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### Practising co-production and interdisciplinarity Challenges and implications for one health research

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## Practising co-production and interdisciplinarity: Challenges and implications for one health research



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### ABSTRACT

We review the nature of interdisciplinary research in relation to One Health, a perspective on human-animal health which would appear to merit close interdisciplinary cooperation to inform public health policy. We discuss the relationship between biological sciences, epidemiology and the social sciences and note that interdisciplinary work demands attention be given to a range of often neglected epistemological and methodological issues. Epidemiologists may sometimes adopt social science techniques as “bolt-ons”<sup>1</sup> to their research without having a complete understanding of how the social sciences work. The paper introduces a range of social science concepts and applies them to the challenges of understanding and practicing participatory and local epidemiology. We consider the problem of co-production of knowledge about One Health and zoonotic diseases in relation to funding structures, working in large international teams and explore some of the often-neglected realities of working across disciplines and cultures. We do this in part by applying the concept of value-chain to the research process.

### 1. Introduction: the limitations of current technical and didactic approaches to addressing health issues at the human-animal interface in resource poor settings

The One Health approach to the animal-human health interface has at its centre the view that animals and humans occupy a continuous health space. Such an approach requires that human behaviour be taken into account in both understanding and responding to zoonotic diseases (Pfeiffer et al., 2013). Godfroid et al. (2013), write that:

*‘A “OneHealth” framework applied to brucellosis and other endemic zoonoses should encourage actors from the medical, veterinary, wildlife and sociological disciplines to contribute to a holistic understanding of the disease. Gross simplification of the real situation will not help. Professional, scientific and well documented contributions should result in consensual and effective control strategies, which should be seen as an important added value from a societal perspective.’*

The goals are admirable and might indeed contribute to human and animal welfare. However, pursuit of such understandings has lacked

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<sup>1</sup> A few words in this paper are placed in quotation marks “...”. This is to indicate that such words are problematic, disputed, colloquial or may require clarification as between different epistemic communities.

proper conceptualisation as to how such a project might be carried through successfully. This is specifically so in relation achieving a “holistic understanding” and including “sociological disciplines”. These questions are the subject of this paper, a paper which takes as its point of departure that we do not know how to do interdisciplinarity, we do not know how to achieve holistic understandings, and that interventions with regard to both human and animal health (usually taken separately) fail to take account of human behaviour in relation to the “sociological disciplines”, instead adopting a broad public health or individual behavioural perspective. Epidemiology tends toward the broad systemic account, psychology and social psychology inhabit the space of individual behaviour and behavioural solutions to the problems. In contrast, the “sociological disciplines”, notably but not exclusively sociology, social anthropology, neo-classical economics, political economy and political science, offer the excluded middle (Boswinkel, 1963), true engagement with the social – for it is the social which is their object of study. This is not to suggest that the natural sciences on one hand, and social sciences on the other, are not heterogeneous. Both sets contain very diverse disciplines, especially within social sciences, where there are profound methodological differences between disciplines. The differences *between* the two sets are, however, much more fundamental than *within* each set. Discussions of participatory epidemiology and other such techniques sometimes appear to see the social sciences as “bolt-on” additions to established ways of defining the object(s) of study and investigating them in human and veterinary medicine. These additions are usually made as part of the process of translating scientific findings into policy. In this paper we suggest that the questions of interdisciplinary conceptualisation, problem specification and policy formation are more complex and require far more thought than suggested by the tempting (and simplistic) practice of the bolt-on. In doing this we can make progress toward avoiding the “gross simplification of the real situation” referred to above. We must engage with the complexity of the world of infectious diseases in general, zoonoses in particular, and of human behaviour. That is the way forward and doing this engages with fundamental questions to do with what we study and how we study it, in other words questions of methodology.

