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Introduction

Science policy issues implicitly involve questions of demarcation; that is, questions about the difference between science and non-science. How do we decide where a scientist's authority and responsibilities begin and end? How do we distinguish 'scientific' issues from political, cultural or economic ones? What is special about 'scientific knowledge'? In the past, if these questions were addressed at all, it was assumed that some-or-other essential characteristic of science would completely determine the answers. More recently, researchers have begun asking these questions in a different way. Rather than asking metaphysical questions about the essential characteristics of science, we can ask instead how scientists and others actually go about distinguishing science from non-science. Sociologists have been very successful in accounting for how the boundaries of science are maintained and how this 'boundary work' affects the process of science and work in this area has produced some useful insights with direct application to science policy. However, an important site for boundary work has so far received less attention than it deserves. Popular science plays an important role in the process of negotiation. The framework for policy debates is established in popular, not elite contexts.

In this paper, I clarify the concept of a 'boundary' and in so doing I reject the 'cartographic' metaphor that has become prevalent in discussions of the boundaries of science. Boundary work is more akin to network engineering than to 'cultural cartography'. To the already crowded taxonomy of boundary concepts I add a new one: the intermediate dependent entity. This is used to explain the variety of boundary work that can be conducted

simultaneously between science and an adjacent entity (such as government). Intermediate dependent entities are fields, technologies or institutions that need both science and the adjacent field to be meaningful. For instance, 'radiological protection' is an intermediate entity dependent on both physics and government (see below) and therefore a site where 'boundary work' could take place.

I also argue that popular science is a key site for boundary work – perhaps the most important site. The limits, for instance, of physicists' responsibility for the threat of nuclear weapons and their role in the controversy over the use of depleted uranium in ordnance are issues that are decided in popular contexts through the process of boundary work I describe. Thus, the analysis of popular texts is shown to be relevant to questions of science policy. To explore the role of popular science in boundary work I examine the circumstances of two unsuccessful attempts to redefine 'science'. One was a 1996 suggestion that management of the bovine spongiform encephalopathy (BSE) crisis was the responsibility of scientists and the other was an 1880s proposal to involve physicists in the care and resettlement of offenders (by suggesting that physicists should take on the role of torturers). The discussion of the BSE crisis demonstrates how the modified boundary work framework elucidates the dynamics of contemporary policy issues. The discussion of physicists as torturers supports the thesis that, even if there are *a priori* criteria by which we can distinguish science from non-science, the meaning of the adjective 'scientific' and the role of scientists are established through a process of negotiation. Firstly, though, we shall look in general terms at the ways questions about demarcation are addressed.

Demarcation and Science Policy

The demarcation questions discussed above are of two types: one about scientific knowledge and its relation to other types of knowledge and another about who is granted the status of 'scientist' and what this means. We need to account for both issues. The demarcation problem is especially acute in controversial issues such as those surrounding the management of BSE or the use of genetically modified organisms (GMOs) in agriculture. Here, the boundaries of scientists' authority and responsibility come under particular scrutiny. Take, for instance, the question of whether the introduction of a genetically modified variety poses a risk to the balance of an ecosystem. Compare this with the question of whether it poses a risk to the balance of an industry. Are these intrinsically scientific or intrinsically political questions? Who has ultimate authority and ultimate responsibility in each case? Clearly, these

issues depend on what we mean by 'risk' and 'balance' and what is at stake to whom but ultimately they are concerned with how we distinguish science from non-science.

Such questions tend to be addressed in three main ways. The first way of dealing with demarcation issues is the most common – it involves not addressing them at all. Scientists, legislators and the public take the relation between science and adjacent fields to be straightforward, uncontroversial and obvious. We shall see below that this assumption is unfounded but we shall see also see what it is about science that makes the 'null assumption' so plausible.

The second way questions about the boundaries of science are addressed involves reference to the philosophy of science. That is, to understand the limits of a scientist's authority, we ask what type of knowledge science is and what it can and cannot tell us about the world. Adopting the second approach involves the implicit assumption that the 'proper' relation between science and government, say, is determined metaphysically and is thus fixed and independent of each. This may well be the case. If we ask what are the essential characteristics of science in order for it to provide reliable knowledge we may well find its relations with other fields to be prescribed. However, if we ask a slightly different question we arrive at the third way questions about the boundaries of science are approached.

Instead of trying to distil the essence of objective scientific knowledge, we can ask how the boundaries of scientists' authority and responsibility are decided in *practice*. There may or may not be metaphysically determined 'proper' relations between science and adjacent fields but we can choose to put this issue to one side and concentrate instead on how scientists and others who have an interest in the outcome *actually* establish and police the boundaries. The third approach to questions about the relations of science and adjacent fields is thus to address them as practical problems for scientists. The limits of scientists' authority and responsibility are decided in practice by a process of negotiation with adjacent interests (including government). This negotiation may or may not make reference to philosophical ideas of what science 'ought to be'.

