Interdisciplinary Integration: The real Grand Challenge for the life sciences?

Introduction – Grand Challenges and small steps

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Abstract

This collection addresses two different audiences: 1) historians and philosophers of the life sciences reflecting on collaborations across disciplines, especially as regards defining and addressing Grand Challenges; 2) researchers and other stakeholders involved in cross-disciplinary collaborations aimed at tackling Grand Challenges in the life and medical sciences. The essays collected here offer ideas and resources both for the study and for the practice of goal-driven cross-disciplinary research in the life and medical sciences. We organise this introduction in three sections. The first section provides some background and context. The second motivates our take on this topic and then outlines the central ideas of each paper. The third section highlights the specificity and significance of this approach by considering: a) how this collection departs from existing literature on inter- and trans-disciplinarity, b) what is characteristic about this approach, and c) what role this suggests for the history and philosophy of the life sciences in addressing Grand Challenges.

Keywords

- Transdisciplinarity
- Interdisciplinary integration
- Grand Challenges
- Translational research
- Constructive modesty
- Philosophy of science in practice.

[1] The editors are joint first editors and listed alphabetically; both contributed in equal measure to the completion of this collection.

Intelligent practice is not the step-child of theory.
On the contrary theorizing is one practice amongst others
and is itself intelligently or stupidly conducted (Ryle, 1963, p. 27).

Life scientists have to acknowledge and accept
that society is co-shaping their agenda.
Scientists should also realise that vice versa they co-shape society,
rather than just offering knowledge and tools.
In other words, science and society co-evolve
(Swierstra et al., 2013, p. 2)

1. Why should historians and philosophers of biology and biomedicine care about Grand Challenges?

Readers of this journal have already been introduced to the challenge of integration in the life sciences by a special issue which appeared in 2013 (vol. 44, issue 4, part A). While that issue focused mainly on integration *within* the biological and biomedical sciences, the present issue focuses primarily on integration with other disciplines and with stakeholders outside academia. The previous special issue was mainly an answer to the transformations effected on the biological sciences by the emergence of synthetic biology and integrative biology. This new collection addresses the growing demand that the sciences direct their efforts to the problems faced by contemporary societies and individuals. This tendency critically affects the biological and biomedical sciences, both because there is a widespread belief that their growing importance and impact makes this the century of biology and biotechnology (Rifkin, 1999; Venter & Cohen, 2004; Dyson, 2007; Rose, 2007; Dwyer, 2008) and because the life sciences and medicine have a fundamental role to play in addressing many urgent human, social and ecological problems (Wake, 2008; National Research Council, 2009; Robinson et al., 2010; Losos et al., 2013). The papers collected here offer a good sample of domains of research where biological and biomedical sciences meet key issues of our times: the concept of *wellbeing* considered by Efstathiou and that of *integration* scrutinised by O'Rourke, Crawley and Gonnerman, *sustainability science* discussed by Thorén & Breian*, conservation biology* analysed by Brister and *public health* examined by De Grandis.

Grand Challenge-based funding calls have their origins in quite focused funding programmes, such as the Bill and Melinda Gates Foundation "Grand Challenges for Global Health" programme[2]. Such specific Grand Challenges soon became popular among biologists too (Schwenk et al., 2009; Halanych & Goertzen, 2009; Mykles et al., 2010; Gilroy, 2011; Fernie, 2012).[3] But now the concept of Grand Challenges is becoming more ambitious: it increasingly indicates the great problems of our age,

[2] Bill and Melinda Gates Foundation, "Grand Challenges" available at: http://grandchallenges.org; "Grand Challenges Canada" available at: http://www.grandchallenges.ca (last accessed: 05.07.2015).
[3] The first three papers are part of a long series of articles on Grand Challenges in the Journal *Integrative and Comparative Biology*.

which can be understood and tackled only through engaging both scientific knowledge and reflections on the goals of societies and on the forms of good human lives (for an example of this broader meaning of Grand Challenges in the biological literature see Frommer, 2010; for an analysis of narrow and ambitious uses of the notion of Grand Challenges see Efstathiou, this issue).

Take for instance Horizon 2020, the European Commission's current research framework. Horizon 2020 allocates 31748 million euro to "Tackling Societal Challenges" several of which cut across life and medical science and social sciences domains[4]. For instance:

- health, demographic change and wellbeing,
- secure, clean and efficient energy, or
- climate action, environment, resource efficiency and raw materials.

Such challenges are to be addressed by collating expertise across academic disciplines, industry and policy arenas and by producing outcomes that span research to market outputs and are accepted and endorsed by the public.

Grand Challenge calls are the latest expression of a consolidated trend in science policy: namely directing scientific research towards tackling problems that appear urgent and important, instead of waiting that the benefits of research have a spontaneous spillover (see Frodeman, this issue). Such policy trends are the proper subject of critical scrutiny on many levels. Which criteria are used in framing problems as worthy of special attention, how resources are to be allocated among different programmes, what kinds of research are privileged, but also whether funding research is actually an effective, worthwhile and equitable strategy for mitigating grand, cross-cutting and at times urgent problems are all important questions to raise (cf. Edwards, 2008; Brooks et al., 2009; Zachary, 2013; Bos et al., 2014).

