sustained portrait of interdisciplinarity as a problematisation, but one that must be traced through a series of strikingly diverse vectors across an array of practices, institutions and events – vectors that are local and specific to the fields at issue. In this way the volume issues a profound challenge to earlier accounts of interdisciplinarity and propels research in new directions.

In the remainder of this introduction we probe the limits of the existing literature on interdisciplinarity with reference both to our own research and that of our contributors. In the next section we address the status of disciplinarity, multidisciplinarity, interdisciplinarity and transdisciplinarity. In the second section we examine the different types of interrelations between disciplines that are embodied in interdisciplinary assemblages. We question the idea that interdisciplinary research should be understood simply in terms of the synthesis between two or more disciplines and distinguish between three modes of interdisciplinarity. In the third section we describe and interrogate three different logics that are manifest in contemporary interdisciplinarity,

drawing a distinction between what we term the logics of accountability, innovation and ontology. An overview of each of the chapters follows; and in this and the concluding part of the introduction we bring out some core themes running through the analyses presented in them, including the nature of the ecologies that support or inhibit interdisciplinarity, the importance of pedagogy and of the formation of interdisciplinary subjects, how certain interdisciplinary assemblages can be associated with the logic of ontology and thus with the generation of novel objects, subjects and relations of research, and the enduring challenges posed by the evaluation of interdisciplinary work.

Disciplinarity – interdisciplinarity - transdisciplinarity

Much of the heat generated by debates about interdisciplinarity stems from the existence of polarised judgements about the creative or repressive status of disciplinary knowledge. On one side are those for whom disciplines are generative and enabling, the repositories of a responsible kind of epistemological reflexivity. Marilyn Strathern gives voice to such a perspective when she writes that 'the value of a discipline is precisely in its ability to account for its conditions of existence and thus… how it arrives at its knowledge practices' (2004a: 5). On the other side are those who see disciplines as 'inherently conventional', 'artificial "holding patterns" of inquiry' sustained by historical casts of mind 'that cannot imagine any alternatives to the current [disciplinary] regime'. In this view the significance of interdisciplinary research lies in the contrast with what are taken to be the more restrictive structures of disciplinary knowledge. Only interdisciplinarity holds out the promise of 'sustained epistemic change' (Fuller 1993 nd: 1-4).

In thinking about the relations between disciplinarity and interdisciplinarity, however, it would be a mistake to contrast the homogeneity and closure of disciplines with the heterogeneity and openness of interdisciplinarity. On the one hand, interdisciplinary research can involve closure, limiting as well as transforming the possibilities for new forms, methods and sites of research (Weingart and Stehr 2000). On the other hand, disciplines themselves are often remarkably heterogeneous or internally divided (Galison 1996a, 1996b, Bensaude-Vincent and Stengers 1996, Clifford 2005). Consider, for example, the differences between theoretical and experimental high-energy physics (Knorr-Cetina 1999), between computational and laboratory medicinal chemistry (Barry 2005), or between neoclassical, Keynesian and Marxian economics (Amariglio et al 1993). Even more radical internal differences exist between social and biological anthropology (Ingold 2001, Segal and Yanagisako 2005, Eriksen 2007, Harkin 2010) and between the sub-disciplines of geography (Harrison et al 2004, Castree 2005, Bracken and Oughton 2009). Indeed, disciplines are routinely characterised by internal differences; the existence of a discipline does not always imply that there is acceptance of an

agreed set of problems, objects, practices, theories or methods, nor even a shared language or common institutional forms. Yet this heterogeneity is not necessarily a source of instability. In Peter Galison's words, 'the disunified, heterogeneous assemblage of the subcultures of science is precisely what structures its strength and coherence' (Galison 1996a: 13). Disciplines exhibit clear inertial tendencies, and differences within them may exist over long periods of time.[13] They may develop ways of translating across or negotiating not only internal boundaries, but the boundaries between the diverse social worlds involved in any scientific work (Star and Griesemer 1989); or chronic internal intellectual divisions may persist unaddressed through pragmatic working arrangements, and may even be collectively denied. Disciplines should not therefore be regarded as homogeneous, but as multiplicities or heterogeneous unities marked by differences that are themselves enacted in numerous ways (cf Laclau and Mouffe 1985: 96). The existence of disciplines tends to revolve around a historically evolving and heterogeneous nexus of problems, methods, canonical texts, theories and institutions that it is thought to be worth both contesting and defending. The boundaries of disciplines and the forms in which they should exist, then, are in question and in play. Disciplinary boundaries and are neither entirely fixed nor fluid; rather, they are relational and in formation.[14] These dynamics are captured by Stefan Collini in a powerful metaphor when discussing the emergence of cultural studies from its disciplinary progenitors: 'Cultural studies is part of the noise made by the great academic ice-floes of Literature, Sociology and Anthropology…, as their mass shifts and breaks apart' (Collini 1994: 3).

Further conceptual ground-clearing is necessary in the face of efforts to define three types of cross-disciplinary practice: interdisciplinarity, multidisciplinarity and transdisciplinarity. Commonly, a distinction is made between multidisciplinarity – in which several disciplines cooperate but continue to work with standard disciplinary framings – and interdisciplinarity – in which there is an attempt to integrate or synthesise perspectives from several disciplines.[15] The case for multidisciplinarity is made by Ian Hacking when he argues for 'collaborating disciplines that need not be interdisciplinary' and that presume a strong disciplinary base in the study of complex objects (Hacking nd).

Less clear distinctions are made between interdisciplinarity and transdisciplinarity, and in practice their meanings are often conflated;[16] perhaps the clearest is the assumption that the latter term bears stronger and more radical implications. Yet the terms are also rooted in particular national and transnational traditions. In the Anglo-American academy, the concept of interdisciplinarity has been dominant and has been widely adopted by researchers and funding organizations alike. In this context, interdisciplinarity is often closely linked not only to notions of accountability and innovation, but also to ideas of problem-solving; indeed, the demands of problem-solving are taken

to provide 'axiomatic evidence of the need for multiple perspectives and collaborative work' (Strathern 2004c: 80, 2011).

The idea of transdisciplinarity, in contrast, has wider currency in the French and German speaking worlds. It is said to have been coined at an OECD meeting in Nice in 1970 and was articulated in a subsequent volume, *Interdisciplinarity: Problems of Teaching and Research in Universities* (1972), edited by the Belgian philosopher Leo Apostel. Apostel himself developed a radical proposal that the 'socialist manager of a non-bureaucratic society constantly breaking up monopolies' should 'rotate' persons between production and research, in this way attempting 'to realise a strongly interdisciplinary science' (Apostel 1972: 145). In the same volume, the idea of transdisciplinarity was explicitly linked to the putatively transdisciplinary status of structuralism and systems theory, as well as to what was imagined to be the transdisciplinary practice of 'mathematic' (sic). The term transdisciplinarity itself was introduced by three authors. The systems theorist Erich Jantsch articulated it as a yet-to-be-realized ideal associated with his vision of a cybernetic university (Jantsch 1972). André Lichnerowicz, a Professor of Mathematics at the Collège de France, proposed that transdisciplinarity should be based on the kinds of structuralist analyses already established in mathematics, which, he argued, were also developing in the human sciences, indicating that the social sciences were beginning to realize 'the way in which science is built up' (Lichnerowicz 1972: 125). The developmental psychologist Jean Piaget, for his part, looked forward to the emergence of a type of transdisciplinarity that would allow specialized research projects to be 'placed within a total system without any firm boundaries between disciplines' (Piaget 1972: 138).[17] As an alternative to the formalism of the continental thinkers, the historian Asa Briggs, the only British contributor to the volume, outlined the liberal curriculum of the recently founded University of Sussex (Briggs and Michaud 1972), which drew some inspiration from the model of education offered to Oxford undergraduates in Greats and Philosophy, Politics and Economics. Indeed, according to another Sussex academic, the University's institutionalized interdisciplinarity had the merit of adapting 'the tutorial system, as developed in Oxford and Cambridge, to the conditions of the modern university' (Corbett 1964: 27).

It is therefore in the French and German speaking worlds that the idea of transdisciplinarity has been most prevalent in recent decades (eg Morin 1997, Nowotny 2003, Hirsch Hadorn et al 2008, Osborne 2011). In comparison with interdisciplinarity, transdisciplinarity is taken to involve a transgression against or transcendence of disciplinary norms; in some influential writings, as we have seen, it is linked to wider directions in twentieth-century thought including structuralism, systems theory and quantum mechanics (Nicolescu 2008, Schmidt 2010). Against this background, Nowotny

et al's bold thesis linking transdisciplinarity to Mode-2 knowledge production went further than earlier formulations by endowing the concept with greater sociological and historical significance than hitherto. In their summarizing words, '[i]ts reflexivity, eclecticism and contextualization mean that Mode-2 knowledge is inherently transgressive…. [It] transcends disciplinary boundaries. It reaches beyond interdisciplinarity to transdisciplinarity' (Nowotny et al 2001: 89). Following Nowotny et al, recent discussions of transdisciplinarity have tended to place less emphasis on the importance of systemic theories, stressing instead the need to reduce the distance between specialized and lay knowledges in problem-solving (Lawrence and Despres 2004: 398-400, Klein 2004). Whatever the strengths of the concept of transdisciplinarity, in view of the continuing disputes both over its provenance and over its kinship with or difference from interdisciplinarity, in this introduction we attempt neither to define nor to arbitrate between the two terms. Instead, we take 'interdisciplinarity' to be a generic expression, while recognizing that interdisciplinarity and transdisciplinarity are indigenous concepts with variable significance in particular circumstances.

Yet despite the varied meanings attributed to them, many accounts of interdisciplinarity and transdisciplinarity are united by the conviction that they proffer a privileged means for the solution of complex 'real-world problems' (Krohn 2010: 31-32) that are taken as given (Klein 2004: 523, Klein 2010: 26, National Academy of Sciences 2004; Baerwald 2010: 495). Rather than taking this conviction as self-evident, it is productive to distinguish between two ways of conceptualizing problems (Maniglier 2012). One is to view problems negatively as obstacles that need to be overcome or as issues that need to be managed or that require a solution. This is the customary stance adopted by many writers on interdisciplinarity. Against this, we want to pose a positive conception of problems, one that directs us to the way that the problematisation of certain situations may demand and generate novel responses (Foucault 1994: 118, Maniglier 2007, Laurent 2011, Barry 2012).[18] As we shall see, one of the issues raised in contemporary debates is whether the promotion of interdisciplinarity is better understood as a response to given problems or as a means of generating questions around which new forms of thought and experimental practice can coalesce.

Modes of interdisciplinarity

It should be obvious that interdisciplinarity should not be thought of as an historical given, but as mobilizing in any instance an array of programmatic statements, policy interventions, institutional forms, theoretical statements, instruments, materials and research practices – interdisciplinary assemblages that have acquired a remarkable and growing salience. Such assemblages enact a variety of interrelations between disciplines. Yet for all this apparent diversity, we propose in this section

that it is possible to identify three modes of interdisciplinarity, by which we mean three ideal-typical arrangements of the interrelations between disciplines.

In broad terms, recent policy interventions and theoretical literatures on interdisciplinarity have tended to assume an integrative or synthesis model of interdisciplinarity, in which a given interdisciplinary practice proceeds through the integration of two or more 'antecedent disciplines' in relatively symmetrical form (Tait and Lyall 2001, Ramadier 2004, Mansilla 2006, Nowotny nd). A prominent study of interdisciplinarity articulates this position clearly:

> In this integrative approach it is proposed that interdisciplinary work should be judged according to the criteria of the 'antecedent disciplines' and the value will be assessed in terms of these additive criteria. Our goal was to understand qualities of expert interdisciplinary work in order to inform educational practice that fosters interdisciplinary understanding. In this study we defined 'interdisciplinary work' as work that integrates knowledge and modes of thinking from two or more disciplines. Such work embraces the goal of advancing understanding (eg explain phenomena, craft solutions, raise new questions) in ways that would have not been possible through single disciplinary means. (Gardner and Mansilla, nd: 1)[19]

This model, and the view that interdisciplinary research should lead to the integration of different disciplinary approaches, has been performative. In climate change research, for example, there is a prevalent view that social scientists should provide an account of social factors ('society', 'the economy') that impact on climate change, and that in turn are impacted by climate change (Jasanoff and Wynne 1998: 3). In principle, it is thought that natural scientific and social scientific accounts of impacts should be integrated into a more general model of climate change. The creation of mathematical models provides one set of ways in which such a synthesis or integration can be achieved. Yet it is also notable that far from leading to the formation of novel heterogeneous fields, the development of increasingly 'universal' models can lead to new forms of closure effected through synthesis (Bowker 1993).

In our view, however, interdisciplinary practice should not necessarily be understood additively as the sum of two or more 'disciplinary' components or as achieved through a synthesis of different disciplinary approaches, whether through a process of integration or negotiation (Petts et al 2008). If we take the *integrative-synthesis* mode as a first type, we want to propose two additional ideal-typical modes of interdisciplinary practice, both of which figure prominently in our research and which may co-exist in some fields. In the second, *subordination-service* mode, interdisciplinarity takes a form in

which one or more disciplines occupy a subordinate or service role in relation to other component disciplines. This points to the hierarchical division of labour that characterizes many forms of interdisciplinarity (and that may indeed be the nature of the articulation in putatively 'integrative' interdisciplinarity). In this mode the service discipline(s) is typically conceived as making up for, or filling in for, an absence or lack in the other, (master) discipline(s). In some cases the social sciences are understood precisely in such terms. They appear to make it possible for the natural sciences and engineering to engage with 'social factors' that had hitherto been excluded from analysis or consideration (Marcus 2002). Social scientists are expected to 'adopt the "correct" natural science definition of an environmental problem "and devise relevant solution strategies"' (Leroy 1995, quoted in Owens 2000: 1143, n. 3); or they may be called upon to assess and help to correct a lack of public understanding of science (Irwin and Wynne 1996). In a nuanced analysis of his role as a social scientist working in an interdisciplinary nanotechnology research centre, Robert Doubleday suggests that in these circumstances "'social science" runs the risk of taking on the role of protecting an inner experimental core from wider complexities of the public meanings of nanotechnology research' (Doubleday 2007: 173). In effect, the social scientist can come to represent 'society' in the laboratory, leaving the conduct of natural scientific research both largely unaffected by the presence of the social scientist and remote from any wider social engagement. While in the field of art-science, particularly in the UK, funding has often been predicated on the notion that the arts are expected to provide a service to science, rendering it more popular or accessible to the lay public, or enhancing and publicising aesthetic aspects of scientific materials or imagery that might not otherwise be appreciated or known. Ironically, our research suggests that in the microsocial space of interdisciplinary practice, the hierarchy entailed in the subordination-service mode can be inverted. In art-science, for example, scientists sometimes adopt a service role for their artist collaborators, providing resources and equipment that are used to further a project conceived largely in artistic terms (cf. Born 1995).

In the third, *agonistic-antagonistic* mode, in contrast, interdisciplinarity takes the form neither of a synthesis nor of a disciplinary division of labour; rather, it is driven by an agonistic or antagonistic relation to existing or prior forms of disciplinary knowledge and practice. Here, interdisciplinarity springs from a self-conscious dialogue with, criticism of or opposition to the limits of established disciplines, or the status of academic research or instrumental knowledge production in general. This does not mean that what is produced can be reduced to these antagonisms, nor that it is necessarily 'oppositional' or 'critical'. By pointing to the *agonistic-antagonistic* mode we highlight how this kind of interdisciplinarity commonly stems from a commitment or desire to contest or transcend the given epistemological and/or ontological assumptions of specific historical disciplines, a move that makes

the new interdiscipline irreducible to its 'antecedent disciplines'.[20] This indicates in turn how such a move can only be grasped diachronically by tracing a genealogy of the relevant field, one that is attentive to the particular problematisation entailed, which may generate interdisciplinarity. We might note, for example, how certain advocates of ethnography in the IT industry, faced with the instrumental expectations of the corporation, challenge the view that ethnography should have any direct utility for engineers or designers. Indeed, as we will argue, some industry ethnographers seek explicitly to constitute ethnography as a field that may, to a greater or lesser extent, be antagonistic both to existing sociological approaches to the study of technology[21] and to narrowly scientific and technical understandings of the properties and uses of technical objects and devices (Suchman 1987, Suchman this volume, Dourish 2001).