Epidemiology has been successful in identifying factors promoting and preventing a range of infections, and in developing interventions which could effectively reduce, or even eliminate, the risk and /or the consequences of these infections. These interventions always rely, to a certain degree, on behaviour change(s) among targeted populations. Even if intervention takes the form of novel and sophisticated technologies such as a vaccine or treatments, their epidemiological outcomes still ultimately depend on levels of uptake by humans. Uptake rates are closely connected to how people understand and speak to each other about inoculation, vaccines, their use, efficacy, safety, side effects, cost and, indeed, how these technologies are produced and marketed (Larson, 2016; Pollock, 2019). For the most part, behaviour change depends heavily on didactic approaches – telling people what is the right thing to do and persuading them to do it. Yet, even for the most affordable and effective technologies, focusing interventions solely or centrally on *individual* behaviour change alone (Michie et al., 2014) (particularly those based on Knowledge, Attitudes, Behaviours and Practice [KABP] studies) can be met with limited success, as indeed may those dependent on regulation. This may be because didactic approaches ignore the social, economic, historical and cultural factors which bring into being those behaviours and *risk environments* (Barnett and Blaikie, 1992; Barnett and Whiteside, 2002; Rhodes et al., 2005) in the first place. In the case of animal production and trading for example, the structure of supply chains, profit margins, scales of production, local political organisations, may all play a significant role in determining producers’ and traders’ propensity to adopt or practice good hygiene, vaccination, bio-security, food hygiene and the host of other links in the chain which convert living creatures into food items (Fournié et al., 2017; Høg et al., 2018).

Social sciences provide ways of analysing the contribution of social, economic, historical and cultural factors in forming the environments within which and by means of which many biological processes take place. This is because human actions and beliefs form the matrices within which many biological causal and effect pathways come into existence. If effective interventions are to be designed, the biological and the social realms should be seen as constituting a continuous space wherein these realms are entwined (Bourdieu et al., 1987). To do this requires interdisciplinary work and, as has been already noted, such interdisciplinary working is often said to be a good thing. But it is rarely practised and the challenges to such work are significant. This paper reviews some of these challenges in relation to technical engagement with informing policy and effective interventions. It confronts the difficulty that in some respects the natural sciences and the social sciences seem to occupy quite distinct intellectual universes at worst, and only tangentially overlapping intellectual universes at best. This is most evident where natural scientists seek and claim objectivity while social scientists may problematise objectivity itself as a goal, seeing it as a cultural and historical product. In doing this, they may also problematise their own position as observers, researchers’ use of language, and indeed the assumed authority of the author’s voice. This has implications for how some social scientists perceive data, recognising that the people they study inhabit subjective worlds of meaning, meanings that affect what they do and how they understand, reflect and indeed theorise about what they do and thus assumptions as to rationality and irrationality (Godelier, 1972; Toth, 2013; Howley et al., 2015). The situation is not helped by the fact that rather few social scientists know much about natural sciences and few natural scientists know much about social sciences beyond the application of some research methods applied in the absence of a broad theoretical background.

Here we discuss some key challenges relating to interdisciplinarity, epidemiology, participatory epidemiology and local epidemiology (Fischer and Chenais, 2019). Clarification of these challenges as they apply to the difficult practice of interdisciplinary research may contribute to our understanding and response to infectious diseases and their effects on human and animal health and welfare. The challenges we address are: (i) conceptualisation of epidemiology and One Health as *discourses*; (ii) engagement with the diversity of (a) epistemological perspectives and (b) different objects of study across disciplines; (iii) conflicting tempos of research and research funding; (iv) the meanings of participatory research and co-production of knowledge, and; (v) outline suggestions as to a way forward toward effective interdisciplinary research in which knowledge derived from natural and social sciences may be more effectively combined to illuminate the practice of the One Health approach.

## 2. Conceptualising epidemiology and one health as *discourses*

Two currently important theoretical terms in the social science are *discourse* and *narrative*, the stories that people tell themselves and others about the way the world “is”. *Discourses* may be thought of as big stories (for example about nations, ethnicities, gender relations, peoples, histories, traditions) while *narratives* may be thought of as smaller stories. Among these discourses and narratives are those of objectivity and indeed science. Both are considered by social scientists as objects of study and thus as constructions and products of specific historical societies and epochs.

Social science concepts (as with the terms *discourse* and *narrative*) are italicised in what follows. This is to indicate their use as technical terms. Each of these is accompanied by citations which offer, in the spirit of interdisciplinarity, pointers should non-social scientists wish to pursue those ideas further. None of the foregoing should be taken to suggest that the present authors consider science as *merely* a social construction; rather it is to note that social scientists problematise science through the concept of *discourse* to better understand the role it plays in human affairs and that they use a complex set of theories and