But this is not a collection of critical examinations of current science policy. Although we are fully convinced that such critical work is extremely important and badly needed, here we consider the impact of these policies on how research is carried out: the opportunities and challenges that transdisciplinarity generates for researchers and for their non-academic partners (cf. a recent Special Issue of Nature, 2015). Funding schemes like Grand Challenges are with us: they exemplify what scientific research is becoming in the post *laissez faire* science policy regime and, more mundanely they make significant resources available. It is therefore of the greatest relevance to illustrate and understand which research practices they assume or mandate.

To put it another way, science policies are interesting and important in two ways. We can inquire both 1) how policies are produced in order to expose and assess their assumptions, values and justification, and 2) what research opportunities, practices and challenges they create. The first kind of inquiry can be described as the philosophy of science policy (see for instance Sarewitz, 1996; Guston, 2000; Guston and Sarewitz, 2006; Frodeman, 2014), the second as the philosophy of science in practice (Ankeny et al., 2011). Adopting this latter perspective, this collection focuses on how

[4] Horizon 2020 "Societal Challenges" available at: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges (Last accessed: 05.07.2015). The UK Research Councils similarly specify six "big challenges" as in need of cross-disciplinary research several of which would also involve work spanning the life sciences; see http://www.rcuk.ac.uk/research/xrcprogrammes/ (last accessed: 05.07.2015).

Grand Challenges and interdisciplinary integration change the practices of the biological and medical sciences and in so doing gradually reshape their methods and ethos. However, we want to insist that our focus should not be taken to suggest that this task should be given priority over a critical appraisal of science policy formation, nor as a sign of uncritical acceptance of the rhetoric of Grand Challenges. We believe that both are necessary and they often overlap.

2. The content of this collection

2.1. Two hurdles for cross-disciplinary work on Grand Challenges: translation and integration

The contributions in this volume suggest that working successfully across scientific disciplines and public sectors on socially relevant issues can itself be a Grand Challenge. The first challenge is how to address problems that arise in 'wild', uncontrolled environments in systematic and principled ways. Grand Challenges may resist neat causal analysis because they are neither isolated, nor static, and furthermore they are altered by human interventions, while these in turn are influenced by a bewildering array of factors: emotional, cognitive, cultural and so on and so forth. The second challenge is that different scientific disciplines have profoundly different subjects, objectives and ethos and thereby very different epistemic cultures, standards and values. We thus identify two hurdles for cross-disciplinary work on Grand Challenges[5]: 1) a problem of adaptation that following a trend coming from the clinical sciences we call a problem of ***translation***[6] –i.e. of adapting knowledge about some "controlled" environment to "wild" environments and 2) a problem of cultural-epistemic ***integration***–i.e. how to enable disciplines in the biological and medical sciences to join in collaborative efforts whereby their own internal rules and criteria may well conflict with those of other disciplines[7].

[5] We use the term cross-disciplinary to encompass multi-, inter- and trans-disciplinary work. For the purposes of this collection the most important concepts are those of interdisciplinarity and transdisciplinarity. Most of the historical and theoretical work on the obstacles of crossing boundaries and methods for bringing together people with different expertise has used the concept of interdisciplinarity (cf. e.g. Klein, 1990; Frodeman et al., 2010). Recently transdisciplinarity has increasingly been used to identify research that includes extra-academic partners (industry, NGOs, public sector, civil society). In this particular, but now popular, understanding it is clearly central to Grand Challenges.

[6] We borrow the word '**translation**' from what is called 'translational clinical science' (or 'translational medicine'), an enterprise well explained by the slogan 'from bench to bedside', i.e. by the process of trying to bring basic research to use in real-world circumstances. In philosophical terms this is the problem of external validity, or of how to extrapolate results that are validated in a controlled but specific environment to a new target context. The problem is further complicated by what philosophers call "unstable enablers", and by variables that cannot be controlled and/or operationalised into parameters. A further useful concept here is the biological concept of ***exaptation***, which refers to the use of something for a purpose different from the one for which it had evolved. While translation emphasizes an intentional effort, exaptation captures the random and unintended path of some discoveries to their practical application. Adaptation of research to reality happens in both ways –deliberately and erratically– but we have decided to use 'translation' because it is becoming a familiar term –beginning to appear also in environmental science and science policy– while exaption still sounds rather esoteric. Furthermore, the process is becoming increasingly planned and intentionally driven.

[7] The notions of *translational integration* as Leonelli discusses (2013) and of *practical integration* introduced by De Grandis (this issue) highlight how these two problems come together.