Thus, we have distinguished two positive approaches to the question 'what is science?' plus a 'null approach'. On the one hand, we can try to objectively discern the independent characteristics of scientific knowledge and the scientific community. On the other hand, we can ask: given that people disagree about a) what constitutes scientific knowledge and b) who can legitimately call themselves 'scientist' and c) what the job of a scientist entails, how do people *actually* go about distinguishing science from non-science? Loosely we can dub the first approach 'philosophical' and the second approach 'sociological'. Recent years have seen

a shift towards this sociological approach to demarcation problems. Surprisingly, adopting a sociological framework has proved to be philosophically more interesting than adopting a purely metaphysical framework[1].

This paper looks at how science is defined by its relations with things that are not science and how these relations frame policy debates. The shift from metaphysics to actual practice is significant in questions of science policy as it places emphasis on what different groups in society have invested in particular scientific enterprises. Following a brief introduction to the concept of boundary work, I explain how its current formulation draws too heavily on a cartographic metaphor. That is, I argue that the problem that prevents boundary work approaches being as useful as they might be to questions of science policy is that they conceive the relations between science and adjacent fields like geographical boundaries between countries.

The problem with this conception is that science has not one but many boundaries with each adjacent field and the cartographic metaphor fails to address this. Scientists and non-scientists are often discussed as if they were two identifiable groups with clearly articulated interests, but boundary work is not a simple power struggle between 'scientists' on the one hand and 'non-scientists' on the other. Instead, various different groups with various different interests have engaged at various different boundaries between science and non-science. As an alternative to the cartographic metaphor, I introduce a new concept – the intermediate dependent entity – that provides insight into the full complexity of the relations of science and adjacent fields.

This new formulation of the concept of boundary work provides greater insight into policy issues such as the controversy over GMOs because it offers a coherent way to speak of all the various interventions in a scientific issue together. Boundary work allows us to compare, say, newspaper cartoons with textbooks and to understand the role of each in a way that other approaches preclude. This reveals a surprisingly important role for 'downstream' or popular texts (such as newspaper cartoons) in the process of establishing what 'science' is taken to mean at any moment, which partly explains the emphasis in this paper on the analysis of texts[2].

The conception of boundaries outlined below also provides a new handle on issues that have already attracted considerable attention such as 'two cultures' debates. For instance, rather than looking at science and art as two monolithic entities the relation between them is understood with reference to the 'intermediate entities' that depend on them both. (These can be as various as paint technology and the aesthetics of electron micrographs.) Rather than a

single boundary between the two we find several. Boundary work is understood as a 'negotiation' over the ownership and rules that govern these intermediate entities. Conceiving the 'two cultures' this way avoids the vagueness that characterises many of the arguments suggesting that art and science are 'basically the same' or 'irreconcilably different'. The emphasis here though is on questions of science policy.

Boundary Work and the Philosophy of Science

Before discussing what is meant by 'boundary work', we must address two related issues: the place of the philosophy of science in all this and the remarkable ease with which demarcation issues can be ignored. In accounting for the latter issue we can identify two assumptions that underlie many accounts of science and can be thought of as the 'common-sense' on the matter. These common-sense assumptions are responsible for the pervasive sense that the boundaries of science are fixed and immutable (if not immaculate!)

The first assumption is that there are a priori criteria for distinguishing science from non-science. That is, we assume that there is some essential quality (or a family of qualities) that all things scientific share. The effect of this assumption is to blind us to the ways in which the boundaries of science are actually maintained in practice. The assumption of independent criteria prevents us looking at demarcation as a practical problem for scientists. But whether or not there are essential characteristics that *ultimately* distinguish proper scientists from charlatans, this does not mean that there will be no struggle over definitions. Even if there is a 'true' or 'natural' boundary, there is no way of discursively demarcating science that will be convincing in all circumstances. However *necessary* essential characteristics may be to science, they are not *sufficient* to explain scientists' cultural authority.

The second assumption is that the boundaries are not disputed. We believe this because at any moment in history the boundaries *seem* unproblematic. We feel we know what science is in the sense that we could point to anything, any practice or piece of knowledge and say whether it was scientific or not. We might not feel empowered to judge its validity but, for most things, we believe we can identify which category it belongs in without difficulty. For instance, phrenology is uncontroversially placed in the 'non-science' category today whereas anatomy and physiology are undoubtedly sciences[3]. Astrology is clearly non-science while astronomy is equally clearly a science. Cloning is science (though some would dub it 'technology') but deciding whether we *should* clone humans is ethics or politics or maybe theology but not science. For most boundaries, making these sorts of decisions is so easy that it is hard to believe that there is any 'work' or negotiation going into maintaining them. They

seem obvious and timeless and natural. This is itself a moot point as, in general, the boundaries between science and non-science are not natural but have instead been 'naturalised'. Science texts can operate at the level of 'myth' in the sense described by Roland Barthes[4] – both disguising and disguised-by the work that goes into maintaining boundaries.