An intriguing aspect of our research was ethnographic engagement with informants who themselves had cogent analyses of interdisciplinary practice.[22] One such account was articulated by a key art-science figure: Simon Penny, an artist-engineer and the founding director of the Arts, Computation and Engineering Masters program at the University of California at Irvine (n. 6). Simon distinguished between three kinds of interdisciplinary practice corresponding broadly to our three modes. The first is akin to the integrative-synthesis mode; for Simon it is the least interesting form and one that tends to be officially licenced since it is the least troubling. This is when 'interdisciplinarity [occurs] between separate disciplines which at root have exactly the same commitments; so, for instance, to establish an interdisciplinary project between electrical engineering and material science doesn't really challenge the basic assumptions of the practitioners. The commitments to the nature of knowledge are much the same'. His second form, corresponding to our subordination-service mode, is when 'practitioners who are firmly rooted in one discipline, and have a strong internal sense of [its] authority – who feel that they hold the master discourse, as it were - go on looting expeditions to grab some subject matter or [methodology] from some outlying discipline and drag it back to mine or exploit or reprocess it'. Simon contrasted these types with a third form, analogous to our agonistic-antagonistic mode, on which he founded the ACE program. This is when, 'coming in as an outsider to a discipline, with a different set of values, the fundamental assumptions by which that discipline is structured are revealed – assumptions that remain largely invisible to insiders…. This kind of interdisciplinarity can be fruitful… in enabling a context for the mutual critique of the fundamental assumptions of the different disciplines, and indeed of how the disciplines are in fact identified as disciplines…. [At stake is a readiness] to accept that one's commitments in one's own discipline may be revealed to be faulty or unreliable'. Simon continued by drawing out the personal implications: 'I'm in an odd position professionally in having been hired half in the Electrical Engineering Department and half in the Studio Art Department. I don't really

identify with the practices of either, and nor do they recognise me as one of them'.[23] In Simon's eyes, the ACE program's commitment to an agonistic-antagonistic interdisciplinarity was a test-bed for a pedagogy that cut against the grain of the disciplinary values and procedures of the university. The ACE program returns as a focus of Chapter 11.

We have suggested that interdisciplinarity enacts an array of interrelations between disciplines, with distinctive effects – a diversity that the discourse of Mode-2, with its focus on an epochal shift in the forms of knowledge production, tends to overlook. If the integrative-synthesis mode can augur epistemic transformations, and if the service-subordination mode, with its disciplinary division of labour, is unlikely to afford even this, then what is striking about the agonistic-antagonistic mode is that it can be associated with more radical shifts in knowledge practices, shifts that may be epistemic and/or ontological. Indeed in what follows, with reference to the interdisciplinary fields that we studied and certain chapters in this volume, we propose that a privileged relation can be discerned between the agonistic-antagonistic mode and what we will call the logic of ontology. To demonstrate this it is necessary to employ the framework outlined earlier and specifically to do two things: first, through an account of the genealogies of each field, to indicate how the agonistic-antagonistic mode can only be understood diachronically in terms of a dynamic imperative to supersede prior epistemological and/or ontological commitments; and second, to convey how this dynamic cannot be grasped by attributing a spurious unity. Instead, each interdisciplinary field must be analysed as precisely in formation and 'in play' – as a heterogeneous unity or multiplicity.

Logics of interdisciplinarity

If the identification of modes of interdisciplinarity highlights the diverse ways in which the interrelations between disciplines can be configured, it tells us little about why interdisciplinarity is thought to be necessary, nor about the transformations in research practice that it aims to bring about. In what follows we address these issues by pointing to three distinctive logics guiding the present burgeoning of interdisciplinarity. We call these the logics of accountability, of innovation, and of ontology. In distinguishing between them, we wish to make three initial points. First, we do not imply that the list is exhaustive. It might well be possible to multiply the number of logics governing the development of interdisciplinarity and to make further differentiations within them. Nor do we imply that interdisciplinary research has always been guided by them. Rather, we point to the three logics in order to emphasize the distinctive nature of the rationales and techniques governing the contemporary development of interdisciplinarity which, as mentioned, are sometimes

elided in earlier discussions. We want to retain here a sense of the multiplicity of logics, but also to make visible differences that matter for our analysis.

Secondly, when writing of logics, we do not think of them merely as states of mind or ideas. What we have called the logic of accountability has been fostered and developed through an array of technologies and devices which take specific material and immaterial forms - including voluntary agreements, websites, legislation, public inquiries, public consultations and voting procedures (Barry 2002, 2006, Latour and Weibel 2005). We therefore understand the logic of accountability through its relation to a range of practices and technologies of government oriented towards the conduct of research. Similarly, the logic of innovation depends on the activity of researchers, designers, engineers, marketers, accountants, economists and journalists in their practical engagement with a series of material and informational objects. Through this activity, certain investments in new practices and technologies become possible, desirable and visible (Power 1996, Callon et al 2007). The logics that we discern, then, are imagined, empractised and worlded: they come to exist in material, informational and social forms, and they may have inventive and anti-inventive consequences (Barry 2007).

Thirdly, the logics of interdisciplinarity that we describe here can be interdependent; they may also be confused. It is notable, for instance, that concepts of 'users', 'user needs' and 'user engagement' have migrated and may now be taken to index not only accountability to publics, but the involvement of stakeholders or a responsiveness to consumers or to industry. Our aim in identifying the three logics, then, is to indicate how they are imbricated in the interdisciplinary fields that we studied. If accountability and innovation are often linked to the contemporary discourse on interdisciplinarity, in what follows our primary focus is their heterogeneous practico-material and discursive expression in these fields, and on how they can be entangled with a logic of ontology.

According to a number of authors and policy initiatives, interdisciplinary research can be governed by a logic of accountability (Nowotny et al 2001, Strathern 2004). In this view, as already noted, interdisciplinarity is understood to foster a culture of accountability, breaking down the barriers between science and society, leading to greater interaction, for instance, between scientists and various publics. In Nowotny's terms, 'science can no longer assume that support for its activities are self-evident…. The culture of autonomy of science has shifted to a culture of accountability which can take many different forms' (Nowotny 2003: 211-2). In our research this logic appeared in several guises. It could be a matter of defending or legitimising the sciences by providing them with a protective layer of social scientific expertise or public 'engagement' – in this way deflecting

potentially more disruptive criticisms, or meeting legislative requirements or guidelines for public consultation.[24] In some cases, as we have seen, it appeared as though the minimal performance of interdisciplinarity through the employment of social scientists in a natural scientific laboratory could be taken as an indicator of accountability (Doubleday 2007, Strathern 2007). An analogous situation pertained in the British art-science field, which emerged in the 1990s in response to a series of funding schemes including the Wellcome Trust's Sciart programme and Arts Council England/AHRB's Art-Science Fellowships.[25] Prominent in the rationale for such funding was the 'public understanding of science' paradigm: that art can be used to popularize or communicate science and its social, cultural and ethical dimensions, whether through aesthetic elaboration or by rendering scientific discovery exciting or palatable by expressive means. Here, artists' collaboration with scientists was expected to effect a wider social engagement, on occasion providing an aesthetic legitimation (Born and Barry, this volume).

But it would be wrong to contend that the social sciences or arts invariably function as instruments of legitimation, defending against the possibility of public criticism, or enabling legislative guidelines to be met. There is evidence that critical social movements, in alliance with social scientists, can play an active role in directing or conducting scientific research (Irwin 1995, Epstein 1996, Rabeharisoa and Callon 1999, Callon et al 2001). Moreover, social scientists have developed potentially inventive ways of engaging publics in scientific debate through practices such as deliberative mapping and participatory integrated assessment (Davies 2006, Weszkalnys and Barry, this volume). These interventions can be justified both on the basis that they encourage publics and governments to 'buy into' the results of the research, and on the grounds that they can make scientific institutions more responsive to the demands and concerns of non-scientists.

In our study of environmental research, the German Öko-Institut can be seen as representing a radical vision of 'accountability' through its inversion of the standard hierarchy of relations between the natural sciences and social sciences or political activism. When it was founded in 1977, the Öko-Institut was understood by environmental activists and civic action groups in southwestern Germany to be serving their movements through the production of scientific research - what they termed a counter-science (*Gegen-Wissenschaft*) - that would endow their protests with strong foundations. We see a similar inversion in some areas of art-science. On the one hand, the idea of public understanding of science represents the hierarchical arrangement in which art serves to render science communicable, comprehensible or non-alienating. On the other hand, in an alternative lineage of art-science, such instrumental orientations are resisted: instead, the field is contaminated by a series of troubling genealogies, notably certain conceptual art and art and

technology movements, which animate practices and events that are incommensurable with disciplinary art or science. In this way art-science is caught up in a nexus of imperatives stemming from conceptual art's refusal of notions of autonomous art and its foregrounding of art's social embeddedness, including public art as social research, art that probes mediation and publicity, and art that engages with the politics of science and technology (Osborne 2002, Corris 2004, 2005, Buchman 2005, Da Costa and Philip 2008). A multiplicity of accountabilities are therefore manifest in interdisciplinary assemblages, from legitimation and regulation to critical and radically militant forms.

Yet while accountability has been central to a variety of initiatives involving social scientists and artists in the environmental, techno- and biosciences, this is not the exclusive logic governing such interdisciplinary engagements. Arguments for the involvement of social scientists and sometimes artists in natural science and engineering research have been guided also by a logic of innovation.

In our research, the logic of innovation was most pronounced in the growth of ethnographic research in the IT industry, where ethnography has been widely promoted as a solution to the problem of connecting businesses to the 'unarticulated desires' of their customers, desires that are not sufficiently identified or evoked by more conventional methods of market research and that it is believed can drive innovation (Thrift 2006, Barry and Thrift 2007). We might say that ethnography in the IT industry offers a set of techniques through which businesses are expected to be able to transform their knowledge of and engagement with those micro-spaces of social life, replete with social and cultural difference, to which they previously did not have access (Thrift 2005, 2006: 283).[26] To this end, ethnographers in industry may collaborate closely with designers and engineers in small teams, forging relations with different communities of practice within the firm (Amin and Cohendet 2004). They may attempt to fine-tune the design of products by offering analyses of how they are likely to be of value to users; the interdisciplinary teams may also develop prototypes, as this ethnographer describes:

> Some people did actually do designs, prototypes, that ended up being transferred into the product divisions - but that's very hard to do. We tried to do it with the end-user programming stuff. We had a prototype that my group worked on, and we thought it was good, but we couldn't convince the product divisions that they wanted to put their money into it. The idea with research groups is that you find a bunch of smart people, and maybe 10 to 15 per cent of the designs they come up with are going to end up in the product divisions – and that's true at any company.[27]

Ethnography can therefore have implications that depart from any immediate utility for the corporation, providing, for example, portraits of diverse contexts of consumption that feed into thinking about long-term strategies such as openings in and demands from emerging markets (Thrift 2005). Moreover, in directing corporations to consider the ways and contexts in which technology is used, ethnography can be employed to challenge narrowly technology-driven investment strategies (Miller and O'Leary 2007). According to a leading IT corporate innovation strategist,

> Success exists at the intersection… of three domains [user value, business value, technology] and reaching the center is inherently a mixed-discipline process. It requires that the technologist or engineer be able to constructively interact with these other, non-technical disciplines [ethnography and market analysis]. That typically requires having a good understanding of why other domains matter, what vocabulary they use, and how their work relates to the engineer's work. (D'Hooge 2005: 4)

In an era in which businesses have increasingly mediated relations with their customers, there is an escalating demand for ethnography to proffer what may appear to be direct and naturalistic connections to those intimate and exotic spaces, relations, practices, bodies and affects that are perceived to be missing or to have been lost – or at least to stage that connection, or provide a proxy for it (Suchman 2000, this volume). In this way, by elucidating the 'real value' of technological products for users, ethnography is expected to access some of those 'external excesses' that are vital to capitalism and the condition of its success (Mitchell 2002: 303).

Likewise, the problem-focused orientation of interdisciplinary environmental and energy research can also entail the logic of innovation. For example, social scientists may be drawn into dialogue with natural scientists and engineers involved in the development of increasingly efficient, affordable and environmentally sustainable technologies such as renewables, carbon capture and storage, and smart grids.[28] This orientation towards innovation may, of necessity, engender a pragmatic approach to the challenge of fostering interdisciplinary research. As an interdisciplinary team manager put it: 'I don't think we sat down and worked out a model of interdisciplinarity. We learned as we went along, and consequently, if you talk to people in different parts of the team, they have different experiences of how interdisciplinarity has evolved'.[29] At the same time, the logic of innovation is likely to be entangled with the logic of accountability in so far as research funding bodies are now convinced that if new energy and environmental technologies are to be successfully introduced, they need to be acceptable to interested publics.

Ontologies and entanglement

The examples of interdisciplinary environmental research and ethnography in the IT industry might appear to support the contention that interdisciplinarity arises primarily in response to wider social and economic demands. But what is striking across a range of interdisciplinary fields today is how they are understood to be governed not only by a logic of accountability or of innovation, but by what we are identifying as an ontological logic.[30] As we emphasised earlier, we should not understand this logic simply as a set of ideas about what the world is, but rather as encompassing a diverse range of rationales, techniques, practices and interventions. It is manifest in an array of efforts to transform the practice of research and training, inside and outside the academy, leading to the generation of novel problems, objects and relations of research, as well as interdisciplinary subjectivities (Greco this volume, Born and Barry this volume). The logic of ontology, as we have insisted, is neither an historical constant nor universal; it exists in relation to other logics, and it responds to and may be elicited by material circumstances and historical currents.

In the chapters that follow we discern various manifestations of the logic of ontology. Crucially, in each case what is at stake are interdisciplinary practices whose orientation to the world cannot be grasped merely in the terms of epistemology, as though they were separate from the world with which they engage. The limits of epistemology as a way of understanding scientific practices has been central to recent developments in the history and sociology of science. A number of writers including Lorraine Daston, Bruno Latour and Annemarie Mol have advanced the proposition that scientific research does not simply represent its objects, but has the effect of generating new entities or enhancing and adding to the properties of existing ones (Latour 1999: 124). Scientific research practices therefore enter into the world, enacting it in multiple forms (Barry 2005). For Mol, this observation leads to the possibility of what she terms an 'ontological politics' such that the question of which entities are brought into being and what relation they have to one another should be recognised as a political matter (Mol 2002). For Daston, rejecting the sterile dichotomy between realism and constructionism, historians must attend to 'how a heretofore unknown, ignored, or dispersed set of phenomena is transformed into a scientific object that can be observed and manipulated, that is capable of theoretical ramifications and empirical surprises, and that coheres, at least for a time, as an ontological entity' (Daston 2000: 5). In tracing the historicity of scientific objects, she advocates an 'applied metaphysics' (ibid: 3), one that revives 'ontology for historians', thereby enabling them to avoid 'slipping back into' the familiar tropes of neo-Kantian epistemology (ibid: 14). This is a project, she says, that stands orthogonally to the realism-constructionism debates, while being attentive to the ways in which scientific research can make entities 'grow more richly real

as they become entangled in webs of cultural significance, material practices, and theoretical derivations' (Daston 2000: 13). Latour, for his part, criticises those philosophies of science that draw a radical distinction between epistemology and ontology, contending that it is necessary to chart how in the course of scientific practice (for example, Pasteur's experimentation with lactic acid fermentation) the entities involved (both Pasteur and the ferment) '*mutually exchange and enhance their properties*' (Latour 1999: 124, emphasis in original). Thus, 'an experiment is an event' in which all the elements are partially transformed (ibid: 126). Rather than maintain, with the philosophers of science, that 'we should never confuse epistemological questions (what our representation of the world is) and ontological questions (what the world is really like)', Latour avers that 'confusing those two supposedly separate domains is precisely what scientists spend much of their time doing' (ibid: 93).

Andrew Pickering (this volume) comes at these issues from another direction, drawing attention to what he calls nonmodern ontologies; his example is cybernetics and its ramifying influence from the mid twentieth century. If the Cartesian modern sciences - physics preeminent among them - 'presume a knowable world, of identifiable entities in specifiable interaction with one another', the nonmodern sciences, Pickering suggests, envisage a world replete with non-dualist couplings of the human and nonhuman, one 'that is ultimately not fully knowable – a world of endless unpredictable emergence and becoming'. In this sense his perspective converges with that espoused by neo-vitalist social theory (Fraser et al 2005, Connolly 2011). As Pickering makes clear, nonmodern ontologies are not merely ideas or conceptions of the world driven by an antagonistic relation to the ontology of the moderns. Rather, nonmodern ontologies have been worked through and demonstrated in a series of practical devices, experimental and control techniques in an expansive array of fields.

We find these perspectives compelling. But in proposing the existence of the logic of ontology, our arguments are both more specific and more historically situated than those advanced by these writers. In this book, we are concerned not with the practice of modern science in general, but with the recent burgeoning of interdisciplinarity. We wish therefore to differentiate between general arguments for an applied metaphysics or for the existence of nonmodern ontologies and the idea of a logic of ontology manifest in contemporary forms of interdisciplinarity which necessitates that we attend - through the genealogy of particular interdisciplinary practices and fields - to its path-dependency and historicity and to the distinctive style in which it is performed.

Four propositions follow. The first is that the logic of ontology can be discerned in the way that certain forms of interdisciplinarity take as a focus of concern how knowledge practices intervene in

the world, bringing the subjects and objects of research into a relational existence. Second, and relatedly, the logic of ontology is manifest in those interdisciplinary practices that are oriented towards the generation of hybrid or relational objects that cannot be broken down into distinct natural, technical and social components. Conversely, it may be that it is the hybridity or relationality of the problem that resists the efforts of disciplinary practitioners to distil them into distinct natural and social fractions; and it is this resistance that may engender interdisciplinary practices that reconfigure or cut across the borders between the natural and social sciences (Latour 1993).