All our contributions analyse these challenges and attempt to articulate the origins of these problems or to provide some tools for handling them. We have purposefully avoided using the word 'solve', because a common feature of our contributions is a marked and explicit modesty: none of our authors boast to have neat solutions or ultimate explanations. The next section offers an overview of the collection by considering how individual authors approach the two key problems of translation and integration.

2.2. Key insights of the contributed papers

The problem of translation is especially prominent in the opening and in the closing essays. The central idea of the opening paper by Sophia Efstathiou is that the concepts in which real-world problems are expressed cannot be adopted by scientists hoping to address Grand Challenges unless they are *founded*, i.e. unless they are transformed to fit norms of clarity and precision decided within cultural discursive spaces of science. This is graphically illustrated by what happens to the meaning of the concept of wellbeing, once founded in scientific domains. Efstathiou argues that development economics measures of 'wellbeing' rely on founded concepts which may well flesh out some aspects of an everyday concept of wellbeing, but which do so at the cost of other possible uses of 'wellbeing', for instance to understand the wellbeing of older people as a concept founded in gerontology might. Efstathiou claims that this process of domain-specific conceptual specification –which she calls 'founding'– is almost second nature for trained scientists (a routine operation) and so often goes unquestioned in specialist work. Further it is only the first stage in the formation of specific research questions, followed by the generation of further contextualised theoretical constructs needed for actually carrying out research.

The notion of founded concepts thus aims to capture a type of scientific concept which is developed after some features of an everyday concept are pruned so as to achieve better fit and consistency with scientific epistemic-cultural norms of rigour or relevance, and which allows different disciplines to further operationalise that concept in order to formulate the questions they are equipped to answer. Founded concepts therefore have a very interesting potential as a meeting point between everyday concepts and scientific constructs on the one hand and between different theoretical constructs generated by different disciplines on the other hand. However, Efstathiou does not present founded concepts as a magic solution to the problems of translation and of integration. On the contrary, the notion of founded concepts and the ensuing picture of the generation of scientific problems suggest both that the challenges of translation and the gap between real problems and scientific problems can be significant, and that conceptual pluralism is a consequence of the quest for rigour and methodological precision. At the same time, coming to consider what founded concepts are guiding economists´ or other scientists´ thinking when defining different constructs could offer some points at which discipline-specific diversification may become visible and discussed.

In sum Efstathiou argues that the gap between scientific solutions and real life problems is genuine and hard to fill and that the diversification of scientific disciplines makes the problem of integration far from trivial. Nevertheless, the notions of founding and of founded concepts may play an important and valuable role both in understanding why we should not expect technoscientific fixes

to suffice in addressing grand, real-world problems, and in finding a common denominator among scientific disciplines, which could be a useful starting point in the integrative effort.

The paper by Michael O'Rourke, Stephen Crowley and Chad Gonnerman focuses on clarifying the very concept of *integration*, which has become so central in the literature on cross-disciplinary research. The authors bring in analyses from philosophy of biology and interdisciplinarity studies in order to consider the diversity and diversification of the notion of integration while arguing that there is nonetheless a fundamental similarity that justifies the use of some unifying concept of integration to describe them all. Their contribution is thus the elaboration of a framework that accounts both for the conceptual unity of the notion of integration and for the many different ways in which the integrative work is carried out in different contexts and domains. In order to achieve this result they define integration as a process of *combination*, i.e. a process through which a multiplicity of diverse inputs are transformed into a set of outputs that are interrelated and interconnected so that they can be treated as a workable whole, even when they do not yet display a fully unified character.

While O´Rourke, Crowley and Gonnermann point out the usefulness of looking at integration both as process and as output, it is clearly the emphasis on integration as process ('attention to process must come first and remain a constant part of the response' p. 11, l. 9) that enables them to develop a framework that manages to reconcile the unity of the concept of integration and the plurality of its types. Their framework identifies three moments –inputs, process and output– two fundamental dimensions –quality and quantity– and three parameters –scale, commensurability and comprehensiveness of integrative work. In different contexts the integrative work will vary in quantity and quality along these parameters and their article´s main claim is that this framework provides help in bringing out and mapping different kinds of integrative work –i.e. different kinds of inputs, processes and outcomes. O'Rourke, Crowley and Gonnerman thus work out an elegant solution to account for the unity of the concept of integration while fully acknowledging the wide variety of its instances. Looking at it as an input/output process whereby the output can be treated as a whole (at least for some uses and purposes) enables them to capture the common core of the integrative process. Potentially their framework could also contribute to the problem of translation if the integrative process is clearly structured and focused around the achievement of practical targets.