methods to investigate these matters (Payrow Shabani, 2003; Emden and Midgley, 2013; Fultner, 2014; von Essen, 2017v). And in this connection and at this time we should not forget that science is not always objective and neutral, and that, allied with power, can be and has been used to provide supposed evidence for and legitimization of, among other things, biological and eugenic theories of racial and class domination (Levine, 2017; Bix, 2018). Since humans took up farming, close connection between humans and the diseases of animals with which they interact have become more intense (Wolfe et al., 2012; Harari, 2015; Scott, 2017). With increasingly rapid and accelerating intellectual movement and human spatial expansion over many centuries toward what we now describe as globalisation, sharing of spaces of all degrees of intimacy and remoteness between microscopic life forms, animals and plants is rapidly overtaken by and encompassed within a range of discourses (Keller, 2011), among these is One Health. Describing One Health as a *discourse* (Aronowitz, 1988; Dunn, 2016) is to note that the idea of One Health is also not a neutral descriptive label. To describe it as a *discourse* is to show that, from a social science perspective, words have consequences and are often associated with *power* (Swartz, 1997) (Weber and Parsons, 1947). One aspect of power is in the framing of problems and how this may affect processes whereby resources are allocated (Roberts and Elbe, 2017). Not only is One Health a *discourse*, situated as it is in the space between science and policy, so too is science itself.

The latter has been investigated in many different ways, most influentially in the last century by philosophers of science such as Karl Popper (Popper, 1959) and by sociologists of science, notably Thomas Kuhn (Kuhn, 1996). Other approaches to the understanding of discourses extend into the tradition of *hermeneutics* (Zimmerman, 2015). In short, *discourses* are important topics of investigation by social scientists. They are objects which are problematised and studied by the social sciences, particularly those concerned with culture and *imaginaries* (Strauss, 2006). Such objects may include the social sciences themselves, for example the highly rationalistic and quantitative school of economics known as *neo-classical economics* (Ferguson, 1969) (Mirowski, 1989). Critical approaches from the perspective of discourse can assist in thinking around and through taken for granted knowledges as to the nature of what kinds of things zoonosis, emergence, risk, health, disease and policy are as cultural phenomena (Canguilhem, 1978; Spicker, 1987; Foucault, 1989, 2013; Bourke and Lidstone, 2015).

Any discourse may be subjected to critical examination, policy discourses among them. These are in their nature problematic, and One Health is no exception. They engage constructive ambiguity, differences of perspective, interests, cultures and most important power – the latter in its broadest sense - over resources, the environment, ideas, human and other bodies. That this is the case is discussed and analysed at length by Galaz et al. (2015) in relation to One Health, and by Davies in relation to the politics of implementing International Health Regulations (Davies, 2019). An illustration of the ways that discourses operate is the term *tropical diseases* (Farrar et al., 2013). It emerged as an apparently neutral descriptive category marked by geography but has subsequently been partially replaced by other nomenclatures – zoonotic, emerging, diseases of poverty. This transition is an example of how description is itself problematic and often carries changing markers of difference between human beings, their needs, entitlements and rights. Hysteresis, the location of something in relation to the history of the system of which it is a part, is of the greatest importance for understanding the relations between pathogens, disease, humans and animals, and policy practices (McNeill, 1976; Farmer, 1999; Goudsmit, 2004; Barnett and Whiteside, 2006; Iliffe, 2006; Moalem, 2007; Byrne, 2008; Pepin, 2011).

### 3. Engaging with the diversity of epistemological perspectives

The notion of *narrative* (Holstein, 2000; Gubrium, 2009) engages the

framing of a problem, objects of research and the technical ways in which such objects can be examined in practice (the methods). These concerns go to the heart of interdisciplinarity and interdisciplinary practices. They are important in turn for understanding how we should think about two related activities: participatory epidemiology and the co-production of knowledge. First, we consider interdisciplinarity. We consider it in relation to science, which, as we have noted, is a particular *discourse*.

Interdisciplinarity may be thought of as participation of multiple disciplines applied to an agreed object of study to address questions scientifically and to inform policy. That this work is specifically scientific points to the way in which interdisciplinary work undertaken with researchers from different cultures and traditions requires that such work is understood as forming part of that internationally understood *discourse* of science. While at a public level that discourse is assumed to have characteristic assumptions and perspectives about how we should think it is of course internally differentiated in many particulars. It is these differences and disagreements that research teams must accept and manage if interdisciplinary scientific work is to be possible at all. The alternative is to become lost in an infinite deconstructive wilderness of theoretical mirrors (Martin, 2003) and perspectives, where, in the words of Karen Barad, "*Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter.*" (Barad, 2003), p. 801.