A third proposition is that the logic of ontology is evident when interdisciplinary practices arise in response to, or encounter, the problem of what the philosopher A. N. Whitehead called the 'bifurcation of nature'. In this way Whitehead pointed to a division between two aspects of nature: namely, the 'nature which is the cause of awareness' and 'the nature apprehended in awareness' (Whitehead 1920: 31) or, in Michael Halewood's exegesis, the 'ostensibly unbridgeable gap between reality as conceived by science and reality as experienced by humans' (Halewood 2011: 8). Once again, our observation here about the logic of ontology is historically specific. It is that we can speak about the logic of ontology to the extent that interdisciplinary practices today address, or are forced to address, the bifurcation of nature. Responses to this challenge can take many forms, such as a recognition of the importance of attending to the aesthetic, affective or social qualities of events as well as their physical or biological dynamics. It is striking in this regard that Whitehead perceived a connection between the philosophical problem of the bifurcation of nature and the organisation of university education into distinct departments or faculties (Whitehead 1926).

A fourth proposition regarding the logic of ontology, which integrates the three previous points, concerns the social arrangements mobilised by distinctive forms of interdisciplinarity. The involvement in scientific research of non-experts, citizens or lay publics, as others have noted, can generate both different objects and different ways of proposing problems (Callon et al 2001, Stengers 2005). In this book we build on this insight by drawing a contrast between practices of 'public understanding' that are intended to interpellate an absent but preformed public, a public that is assumed to exist, which tend to be associated with a logic of accountability, and the potential for participatory practices such as those invoked by ideas of 'public engagement' or user involvement, which can be associated both with accountability and with a logic of ontology (Weszkalnys and Barry, this volume; Born and Barry, this volume). As the chapters by Lucy Suchman and Sarah Whatmore suggest, such participatory methods may engender novel arrangements and can lead to inventive effects; they should not be understood simply as a means of fostering accountability. Rather, the alternative modes of knowledge and experience characteristic of lay publics and non-

experts are likely to enlarge and enrich what must be taken into account. And if it is accepted that the affective and aesthetic dimensions of experience enter as much as physical or biological processes into the constitution of the world, then not only the knowledge of non-experts and lay participants but the contributions to world-making of these dimensions of experience should also be recognised.

Ethnography in the IT industry and the logic of ontology

To discern how the logic of ontology is imbricated in any interdisciplinary field, as we have said, requires a genealogical grasp of its path dependence, and this is so even in apparently applied fields of research. Consider ethnography in the IT industry: a field that might seem most closely oriented to the logic of innovation and the commercial imperatives of the firm. Ethnography in the IT industry has a long history with multiple genealogies. It developed, in particular, from ethnomethodological studies of work (Suchman 1987, Bowker, Star, Turner, and Gasser 1997), as well as sociological and phenomenological critiques of artificial intelligence. It drew additional inspiration from the Scandinavian Participatory Design movement (Schuler and Namioka 1993). In human-computer-interaction (HCI) research in the IT industry and academia, efforts to bring ethnomethodological and other ethnographic approaches together with design led in the mid-1980s to the emergence of the interdisciplinary field of Computer-Supported Cooperative Work (CSCW). Within the broader space of HCI, ethnography appeared to offer 'a means by which the complexity of real-world settings could be apprehended, and a toolkit of techniques for studying technology "in the wild"' (Dourish 2006: 2). More recently, some ethnographers in the IT industry have drawn extensively on academic research in cultural anthropology (eg Clifford and Marcus 1986) and the sociology and anthropology of technology (eg Silverstone and Hirsch 1994, Miller and Slater 2000), while others have been influenced by interaction design (eg Gaver, Dunne and Pacenti 1999). The success and visibility of ethnography in the IT industry has caused the techniques to be imitated across new domains, notably in market research and other industries including banking, media and pharmaceuticals (Born 2005a, ch. 7, Barry 2005).[31]

The result of these complex genealogies is a heterogeneous field dispersed across a range of commercial and academic sites, one that is in formation and the boundaries of which are animated by continuing controversies and differences. These vibrant controversies reveal the extent to which ethnography in the IT industry manifests the agonistic-antagonistic mode of interdisciplinarity. The most prominent area of controversy centres on the imbrication of the logic of ontology and that of innovation. It has two modalities. First, there is a spectrum of positions on the question of the

relation between ethnography and design (Salvador, Bell and Anderson 1999). For some, ethnography in the IT industry should be thoroughly integrated into a practice of user-centred design; for others, the theoretical claims of ethnography should be clearly distinguished from any particular design implications (Dourish 2006). Second, there is an ongoing debate amongst ethnographers in the IT industry, involving multiple perspectives, over the relative merits of different theoretical and methodological accounts of the social, including those derived from the traditions of ethnomethodology, science and technology studies, and social and cultural anthropology, and how they can be articulated with industry and HCI research. A core current concerns the evolving relations between ethnography as it is practised in industry, including ethnomethodology and conversation analysis, and 'anthropological ethnography'. According to one informant, for example, tensions exist between 'old-fashioned,… broad-based' ethnography – by implication holistic, exhaustive and sustained - and what he portrayed as the more attenuated focus of the ethnomethodologists, whose research time-frames are much shorter and where analysis may dwell exclusively on transcripts or on twenty minutes of video – a 'kind of "situated action" perspective'.[32] Yet other actors point to a distinction between those who defend the integrity of ethnography as an established historical body of anthropological theory and methodology and those who claim that ethnography in industry has itself evolved and diffused in recent years to become a pluralistic field – a set of techniques that have been utilised in and refined by different traditions and settings, and that are now quite distinct from ethnography as it is practised academically (Randall et al 2003):[33]

> My argument is that ethnography in different practices [such as CSCW] has built up caucuses and reasoning, and that the reason you do [academic] anthropology at Cambridge is to learn what it is that prior anthropologists have argued about, but also to learn the analytic sensibility…. But likewise,… ethnography in CSCW is different from what it was twenty years ago. I mean, ethnography in CSCW: there's no reason why you should turn to [academic] anthropology; you should just turn to the caucus of stuff that's there.[34]

Within ethnography in industry there are therefore quite conscious, and contested, attempts to distinguish the affordance of interdisciplinary research from demands for better design or new products or organisational forms. Collectively, this question of establishing a distance between the field and demand, or not, has been staged since 2005 in the organisation of the annual EPIC conference (n. 26), a forum where the emerging field performs its reflexive professionalisation and where these and other controversies are agonistically aired. In individual research groups, meanwhile, the performance of distance from the immediate demands of the IT corporation for

improved product or process takes diverse forms. It can involve orienting research towards the production of academic journal articles and conference papers rather than industrial prototypes or designs; it can take the form of a critique of the politics of industrial ethnographic practice (Anderson and Nafus 2006); it can entail the development of designs that are not intended to be the basis for products; and it can take the form of research with no discernible relation to consumer demand or design: 'Our role is not to design a new and better application for X or a new and better gadget'.[35]

There is much to be said about why some ethnographers distance their work from expectations that it should impact on design. It may be difficult for them to demonstrate any direct impact; and even when their work does have implications for design, it may be problematic to discuss these in public because of commercial confidentiality. At the same time, ethnographers are more likely to achieve such distance in those corporations able to pursue a long-term research strategy, as well as those that collaborate with universities or fund university-linked research outfits. In this situation the corporation gains by having researchers that act as a porous interface with their academic counterparts, picking up currents across the Chinese walls (Amin and Cohendet 2004). Moreover, the corporation accrues legitimacy by supporting and being seen to support an interstitial zone of hybrid research, demonstrating its commitment to the generation of research with no immediate economic utility:

> The primary reason I was attracted to the Lab was this open policy of collaboration not just with [corporate] researchers but outside individuals – we are encouraged to bridge those kinds of connections…. It's obvious that there are lots of other people and other disciplines that have looked at this phenomenon [interactions between social life and technology]. They should be part of the dialogue. The main thing is the open policy: it's a great model. I wanted to be able to share things. In the same way this is a very academic-feeling environment, being close to academia.[36]

It would be a mistake to reduce these demonstrations of autonomy from the logic of innovation merely to legitimation or PR, even if they may sometimes be seen as such by corporate managers (cf. Latour and Weibel 2002). On the one hand, they demonstrate the possible contribution of ethnography in the IT industry to debates that are not oriented towards industrial applications or innovation. Indeed, some industry researchers argue that the corporate context makes it possible to carry out inventive types of ethnography that it would be difficult or impossible to undertake in academia, including sustained and intensive collaborations with designers and computer scientists (Cefkin 2009). On the other hand, they express a sense that the justification of the role of

ethnographer is in large part ontological: that s/he must effect an ontological transformation. The rationale for carrying out ethnography, then, is not just that it may impact on design, but that it has the potential to transform the technological object from being merely an object or product into something which, depending on the approach, is locally situated, socially contextualised, encultured or emotionally attached (eg Suchman 1987, 2002, Bowker et al 1997, Nardi and Day 1999, Dourish 2001, Harper 2003, Nafus and Anderson 2009, Dourish and Bell 2011). In this respect ethnography in industry draws on and, through collaboration with designers and computer scientists, contributes to much longer traditions of philosophical and social enquiry concerning the nature of technology. Of course, the ontological contribution of the ethnographer may nonetheless have implications for design, or contribute to increasingly sophisticated market research.

In an irony that is not lost on the actors, the ontological chemistry of corporate ethnography is crystallised in a highly developed rhetoric of naturalism (Anderson and Nafus 2006). We can distinguish at least five techniques by which the ethnographer is able to achieve this chemistry in practice:

1) through *metonymy*: the ethnographer reports on social reality indexically through the use of audio-visual recordings, photographs and ethnographic vignettes – bringing back to the corporation a small part of the real (Salvador, Bell and Anderson 1999, Anderson and Nafus 2006);
2) through *contagion*: the ethnographer as 'I-witness' (Geertz 1988), in direct contact with the real, gives personal testimony and acts as a proxy for social reality – standing in for society in design meetings and conversations with engineers and management;
3) through *transportation*: the ethnographer acts as a guide who takes the executive, engineer or designer physically outside the corporation/the USA for a direct experience of the real (D'Hooge 2005: 7);
4) through *collaboration*: the ethnographer engages in an interdisciplinary practice of user-centred design, transforming socio-technical reality through processes of collaboration;
5) through *scientific observation*: the ethnographer acts as an observer, whose descriptions and findings may or may not have subsequent implications for design (Dourish 2001, 2006).

In these and other ways, ethnography can be employed in efforts to catalyze a transformation of the ontological imagination of the firm towards a conception of the industrial object as a socio-cultural-technical assemblage (Bell, Brooke and Churchill 2003, Dourish 2006, Thrift 2006: 288, Dourish and Bell 2011). The problem faced by corporate ethnographers in seeking to effect such transformations at the level of corporate strategy and imagination is at base, then, a rhetorical one. The challenge

may not be how to provide a detailed and nuanced description of the way that IT mediates the routines of an Indian middle-class home, an American public library, or a Russian street, but how to demonstrate the ontological truth that technical objects have to be understood as situated in particular microsocial, encultured and affective assemblages (Deleuze 1988). Corporate ethnography may be marked by an emphasis on rhetoric and display, but, as Barbara Cassin argues, rhetoric can be necessary for truth to survive in harsh conditions (Cassin 2005).

Interdisciplinary environmental research and the logic of ontology

The logic of ontology is at work in a different guise in the field of environmental and climate change research. As we have noted, interdisciplinary environmental research institutions tend to have a problem-solving orientation and their development has largely been guided by a logic of accountability: because environmental problems are multi-dimensional they demand interdisciplinary approaches, and because they are objects of government and of immense public political concern, they raise issues of accountability.

Yet, along with accountability and problem-solving, it is possible to discern several new arguments and techniques emerging both in environmental and climate change research and in related fields, including environmental geography. A particularly influential set of arguments was associated with the emergence of the field of climate science in the 1970s. As Paul Edwards argues, climatologists in the 1960s represented climate change primarily using long-term statistical databases. However by the late 1970s, computer-based models had become dominant. Since then, in the context of the developing interdisciplines of climate science and earth systems science, the global environment has come to be understood and modelled as a set of systems of varying scales, levels of resolution and complexity (Edwards 2001: 32-3). Within this framework, the contribution of the social sciences was expected to be the provision of one element of an integrated analysis of the global environment. At the same time, the global environment has increasingly been addressed not just as a system or set of systems, but as an object of global government:[37] '[earth systems analysis] is a diagnostic instrument, generating evidence necessary for treatment. This means that we are ultimately confronted with a control problem, a geo-cybernetic task' (Schellnhuber 1999: 20).

More recently, however, a different set of rationales and techniques have emerged in interdisciplinary environmental research influenced by a range of intellectual traditions including political ecology, science and technology studies, social anthropology and cultural geography. Although these arguments have a long history, they did not become visible in environmental research until the late 1990s (Liverman 1999). There are three strands to these arguments, which are

sometimes elided. The first proposes that established understandings of natural science models of the environment have failed to address the ways in which such models are shaped by political assumptions and cultural values: 'it is not that the scientific models and ensuing knowledge are empty of culture and politics, but that they are impregnated with them without even recognising it, let alone the implications' (Shackley and Wynne 1995: 124, Hulme 2009). At the same time, in this view, the uncertainties of scientific knowledge claims, including climate change models, are seldom acknowledged in public debate (Jasanoff and Wynne 1998).

The second strand originated in an awareness of the limitations of scientific expertise as well as recognition of the importance of local and indigenous knowledges with respect to the environment. In this view, lay and non-expert accounts of environmental problems should not be understood merely as perceptions, but recognised as an expression of a kind of 'citizen science' (Irwin 1995, Wynne 1996, Callon et al 2001, Berkhout et al 2005: 12, Leach et al 2005). Both environmental science and policy are understood in this perspective to be immanently cultural and political. Indeed, Brian Wynne contends that non-experts can contribute knowledge and expertise concerning the local, social and historical nature of environmental issues that scientific experts do not possess (Wynne 1996). In this view, while devices such as public consultations and public inquiries may often be anti-inventive, legitimising the authority of established sources of scientific expertise, other techniques for engaging non-experts in environmental debate and research practice can be more generative (Callon et al 2001, Stirling 2005, Turnpenny et al 2005, Davies 2006, Whatmore 2009, this volume). Such inventive modes of inter- and extra-disciplinary practice involving non-experts are frequently justified in terms of their contribution to greater accountability. At the same time, however, both experts and non-experts must perform the difficult task of demonstrating the autonomy of these new interdisciplinary practices from a logic of accountability. That is to say, the involvement of non-experts in research and public debate may have critical implications for policy and practice precisely in so far as it cannot be dismissed either as an expression of a pre-determined politics or as a response to the need for accountability.

Together, these two strands of rationales and techniques suggest that closer attention should be paid to the politics of research and the manner in which non-experts participate in the production of environmental knowledge and in the dynamics of environmental knowledge controversies. In this respect they resonate with Nowotny et al's general claims about the erosion of boundaries between experts and non-experts, as well as the need for scientific knowledge claims to stand up to scrutiny in the public arena. However, together these arguments point to a third, more encompassing ontological orientation evident in recent environmental research according to which the

environment can no longer be cognised as presenting a given set of problems that demand to be acted upon or solved. In this account, environmental research does not confront an external nature or a given set of problems but itself contributes to the problematisation of the environment (Castree 2005, Braun and Anderson 2008). Nor can publics and stakeholders be understood as distinct from the existence of environmental problems which they define and to which they respond (Latour 1999, Liverman 1999, Callon et al 2001, Jasanoff 2004). Instead, the practice of environmental research is understood as animated by and as entering into the ongoing formation and re-formation both of environmental problems and of their publics. Conversely, environmental problems may engender interdisciplinary research practices not because the environment is a complex system containing a number of distinct social and natural subsystems, nor because of demands for greater public accountability, but because the hybridity of environmental problems resists purification into distinct natural and social elements (Latour 1999, 2004, Whatmore 1999). These encompassing ontological and political arguments have been articulated primarily by researchers in science and technology studies, social anthropology and geography (Hinchliffe 2007, Braun and Whatmore 2010). Their implications for the practice and politics of interdisciplinary environmental research as well as for policy and politics remain contested and in process (Whatmore, this volume, Weszkalnys and Barry, this volume).

Overall, the practice of interdisciplinary environmental research appears more fragmented as a field than ethnography in the IT industry. Where ethnography provides a core method or theory around which ontological issues arise, and which, however interpreted, serves to give some sense of unity to the interdiscipline, there is no such core method in interdisciplinary environmental research. Instead, there are a multitude of different ways of researching the environment associated with different social scientific approaches and techniques, including computer modelling, systems analysis, scenario analysis, focus groups, interactive assessment, competency groups and ethnography (Whatmore, this volume, Weszkalnys and Barry, this volume). In these circumstances, interdisciplinary environmental research institutions are often marked by divisions not only between the natural and social sciences, but between alternative interdisciplinary perspectives associated with the different environmental social sciences and their particular articulation of the logic of ontology.