The problem of translation is central in the idea of Mode 2 knowledge production that is extensively discussed by Henrik Thorén and Line Breian. The notion of Mode 2 was introduced by Michael Gibbons and colleagues to reflect the growth of a type of research whose main objective is to contribute to practical problem solving and not to add to the body of disciplinary and theoretical knowledge (Gibbons et al., 1994; Nowotny et al. 2001). Perhaps the most characteristic single feature of Mode 2 is that it develops the kind of knowledge that is needed 'in the context of application'. Thus Mode 2 hopes to remove the problem of translation by anticipating it: real world needs dictate the research questions and the criteria of effectiveness and success. On the other hand, the price for achieving this result is the need to embrace transdisciplinarity wholeheartedly. This demands a concerted and deep collaboration among different academic disciplines, but also the involvement of stakeholders and extra-academic players already at the early stage of problem formulation. If Mode 2 evades the problem of translation through its anticipatory strategy, in exchange it stakes all its chances on the success of the integrative process.

Thorén and Breian test the strength and usefulness of the concept of Mode 2 knowledge production through its contribution to Sustainability Science, a field which is both seemingly paradigmatic of Mode 2 knowledge production and an attempt to address a Grand Challenge. Thorén and Breian´s inquiry is based on a survey of sustainability scientists regarding how they understand Mode 2 knowledge production and their own field. Examining the perceived relations between Sustainability Science and Mode 2 provides a good test case for assessing the power and adequacy of the idea of Mode 2 knowledge production for putting technoscientific expertise in the service of societal needs. The challenges experienced by Sustainability Science –'difficulties in overcoming institutional, cognitive and epistemic obstacles' (p. 7, l 13-4)– suggest that integration is a challenge here and that the frame of Mode 2 knowledge production seems both descriptively inadequate to sustainability science practices and lacking in normative content. However it is this latter criticism that seems to be more central to their argument. First, because they consider the normative emptiness more serious than the descriptive shortcomings, and second because their criticism may be interpreted as suggesting that the lack of clear normative content is a cause of the descriptive inadequacies. How could this be the case?

Thorén and Breian acknowledge that Mode 2 was first put forward as an attempt to describe transformations and emerging trends in knowledge production. Yet they also claim that the notion has very often been understood and used as presenting a model that researchers and projects could aspire to realize and put into practice. Thorén and Breian's analysis suggests that Mode 2, taken as a model for research rather than as the description of a trend, shifts the problem of translation to that of integration, but has not given any concrete and practical guidance on how to address this latter. The lack of normative content has left those looking at Mode 2 as an inspiring model without the necessary guidance about how to achieve effective collaboration and which methods and epistemic standards to adopt. This is how the normative vacuity seems to contribute to why research modalities and schemes within sustainability science only partially mirror Mode 2. Attempts to realize this normatively elusive model seem to have run into difficulties and to be implicated in why Sustainability Science partly assumes older modes of knowledge production. To wit, the Mode 2 idea may be too impressionistic a prophecy to become self-fulfilling.

Evelyn Brister's paper further analyses difficulties with goal-oriented interdisciplinary research, considering the case of addressing the challenge of environmental conservation. Brister articulates difficulties around epistemological integration, based on a study of conservation projects in Central Africa. She analyses the acrimonious controversies between conservation biologists and social anthropologists as epistemological rifts. Then she suggests that in conservation projects the need for interdisciplinary collaboration between natural scientists and social scientists seems to emerge from the problem of translation: how do we design conservation programmes that can be locally successful, i.e. that can win the support and participation of local populations and respect their rights and needs? Brister's account shows that, although both biologists and social scientists acknowledge the need for collaboration, there are fundamental differences in epistemic cultures, in commitments and objectives that undermine the success of the collaboration. A particularly problematic barrier to epistemological integration is what Brister calls *disciplinary capture*: the often unwitting framing of an interdisciplinary problem, research plan, funding call or question in such terms that take for granted the assumptions and commitments of a particular discipline. This early decision sets one particular discipline on a privileged track and makes it harder to accommodate the methods, epistemic culture and goals of other disciplines. One may think of it as a sort of path-dependence

applied to the domain of research. Brister warns against the risk of disciplinary capture and, in order to avoid it, recommends that interdisciplinary dialogue and integration start as early and be as inclusive as possible.

Brister does not expect general methods and strategies for the management of cross-disciplinary collaborations to be able to overcome these challenges. However her pessimism is partly tempered by the belief that solutions may be found if epistemological differences and conflicting aims are tackled early on through exercises aimed at bringing into the light and negotiating different commitments and standards among research participants. This disclosing job seems to be a proper task for philosophers, and Brister suggests that pursuing work as integration facilitators or as embedded philosophers could be a more promising task for philosophers than attempting to build general methodologies for cross-disciplinary research.

While Brister has more trust in local *ad hoc* solutions than in universal and unified theories, she espouses a quite strong view of integration, one that requires 'identifying a shared knowledge base, negotiating many individual instances of evidentiary standards, developing interdisciplinary causal explanations, and finding consensus on the normative issues related to conceptualizing research questions and interpreting research results' (p. 21, ll. 17-21). In other words, Brister rejects methodological universalism, but retains a strong conception of integration as epistemological and methodological unification within a research venture. Her focus on the epistemic obstacles to integration leaves open the question of translation, although it may seem that the early negotiation that she recommends as the best chance for promoting integration could also work to promote translation, at least if stakeholders and civil society manage to specify some goals, priorities and constraints for scientists. However this is beyond the scope of Brister's paper and is instead at the center of the last contribution to our collection.