Sensitivity to these differences of often epistemological perspectives in such an enterprise requires that scientists involved in the research endeavour to achieve some understanding of what different disciplines might offer and in particular the ways that they see the world (Barthes and Duisit, 1975; Czarniawska-Joerges, 2004) via the discipline (assumptions and rules as to evidence, hypothesis formation, structures and forms of argument, traditions and taken for granted knowledge) of their disciplines. Above all it is vital that researchers working within a scientific frame do not forget that science is and should always be critically deconstructive and questioning of established knowledge and theories (Rovelli, 2015). That is its essence as a specific dominant way of thinking about the world (Barthes and Duisit, 1975; Czarniawska-Joerges, 2004). From a social science perspective, it is at this point that the question of *narratives* within the scientific discourse becomes important in relation to four aspects of research activity. These are: (a) the definition of problems to be studied; (b) the research process and the instruments to be deployed; (c) the voice in which the authority of the author(s) is expressed; (d) the subsequent development, articulation and authority claims of any translation of scientific findings into policy. In the next section, we illustrate some of the ways that these factors interact by considering in general terms the conceptualisation and use of the very frequently deployed term risk.

### 4. Accounting for diverse and divergent objects of study

We begin with a conventional working definition of three key terms: hazard, risk and uncertainty. Hazard is a possible source of harm, risk is the chance, high or low, that a hazard will actually cause harm, and uncertainty is a statement of the probability of knowing about the extent of risk and judgement of how good our knowledge is in estimating that probability (Wildavsky and Dake, 1990; Beck, 1999; Tansey and O'Riordan, 1999; Weiss and McMichael, 2004; Larson et al., 2005; Helbing, 2010). These definitions may appear familiar. But from a social science perspective they are culturally and linguistically embedded and relate to the concepts of *narrative* and *discourse* discussed above.

It is a truism that not everybody (including research teams from different cultures as well as different people within a nation state or cultural group) sees hazard, risk (or probability) and uncertainty in the same way. Put simply: (a) different social groups have different assessments of hazard and the associated risk; (b) definition of any particular risk or hazard differs between the scale of the system which is being considered – national or local, men or women, rich or poor, and

many other categories reflecting the dynamic and fluid diversity of all human societies; (c) scale and definitions feed into and define narratives. This point has important implications. **What** is investigated, **how** it is investigated and the resulting **story** that will be communicated to the research end-users depends on who exercises power over the creation of both the research narrative (identifying and defining the object of research) and the policy narrative. These narratives are, after all, reflections of the ways in which power is organised in social life. They are not necessarily rational in the simple sense that everybody agrees on the right way forward.

To give extremely clear divergent characterisations (and to a degree caricatures) of this problem, some epidemiologists may see the problems (or even the causes) of zoonotic transmission risk as inhering solely in the behaviour of individuals and the solution in didactic interventions with those individuals. Some social scientists may see the problems (or causes) as inhering solely in the ways that poor people's marginal livelihoods drive them to take risks because they must survive from day to day and therefore take short term risks.

Such divergent views reflect the strong possibility that epidemiologists setting out to investigate the association between behaviours and disease are not looking at the same object of study as social scientists who set out to explore the socio-economic structural factors which underlie those presumed associations. This is where the tangential relationship between natural and social sciences, briefly touched upon above, is most clearly seen. It often results in natural and social scientists disagreeing as to the objects of research, and either the two broad areas of research remaining in their respective silos, or social sciences playing the role of extra in the main scientific research being done on pathogens in laboratories. Yet, it is here that the role of *narratives*, taken for granted knowledges, and the exercise of various forms of power (economic, gender, symbolic) may intersect in co-producing understandings of the relationship between pathogens, their hosts, people, behaviours, livelihoods and the *political economy* (Wittman and Weingast, 2008) of an entire sector of production, from concentrated corporate ownership of intellectual property in the genetic material of livestock strains to chopped up meat ready for the pot (Polanyi, 1957; Wittman and Weingast, 2008; Wallace, 2009; Wallace et al., 2010; Piketty, 2014; Wallace et al., 2015). It is exactly at this intellectual point that this kind of interaction, fruitful co-production between social and natural scientists, can, should and sometimes does take place (Wallace, 2009; Wallace et al., 2015).

As the presumed nature of the object of study may differ greatly across and between disciplines, so prioritisation of the risk to be investigated and its framing (for example as a potential global pandemic or as a risk to the health of a few isolated chicken farmers) will also be affected by who is able to set the research agenda. For instance, what is defined as a major risk at the international level or for what is described as the global community (as in the case of highly pathogenic avian influenza – HPAI) may not be a problem at all for national health services (Davies, 2019) and for small-scale farmers who manage endemic diseases in their flocks as a matter of day to day normality. The overarching implication is that in a world of competing narratives and inequalities of power, wealth and cultural prestige, policy which engages with risk and hazards associated with human and animal diseases should endeavour to take all these perspectives into account. Yet some versions of One Health or the International Health regulations can end up ignoring certain risk perspectives, local and even national (Davies, 2019). This is a huge challenge for those who research bio-medical issues whether from a laboratory or social sciences perspective.