Art-science and the logic of ontology

Of our three interdisciplinary fields, perhaps the clearest manifestation of the logic of ontology occurs in the burgeoning field of art-science: an exemplary instance of interdisciplinary endeavour across the 'two cultures' (Snow 1959). Art-science is a field recognised by practitioners, funders and

arts institutions alike. It emerged in its current guise in the mid-1990s, but its identity continues to evolve through its close association with an array of other practices – including installation and robotic art, bio art and wet art - that occupy the borderlands between the arts, sciences and technologies (Wilson 2002, Popper 2007, da Costa and Philip 2008, Reichle 2009). We might consider art-science, then, as an emergent interdiscipline.[38] At its core lie retentions of long-standing currents dating from the mid-twentieth century that problematize the ontological grounds of what art is or can be, causing this to be cast in doubt and to be radically transformed. Such ontological transformations can be grasped by tracing its plural genealogies, in particular through diachronic analysis of the unfurling in recent decades of an evolving set of concerns with the interconnections and mediations between both art and technology and art and the social. Although the perspective varies according to individual and institutional commitment and location, the genealogy of art-science encompasses the mutual entanglement of at least three currents, notably (post-)conceptual art, movements articulating art and technology, and practices in which art engages with the bio, computational and information sciences.

Conceptual art, which originated in the post-War period in a wave of heterogeneous expressions of the rejection of formalist modernisms, generated a series of directions that remain influential across a range of contemporary art practices, including art-science. Its basic premise is a commitment to an entirely distinctive ontology of art, indeed to pluralizing art's ontologies (Newman 2002, Doherty 2004, Skrebowski 2009, Born and Barry, this volume). This premise is evident both in art-science practices that have taken as the locus of experimentation materials and media, and in those practices that have been oriented more towards social and political experiment (Buchmann 2005). In the politicised lineages of art-science, both science and technology studies and critical and feminist theories may be brought into the mix in an attempt to build a systematic critical reflexivity into the new practices. Art-science engages science, then, in plural ways: in terms of mining the conceptual and material armouries of the sciences, in terms of convergent interests in experimentation and innovation, and in the guise of animating critiques of science. Together, the genealogies of art-science etch out a decidedly artistic space, but one that intersects with technological and scientific experimentation and controversy, such that art is retooled - as one practitioner put it - as a kind of 'interdisciplinary production'.

Prominent in Britain, as mentioned earlier, are currents linking art-science to accountability. Whether in the Wellcome Trust's 'public understanding of science' funding paradigm or its 'public engagement' successor, art-science 'has been sold around a very pragmatic and instrumentalist notion' of reaching new audiences for science (see Born and Barry, this volume).[39] Despite efforts to

combat this limiting image, there is a perception that this instrumental conception along with the limited collaborations allowed by project-based funding for art-science make for conditions that prey on artists' precarious financial standing and can result in poor work.[40] This points to a key line of dissent within the field in which the output from such project-based funding schemes - where collaboration between artist and scientist is often short-lived and the division of labour remains intact; that is, where art-science labours in a subordination-service mode under the logic of accountability - is commonly characterized as 'decorative', 'celebratory' or superficial. In contrast, originality and invention in art-science are invariably associated by those in the field with practices in which the engagement or confrontation between art and science is deeper and sustained, and in which artists are able - or are trained - to make full and knowledgeable use of the 'special facilities of the scientific lab', engineering workshop or computer workstation.[41]

As visible as the public understanding of science rationale for art-science has been an orientation towards the logic of innovation. This is exemplified by an influential report, commissioned by the Rockefeller Foundation, which emphasizes the 'studio-lab' as a site of experimental activity in which artistic practices can 'co-evolve' with new technologies and new media, engendering creative applications (Century 1999; cf Born 1995). Here the 'studio-lab' is portrayed as a key site for fostering innovation, while science is seen as proffering new subject matters, concepts, imagery, technologies and materials that elicit artistic experimentation. More generally, artists' engagements with scientific and technological research are taken by commentators to offer a range of potential stimuli or aids to innovation. Collaborative projects between artists and scientists may provoke and enrich scientific research, triggering unforeseen directions; they may assemble an unconventional mix of disciplinary skills and talents; the artist can offer the content required for the testing of new technological tools; artists' responses to new research, concepts or materials can allow scientists to observe human responses and behaviour; artists may act as particularly acute or creative 'lead users', generating further research or development; or the artistic exhibition of research outcomes may act as a test-bed for their launch in the real world (cf. Naimark 2003). In Britain, an Art and Science Research Fellowship programme initiated in 2003 by Arts Council England and the Arts and Humanities Research Board was founded on the conviction that art-science could embody the entanglement of the logics of innovation and ontology. The scheme responded explicitly to calls from government bodies such as the 2001 Council on Science and Technology for the arts and humanities to contribute to the knowledge economy (Ferran 2006: 443). Yet at the same time, collaborations between artists and scientists funded by the programme were expected to be guided by an ontological logic in which the collaborative endeavor was envisaged both as methodology and

as the 'work': 'we consider our overall objective as a new kind of social "material", aiming to create new cultures of technological collaboration and artistic production' (Blackwell and Biggs 2006: 471).

In our institutional case studies these inventive modalities of art-science, combining the logics of ontology and innovation, were particularly apparent in the USA and Australia. In these settings, university-based salaried artists were able to achieve intensive collaborations with scientist colleagues through prolonged encounters with or immersion in scientific environments, thereby incorporating scientific problematics into their work to occasionally extraordinary synergistic effect (Born and Barry, this volume). Such conditions provided the basis for transcending the disciplinary division of labour, sometimes through a commitment to the cultivation of 'interdisciplinarity in one person'. It was this approach that motivated the pedagogy of the Arts, Computation and Engineering (ACE) Masters program at UC Irvine, described in Chapter 11. Transcending mere 'decorative' art-science, the ACE program was engaged in subjectifying a new generation of art-science practitioners with the resources to imagine and navigate new ontologies in the fertile borderlands between artistic, technological and scientific practice.

The chapters

The following chapters offer contrasting challenges to dominant understandings of interdisciplinarity. Simon Schaffer's starting point is the recognition that the discourse of interdisciplinarity 'evidently, if oddly, takes as accurate history the stories that disciplines have told about themselves'. To question these stories, Schaffer probes the period of the late eighteenth through the mid nineteenth century, a period that was both 'key for disciplinary society' and for the constitution of disciplines as well as the labile relations between them. His aim is to undermine the functionalist view 'that the order of disciplines is simply the expression of a utilitarian division of intellectual labour set up in the early nineteenth century… [a functionalism resting] on a kind of forgetting of discipline's indisciplined history'. In place of such a view, Schaffer offers a genealogy of discipline that traces its connection back through the work of Jeremy Bentham to the practice of colonial education. Bentham's *Chrestomathia* educational project fuelled a metropolitan experiment in schooling involving 'up-to-date principles of utility, accountancy, economy, the division of labour, surveillance and a monitorial system'. But Schaffer's primary focus is the 'Madras System', an exemplary institution of pedagogic discipline developed by the Scottish natural philosophy lecturer Andrew Bell in the 1790s, which greatly influenced Bentham. Schaffer shows how Bell's project had hybrid origins, drawing extensively on the disciplined pedagogic practices of Tamil culture. Only later would this pedagogic technology be brought to the imperial metropolis. Tracing the complex

and recursive circuits of mimesis in this history, Schaffer highlights, not without irony, how Bell's 'system of training had originally been adopted and adapted from Halle pietism and Tamil pedagogy. It was turned into a form of economic and scientific discipline for "half-caste" Indo-European trainees destined for service in the East India Company's administration and surveys. Later, within the imperial metropolis, utilitarian and romantic writers then saw in this system powerful tools for securing social discipline, moral order and scientific advance'. Eventually, 'British administrators and historians saw such disciplinary systems as the necessary means by which what they saw as Indian culture could at last be redirected and modernised'. If Bentham has been taken by readers of Foucault as one of discipline's most ardent proponents, then the origins of discipline are to be found in the Indian sub-continent as much as in Britain or France. Schaffer directs our attention to the 'genealogy of global networks and their entanglements throughout the histories of disciplinary formation', as well as the close interrelations between the history of the disciplines and the history of colonialism and its aftermath. At the same time he issues a timely reminder, before we make too many assumptions about interdisciplinarity today, that it would be wise to interrogate the stereotypes of disciplinary history, homogeneity and hegemony that are shared by the proponents of disciplines and their interdisciplinary and transdisciplinary critics alike.

In the following chapter, Thomas Osborne offers a lively rejoinder to the present enthusiasm for interdisciplinarity, probing the nature of disciplinarity particularly in the social sciences with a focus on sociology, economics and social anthropology. His argument begins with the observation that the natural sciences continue today to have 'more circumscribed epistemological profiles' than the social sciences and humanities. Taking off from this 'backward brand of C. P. Snowism', he takes issue with ideas of disciplinary insulation or indeed any notion 'that disciplines are implicitly akin to monads'. Rather, 'all disciplines are hybrid'; indeed 'there is a basic transparency or porosity to disciplines, and some more so than others'. The social sciences, he suggests, are especially porous and even promiscuous in their aptitude for certain kinds of mobility across and cross-fertilization with other areas of inquiry; but this is a mark precisely of their disciplinarity, not of interdisciplinarity. Osborne's key concern is to identify the distinctive styles of mobility exhibited by the social sciences, to excavate the ways in which as part of their normal operation these disciplines produce relations of exteriority. In this sense he adds to the project of this book by pointing to what might be called characteristic modes not of interdisciplinary but of (inter-)disciplinary practice, along with their epistemological entailments. Osborne dwells on three such modes: parasitism, which he identifies primarily with anthropology; trespassing (and its big brother, imperialism), which he associates with economics; and poaching, which he links to postmodern social theory and sees as the product of 'disciplinary deficit'. Anthropology, for instance, exemplifies a creative parasitism (in a

descriptive rather than pejorative sense): ethnographers go into the field these days to study scientific laboratories, businesses or indeed interdisciplinary research projects, aiming to develop an intimate knowledge of the domain being studied, to be 'absorbed' into it whilst 'leaving their own disciplinary core intact'; and an analogous parasitism, Osborne points out, occurs in some branches of the philosophy of science. In comparison, the trespassing that characterizes the work of economists, according to Osborne, involves the imposition of their 'own view of the terrain on another disciplinary area', thereby 'bringing the other discipline into [their] own'. Indeed rational choice theory is what eventuates, he argues, 'when utilitarian economics trespasses on domains other than economics in the social sciences'. This can be a reductive exercise, but such 'reductiveness can be part of the creativity of the endeavor itself'. For Osborne, 'interdisciplinarity is not the opposite of disciplinarity', nor does it pose a threat to those disciplines that have a strong identity (such as, quite differently, anthropology and economics). But it may pose a threat to certain disciplines (his example is sociology) that are weakly formed or lack a clear sense of their distinctive disciplinarity.

While Osborne considers how established disciplines are in distinctive ways immanently (inter-) disciplinary, Sheila Jasanoff gives an account of the emergence out of a ferment of interdisciplinary activity of what she regards as a new discipline, Science and Technology Studies (STS) - a process in which she played an influential part. Her chapter therefore initiates a series of reflexive contributions to the volume. Although Jasanoff recognises that there are external pressures for greater interdisciplinarity, she makes a strong case for the importance of bottom-up initiatives from scholars who, 'possibly at the margins of their own disciplinary enclaves, start asking questions that demand new modes of inquiry'. Her account of the gradual disciplining of STS revolves around three phases in the history of the field. The first centres on the so-called Science Wars that erupted in the USA in the 1990s following publication both of Paul Goss and Norman Levitt's broadside against the academic left, *Higher Superstition*, and of the physicist Alan Sokal's hoax contribution to the journal, *Social Text*. Crucially, she argues, the Science Wars undermined the commitment of STS scholars to the principle of symmetry, according to which true and false claims to scientific knowledge should be analysed in identical terms. If the Science Wars tell us about the potential for antagonistic relations between STS and the natural sciences, Jasanoff's second phase centres on the continuing existence of unresolved and agonistic relations between STS and its cognate fields, including history, sociology and philosophy. Here her analysis dwells on differences between the contents of two major collections that aspired to be definitive of STS: the 1995 *Handbook of Science and Technology Studies* (of which she was an editor) and the 1999 *Science Studies Reader*. Jasanoff notes that while the latter presented the field as a combination of contributions from distinct disciplines, the editors of the *Handbook* sought to map the contours of an emerging disciplinary form. In an evocative

metaphor, Jasanoff argues that the formation of STS should be likened to the charting of the high seas, rather the construction of a highway between clearly defined fields. But her contribution also foregrounds another theme of this collection, evident in the chapters by Schaffer, Greco, and Born and Barry: the critical importance of pedagogy in the formation of interdisciplines and disciplines, embodied in the development of teaching programs and departments and, for STS, the publication of handbooks. In the course of what Jasanoff suggests is a third phase, STS has become an established discipline marked by increasing engagement with politics and policy. In tracing these three phases in the history of STS, Jasanoff suggests that the formation of any discipline is likely to be marked by disagreement over whether it should coalesce as a distinct discipline or remain an interdiscipline. Importantly, her analysis points to the politics of the relations between disciplines as their proponents struggle for authority, institutional standing, resources, and intra- and extra-academic influence.

The chapter by Marilyn Strathern and Elena Khlinovskaya Rockhill introduces a group of contributions that respond, in various ways and to different degrees, to the framework set out in this introduction. It focuses on a particular institution, the Cambridge Genetics Knowledge Park, on which they carried out research in the mid 2000s.[42] The approach taken by Strathern and Khlinovskaya Rockhill is ethnographic and methodologically internalist. Their study opens an important seam of analysis running through this collection, uncovering how the intellectual, social, institutional and economic conditions within which interdisciplinarity is cultivated make a difference. Specifically, their analysis shows that even if funding is provided and research policies are conducive, if interdisciplinarity is implanted within unresponsive or hostile organizational surroundings, it will fail to thrive. In terms of the expression and imbrication of the logics of accountability and ontology, the CGKP provides a striking contrast to our studies of interdisciplinary environmental and art-science research; indeed, it presents a negative case. The Knowledge Park was an institution that laid claim to its interdisciplinarity as an index of its accountability to society. Yet the institution was so purely driven by the logic of accountability that there was in practice no commitment to what else interdisciplinarity might deliver in epistemological or ontological terms. Thus, despite the Knowledge Park's avowed and explicit remit to consider the Ethical, Legal and Social Implications of scientific studies of genetics for public health and policy, at the heart of their account is an analysis of the marginalisation within the CGKP of 'research' in general and of the social scientific research represented by ELSI in particular. There was therefore little support for interdisciplinary collaboration, nor any attempt to reconfigure the relations between the social sciences and natural sciences. The marginalisation of social science in this context was evidence of what the authors term a 'ricochet effect', occurring in several directions. One manifestation of this effect was difficulty in

evaluating the Knowledge Park: the problem of demonstrating the value of social research internally was both mirrored and amplified externally in the difficulty the Knowledge Park had in demonstrating its value to those bodies required to assess its performance. Another manifestation was that the internal marginalisation of ELSI within the institution was magnified in the intensified marginalisation of the most 'social' of ELSI's component disciplines: sociology. While the CGKP appears to exemplify the subordination-service mode, in that social research was required to take a service role with respect to the Knowledge Park's dominant orientation towards public health genetics, Strathern and Khlinovskaya Rockhill insist on the need to retain an interest in its singularity. Indeed, they report an unexpected finding: 'for all its protested aversion to research, there are many features of [the CGKP management's] open-horizons ideology and equal aversion to the micro-management of performance indicators that brought it closer to a research ethos than its directorate would have admitted'.

Lucy Suchman's chapter traces reflexively, in part through her own experience and pioneering work at the Xerox Corporation's Palo Alto Research Center (PARC), how anthropology and its method of ethnography entered the world of the IT corporation and became part of the means of constituting markets. Overall, her argument is that in recent decades, through such interdisciplinary engagements, anthropology has itself become an 'object of consumption within the worlds of commercial research and development', playing its part in the promotion of the 'cultural turn' in the global economy, and assisting in the era of lifestyle marketing and branding in 'the expansion and deeper penetration of cultures of capitalism'. Interrogating the media's 'discovery' of and fascination with corporate ethnography from the early 1990s, Suchman finds in it an echo of Strathern and Khlinovskaya Rockhill's fractal-like 'ricochet effect': an ironic juxtaposition in which the ethnographer as investigator of those exotic others sought by the global corporation when expanding into new markets is mirrored by the anthropologist as herself an exotic other within the corridors of the corporate workplace. But lest we collapse this history into teleology, Suchman is at pains to show how, in the early period of the 1980s to mid 1990s, ethnography in industry as it was being invented at PARC was able to incubate - in part through connections to the Department of Anthropology at the University of California at Berkeley - a space for 'critical anthropology'. Indeed, her account of the period suggests that the logic of innovation and the logic of ontology were entwined at PARC. On the one hand PARC's ethnographers, through collaborative experiments with computer scientists and co-workers from other disciplines, engaged in the development of prototype commercial information systems. On the other hand, influenced by the Scandinavian participatory design movement and its advocacy of workplace democracy, PARC's ethnographers and their collaborators cultivated an 'agonistic interdisciplinarity'. Through the example of a

participatory project in the mid 1990s with the California Department of Transportation, she shows how such projects were crafted by the actors to pursue the design-oriented and commercial requirements of the corporation while also engaging in dialogical and material exchange practices that, in the terms of Michel Callon (1998), 'overflowed' any market rationale. By reframing technologies as sociomaterial practices and enriching the corporate engagement with the social embeddedness of information systems, they opened up 'margins of manoeuvre… that overflowed the conventional market frame'; although in doing so, she admits, it was often necessary to make implicit the political values that underlay 'superior design outcomes'. This was a phase of possibility, as Suchman makes clear, that was eventually eclipsed by more purely commercial imperatives. The story of ethnography at PARC is therefore one in which such practices were at times afforded and at other times foreclosed by changing institutional conditions as they refracted in turn the evolving political economy.