Giovanni De Grandis brings back to central stage the problem of translation: indeed his notion of *practical integration* can be interpreted as the attempt to explicitly orient research towards the achievement of its practical goals and to see epistemic integration as subordinated to the effective targeting and implementation of the solutions. De Grandis's central proposal is that Grand Challenges, or more generally goal-driven research, are better understood as neither science nor politics, but as a sort of hybrid phenomenon that can be usefully conceptualized as *collective practical reason*. The associated idea of practical integration is centred around the necessity of acting effectively in addressing a problem that is perceived as urgent and serious. This process of integration is thus geared towards developing viable initiatives for improving the problematic situation. What is desirable and what is feasible is more crucial than what is epistemically justified. Thus, De Grandis sees translation as indicating the goals and priorities, the constraints and affordances of integration. This priority of the practical leads to the strong claim that work done under Grand Challenges and other calls aiming to use science and technology to tackle practical human problems should not be understood as cases of scientific activity. They are practical and hence governed by pragmatic rather than by epistemic standards.

De Grandis comes to these conclusions through a historical and philosophical analysis of the development of Victorian Public Health and post WWII Town Planning in Britain. In these he finds examples of early attempts to improve society through the large-scale application of biomedical and technical expertise. These examples show that effective action is not simply a matter of having

scientific knowledge, but that an alignment and fruitful dialectic between social values, science and technology, and institutions (both formal and informal) is necessary. Incidentally they also show that gaining more knowledge before acting is at times the best thing to do. The practical lesson to be drawn is that if thorny practical problems are the real target (and not only a slogan to attract funds and to enhance the social importance of science), then epistemic standards alone are not the appropriate criteria for effective action: much more needs to go into the integrative mix and, according to De Grandis, the three key components are Values, Institutions and Knowledge (abbreviated as the VIK perspective).

The case studies make clear that De Grandis is neither downplaying the importance of robust knowledge, nor dismissing epistemic standards. Sound knowledge of urban realities and of disease aetiologies were fundamental in the advance of public health and in building its scientific credibility, just as complacency about technical knowledge and superficiality about local knowledge seriously limited the achievements of town planners. Though De Grandis is careful to preserve the autonomy of scientific knowledge and epistemic standards, which should not be improperly affected by political or pragmatic considerations, he is adamant that the pursuit of practical goals requires strategies in which compromises and 'impure' standards and reasons loom large. And here is where the separation of 'science' from 'collective practical reason' becomes useful: it prevents necessary practical compromises to be fed back and rationalized into scientific theories. The moral of the story is that what meets ideal standards (be they epistemic or ethical) does not immediately fit the world, and what fits the world is very unlikely to meet ideal standards. De Grandis wants reason to be able to adapt to –and work in– both ideal worlds (defined by normative principles) and the real world, but there is no illusion that these could go together. Grand Challenges are obviously occasions in which reason should fit the real world at the expense of occasionally twisting ideal standards.

2.3. Future directions: Team responsibility

Current research structures imply that the burden of integration and translation demanded by existing funding calls are increasingly falling on research teams and the communities with whom they work. Medical and bioscience researchers involved in goal-driven research along with their extra-academic partners are to be responsible for both defining their tasks sensibly in order to meet societal needs and carrying them out effectively. This collection suggests that this is a tall order, indeed an intimidating one if we consider that we are talking about research oriented towards supposedly urgent human problems. We do not dispute that both integration and translation impose responsibilities to researchers and involved stakeholders, but the extent and contours of these responsibilities need to be carefully worked out. Otherwise appeals to team responsibilities become just rhetorical attempts to pass on to them a disturbing onus. To attribute responsibilities in a reasonable way we need to carefully explore several complicated issues. To just begin some reflection here:

- Responsibilities are of various kinds –i.e. internal responsibilities towards other members of transdisciplinary teams, and external responsibilities towards a broad spectrum of stakeholders, ranging from future generations to funding agencies, from local communities to transnational institutions. On top of this, many would include responsibilities towards natural entities (e.g. animals and ecosystems), and towards ideals and values that are

potentially conflicting (e.g. modernisation and cultural inheritance, economic development and natural resource conservation, inspiring visions and feasibility, transparency and discretion).