## 5. Conflicting tempos of research and research funding

Working across disciplines and perspectives is constrained by the tempo of research funding and evaluation. Questions of narratives and

power are nowhere more evident than when researchers are judged by how far their science results in policy outcomes (Parkhurst, 2017) which may, in practice, be very short-term given that the life of a funded project rarely exceeds five years. The question of time perspective for research outcomes is very important in the constant competition for research funding. Nowhere is this more apparent than when, for example, criteria of success are contained within a management tool such as the theory of change (Taplin and Clark, 2012). This project design and management tool, adopted by funding agencies of some major donor countries, embeds policy relevance, participation, sustainability and other often politically desirable policy outcomes into large-scale projects and can threaten to have perverse outcomes where the output tail wags the research strategy dog. While the theory of change planning tool is intended to encourage research teams to cooperate and consult in the participatory development of goals, activities and outcomes, in practice given the time scale for funding applications, it can turn out to be highly managerial rather than to any extent participatory. When the emphasis is on its managerial function, it can bend scientific research programmes to fit with existing government strategies (and even a component of “soft power”) under the guise of creating new knowledge. In such a context, funding sources, government strategies, research institutes' hunger for finance, and individual career aspirations may all combine to exclude the complex detail of the lives of poor people, the fine textured questions of environmental sustainability (Scheffer, 2009; Scheffer et al., 2009; Scheffer, 2010), understanding of the long term nature and deep socio-economic roots of risk, and thus long term policies, instead identifying politically acceptable policies - often couched in the *faux* radical language of the development aid sector (Ferguson, 1985; Grillo and Stirrat, 1997; Tribe, 2010).

## 6. What does it mean to “participate” and to “co-produce” knowledge?

We have seen above how consideration of such apparently straightforward notions as risk, hazard and uncertainty, all stock in trade to those working in public health and One Health, may appear less than straightforward from a social sciences perspective. Social science perspectives often (irritatingly) problematise the straightforward/taken for granted narratives, methods and even research objects assumed as unproblematic by other disciplines. This is the case regarding the ideas and practices of participation and co-production of knowledge.

Participatory epidemiology is described as:

“... the systematic use of participatory approaches and methods to improve understanding of diseases and options for animal disease control. This definition refers to both a ‘participatory approach’ and ‘participatory methods’, indicating that an understanding of both approach and methods are needed to define PE. We propose that the term ‘participatory’ in PE is used to refer to the essential involvement of communities in defining and prioritizing veterinary-related problems, and in the development of solutions to service delivery, disease control or surveillance. As we explain later in the review, use of the term PE that does not involve communities in these ways is considered to be a misnomer.” (Catley et al., 2012), p. 151.

And as these authors indicate, this largely veterinary creation owes a great deal to work on participation in relation to rural appraisal and planning by the distinguished development policy thinker, Robert Chambers (Chambers, 1974, 1997; Chambers, 2007) whose concern with non-participation doubtless has some of its roots in his early career in the British colonial civil service in Kenya, explored in his study of centralised (and securitised) irrigation developments as part of the British colonial government's efforts to combat civil unrest and opposition to colonial rule in the early 1950s (Chambers, 1969).

Local epidemiology is a response to the extractive nature of some participatory epidemiology (PE). Fischer and Chenais note that:

“...more research in epidemiology is needed that is truly participatory and considers local heterogeneity and power. This version of PE can usefully be influenced by the methodological development of participatory research.”

and

“when aiming for (semi)quantitative results, or when research cannot be fully open to community participation, traditional, less participatory PE will still be useful. To avoid false expectations, we suggest renaming this version of PE as ‘local epidemiology’.” (Fischer and Chenais, 2019).

There is a long tradition of intellectuals and politicians claiming privileged access to the minds of “the people”. Practitioners of participatory techniques of investigation must navigate the treacherous seas between the jagged rocks of making unsustainable assumptions, infantilising or dominating “the people”, inventing and/or homogenising social groups, merely extracting information in a characteristic uneven exchange (Emmanuel, 1975). Moreover, with research conducted across cultural and social contexts, whether aiming for participatory approaches or not, there is also the danger of assuming an imperious authorial voice about the lives and ideas of others, all delivered in the name of science.