Geography, as an interdisciplinary discipline, is apparently well-placed to respond to the escalating research initiatives demanding interdisciplinarity. In her chapter, Sarah Whatmore documents her experience as a geographer of another set of institutional conditions: a call for proposals from the UK research council-funded Rural Environment and Land Use (RELU) research programme in 2004, 'the first and largest programme in the UK to make collaboration between natural and social scientists a precondition of project funding'. As she explains, the call posed applicants the challenge of giving as much attention 'to promoting novel cross-disciplinary couplings' and 'involving stakeholders in all stages' as to 'further refinement of established interdisciplinary methods and techniques'. In their response to the call, Whatmore and her colleagues sought to develop a novel interdisciplinary approach to the problem of flood risk, one that involved not just physical and human geographers but also 'competency groups': an experimental practice trialled by the project that brought local people with direct experience of flooding into the research collective. In this way her contribution pursues another theme of this volume, evident also in Suchman's chapter: the place of participatory practices and, in particular, the involvement not only of lay or non-expert knowledges but of lay participants' practical and experiential competencies in experimental forms of interdisciplinarity. Whatmore poses the terms of the situation starkly through a dualism in which the normative Interdisciplinarity envisaged by the RELU programme, where 'research is positively allied to governmental and business agendas… in the name of environmental problem-solving', was reshaped in their successful application into an alternative, 'inventive inter-disciplinarity [premised on] a practiced attentiveness to the ontological demands of the complex artefacts and processes assembled in/as "environmental problems"'. Where the first Interdisciplinarity entails 'an *a priori* separation of "human society" from "the environment"', she contends, 'the second insists on the

ontological impossibility of sustaining the binary conception – human and environment'. Here she takes as a compass Jane Bennett's argument that 'humans are always in composition with nonhumanity, never outside a sticky web of connections or an ecology' (2004: 365). In this light, a core aim of Whatmore's project was to reframe the research agenda so as to 'direct attention to the techno-scientific practices of environmental "problem-solving" as ecologically constitutive themselves and, hence, as matters of crucial analytical (and political) concern'. Indeed, counterposing the two interdisciplinarities, Whatmore argues, exemplifies the 'perpetual interaction' evoked by Deleuze and Guattari between 'royal' (machinic) and 'minor' (or nomadic) science. Interweaving the logics both of ontology and of accountability, the task of Whatmore's flood risk project was not to address already defined problems, nor to engage in critique, but to generate positive problems through an intervention that responded to the need to invent novel practices and engagements. Her contention is that 'the ontological logic of our experiment in geography's inter-disciplinary inventiveness allies research with the potential for knowledge controversies to act as democratic force-fields'.

Where Whatmore's project formed one element of a much larger research programme that was explicitly interdisciplinary, Gisa Weszkalnys and Andrew Barry report the findings of a comparative study of three major interdisciplinary research institutions, all three of which were concerned, in Whatmore's terms, with 'environmental problem solving'. They are the German Öko-Institut, the Tyndall Centre for Climate Change Research in the UK, and the Earth Institute located at Columbia University in New York. The chapter develops two general arguments, while stressing the need to attend to the particular genealogies and institutional trajectories of the three institutions. The first argument focuses on the specificity of the relations between the development of these institutions, each of which brings together researchers in the natural sciences and social sciences, and the logic of accountability. The authors link the emergence of the Öko-Institut in the 1970s both to Nowotny's notion of transdisciplinarity and to the practice of what was called counter-science (*Gegen-Wissenschaft*), an idea encapsulated in Ulrich Beck's contention that radical environmental politics is not possible without 'the aid of the entire arsenal of scientific measurement, experimental and argumentative instruments' (Beck 1992: 162-163). The formation of the Tyndall Centre drew on a longer British history of interdisciplinary research in the new universities of the 1960s, but it also reflected a growing stress in the UK in the 1990s and 2000s on the importance of involving users and stakeholders in environmental research. The interdisciplinarity of the Earth Institute, in contrast, developed as a response to the complexity of the global policy problems that its researchers were expected to address. Reflecting on the researchers' experience of the continuing importance of disciplinary forms of peer review at the Earth Institute and the Tyndall Centre,

Weszkalnys and Barry point to contingency of the relations between interdisciplinary research and 'society' that is associated with the logic of accountability. The authors' second argument focuses on the centrality of the common trope of 'integration' to interdisciplinary environmental research. Integration, they argue, should not be understood as an end result, but as a set of practices that take multiple and often agonistic forms; what is called integration, then, may or may not correspond to what we have termed the integrative-synthesis mode of interdisciplinarity. For many researchers, the challenges posed by integration are oriented towards the solution of problems and are primarily organizational and methodological. However, Weszkalnys and Barry contend that there are incipient signs of the logic of ontology in 'integrated' environmental research. This is evident, for example, in the ways that stakeholders have been brought into the research process through the development of such methods as interactive assessment and scenario analysis, suggesting that 'environmental research has become increasingly entangled in the world that it analyses'. The authors conclude by observing that despite the growing attention paid to the bifurcation of nature and notably to the importance of affective and aesthetic experience in geographical research on the environment, a concern with the realm of experience still appears to be marginal to the work of environmental research institutions.

In the next chapter, Andrew Pickering offers a quite different exploration of the 'ontological thread' spun by this introduction, following it through a series of fields that he identifies as antidisciplines and that he associates with varieties of 'ontological nonmodernity'. Examples include alchemy, *naturphilosophie*, those fields grouped under the heading of 'complexity', and certain interpretations of quantum mechanics. For Pickering, such 'nonmodern sciences' evidence 'not so much [a] combination of distinct disciplines, but… the eruption of a relatively unified approach to the world across the disciplinary map'. The focus of Pickering's paper is a particular and exemplary antidiscipline: cybernetics. As he shows, the emergence of cybernetics was bound up with the development of models, machines and assemblages, notably the homeostat, which figured as the centerpiece of Ross Ashby's *Design for a Brain* (1952). In Ashby's account, the cybernetic brain was performative and adaptive, not representational; it should be regarded, Pickering argues, not only as contribution to brain science but to ontology. In turn, the implications of multi-homeostat assemblages could not be confined to brain science but rapidly radiated out to infect a multiplicity of fields, among them philosophy, aeronautics, engineering, robotics, psychiatry, management and biological computing. In the work of Stafford Beer, cybernetic ambitions spanned interactions with pond ecosystems - where 'the idea was that nature is already full of adaptive systems which one could seek to entrain in human projects' – to the application of Beer's Viable System Model to the entire Chilean economy under Allende's socialist regime in the 1970s. For Pickering, such

antidisciplinarity was not built on prior antipathy to specific disciplines or to disciplinarity *per se*; rather, it was an effect of the 'working out of a nonmodern ontological stance', one that fuelled the 'transformative displacement' of the disciplines it encountered. Pickering nonetheless acknowledges an antagonistic moment in cybernetics, arguing that if the modern sciences foster the asymmetric domination of nature and the world, then 'cybernetics problematized this stance'. Such a problematisation is signaled by the prefix 'anti' commonly attached to cybernetic forays into other fields, for example in the anti-psychiatry movement that coalesced around Gregory Bateson's critique of the social relations of psychiatry and Ronald Laing's experiments in non-hierarchical therapeutic communities. In sociological and institutional terms, Pickering's cybernetics appears to be the opposite of Jasanoff's STS: if the burgeoning discipline of STS is bedding down in the heartlands of the academy, Pickering shows that cybernetics has always been antithetical to institution-building and PhD programs, flourishing at the margins of academia where disciplinary policing is at its weakest. Cyberneticists, Pickering notes, came together 'almost orthogonally to their modern counterparts'. If cybernetics is one incarnation of a logic of ontology, it should not be understood, according to Pickering, as an interdiscipline at all.

Many accounts of interdisciplinarity focus on the conduct of research, or on relations between research and the arena of its application. Rather than take these as her starting point, Monica Greco places at the centre of her analysis of the interdisciplinary field of medical humanities its gathering around a 'sense of a "mission" whose practical expression is primarily pedagogical'. Her contribution foregrounds a theme of this book pursued also in the chapter that follows. It is the role of pedagogical initiatives in catalyzing and consolidating interdisciplinarity through the formation of interdisciplinary subjects. In part, Greco's interest is in charting how this novel 'pedagogical agenda… aims to be effective at a capillary level'. But in addition, in a particularly acute exploration of how the logic of ontology 'blurs into' the logic of accountability, her critical insight is that an ontological logic 'is apparent in the pedagogical intention that lies at the core of medical humanities. Contrary to the expectation that an ontological commitment should refer to the nature of the medical *object* – leaving the subject of knowledge un-problematised – this logic is addressed in the first instance to fostering processes of "aesthetic and ethical self-forming"'. The intention is to produce 'doctors as different kinds of *subjects*… reflexive practitioners educated in the dangers of "misplaced concreteness" (Whitehead 1926: 64) and in the creative use of their imagination'. Certainly, the field realizes the long-standing contention that medicine must include 'an irreducible element of "art"'. Yet at the same time, by highlighting the 'multiple dimensions of subjectivity in medicine' as well as the 'uncertainty and indeterminacy of clinical situations', medical humanities also shows its commitment to a different understanding of the object of medical knowledge.

Overall, Greco suggests, medical humanities arose from a problematisation of the assumption that the mechanistic, reductive 'scientific approach currently employed in the context of medicine is adequate to its purpose'. In developing her case, Greco's chapter exemplifies the method of genealogy advocated in this introduction as a means of charting the moments and types of critique, difference or détournement, as well as the continuities, that signal an agonistic-antagonistic interdisciplinarity, which can in turn be associated – as it is in this case - with a logic of ontology. She traces through the appearance in recent decades of new programmes and institutions as well as changes to key journals the emergence of medical humanities from its several progenitors, notably the opening up of medical ethics and bioethics beyond traditional moral philosophy to such techniques as narrative ethics. Greco stresses both the heterogeneity of the emergent interdiscipline and its problem of individuation, of becoming more than just 'parasitic upon medical education'. Arguing against those who are sceptical about the significance of medical humanities, she insists that such views 'overlook how [its] pedagogical intention... not only does point to an ontological commitment, but also transforms how we might understand and what we might expect as the expression of such a commitment'. In this way she offers a compelling portrait of how medical humanities enacts a logic of ontology, while criticising the 'anti-political' (Barry 2001) effects of reducing the field merely to accountability or public relations.

While Greco touches on the importance of the arts in medical pedagogy, in the final chapter Born and Barry examine another interdisciplinary borderland between the arts and humanities, on the one hand, and the natural sciences, on the other: the emergent field of art-science. Their account draws on ethnographic research on practitioners and initiatives in the USA, UK and Australia, including an experimental pedagogical programme. Two themes run through the chapter. Of all the chapters in the volume it develops at greatest length, in a way comparable to Greco's, an account of the logic of ontology as it can be manifest in art-science and its interdisciplinary pedagogy and as it is entangled with the logics of innovation and accountability. The second theme concerns the distinctive public-making propensities of interdisciplinarity, highlighting through the example of art-science alternative ways in which publics may be assembled. At the outset of the chapter Born and Barry draw out the heterogeneity of art-science through its multiple genealogies and their mutual interference. In particular, the authors trace two broad genealogies subtending the field: one stemming from the growing concern in the scientific community from the mid 1980s with the 'public understanding of science', the other from the diverse movements spawned from the late 1960s by conceptual art. If the former trajectory led by the 1990s to a spate of art-science funding programs in which art was enrolled to enhance the public communication of science, the latter disturbed such 'aestheticising' rationales by mobilizing an alternative history, one that problematized art's entanglement with

science and technology. At the heart of the chapter is an ethnographic analysis of one contemporary manifestation of the latter trajectory: the Arts, Computation and Engineering (ACE) Masters program at UC Irvine. ACE was devoted to cultivating interdisciplinary subjects through a training that encompassed not only aspects of the arts, computation and engineering but their articulation with a range of critical theories. The program foresaw a generation possessed of a growing intimacy with these disciplines, equipped to develop rich 'interlanguages' (Galison 1997) between them, and endowed with a reflexive sense of the epistemological and ontological implications of this project: subjects empowered to negotiate a transition to a novel, potentially inventive ontological space. Through the case of an art-science work, PigeonBlog, by the ACE faculty member Beatriz da Costa, the third part of the chapter expounds the concept of a public experiment. Drawing on Barbara Cassin's distinction between two rhetorical forms, Born and Barry point to the difference between an interdisciplinary practice of public understanding and one of public experiment, as exemplified by Pigeon Blog. 'Public experiments', they argue, 'do not so much present existing scientific knowledge to the public as forge relations between new knowledge, things, locations and persons that did not exist before - in this way producing truth, public, and their relation at the same time'. In an epilogue, the authors anatomise the difficulties of legitimizing as interdisciplinary an entity as ACE. They chart forces leading to the recent closure of the ACE program, notably the 'ricochet effect' embodied in contradictory values and structural processes bearing both on the program and on its individual faculty that caused chronic problems of evaluation. Despite favourable institutional conditions signaled by a university-wide commitment to interdisciplinarity that enabled the experimental ACE program briefly to flourish, within a few years - in this increasingly neo-liberal public university - those conditions were eclipsed.

Conclusions

The case of art-science encapsulates four key themes running through this collection. The first centers on the relation between interdisciplinarity and the generation of novel objects and practices that are irreducible to their antecedent conditions and disciplinary progenitors. Andrew Pickering's account of the wild anti-discipline of cybernetics, which has drawn inspiration throughout its history from the creation of experimental models, Lucy Suchman's depiction of the potentially inventive collaborative and participatory practices of ethnography in the IT industry, Sarah Whatmore's analysis of the vital potential of competency groups, and Monica Greco's excavation of the subtle and evolving ontological project of medical humanities: all draw attention to the inventiveness of specific forms of interdisciplinarity and their relation to the logic of ontology. In all of these cases, moreover, interdisciplinary practices address the problem of how to reconfigure the relations

between the natural and social sciences, albeit in distinctive ways. A second theme of the book concerns the variant, often unstable and sometimes surprising ecologies within which interdisciplinarity is cultivated. The chapters show how the historical and institutional conditions within which interdisciplinary initiatives are implanted make a difference. They indicate, as we have remarked, how such initiatives can fail to take root or grow even when research policies and funding are supportive; while also suggesting that initiatives that emerge from the 'bottom up' or that are fomented in the academic margins may be especially fertile, resilient and long-lasting – perhaps fuelled by counter-hegemonic energies. A third, related theme arising from the chapters concerns the chronic difficulty posed by the evaluation of interdisciplinarity. This problem lies at the heart of Strathern and Rockhill's analysis of the marginalization of 'social' research at the Cambridge Genetics Knowledge Park; it is recapitulated in Weszkalnys and Barry's account of interdisciplinary environmental research, and Born and Barry's depiction of experimental art-science in the ACE program. In each of these instances interdisciplinarity has a fragile existence due in part to tensions stemming from the submission of interdisciplinary practices to disciplinary evaluation. If interdisciplinarity is sustained, it is often only in very particular and temporary ecological niches, niches that may dissolve under various pressures - of legitimation, or of perceived lack of economic or cultural value or policy relevance. A fourth seam running through the collection is the critical importance of pedagogy, highlighted in the chapters by Schaffer, Greco, and Born and Barry. Auspicious interdisciplinarity, as we have seen, is associated not only with the constitution of new objects, but with the cultivation of interdisciplinary subjectivities and skills – sometimes as its primary orientation.

At the start of this introduction we contrasted our approach with the analysis of the transition to Mode-2 knowledge production developed by Nowotny et al. Nowotny and her collaborators emphasize the correlations between changes in knowledge production, on the one hand, and broader societal changes, on the other. But if the approach advocated in this book differs from the externalist account of scientific change offered by Nowotny et al, it differs also from the internalism propounded by other influential writers. Exemplary in this regard is Andrew Abbott's *Chaos of Disciplines* (2001) which, with reference to the social sciences, portrays interdisciplinarity as a recurrent feature of an essentially disciplinary academic system that is subject to cycles of disciplinary division and subdivision, producing a fractal effect. Abbott dwells in particular on the mutating relations between history and sociology and the reasons why, over a period of time, they have never led to a synthesis of the two disciplines (Abbott 2001: 119). His analysis of interactions between history and sociology is not intended to provide a general model of interdisciplinarity. For he goes on to argue that 'interdisciplinarism' in the social sciences has largely been driven by the

appearance of problems that 'have their own life cycle' (ibid.: 134); and it is the proliferation of such problems that, in his view, generates short-lived interdisciplinary fragments. In these circumstances, he argues, two obstacles prevent what might be called the chaotic proliferation of such interdisciplinary fragments. One is the enduring structure of the academic labour market and the resilient departmental organisation of undergraduate programs in the United States. The other obstacle is that 'a university organized around problems of investigation would be hopelessly balkanized', and therefore unmanageable (ibid.: 135). Moreover, in contrast to interdisciplines, he contends, disciplines have the virtue that they generate 'problem-portable knowledge' (ibid.). Thus, according to Abbott, 'a long historical process has given rise to a more or less steady, institutionalised social structure in American academia: a structure of flexibly stable disciplines, surrounded by a perpetual hazy buzz of interdisciplinarity' (ibid.: 136).