- Formulating Grand Challenges calls and taking them up comes with distinct roles for those setting the agenda and those delivering work packages. There is thus an issue of delegation that tends to blur responsibilities between research patrons and performers, between principal and agents[8].
- Attributions of responsibilities should be based on a comprehensive view of the process and realistic appraisal of roles and powers. The allocation of responsibilities needs to include all stakeholders and every stage of scientific research, design, implementation and assessment. The outcome should be such that each demand for accountability takes into account the burden and relative weight of competing demands so that resulting responsibilities are concrete and coherent. Otherwise we produce an inflation of responsibilities that leads to their devaluation. Without clear specification of their bounds and actual implications, responsibilities soon become meaningless (Ricoeur, 2000). Clearly things are different if emphasis is placed on team responsibility so that all are responsible for the final results and have a strong incentive to tend the overall aim. However, strong team responsibility typically requires open and flat organizations, as well as shared incentives to collaborate. In practice we need to calibrate the balance between team responsibility and individual responsibilities depending on the type of institutions and organisations we deal with. Besides, team responsibility raises ethical issues similar to those of strict liability.
  In sum, vague and rhetorical appeals to responsibility are useless, but in deciding the strategy for specifying and allocating responsibilities we face a tension between being fair to individuals and providing incentives that maximize outcomes.
- Frameworks that can help assess, weigh and allocate ethical responsibilities associated with research on Grand Challenges are only beginning to emerge[9].

Developing knowledge and competence here are formidable tasks, as is building institutional mechanisms that support moral agents without trivializing their roles (Thompson, 2005; Parker et al., 2011; Carusi & De Grandis, 2012). It is urgent to understand under which conditions individual researchers or teams can fulfil which responsibilities. On the one hand responsibilities should be

[8] We follow Guston (2000) pp. 4-5 in using the principal/agent approach in this context.

[9]Current policy is increasingly geared to encourage Responsible Research and Innovation or RRI, understood as research that is attentive to societal and ethical values, as well as epistemic rigour, and that is pursued in tandem with engagements with relevant stakeholders of the given research. See Owen et al. (2013) and contributions therein. A related literature is that on Technology Assessment, spanning different approaches for how to assess and anticipate the impacts of technological innovations. We may see in that area an interest in feeding into practical problems with theoretical insights as well as with particular methodologies, for instance as pursued through Constructive Technology Assessment, as in Rip et al. (1995) and Schot and Rip (1996), and real-time technology assessment, as discussed by Guston and Sarewitz (2002). Some approaches propose to modulate decision-making involved in scientific work by bringing humanists into laboratory settings, for instance through what is called “mid-stream modulation” by Fisher and Mahajan (2006), or through a “symmetric” mode of integration as proposed by Nydal et al. (2012). See Fisher et al. (2015) for an overview of “integrative” socio-technical work aimed to assess and modulate technology development.

specific and clear, but on the other hand it must be clear that no full specification is ever possible and that people need to become morally alert, prepared to fill regulatory gaps and apply their moral judgment actively. There are signs, from policy arenas as well as from research milieus now interested in developing "Responsible Research and Innovation" frameworks that humanists and social scientists can contribute to this task.

3. The significance of this collection

3.1. How does this collection add to existing literature?

Let us first consider the existing literature on interdisciplinarity especially as concerns the life and medical sciences. Literature on interdisciplinarity can usefully –if a little schematically– be divided into two main strands: the first offering visions of interdisciplinary futures based on emerging trends and perceived knowledge needs of society (e.g. Jantsch, 1972; Funtowicz and Ravetz, 1993; 1994; Gibbons et al., 1994; Nowotny et al., 2001; Klein et al., 2001), and the second proposing tools and guidelines for interdisciplinary research building on experiences accumulated from cross-disciplinary projects (e.g. National Research Council, 2004; Bergmann et al., 2005; Hirsch Hadorn et al., 2006; Pohl and Hirsch Hadorn, 2007; Jahn et al., 2012; Lang et al., 2012) [10]. We believe that a gap exists in grand visions and handbook guidelines, both of which struggle to get to grip with the reality of cross-disciplinary research. In the attempt to offer some general model, these approaches inevitably gloss over the extreme diversity that characterizes responses to Grand Challenges.

Pluralist and contextualist understandings of science have been crucial for understanding the diverse practices and ontologies of the biological sciences (Dupre 1995; Mitchel 2003). This is also the case with science aiming to tackle grand societal challenges. For each attempt at tackling a grand challenge there will be a unique constellation of players involved, relations among them and different contexts, expectations and resources. Scholars trying to provide a unifying theory or a method of general applicability thus run into a formidable obstacle: confronted with the plural reality of actual cross-disciplinary research practices, their models lack specificity –as it happens, according to Thorén and Breian (this issue), in the case of Mode 2 knowledge production.