But what of the existing work on the demarcation problem? In seeking answers to the question 'what is science?' in cultural representations of science, I am *ipso facto* rejecting essentialist approaches to the question. Much recent work in history, philosophy and social studies of science shows that such a move is justified by the sheer heterogeneity of science[5]. However, the approach adopted here is not aimed at arbitrating on epistemological questions. The following discussion is consistent with many metaphysical positions. This is because it does not address the validity of scientific knowledge, just the way it is employed in discourse.

Whatever the metaphysical foundations of science, the way it is invoked in popular culture is not determined by *a priori* criteria; the profuse meanings of the word 'science' are not prescribed by metaphysics. If we are interested in the cultural functions of science then it is as well to adopt a functionalist approach to its definition and understand 'science' from the perspective of power within society. Thus I concentrate on the cultural processes that lead to conceptions of science becoming dominant. However, this does not obviate philosophical approaches to the question 'what is science?' Indeed, part of the motivation for this move is to permit philosophical inquiry into otherwise complex and intractable knowledge.

The conception of dynamic boundaries between science and non-science is not in itself an adequate explanation of scientific practice. I follow Sismondo in claiming that metaphysics, or something very much like it, still has a place in the study of science when we adopt the deflationist attitude[6]. However, by adopting this conception of boundaries we can show that much of the effort that goes in to analytic descriptions of the category 'science' is misplaced. Our principal motivation for doing so here is to elucidate the relations of science and adjacent fields to facilitate the creation of coherent science policy.

Questions about the 'true' nature of the boundaries belong to the realm of metaphysics. The present account does not support or refute any particular epistemological position. Here we concentrate on changing patterns of *authority* and deal with the topic on a pragmatic level. The question is not so much 'what is science?' but 'given that people disagree about what science is, how is the answer decided and what is the source of the conflict in the first place?' Such an analysis has application within *several* metaphysical frameworks.

Especially in the wake of the 'Science Wars', the exact nature of the claims being made need to be spelled out very clearly – so I reiterate: To argue that the authority of scientists is based on the social function of science is *not* to argue that scientists *do not* have privileged access to reliable knowledge. Although I argue that what counts as scientific knowledge is often decided in popular forums, the universality of any particular element of knowledge is not a product of the attitude adopted towards it. The case made below is simply that knowledge is not the same as authority or, to put it another way, authority is not a simple function of knowledge. To fully understand science we need to understand authority as a social relation. This means we have to 'bracket off' questions about the validity of scientific knowledge.

The Cartographic Metaphor

So far, the notion of a boundary between science and non-science has been only vaguely defined. For sociologists the mere existence of a boundary is often enough. There is no need to develop a general 'taxonomy' of them. Indeed, the imperative for a sociologist to avoid being prescriptive about science is often more pressing than any desire to generalise. Sociological accounts place emphasis instead on the *particular*. Following a discussion of boundaries with respect to parapsychology, Barry Barnes (who Gieryn credits with theoretically setting up the 'boundary problem')[7] sums up his approach,

> From a sociological point of view there is little more to be said about [parapsychology] or about the boundary of science in general. The boundary is a convention: it surrounds a finite cluster of concrete instances of science without implying that there is any essence which they share; the instances are the accumulated outcome of a historical process of negotiation. Any attempt to eject instances from the cluster, or to add instances presently rejected, is to employ the term 'science' in an evaluative sense, and to participate in the process of boundary-drawing which, as sociological observers, we should be describing[8].

Gieryn discusses a variety of sociological approaches to the boundary problem. His account includes a discussion of the sociology of professions and of 'social worlds' (an idea that places emphasis on the workplace as a site where diverse people meet)[9]. Gieryn also distinguishes four broad types of boundary work: monopolisation, expansion, expulsion and protection[10]. In *Cultural Boundaries of Science*, this is refined to three 'genres' of boundary work: expulsion, expansion and protection of autonomy[11].

However, to develop boundary work as a *practical* concept that can inform the formulation of policy, we need to be clearer still about the *types* of boundaries that may be addressed and the types of boundary work that may be undertaken in popularisations. The concept of boundaries is primarily a cartographic metaphor in which we relate 'social space' or 'intellectual space' to physical space. As Shapin and Schaffer note,

> The cartographic metaphor is a good one: it reminds us that there are, indeed, abstract cultural boundaries that exist in social space. Sanctions can be enforced by community members if the boundaries are transgressed[12].