In many ways Abbott's account of interdisciplinarity is a mirror image of that given in *Rethinking Science*. Where Nowotny et al. understand the growth of transdisciplinary research as bound up with wider social and economic changes, Abbott views the disciplinarity-interdisciplinarity couplet as a perennial product of the internal organisation of the American university system. Nowotny et al's sense of the systemic relations between changes in society, economy and politics and transitions in the mode of production of knowledge is in marked contrast to Abbott's preoccupation with the internal structure and reward system of the American disciplines;[43] just as, in an irony that would not be lost on Abbott, Nowotny et al.'s emphasis on discontinuity in the history of the institutions of knowledge production contrasts strikingly with Abbott's stress on cyclical continuity.

In pointing to the existence in the present conjuncture of three modes and three logics of interdisciplinarity, the framework outlined in this introduction and embodied in some of the chapters in this collection departs from the models provided both by Abbott and by Nowotny et al.. On the one hand, this framework does not ignore the need to take account of dynamics internal to the emergence of specific interdisciplinary fields, by tracing their field-specific (and sometimes multiple) genealogies, the irreducible departures and novel directions augured by the agonistic-antagonistic mode of interdisciplinarity, and the problematisation that often marks particular interdisciplinary turns. At the same time, the contributions to this book indicate the manner in which interdisciplinarity has emerged in varied institutional and political conditions, some of which differ considerably from the singular ecology of the American university system. On the other hand, rather than trace the co-evolution of two entities, science and society, by drawing attention to the logics of accountability, innovation and ontology the framework developed here highlights three prevalent and unlike, if entangled, ways in which the 'social' is mediated by practices of

interdisciplinarity; while a number of chapters also detail the complex nexus of circumstances bearing on the growth and demise of heterogeneous interdisciplinary assemblages.

In this way the framework advanced in this volume also offers a different account of the temporalities of interdisciplinarity than that provided both by Abbott, with his portrayal of a dominant disciplinarity that cyclically begets but then reincorporates its interdisciplinary splinters, and by Nowotny et al., with their periodization in which Mode-2 knowledge and society, have progressively superseded their Mode-1 counterparts. The chapters in this book offer cogent analyses of more diverse temporal processes, encompassing various speeds, gradients and curves of the waxing and waning of interdisciplinary institutions and initiatives in particular conditions (Barry 2010, Born 2010). Remarkable in this regard are three examples of what appeared at the outset in each case to be sustainable interdisciplinary programmes with extraordinary promise – the early period of ethnographic research at Xerox PARC, art-science in the ACE program at UC Irvine, and the ELSI unit in the Cambridge Genetics Knowledge Park – of which, arguably, the first two were wound up after a short period despite having 'delivered' considerable successes in their own terms, while the third was effectively stillborn. However, equally strikingly, the collection includes important examples of new interdisciplines (and possibly disciplines) that, *contra* Abbott, have gathered pace cumulatively over long periods of time and show no immediate signs of dissolution. Particularly salient in this regard is the establishment of both science and technology studies and medical humanities as recognized interdisciplinary academic fields with their own teaching programmes, journals and conferences, as well as the proliferation of the various interdisciplines that compose environmental research, and the enduring inter-/anti-disciplinarity and extra-academic history of cybernetics.

In this introduction, while recognizing the importance of their intervention, we have been critical of some of the claims made by Nowotny et al. concerning the emergence of Mode-2 knowledge production. But we are equally sceptical about Abbott's general suggestion that the history of interdisciplinarity is a continuous one, and that it can be understood largely as problem-driven. For both accounts – as this collection makes plain - make it difficult to recognize the diversity of the recent animated engagements with interdisciplinarity and transdisciplinarity on the part of funding organisations, research and teaching programmes, scientific labs and artists' workshops, research collaborations and individual practitioners alike. Moreover, instead of assuming that there is an underlying similarity between the strategies and interests guiding different forms of interdisciplinarity, the chapters in this book attest to the heterogeneity that characterizes both disciplines and interdisciplines and the necessity of probing the genealogies of particular

interdisciplinary problematics. Our typology of modes and logics of interdisciplinarity is intended neither to be exhaustive, nor fine-grained, nor ahistorical; rather, it is intended to provide the basis for illuminating the singularity and the particular historicity of the emergence of distinct interdisciplinary formations.

At the heart of this collection is a topic that does not figure at all in Abbott's analysis. This is the question of the reconfiguration of the relations between the natural sciences, the social sciences, and the arts and humanities. Abbott's contention is that 'sociology provides within a single disciplinary compass examples of many of the processes I am discussing at the level of social science in general' (ibid.: 3). He is therefore quite unconcerned with those disciplines and interdisciplines – some with long histories, others burgeoning particularly strongly in recent decades - that traverse the boundaries between the social and natural sciences. Geography and anthropology provide instructive examples, for both disciplines were formed around the idea that it was necessary in principle, and possible in practice, to establish fields that brought together the sciences of the natural and the material, on the one hand, and the social and the cultural, on the other. Despite their multiplicity and their persistent lack of 'integration', the continuing existence of these interdisciplinary disciplines is a reminder that a concern with the interaction between the social and natural sciences, although it has taken varied forms, is far from new (Livingstone 1992, Ingold 2001, Castree 2005, Segal and Yanagisako 2005). A key interest of the topic of interdisciplinarity is therefore that it directs us to consider the diverse ways in which the reconfiguration of the relations between the social and natural sciences is today being posed anew, whether this is manifest in the emergence and evolution of science and technology studies, ELSI research, ethnography in the IT industry, environmental research, medical humanities, or art-science, or in the latest flowering of the recurrent interest in materiality and experimentation across geography, anthropology and sociology (Fraser 2002, Latour and Weibel 2005, Henare et al 2006, Küchler 2008, Bennett and Joyce 2010, Braun and Whatmore 2010, Hicks and Beaudry 2010, Thrift 2011, Harvey et al 2012). While research policy-makers tend to emphasise the link between interdisciplinarity and innovation or accountability, a significant proportion of these interdisciplinary developments, as we have insisted, are oriented as much towards variants of the logic of ontology.

Finally, we want to raise the prospect of a re-evaluation of interdisciplinarity. It should be plain that we are emphatically not enthusiasts for interdisciplinarity *per se*; nor do we mean to suggest that there is a necessary or privileged affinity between interdisciplinary research and invention. As we have indicated, any analysis of the inventiveness of interdisciplinarity must attend to the path-dependence of specific interdisciplines, their genealogies and multiplicity, and in this light the extent to which

any particular interdisciplinary practice can be judged inventive (Barry and Born 2007; Born 2010b: 242-246). At the same time, it may be tempting to posit a straightforward equation between the disruption of disciplinary boundaries and the erosion of autonomy. The links made between interdisciplinarity and the logics of accountability and innovation certainly encourage that belief. In these circumstances it is perhaps not surprising that, in reaction against the drive in science and research policy to expand interdisciplinarity, some scholars and authorities seek to defend disciplinary purity as a way of protecting a threatened academic autonomy. But, as we stated at the outset, disciplines are not infallibly autonomous or inventive: they have unproductive phases and may exhibit inertial and anti-inventive dynamics. In this introduction we refer to autonomy not in order to criticize this ideal, but to point to the existence of forms of *inter*disciplinary autonomy and rigorous interdisciplinarity that can lead to the production of new objects, subjects and relations of knowledge, practices that are irreducible both to previous disciplinary formations and to accountability and innovation.

References

Abbott, A. (2001) *Chaos of Disciplines*, Chicago: Chicago University Press.

Althusser, L. (1990) 'Philosophy and the Spontaneous Philosophy of the Scientists (1967)' in *Philosophy and the Spontaneous Philosophy of the Scientists and other essays* (pp.69-165), London: Verso.

Amin, A. and Cohendet, P. (2004) *Architectures of Knowledge: firms, capabilities and communities*, Oxford: Oxford University Press.

Amariglio, J., Resnick, S. and Wolff, R.D. (1993) 'Division and difference in the "discipline" of economics', in E. Messer-Davidow, D. Shumway and D. Sylvan (eds) *Knowledges: Historical and Critical Studies in Disciplinarity* (pp. 150-184), Charlottesville and London: University of Virginia Press.

Anderson, K. and B. Braun (eds.) *Environment,* Aldershot: Ashgate.

Apostel, L. Berger, G. Briggs, A. and Michaud, G. (eds.) (1972) *Interdisciplinarity: Problems of Teaching and Research in Universities*, Paris: Organisation for Economic Cooperation and Development.

Anderson, K and Nafus, D. (2006) 'The Real Problem: Rhetorics of Knowing in Corporate Ethnographic Research', EPIC 2006 conference proceedings, American Anthropological Association.

Arends, B. and Thakara, D. (eds.) (2003), *Experiment: Conversations in Art and Science*, London: The Wellcome Trust.

Baerwald, T. (2010) 'Prospects for Geography as an Interdisciplinary Discipline', *Annals of the Association of American Geographers,* 100 (3): 493-501.

Barry, A. (2001) *Political Machines: Governing a Technological Society*, London: Athlone.

Barry, A. (2002) 'The anti-political economy', *Economy and Society*, 31 (2): 268-284.

Barry, A. (2004) 'Ethical Capitalism' in Larner, W. and Walters, W. (eds.) *Global Governmentality* (pp.195-221), London: Routledge.

Barry, A. (2005) 'Pharmaceutical Matters: the invention of informed materials', *Theory, Culture and Society*, 22: 51-69.

Barry, A. (2006) 'Technological Zones', *European Journal of Social Theory*, 9: 239-253.

Barry, A. (2007) 'Political Invention', in Asdal, K., Brenna, B. and Moser, I. (eds.) *Technoscience: the Politics of Interventions* (pp. 287-308), Oslo: Unipub.

Barry, A. (2010) 'Tarde's method: between statistics and experimentation', in Candea, M. (ed.) *The Social after Tarde: Debates and Assessments* (pp.177-190), London: Routledge.

Barry, A. (2012) 'Political Situations: Knowledge Controversies in Transnational Governance', *Critical Policy Studies*, 6 (3): XXX-XXX

Barry, A. and Born, G. (2007) 'Interdisciplinary Research and Evaluation', unpublished ms. Prepared for the ESRC, 5pp.

Barry, A and Thrift, N. (2007) 'Gabriel Tarde: Imitation, Invention and Economy', *Economy and Society*, 36(4): 509-525.

Beck, U. (1992) *The Risk Society: Towards a New Modernity*, London: Sage.

Bell, G., Brooke, T. and Churchill, E. (2003), 'Intimate (ubiquitous) computing', Proc UbiComp workshop, http://www.intimateornot.ocm/papers/Intimate_computing_CFP82.pdf

Bennett J. (2004) 'The force of things. Steps to an ecology of matter', *Political Theory*, 32/3: 347-372.

Bennett, T. and Joyce, P. (2010) *Material Powers: Cultural Studies, History and the Material Turn*, London: Routledge.

Bensaude-Vincent, B. and Stengers, I. (1996) *The History of Chemistry*, Cambridge, MA: Harvard University Press.

Berkhout, F., Leach, M. and Scoones, I. (eds.) (2005) *Negotiating Environmental Change: New Perspectives from Social Science*, Cheltenham: Edward Elgar.

Boltanski, L and Thévenot (2006) *On Justification: Economies of Worth*, Princeton: Princeton UP.

Born, G. (1995) *Rationalising Culture: IRCAM, Boulez and the Institutionalisation of the Musical Avant-Garde*, Berkeley, CA: University of California Press.

Born, G. (2005a) *Uncertain Vision: Birt, Dyke and the Reinvention of the BBC*, London: Vintage.

Born, G. (2005b) 'On musical mediation: Ontology, technology and creativity', *Twentieth Century Music*, 2, 1: 7-36.

Born, G. (2010a) 'The social and the aesthetic: For a post-Bourdieuian theory of cultural production', *Cultural Sociology*, 4 (2): 1-38.

Born, G. (2010b) 'On Tardean Relations: Temporality and ethnography', in Candea, M. (ed.), *The Social After Gabriel Tarde: Debates and Assessments* (pp. 232-249). London: Routledge.

Born, G. (2011) 'Complexity as method? Experimenting with ethnographic agonism in research on digital musics', paper presented to the American Anthropological Association conference, Montreal, November.

Born, G. and A. Barry (2010) 'Art-science: From public understanding to public experiment', *Journal of Cultural Economy*, 3, (1): 107-123.

Born, G. and Weszkalnys, G. (2007) 'Irreducible heterogeneities and interdisciplines in-formation, or the possibility of art-science', paper presented to the colloquium, 'Interdisciplinarity and Society', St Catherine's College, Oxford, February 2007.

Bourdieu, P. (1975) 'The Specificity of the Scientific Field and the Social Conditions of the Progress of Reason', *Social Science Information,* 14 (6): 19-47.

Bowker, G. (1993) 'How to be Universal: Some Cybernetic Strategies, 1943-70', *Social Studies of Science* 23: 107-27.

Bowker, G., Star, SL., Turner, W. and Gasser, L. (eds.) (1997) *Social Science, Technical Systems and Cooperative Work*, Mawah, NJ: Lawrence Erlbaum.

Bracken, L. and Oughton, E. (2009) 'Interdisciplinarity within and beyond geography: introduction to special section', *Area*, 41 (4): 371-374.

Braun, B. and Whatmore, S. (eds.) (2010) *Political Matter: Technoscience, Democracy, and Public Life*, Minneapolis: Minnesota University Press.

Briggs, A. and Michaud, G. (1972) 'Problems and Solutions', in Apostel, L. et al (eds.), pp.185-280.

Bruce, A., Lyall, C., Tait, J. and Williams, R. (2004), 'Interdisciplinary integration in Europe: The case of the Fifth Framework Program', *Futures*, 36 (4): 457-70.

Buchmann, S. (2005) 'From systems-oriented art to biopolitical art practice', paper presented to the 'Open Systems: Rethinking Art c. 1970' conference, Tate Modern, September. Last accessed February 2007 at:
http://publication.nodel.org/From-Systems-Oriented-Art-to-Biopolitical-Art-Practice

Callon, M. (1998) (eds.) *The Laws of the Market*, Oxford: Basil Blackwell.

Callon, M., Lascoumes, P. and Barthe, Y. (2001) *Agir dans un monde incertain: essai sur la democratie technique*, Paris: Seuil.

Callon, M., Millo, Y. and Muniesa, F. (eds.) (2007) *Market Devices*, Oxford: Basil Blackwell.

Cassin, B. (2005) 'Managing Evidence' in Latour, B. and Weibel, P. (eds.) *Making Things Public: Atmospheres of Democracy* (pp.858-864), Cambridge, MA: MIT press.

Castree, N. (2005) *Nature*, London: Routledge.

Cefkin, M. (ed.) (2009) *Ethnography and the Corporate Encounter: Reflections on Research In and Of Corporations*, New York and Oxford: Berghahn.

Century, M. (1999) *Pathways to Innovation in Digital Culture*, Report for the Rockefeller Foundation.

Clifford, J. (2005) 'Rearticulating Anthropology', in D. Segal and S. Yanagisako (eds.) *Unwrapping the Sacred Bundle: Reflections on the Disciplining of Anthropology* (pp.24-48), Durham, NC: Duke University Press.

Clifford, J. and Marcus, G. (eds.) (1986) *Writing Culture: the Poetics and Politics of Ethnography*, Berkeley: California University Press.

Collini, S. (1994) 'Escape from DWEMsville', *Times Literary Supplement*, 27th May.

Connolly, W. (2011) *A World of Becoming*, Durham, NC: Duke University Press.

Da Costa, B. and Philip, K. (eds.) (2008) *Tactical Biopolitics: Art, Activism, and Technoscience*, Cambridge, MA. And London: The MIT Press.

Davies, G. (2006) 'Mapping deliberation: calculation, articulation and intervention in the politics of organ transplantation', *Economy and Society*, 35 (2): 232-258.

Corbett, J.P. (1964) 'Opening the Mind' in Daiches, D (ed.) *The Idea of New University: an Experiment in Sussex* (pp.22-39), London: Andre Deutsch.

Corris, M. (2004), *Conceptual Art: Theory, Myth and Practice*, Cambridge: Cambridge University Press.