Acknowledging this situation does not mean overlooking or underestimating the challenges that it poses. Working outside well-established theoretical and methodological frameworks can be unsettling and tiresome. Cross-disciplinary work can leave people more exposed, more vulnerable and provide less protection and counterweight against the pressure of interests and power. Similarly some participants may feel that their contribution and skills are not really valued and that their presence is simply functional to give an appearance of interdisciplinarity (Viseu, 2015). Cross-disciplinary work can deprive researchers and participants of the common ground that proves so helpful in solving disputes and disagreements (Davies, 2011). Moreover cross-disciplinary work may feel especially frustrating, as conflicts often emerge when least expected, and setbacks can at times make it feel like Sisyphean work that takes too much time and energy. Therefore even granting that working outside settled paradigms can be liberating, that it can at times unleash originality and

[10] Gabriele Bammer's (2012) ambitious vision of 'Integration and Implementation Sciences' is an interesting attempt of providing both a vision and a detailed blueprint.

creativity, or shake complacency and dogmatism, let us not cultivate any facile illusion that all is well with the lack of well-established theoretical and organizational frameworks. Conversely, uneasiness does not justify wishful thinking: the fact that we would feel more comfortable under the shelter of tidy theories and comprehensive methods is not a compelling reason for thinking that we can have them nor that we should impose them. Adopting already formulated research frameworks can stifle initiative, and block questions and strategies emerging from the collaborative dynamics of the research team (cf. Fitzgerald and Callard, 2014).

Two recent special issues address the challenges of interdisciplinarity and transdisciplinarity from perspectives close enough to ours. The 2013 special issue in *Synthese*, edited by Michael Hoffmann and colleagues on "Philosophy of and as Interdisciplinarity" collected philosophical contributions on whether and how philosophy can help understand interdisciplinary work or be itself a form of interdisciplinary thinking (Hoffmann et al., 2013). The 2015 special issue in *Futures* edited by Roderick Lawrence celebrated 10 years since a first special issue on transdisciplinarity, collecting even more diverse perspectives from authors of multiple disciplinary background and with first-hand experience of team research (Lawrence, 2015). The collection presented here sits somewhere in between: in the spirit of philosophy of science in practice, it assembles work by philosophers who reflect on issues emerging from the involvement of biological and biomedical sciences in cross-disciplinary work. These studies have both the theoretical aim of understanding changes in scientific practices and the practical ambition to help researchers to deal with new challenges, in so doing they indicate a distinctive approach to the study of goal-driven cross-disciplinary research. It is thus more philosophical than the collection in *Futures* and more practice-oriented than the essays in *Synthese*. That being said, this is a collection of philosophical, including historically informed, essays on how grand challenges in the life sciences can be understood and addressed through cross-disciplinary research. In this connection, a recent Special Issue of *Nature* (September 2015) is also worth mentioning, since it explicitly relates interdisciplinarity to the need of mobilizing science to meet the Grand Challenges of our times, though without pursuing any philosophical or historical analysis (see in particular Ledford, 2015; and on the shortcomings of integration see Viseu, 2015).

3.2. Constructive modesty

In responding to the above described circumstances and challenges, contributions to this collection embrace a middle way that can be described as constructive modesty, i.e. the conviction that even without some comprehensive grand theory it is possible to offer theoretical tools and viewpoints that have practical value. The strategy of these papers looks like modular rather than systematic theory. The building blocks of such a modular approach are concepts, patterns of interactions, analytical and interpretive tools, or frameworks that can be used, adapted, combined and recombined according to needs and circumstances of specific inquiries. These are theoretical objects because they are not facts or pieces of information –although inspired by an analysis of facts, cases and examples– but instruments for organizing and making sense of data and experiences –to wit, here we have theory for practice's sake. These theoretical modules are not systematic because they are not comprehensive, and they do not amount to a grand scheme that allows one to capture and organize the whole complexity of a Grand Challenge or of a cross-disciplinary collaboration. They help to organize and interpret parts of them. The provisional and incomplete synthesis is left to those

who are involved in each particular project, for they alone have access to the wealth of particular information that is necessary –though not sufficient– for performing the synthetic work. Hence the alternative sketched in this collection can be described –borrowing a concept from the politics of decentralization and local autonomy– as devolutionist, because the responsibility for realizing the architecture of the collaboration is devolved to the participants –though hopefully we have not only passed them the onus of integration, but also the first elements of a toolbox.

This approach is not unique in the field of philosophy and history of science. Our collection builds on work aimed at better connecting history and philosophy of science with practical issues. In general philosophy this aspiration has been voiced times and again from various corners. For instance it was clearly articulated by pragmatists like James and Dewey, with their commitment to a philosophy that addresses problems emerging from everyday experience and real life. This commitment to improve human experience and life through sustained and intelligent effort is at the core of the concept of *meliorism* (Hildebrand, 2013). In the philosophy of science a similar attention to practically relevant problems has been pursued through two philosophical communities, one that has come to be called "socially responsible" philosophy of/in science and engineering (SRPoiSE), and the second called "philosophy of science in practice" (SPSP), the former with a stronger presence in the US, and the latter more EU-centered[11]. Although there is nothing like a strong shared imprinting coming from an allegiance to a 'school' –and indeed the articles do not display any strong similarity in style and method– a common orientation does emerge. This is an interest in questions that arise in biological, medical or other scientific practice –flagged by practitioners, or developed through working with science projects– as opposed to addressing theoretical, philosophical problems remote from reality and experience. All contributions to this collection exemplify what we call practice-relevant and practice-inspired theoretical work, or –if you prefer– they approximate what Robert Frodeman calls 'field philosophy' (Frodeman, 2010; Briggle et al, 2015). The papers clarify and articulate actual problems, evaluate theories' and methods' strengths and limits, analyse and probe concepts, and finally develop tools, ideas and viewpoints that provide additional resources to practitioners and theorists. These ideas can be used, but do not, and cannot, specify in advance the rules of their use. Integration is a skill at which we can become ever more proficient, not a question for which there is a final answer.