Participation can all too easily become a way of legitimising a research (or political) community’s view of the world. It has appeared in various forms and can be traced back historically to, for example (but by no means solely), the Narodnik movement in nineteenth century Russia (Pedler, 1927; Chayanov, 1986). At a conceptual level the notion of participation must be used sensitively as it can reify communities and attribute significance to certain differentiations between human beings which are the object of investigation, while failing to observe that such communities are often internally differentiated (not least by income, ethnicity, gender, belief, age). When this is done, use of such participatory tools as transects, focus groups, village (or other spatial) mapping, role plays, while producing knowledge may not involve co-production of knowledge as between the investigator and the community, instead erring seriously, as outsiders search for genuineness in communities (Chambers, 2007). Co-creation of knowledge which involves shared decision-making demands that we recognise co-production as a challenging process requiring time, role clarity, constant attention to power imbalances, difficult discussions about research rigour versus research relevance, and constant monitoring (Oliver et al., 2019). It also means putting in place the mechanisms to support these demanding activities, working across scales, across diverse and divergent interest groups and stakeholders. Above all – if we are honest – it is likely to involve complex debates about the nature of “evidence” and the way that putative co-producers understand knowledge itself. And there is the risk that co-producers (between disciplines, and between researchers and community stakeholders) appropriating specialist language and evidence, without understanding the way this knowledge came into being, and its limitations (von Essen, 2017v).

Participation at different scales will also produce competing world views and reveal different interests. This observation engages a key point: it is not only the usual suspects in the categories of the deprived, powerless and excluded who miss out in the process of co-production. They are of course vital participants. But the world is stratified and fragmented in many and fluid ways to produce structural exclusion and disadvantage of many different kinds (Desmond, 2019). And in our epidemiological investigations we should not always jump to the most easily identifiable excluded or vulnerable population fragments while ignoring the diverse loci of disempowerment in the *value chain* of the research process itself. These value chains run from funding bodies (e.g. national governments, philanthropic or political foundation), through individual researchers, research institutions in different countries, to

people on farms and forests, in trade networks, in families, local associations, to policy think tanks and back to governments and NGOs. It is in this complex ecology of the scientific research process that we must assiduously seek both our understanding and our practice of both participation and co-production of knowledge (Oliver et al., 2019).

## 7. Finding a way forward

The following quotation, combining ideas from science, philosophy, human history and meat consumption, is both amusingly and seriously relevant to the questions addressed in this paper:

“When we talk about the Big Bang or the fabric of space, what we are doing is not a continuation of the free and fantastic stories which humans have told nightly around campfires for hundreds of thousands of years. It is the continuation of something else: of the gaze of those same men in the first light of day looking at tracks left by antelope in the dust of the savannah – scrutinizing and deducting from the details of reality in order to pursue something which we can’t see directly but can follow the traces of. In the awareness that we can always be wrong, and therefore ready at any moment to change direction if a new track appears; but knowing also that if we are good enough we will get it right and will find what we are seeking. This is the nature of science. The confusion between these two diverse human activities – inventing stories and following traces in order to find something – is the origin of the incomprehension and distrust of science shown by a significant part of our contemporary culture. The separation is a subtle one: the antelope hunted at dawn is not far removed from the antelope deity in that night’s storytelling. The border is porous. Myths nourish science, and science nourishes myth. But the value of knowledge remains. If we find the antelope we can eat.” (Rovelli, 2015).

Its substantive point resides in its pithy summary of the problematic relation between different discourses in processes of truth seeking in the world - and indeed the existence of different kinds of truth.

A possible way forward for all of us would be to do two challenging things:

- (a) take time to think *collectively* about the possibility and forms of interdisciplinary working and thinking, about why we have disciplines and how and why these divisions are maintained and might be made permeable. This might be done as part of day to day work in the laboratory, the seminar, the conference, the lecture theatre – the common locales of the working researcher;
- (b) seek opportunities for discussion and investigation of interdisciplinary working and knowledge in the formal training of those who are commencing their study of “disciplines” so that they can know from the start that the complexity of the world they wish to investigate is reflected within the complexity of the processes by means of which they come to investigate, to know and to learn about that world.

Finally, knowledge production should always be located within the discourse of science, a discourse which, constrained and limited as are all discourses, has the advantage of being subject to constant critique, specification of evidence and its reformulation, and located in relation to the material world (Barad, 2003).

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## Appendix A. Supplementary data

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