Corris, M. (2005) 'Recoding of information: Knowledge and technology', paper presented to the 'Open Systems: Rethinking Art c. 1970' conference, Tate Modern, September. Accessed February 2007 at http://publication.nodel.org/Recoding-of-Information

Council of Science and Technology (2001) *Imagination and Understanding: A Report on the Arts and Humanities in Relation to Science and Technology*
http://www.bis.gov.uk/assets/bispartners/cst/docs/files/whats-new/01-1051-imagination-understanding.pdf

Da Costa, B. and Philip, K. (eds.) (2008) *Tactical Biopolitics: Art, Activism, and Technoscience*, Cambridge MA: MIT press.

Daston, L (2000), 'The Coming into Being of Scientific Objects', in Daston, L. (ed.) *Biographies of Scientific Objects* (pp.1-14), Chicago: Chicago University Press.

Davies, G. (2006) 'Mapping deliberation: calculation, articulation and intervention in the politics of organ transplantation', *Economy and Society*, 35, 2: 232-258.

Deleuze, G. (1988) *Foucault*, London: Athlone.

Demeritt, D. (2001) 'The construction of global warming and the politics of science', *Annals of the Association of American Geographers*, 91 (2): 307-337.

D'Hooge, H. (2005) 'User-centred research fuels technology innovation at Intel', Technology Intel Magazine, April http://www.intel.com/technology/magazine/research/user-centered-innovation-0405.pdf

Doherty, C. (2004), *Contemporary Art from Studio to Situation*, London: Black Dog.

Doubleday, R. (2007) 'Organizing accountability: Co-production of technoscientific and social worlds in a nanoscience laboratory', *Area*, 39 (2): 166-175.

Dourish, P. (2001) *Where the action is: foundations of embodied interaction*, Cambridge, MA: MIT press.

Dourish, P. (2006) 'Implications for Design', CHI, Montréal, April 22-27 2006, http://www.ics.uci.edu/~jpd/classes/readings/Dourish-Implications.pdf

Dourish, P. and Bell. G. (2011) *Designing a digital future: mess and mythology in ubiquitous computing*, Cambridge, MA: MIT press.

Edgerton, D. (2006) *Warfare State: Britain, 1920-1970*, Cambridge: Cambridge University Press.

Edwards, P. (2001) 'Representing the global atmosphere: computer models, data, and knowledge about climate change' in C Miller and P Edwards, *Changing the Atmosphere: Expert Knowledge and Environmental Governance* (pp.31-66), Cambridge, MA: MIT press.

Epstein, S. (1996) *Impure Science: AIDS, activism and the politics of knowledge*, Berkeley: California University Press.

Eriksen, T. (2007) 'Tunnel Visions', *Social Anthropology*, 15 (2): 237–243.

Feltham, O. and Clemens, J. (2003), 'Introduction' to Badiou, *Infinite Thought* (pp.1-38), London: Continuum.

Ferran, B. (2006), 'Creating a program of support for art and science collaborations', *Leonardo*, 30 (5): 442-6.

Foucault, M. (1972) *The Archaeology of Knowledge*, London: Tavistock.

Foucault, M. (1994) 'Polemics, Politics, and Problematizations', in *Ethics: the Essential Works, volume 1* (pp.111-120), London: Penguin.

Foucault, M. (2001) 'Le souci de la vérité' in *Dits et Écrits II, 1976-1988* (pp.1487-1497), Paris : Gallimard.

Fraser, M. (2002) 'What is the matter of feminist criticism ?', *Economy and Society*, 31 (4): 606-625.

Fraser, M., S. Kember and C. Lury (eds.) (2006) *Inventive Life: Approaches to the New Vitalism*, London: Sage.

Fuller, S. (1993) *Philosophy, Rhetoric and the End of Knowledge*, Madison: University of Wisconsin Press.

Fuller, S. (2002) *Social Epistemology*, Bloomington: Indiana University Press.

Fuller, S. (nd) **'**Interdisciplinarity: The loss of the heroic vision in the marketplace of ideas', accessed March 2007 at: http://www.interdisciplines.org/interdisciplinarity/papers/3**.**

Galison, P. and Stump, D. (eds) (1996) *The Disunity of Science: Boundaries, Contexts, and Power*, Stanford: Stanford University Press.

Galison, P (1996a) 'Introduction: the context of disunity' in Galison and Stump (eds.), pp.1-36.

Galison, P (1996b) 'Context and Constraints' in Buchwald, J. (ed) *Scientific Practice*, Chicago: Chicago University Press, pp.13-41.

Galison, P (1997), *Image and Logic: A Material Culture of Microphysics*, Chicago Ill.: University of Chicago Press.

Gaver, W., Dunne, A. and Pacenti, E. (1999) 'Cultural Probes', *Interactions*, vi (1): 21-29.

Geertz, C. (1988) 'I-witnessing: Malinowski's children', chapter 4 in *Works and Lives: The Anthropologist as Author*, Cambridge: Polity.

Gibbons, M., Limoges, C., Nowotny, M.,Schwartzman,S., Scott, P. and Trow, M. (1994) *The New Production of Knowledge*, London: Sage.

Goldstein, J. (1984) 'Foucault among the sociologists: The "disciplines" and the history of the professions', *History and Theory*, 23 (2): 170-192.

Guattari, F. (1992) 'Félix Guattari et l'Art Contemporain', Interview with Olivier Zahm, *Chimères*, accessed May 2012 at http://www.revue-chimeres.fr/drupal_chimeres/files/23chi04.pdf

Hacking, I. (nd) 'The complacent disciplinarian', accessed March 2007 at: http://www.interdisciplines.org/interdisciplinarity/papers/7.

Harkin. M. (2010): Uncommon Ground: Holism and the Future of Anthropology, *Reviews in Anthropology*, 39 (1): 25-45.

Harper, R. (2003) 'Introduction' to *Inside the Smart Home*, London: Springer.

Harrison, S. et al (2004) 'Thinking across the divide: perspectives on the conservations between physical and human geography', *Area* 36: 435-442.

Hart, D. and Victor, D. (1993) 'Scientific elites and the making of US policy for climate change research 1957-74', *Social Studies of Science*, 23: 643-80.

Harvey, P., Casella, E., Evans, G., Knox, H., MacLean, C., Silva, E., Thoburn, N., Woodward, K. (2012) *Objects and Materials: a Routledge Companion*, London: Routledge.

Henare, A., Holbraad, M. and Wastell, S. (2006) *Thinking Through Things: Theorising Artefacts Ethnographically*, London: Routledge.

Hicks, D. and Beaudry, M. (eds.) (2010) *The Oxford Handbook on Material Culture*, Oxford: Oxford University Press.

HM Treasury (2006) *Science and Innovation investment framework 2004-2014: next steps*, London: HMSO.

http://www.interdisciplines.org/interdisciplinarity

Hinchliffe, S (2007) *Geographies of Nature: Societies, Environments, Ecologies*, London: Sage.

Holmes, D and Marcus, G. (2005) 'Cultures of expertise and the management of globalization: Toward a re-functioning of ethnography', in Ong, A. and Collier, S. (eds) *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems* (pp.235-252), Malden, MA: Blackwell.

Hulme, M. and Turnpenny, J. (2004) 'Understanding and managing climate change: the UK experience', *The Geographical Journal*, 170: 105-115.

Hulme, M. (2009) *Why we disagree about climate change*, Cambridge: Cambridge University Press.

Huutoniemi, K, JT Klein, H Bruun, J Hukkinen (2010) 'Analyzing Interdisciplinarity: Typology and Indicators', *Research Policy*, 39 (1): 79-88.

Ingold, T. (2001) 'From complementarity to obviation: on dissolving the boundaries between social and biological anthropology, archaeology and psychology', in Oyama, S., Griffiths, P. and Gray, R. (eds.), *Cycles of contingency: developmental systems and evolution* (pp. 255-279), Cambridge, MA: MIT Press.

Irwin, A. (1995) *Citizen Science*, London: Routledge.

Irwin, A. and Wynne, B. (eds) (1996) *Misunderstanding Science*, Cambridge: Cambridge University Press.

Jasanoff, S. and Wynne, B. (1998) 'Science and decisionmaking' in Rayner and Malone (eds), pp.1-87.

Jasanoff, S. (ed.) (2004) *States of Knowledge: the co-production of science and social order*, New York: Routledge.

Jones, S. (2006) 'From Ancestors to Herbs: Innovation according to the 'Protestant Re-formation' of African Medicine', Ethnographic Praxis in Industry Conference (EPIC), pp. 177-197.

Klein, JT (2004) 'Prospects for Transdisciplinarity', *Futures*, 36: 515-526.

Klein, JT (2010) 'A Taxonomy of Interdisciplinarity', in Frodeman, R et al (eds.), pp.15-30.

Knorr-Cetina, K. (1999) *Epistemic Cultures: how the sciences make knowledge,* Cambridge, MA: Harvard University Press.

Khlinovskaya Rockhill, E. (2007) 'On interdisciplinarity and models of knowledge production'. *Social Analysis,* 51 (3): 121–147.

Küchler, S. (2008) 'Technological Materiality: Beyond the Dualist Paradigm', *Theory, Culture and Society*, 25(1):101-120.

Laclau, E. and Mouffe, C. (1985) *Hegemony and Socialist Strategy*, London: Verso

Lash, S., Swersznski, B. and Wynne, B. (eds.) (1996) *Risk, Environment and Modernity: Towards a New Ecology*, London: Sage.

Lamont, M. and Molnar, V. (2002) 'The study of boundaries in the social sciences', *Annual Review of Sociology*, 28: 167-195.

Latour, B. (1993) *We Have Never Been Modern*, Hemel Hempstead: Harvester Wheatsheaf

Latour, B. (1999) *Pandora's Hope: Essays on the Reality of Science Studies*, Cambridge, MA: Harvard University Press.

Latour, B. and Weibel, P. (eds) (2002) *Iconoclash: Beyond the Image Wars in Science, Religion and Art*, Cambridge, Mass.: MIT press.

Latour, B. and Weibel, P. (eds) (2005) *Making things Public: Atmospheres of Democracy*, Cambridge, MA: MIT press.

Laurent, B. (2011) *Democracy on Trial: Assembling Nanotechnology and its Problems*, Doctorat ParisTech, l'École nationale supérieure des Mines de Paris.

Lawrence, R. and Després, C. (2004), 'Introduction: Futures of transdisciplinarity', *Futures*, 36 (4): 397-406.

Leach, M., Scoones, I. and Wynne, B. (eds) (2005) *Science and Citizens: Globalisation and the Challenge of Engagement*, London: Zed Books.

Leroy, P. (1995) 'Environmental science as a vocation', Inaugural lecture at the University of Nijmegen, 9th June.

Lichnerowicz, A. (1972) 'Mathematic and Transdisciplinarity', in Apostel (ed.)

Livingstone, D. (1992) *The Geographical Tradition*, Oxford: Basil Blackwell.

Livingstone, D. (2003) *Putting Science in its Place*, Chicago: Chicago University Press.

Lyall, C., Bruce, A., Tait, J. and Meagher, L. (2011) *Interdisciplinary Research Journeys: Practical Strategies for Capturing Creativity*, London: Bloomsbury Academic.

Mackenzie, D., Muniesa, F. and Siu, L. (eds) (2007) *Do Economists Make Markets: On the Performativity of Economics*, Princeton, NJ: Princeton University Press.

Maniglier, P. (1997) *De la position des problèmes*, Diplôme d'Etudes Avancées, Université Paris X Nanterre / École Normale Supérieure.

Maniglier, P. (2012) 'Problem-Sharing : the Role of Problems in Transdisciplinarity from the Standpoint of the French Epistemological Tradition, paper presented at the workshop on *Transdisciplinarity and the Humanities*, Kingston University, January.

Mansilla V. B. (2006) 'Symptoms of quality: Assessing expert interdisciplinary work at the frontier - an empirical exploration', *Research Evaluation*, 15 (1): 17-29.

Mansilla, V. B. (nd) 'Interdisciplinary work at the frontier: An empirical examination of expert interdisciplinary epistemologies'. Cambridge MA: Interdisciplinary Studies Project, Harvard Graduate School of Education.

Mansilla, V.B. and Gardner, H. (nd) 'Assessing interdisciplinary work at the frontier: An empirical exploration of "symptoms of quality"', last accessed March 2007 at: http://www.interdisciplines.org/interdisciplinarity/papers/6.

Marcus, G. (2002) 'Intimate Strangers: The Dynamics of (Non) Relationship between the Natural and Human Sciences in the Contemporary U.S. University, *Anthropological Quarterly*, 75 (3): 519-526.

Miller, C. (2004) 'Climate Change and the making of a global political order', in Jasanoff (ed), pp.46-66.

Miller, D. and Slater, D. (2000) *The Internet: an Ethnographic approach*, Oxford: Berg.

Mirowski, P. and Mirjam Sent, E. (eds) (2002) *Science Bought and Sold: Essays in the Economics of Science*, Chicago: Chicago University Press.

Mitchell, T. (2002) *The Rule of Experts: Egypt, Techno-Politics, Modernity*, Berkeley: University of California Press.

Mol, A. (2002) *The Body Multiple: Ontology in Medical Practice*, Durham, NC: Duke University Press.

Morin, E (1997) 'Réforme de pensée, transdisciplinarité, réforme de l'Université', Communication au Congrès International, *Quelle Université pour demain ? Vers une évolution transdisciplinaire de l'Université* , Locarno, Switzerland, 30 April – 2 May 1997. Accessed May 2012 at : http://basarab.nicolescu.perso.sfr.fr/ciret/bulletin/b12/b12c1.htm

Nafus, D. and Anderson, K. (2009) 'Writing on Walls: the Materiality of Social Memory in Corporate Research', in Cefkin, K. (ed.), pp.137-157.

National Academy of Sciences (2004), *Facilitating Interdisciplinary Research*, Washington DC: National Academies Press.

Newman, M. (2002) 'Conceptual art from the 1960s to the 1990s: an unfinished project?', in P Osborne, *Conceptual Art*, London: Phaidon.

Nicolescu, B. (2008) 'In Vitro and In Vivo Knowledge – Methodology of Transdisciplinarity' in B. Nicolescu (ed) *Transdisciplinarity: Theory and Practice*, Cresskill, NJ: Hampton Press.

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

Nowotny, H. (2003) 'Science in search of its audience', *Nova Acta Leopoldina* NF 87, 325, 211-5.

Nowotny, H. (2005) 'The Changing Nature of Public Science' in H Nowotny, D Pestre, B Schmidt-Assmann, H. Schulze-Fielitz and H-H Trute (eds) *The Public Nature of Science under Assault: Politics, Markets, Science and the Law*, Berlin: Springer.

Nowotny, H. (nd) 'The Potential of transdisciplinarity', accessed March 2007 at: www.interdisciplines.org/interdisciplinarity/papers/5.

Osborne P. (2002), *Conceptual Art*, London: Phaidon.

Osborne, P. (2011) 'From Structure to Rhizome: Transdisciplinarity in French thought (1)', *Radical Philosophy*, 165, 15-16.

Osborne, T. (2004) 'On mediators: intellectuals and the ideas trade in the knowledge society', *Economy and Society*, 33 (4): 430-447.

Owens, S. (2000) "Engaging the public': information and deliberation in environmental policy' *Environment and Planning A*, 32, 1141-1148

Petts, J., Owens, S.and Bulkeley, H. (2008) 'Crossing Boundaries: Interdisciplinarity in the Context of Urban Environments', *Geoforum*, 39 (2): 593-601.

Pickering, A. (1995a) *The Mangle of Practice: Time, Agency and Science*, Chicago: University of Chicago Press.

Pickering, A. (1995b) 'Cyborg history and the World War II regime', *Perspectives on Science*, 3 (1): 1-48.

Popper, F. (2007) *From Technological to Virtual Art*, Cambridge, MA: MIT press.

Power, M. (ed.) (1996) *Accounting and Science: Natural Inquiry and Commercial Reason*, Cambridge: Cambridge University Press.

Rabeharisoa, V. and Callon, M. (1999) *Le Pouvoir des Malades*, Paris: Les Presses de l'École des Mines.

Rabinow, P. (2005) 'Midst Anthropology's Problems', in Ong, A. and Collier, S. (eds.) *Global Assemblages: Technology, Politics and Ethics as Anthropological Problems* (pp.40-53), Oxford: Blackwell.

Ramadier, T. (2004) 'Transdisciplinarity and its challenges: the case of urban studies', *Futures*, 36 (4): 423-440.

Rancière, J. (2006) 'Thinking between Disciplines: an Aesthetics of Knowledge', *Parrhesia*, 1: 1-12.

Randall, D., Harper, R. and Rouncefield, M. (2005), 'Fieldwork, ethnography and design: a perspective from CSCW', in K Anderson and T Lovejoy *EPIC 2005: Ethnographic Praxis in Industry Conference*, Redmond WA, Seattle, American Anthropological Association, Arlington,, VA, pp.88-99

Rayner S. and Malone, E. (eds) (1998) *Human Choice and Climate Change v1-4*, Columbus, OH: Batelle Press.

Reichle, I. (2009) *Art in the Age of Technoscience: Genetic Engineering, Robotics, and Artificial Life in Contemporary Art*, Vienna: Springer.