3.3. A role for philosophy of biology and biomedicine, and more broadly for the arts and humanities, in tackling Grand Challenges

As scientists are urged to step out of their disciplines, to consider expert and lay stakeholders' knowledge and interests in order to develop science in the service of society, so humanists face the

[11] The first meeting of the Society for Philosophy of Science in Practice took place in 2007 in Exeter. In 2008 an American Philosophical Association mini-conference on Making Philosophy of Science More Socially Relevant, co-chaired by Katie Plaisance and Sophia Efstathiou, resulted in a 2010 special issue in *Synthese* and contributed to the formation of SRPoiSE. Relevant work in philosophy of science includes examinations of the importance of values in science -for instance work by Philip Kitcher (2001) and Heather Douglas (2009) or the volume edited by Harold Kincaid and colleagues (2007). See also Kaiser and colleagues (2014) for an analysis of interdisciplinary relations between philosophy of science and particular sciences or history and social science approaches to the study of science –though socially relevant issues are not in focus here. Several articles contributed to this collection were presented at the 2013 SPSP meeting in Toronto.

call and the responsibility to offer their own contributions. For humanists do have expertise that can valuably contribute to tackling Grand Challenges. As already suggested, philosophical and historical studies of the ideals, genesis and development of science and technology reveal a multiplicity of patterns, many unintended and accidental, other more amenable to predictable cultural and institutional logics. Awareness of the dialectics between societal, political and various cultural epistemic factors can be extremely enlightening: it helps to avoid idealized and simplistic pictures that lead to false expectations and disappointments. Such insights could potentially go very far in helping to imagine and design technoscientific infrastructures and processes for 'the messy world that we inevitably inhabit' (Cartwright, 1999, p. 18). Moreover the humanities can supplement scientific discourse with richer and more nuanced interpretations as well as instruments for framing and conceptualizing problems respecting their complexity.

Participating in goal-driven transdisciplinary research forces all participants to work outside their comfort zone, to rethink and redefine their role, priorities and ethos (Efstathiou and Mirmalek, 2014). This work of re-positioning oneself within a new and different context touches on issues of identity, history and values as well as a readiness to question one's disciplinary assumptions and cognitive frameworks. The arts and humanities have a lot to offer here for a number of reasons: they are more used to work outside well-established epistemological frameworks, and have elected what is singular and unique –the subject of idiographic understanding– as their own proper domain. The humanities' techniques, artworks and concepts can facilitate the expression, communication and development of ways of dealing with a diversity of human perspectives. Further, the humanities are interested not only in facts but also in impressions, emotions, values and meanings. In other words the arts and humanities look at the interaction between facts and humans, for example what happens when some 'brute' facts are re-described as Grand Challenges: as facts calling for a specific human reaction. This interest in human responses takes a variety of forms including sympathetic understanding, critical self-examination, questioning of assumptions and attempts to express what escapes our concepts and cognitive frameworks.

It is important to acknowledge that the constructive, participant roles proposed here for historians and philosophers of the biological and biomedical sciences represent only one possibly productive approach to applied research. Other more detached and critical approaches perform equally important functions, as we explained at the beginning of this introduction. Furthermore, although our contributors have found inspiration and resources outside philosophy, this collection relies mostly on philosophical inquiries, without exhausting the potential of humanistic perspectives.

Developing the actionable and diverse knowledge needed to address the big problems of our time is no simple academic exercise: it requires time, resources and a fair supply of good luck besides dispositions like for instance humility, respect for diversity, sympathy for alien needs and aspirations. We surely have no recipe for getting all these! We only offer reflections on some obstacles encountered by the biological and biomedical sciences in the process of engaging real-life problems. Whether you are interested in understanding how science is changing in the early twenty first century or in offering your contribution to a Grand Challenge, we hope you will find something interesting here.

Acknowledgements

We would like to thank all the contributors to this collection –including Julie Thompson Klein and Bob Frodeman– for their supportive feedback and insightful and meticulous work on this collection. We would like to especially thank Evelyn Brister for helpful suggestions that we have incorporated in the final version of this introduction. We give heartfelt thanks to Bjørn Kåre Myskja and the NTNU RESET group for their continued support for this project despite the taxing resources of research time it required. Finally we would like to thank the chief editor of *Studies C*, Gregory Radick, whose encouraging and helpful suggestions kept steering this collection in what we hope is a useful and interesting direction.

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