Rhoten, D. (2004) 'Interdisciplinary Research: Trend or Transition' *Items and Issues*, 5, 6-12, http://www.ssrc.org/publications/items/items_5.1-2/interdisciplinary_research.pdf

Salvador, T., Bell, G. and Anderson, K. (1999) 'Design Ethnography', *Design Management Journal*, 10 (4): 35-41.

Schaffer, S. (1996) 'Where experiments end: tabletop trials in Victorian astronomy' in J Buchwald (ed.) *Scientific Practice* (pp. 257-299), Chicago: Chicago University Press.

Schaffer S. (2007), 'On disciplines and interdisciplines', paper presented at colloquium on *Interdisciplinarity and Society*, St Catherine's College, Oxford, February 2007

Social Epistemology, 1995 (19, 2) Special issue on boundary rhetorics and the work of interdisciplinarity

Schellnhuber, H J. (1999) '"Earth system" analysis and the second Copernican revolution', *Nature* supplement, 402, 19-23, December 2nd

Segal, D. and Yanagisako, S. (eds.) (2005) *Unwrapping the Sacred Bundle: Reflections on the Disciplining of Anthropology*, Durham, NC: Duke University Press.

Schuler, D. and Namioka, A. (ed) (1993) *Participatory Design: Principles and Practices*, Lawrence Erlbaum

Shackley, S. and Wynne, B. (1985) 'Integrating Knowledges for Climate Change: Pyramids, nets and uncertainties', *Global Environmental Change*, 5 (2): 113-126.

Silverstone, R and E Hirsch (eds.) (1994), *Consuming Technologies*, London: Routledge.

Skrebowski, L (2009), *Systems, Contexts, Relations: An Alternative Genealogy of Conceptual Art*, PhD thesis, Centre for Research in Modern European Philosophy / History of Art and Design, Middlesex University (September)

Snow C.P. (1959) *The Two Cultures*, Cambridge: Cambridge University Press.

Star, SL. and Griesemer, J. (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.

Stirling, A. (2005) 'Opening up or closing down: analysis, participation and power in the social appraisal of technology', in Leach, M., Scoones, I. and Wynne, B. (eds) *Science, Citizenship and Globalisation* (pp.218-231), London: Zed books.

Stengers, I. (1997) *Power and Invention: Situating Science*, Minneapolis: Minnesota University Press.

Stengers, I. (2005) 'The Cosmopolitical Proposal', in Latour, B. and Weibel, P. (eds.), pp. 994-1003.

Strathern, M. (2004a) 'In crisis mode: A comment on interculturality', in *Commons and Borderlands* (pp.1-14), Wantage: Sean Kingston.

Strathern, M. (2004b) 'Accountability across disciplines', in *Commons and Borderlands* (pp.68-86) , Wantage: Sean Kingston.

Strathern, M. (2004c) 'Social property: An interdisciplinary experiment', *PoLAR (Political and Legal Anthropology Review)*, 27: 33-50

Strathern, M. (2006) 'A Community of Critics? Thoughts on New Knowledge', *Journal of the Royal Anthropological Institute*, 12 (1): 191-209.

Strathern, M. (2011) 'An Experiment in Interdisciplinarity: Proposals and Promises', in Camic, C. Gross, N., and Lamont, M. (eds.) *Social Knowledge in the Making* (pp.257-284), Chicago: Chicago University Press.

Suchman, L. (1987) *Plans and situated actions: the problem of human-machine communication*, Cambridge: Cambridge University Press.

Suchman, L. (2000) 'Anthropology as brand: reflections on corporate ethnography' http://www.lancs.ac.uk/fss/sociology/papers/suchman-anthropology-as-brand.pdf

Suchman, L., Blomberg, J. and Trigg, R. (2002) 'Working Artefacts: Ethnomethods of the Prototype', *British Journal of Sociology*, 53 (2): 163-79.

Tait, J. and Lyall, C. (2001) *Investigation into ESRC funded interdisciplinary research*, http://www.supra.ed.ac.uk/Publications/ESRC_report_Interdisiplinary_research.pdf

Tarde, G. (2001) *Les Lois de L'Imitation*, Paris: Les Empêcheurs de Penser en Rond.

Thompson, M and S Rayner (1998) 'Risk and Governance part I: the discourse of climate change' *Government and Opposition*, 33 (2): 139-166.

Thompson, M., Rayner, S. and Ney, S. (1998) 'Risk and Governance part II: policy in a complex and plurally perceived world', *Government and Opposition*, 33: 330-354.

Thrift, N. (2005) *Knowing Capitalism*, London: Sage.

Thrift, N. (2006) 'Re-inventing invention: new tendencies in capitalist commodification', *Economy and Society*, 35 (2): 279-306.

Thrift N. (2011) 'Lifeworld Inc—and what to do about it', *Environment and Planning D: Society and Space*, 29(1): 5 – 26.

Tompkins, E. (2005) *Review of interdisciplinary environmental science centres of excellence*, report to MISTRA, Swedish Foundation for Environmental Research.

Turner, S. (2000) 'What are disciplines? And how is interdisciplinarity different?', in P Weingart and N Stehr, *Practicising Interdisciplinarity* (pp.46-65), Toronto: University of Toronto Press.

Turnpenny, J. and O'Riordan, T. (2007) 'Putting sustainability to work: assisting the East of England region to respond to the challenges of climate change', *Trans Inst Br Geogr* NS 32: 102-105.

UNECE (1998) Convention on Access to Information, Public Participation in Decision-Making and Access to Justice on Environmental Matters, done at Aarhus, 25th June 1998, http://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf

Wallerstein, I. et al (1996) *Open the Social Sciences: Report of the Gulbenkian Commission on the Restructuring of the Social Sciences*, Stanford, CA: Stanford University Press.

Weingart, P. and Stehr, N. (eds.) (2000) *Practicising Interdisciplinarity*, Toronto: University of Toronto Press

Whatmore, S (1999) 'Hybrid Geographies: Rethinking the 'Human' in Human Geography', in Massey, D., Allen, J. and Sarre, P. (eds.) *Human Geography Today* (pp.22-39), Cambridge: Polity.

Whatmore, S. (2009) 'Mapping knowledge controversies: environmental science, democracy and the redistribution of expertise'. *Progress in Human Geography*, 33 (5): 587-599.

Whitehead, A. N. (1920) *The Concept of Nature*, Cambridge: Cambridge University Press.

Whitehead, A.N. (1926) *Science and the Modern World*, Cambridge: Cambridge University Press

Wilson, S. (2002) *Information Arts: Intersections of Art, Science and Technology*, Cambridge MA.: MIT.

Wissenschaftsrat (2000) *Thesen zur künftigen Entwicklung des Wissenschaftssystems in Deutschland*, Drs. 4594/00, Berlin.

Wynne, B. (1996) 'May the sheep graze safely? A reflexive view of the Expert-Lay Knowledge divide' in Lash et al (eds), 27-43.

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[1] *Discipline*: 'a system of rules governing conduct' and 'a field of study'; 'to train… by instruction and exercise, *esp.* in obedience and self-control' and 'to punish or penalize…for the sake of discipline'; *disciple*: 'a pupil or follower', *New Penguin English Dictionary* 2000. We are indebted to Simon Schaffer for drawing to our attention the aggregate of meaning around 'discipline' (Schaffer 2007). On Foucault's theoretical contributions to the historiography of the 'disciplines', by favourable contrast with the historical sociology of the professions, see Goldstein 1984.

[2] For Foucault, 'Problematisation doesn't mean the representation of a pre-existent object, nor the creation through discourse of an object that doesn't exist. It's the set of discursive or nondiscursive practices that makes something enter into the play of the true and false, and constitutes it as an object for thought (whether under the form of moral reflection, scientific knowledge, political analysis, etc.)' (Foucault 2001: 1489, see also Rabinow 2005: 43). In order for this to occur, something 'must have happened to introduce uncertainty, a loss of familiarity; that loss, that uncertainty is the result of difficulties in our previous way of understanding' (Foucault 1994: 598).

[3] The website to which Nowotny was contributing, 'Interdisciplines' (http://www.interdisciplines.org), was sponsored by the CNRS in 2003 and was devoted to the reflexive discussion and enhancement of interdisciplinary exchange and research.

[4] National Academy of Science, National Academy of Engineering and the Institute of Medicine.

[5] While our empirical study focused on the ethnographic research in the IT industry, later in the paper we refer to 'ethnography in industry'. As we note, ethnographic approaches that first developed in the IT industry are now increasingly used across a wide range of industrial sectors.

[6] The ten case studies were: 1) environmental and climate change research: the Tyndall Centre, University of East Anglia; the Earth Institute, Columbia University; the Öko-Institut, Darmstadt and Freiburg; 2) ethnography in the IT industry: three major IT corporations; the Institute for Software Research at the University of California at Irvine; and 3) art-science: the Arts, Computation and Engineering (ACE) Masters program, University of California, Irvine, and Digital Arts Research network (DARnet) of the University of California; the SymbioticA lab, University of Western Australia; and project-based funding programs supported by the Wellcome Trust and Arts Council England.

[7] In the project we did not analyse the growth of interdisciplinary and transdisciplinary research outside corporate and university research institutions in other potentially inventive locations such as think-tanks (Osborne 2004), business schools (Thrift 2005), firms more generally (Amin and Cohendet 2004), or consultancies and NGOs (Barry 2004).

[8] This introduction is a revised and extended version of Barry, Born and Weszkalnys 2008.

[9] The historical particularity of these proposals is apparent through comparison with the importance of interdisciplinary research in the development of military science and technology in the 1940s and 1950s (Pickering 1995b). There is, of course, nothing new in the proposal that scientific research should be directed towards social and economic goals.

[10] There are an escalating number of studies of contemporary interdisciplinarity, among them a burgeoning reflexive and empirical literature in geography and the environmental sciences, as well as surveys of the literature and handbooks on interdisciplinary research. Recent examples include: Tait and Lyall 2001; Bruce et al 2004; Rhoten 2004; Mansilla 2006, nd; Strathern 2005; Tompkins 2005; Buller 2009; Baerwald 2010; Donovan et al 2010; Friman 2010; Frodeman et al 2010; Huutoniemi et al 2010; Lyall et al 2011.

[11] On the importance of imitation in social and political change see Tarde 2001, Barry and Thrift 2007.

[12] Pickering (1995a) coined the term 'antidiscipline' when anatomizing the 'border wars' within science studies between philosophy, history and sociology of science, divisions that fostered what he saw as an unsatisfactory 'eclectic multidisciplinarity' that left the traditional division of intellectual labour intact. Instead, at this time, Pickering advocated what he called the 'antidisciplinary synthesis' proffered by cultural studies of science.

[13] Turner (2000), however, points to the role in the bureaucratisation of modern knowledge of 'the relatively short history of disciplinarity, the historical uniqueness [and conservative effects] of the vast expansion of university education over the last fifty years', arguing that these conditions – regarded by Gibbons et al (1994) as 'normal' or Mode-1 - are in fact 'entirely anomalous' (pp. 61-2).

[14] For an overview of research on the contribution of material and symbolic boundaries in the formation of scientific disciplines and social knowledges, see Lamont and Molnar 2002: 177-181.

[15] See, *inter alia*, Petts et al 2008, Lawrence and Despres 2004: 400, Huutoniemi et al 2010, and the discussion on www.interdisciplines.org.

[16] Petts et al make the helpful observation that the various definitions point to a spectrum: 'at its weakest, interdisciplinarity constitutes barely more than cooperation, while at its strongest, it lays the foundation for a more transformative recasting of disciplines' (2008: 8).

[17] The original author of the term transciplinarity still appears to be disputed. In recent texts, Basarab Nicolescu, a theoretical physicist employed by the CNRS and founder of the International Center for Transdisciplinary Research and Studies, claims that the French-speaking Jean Piaget first proposed the term (Nicolescu 2008: 2); while according to the German sociologist of science Peter Weingart, the Austrian Erich Jantsch 'first coined the term, which was taken up two decades later by Gibbons et al' (Weingart 2010: 12).

[18] The notion of problematisation, introduced by Foucault (note 2), implies a positive conception of the problem. In this collection, we understand the relevance of problematisation in the analysis of interdisciplinarity to have two aspects. On the one hand, the proliferation of different forms and practices of interdisciplinarity is bound up with the problematisation of the conduct of research, as we have already observed. On the other hand, interdisciplinary research in specific fields may both respond to and lead to the generation of new problems.
[19] A similar idea is suggested by the US National Academy of Sciences: 'Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialised knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice' (NAS 2005: 26)
[20] It is notable, and lends general support to our argument here, that Nowotny et al. (2001: 259) write of the 'antagonistic' epistemological relation between what they call 'socially robust' Mode-2 knowledge, involving a 'variety of knowledge traditions', and the universalistic claims of Western science. Yet we depart from such a generalisation, advocating an irreductionist analysis of specific genealogies of antagonism, as defined here, that fuel interdisciplinarity.
[21] See, for example, Randall et al's observation about the distance between Computer Supported Collaborative Work (CSCW), a form of what we have termed ethnography in the IT industry, and existing social science disciplines: 'Whether our view is right or wrong, it seems to us that an answer to CSCW's current dilemmas might be produced by considering the distinction between disciplinary assumptions about *method*, substantive disciplinary *concerns*, and disciplinary *sensibilities*. More particularly, we contend that to undertake ethnographic fieldwork for the home or for public spaces (and in other new or in some ways perplexing domains) and attending to the potentialities of new technologies requires a particular open-mindedness about method, a thoughtful selection of concerns, and an artful refinement of disciplinary, particularly design-oriented sensibilities. These cannot be taken lock, stock and barrel from other disciplines' (Randall et al 2005: 1). See also Harper 2003: 6.
[22] Holmes and Marcus (2005) coin the term 'para-ethnography' for this situation, arguing that it entails a particular kind of ethnographic collaboration where the researcher takes locally-produced discourses and critiques to advance scholarly debate. Expert informants become not only research partners, but 'epistemic partners'. For a discussion, see Born 2011.
[23] Interview with Simon Penny, UCI, February 2006.
[24] For example, the Åarhus convention on 'Access to Information, Public-Participation in Decision-Making and Access to Justice in Environmental Matters' (UNECE 1998)
[25] On the Wellcome Trust's Sciart initiatives, and detailing some of the projects funded, see Arends and Thackara (2003). On the AHRB/ACE research programme see Ferran (2006), together with other papers collected together in the special issue on art-science of the journal *Leonardo* (vol 39, 5, 2006).
[26] The published work of industry ethnographers and our participation in the 2006 Ethnographic Praxis in Industry Conference (EPIC) throws up many examples of the evocation of such spaces. They include: the emotional life of the American middle-class home, notions of community on a Brazilian beach, the ways in which PCs are sited and used in Indian bedrooms or Chinese villages (D'Hooge 2005), the use of mobile phones on London buses, the social organisation of space in American public libraries, the mundane use of paper in offices (Sellen and Harper 2002), or how patients actually take medicine in South African townships (Jones 2006).
[27] Interview, 2006.
[28] See, for example, the work of the UK research council programmes 'Living with Environmental Change' (http://www.lwec.org.uk/) and 'Energy Research' (http://www.rcuk.ac.uk/research/xrcprograms/energy/) (accessed May 2012).
[29] Interview, 2006.
[30] In accord with our approach, Lawrence and Despres mention 'ontological frameworks that do not embrace the complexity of the natural and human-made environment' in 'traditional scientific research' as a key obstacle to innovative approaches to the environment that might be redressed by transdisciplinarity (2004: 398).
[31] For a reflexive overview of the emergent field of interdisciplinary corporate ethnography, see Cefkin (2009).
[32] Interview, 2006.
[33] '[W]e contend that to undertake ethnographic fieldwork for the home or for public spaces… and attending to the potentialities of new technologies requires a particular open-mindedness about method, a thoughtful selection of concerns, and an artful refinement of disciplinary, particularly design-oriented sensibilities' (Randall et al 2003: 1).
[34] Interview, 2006.
[35] Interview, 2006.
[36] Interview, 2006.
[37] See Jasanoff and Wynne 1998, Demeritt 2001 and Miller 2004 on the co-construction of the global environment as an object of both knowledge and government. On the lack of relation between climate change science and policy during the 1950s and the 1960s, see Hart and Victor 1993.
[38] It is in the UK that 'science-art' appeared in the period of our fieldwork to have its most stable identity, called into being by the burgeoning of dedicated funding programs from the mid-1990s which, because they were based on a project-based commissioning model, also rendered the field quite fragmentary and discontinuous.
[39] Interview with a British art-science administrator, 2005.

[40] The problem is sometimes also linked to perceived restrictions on artistic activities: the Wellcome Trust, for example, claimed that its science-art schemes tolerate projects that question the norms and power structures of science; but in interview it was conceded that it is difficult for the Trust to fund projects that are highly critical of science.
[41] Interview, 2006.
[42] The CGKP was one of several Genetic Knowledge Parks funded from 2002 on by the British Department of Health and Department of Trade and Industry.
[43] His approach has some similarities to Bourdieu's analysis of the scientific field (1975), although Abbott chooses not to refer to Bourdieu's work, nor to that of other sociologists of science, except in order to show briefly that their positions can be understood fruitfully in his own terms.