In *The Cultural Boundaries of Science*, Gieryn develops the metaphor to a much greater extent[13] and 'cultural cartography' is used synonymously with 'boundary work'.

> [C]ultural maps locate (that is, give a meaning to) white lab coats, laboratories, technical journals, norms of scientific practice, linear accelerators, statistical data, and expertise. They provide interpretative grounds for accepting scientific accounts of reality as the most truthful or reliable among the promiscuously unscientific varieties always available[14].

But, however useful it is, an analogy with borders between countries is *not sufficient* to account for the range of boundary work that we see in science. There are two main problems with the analogy: 1) It suggests that the relations between two entities (science and politics, say) are defined by just one boundary. In fact, there may be several boundaries between the two. 2) It assumes that the entities themselves are relatively stable and just the boundary between them moves one way or the other. However, boundary work in science can have a radical effect on the whole entity.

Gieryn recognises the second problem also but seeks a solution in the cartographic metaphor anyway. When discussing the Hobbes/Boyle debate as an example of 'monopolisation' he gets around the problem by declaring the existence of two maps rather than one – what was 'inside' and 'outside' for Boyle did not necessarily correspond to any features of Hobbes' map of the intellectual landscape[15]. However, as the idea of maps includes the independent reality to which they refer, this is an unsatisfactory fudge. The cartographic metaphor is over-burdened when Gieryn tries to account for how boundary work affects the entities themselves.

Beyond The Cartographic Metaphor: 'Intermediate Dependent Entities'

Because ideas about maps restrict the notion of boundary work and can, in some cases, lead to confusion between the referent and the representation, there is a case for augmenting

or replacing the cartographic metaphor with alternative conceptions of boundaries. The most important addition is the idea of a 'dependent entity'. In considering the boundary between two entities such as physics and politics, we need to consider the intermediate entity that links the two. One intermediate entity in this case might be radiological protection.

The rapid growth of mobile phone use in 1999 made radiological protection a fractious and controversial issue. There were, and still are, questions in the United Kingdom about whether the microwave radiation from handsets is harmful to users and whether it is safe to site base-stations close to schools. At the same time, profits and jobs depended on increased growth. All the actors recognise that physical science has a significant role to play in determining the correct course of action but not all would agree on what that role should be. The issues involved in radiological protection can 'belong' either to physicists or to politicians (or the officials empowered by politicians). Boundary work between politics and physics, then, happens at an intermediate site that is dependent on both of them. When the boundary work is over, the intermediate entity (radiological protection) will still be dependent on both physics and politics to have any meaning but will be sited within the (newly established) boundaries of one or the other.

Rather than thinking of physics and politics as two dominions with a common border, we should concentrate on the entities that depend on both of them to be meaningful. Thus, there are *many* boundaries between physics and politics – one defined by radiological protection; another defined by war technology; yet another defined by science education, etc. In addition to the set of boundaries between physics and politics, there are many others between physics and art, physics and social science, physics and the penal system, etc. All the boundaries make reference to a third entity that all the actors involved have some sort of interest in.

The cartographic metaphor is still important – it is hard to think of questions of intellectual hegemony in other terms – but we should not limit our account of science policy to just those aspects that fit within it. We can list some of the properties of boundaries that may be important when we apply the concept to science policy. In no particular order then, we note:

- Between principal entities there can be areas that are defined by their boundaries but not belong exclusively to either of them. There are two ways this can happen: 1) the intermediate area can be contested, that is, both groups involved seek to gain the area for themselves; 2) the two groups can share the intermediate territory. This is similar to the distinction between 'common-land' (agreed) and 'no-man's land' (disputed).

- If an intermediate area is shared (as in the case of common-land) then rules must be established (through negotiation: proposal and counter-proposal) as to *how* it is shared. The rules are thus an important defining feature of the intermediate area.
- Boundaries do not overlap. Although in figurative speech we often use expressions such as 'blurring the boundaries', it is more useful to think of boundaries between principal entities defining clear and distinct categories. In particular, boundaries distinguish four categories: Intermediate dependent entities belong to one or other principal entity, to both or to neither. (Which corresponds to whether they are found within a boundary, within an agreed intermediate area or within a disputed intermediate area.)
- In some circumstances, intermediate dependent entities can take on quasi-autonomous status. This means that they appear to act as autonomous, independent entities in their own right but are nevertheless dependent on science and some adjacent entity to have meaning. Environmental issues, for instance, can exhibit this quasi autonomy. Under scrutiny though, they are reveal themselves as dependent on science and politics.
- Boundaries themselves can have significant characteristics. For example, they can be virtual, practical, dynamic, fixed, or hostile. They can allow influence to travel one way or both ways or not at all. For a geographical analogy, we can turn to a boundary between areas of farmland. There may be a fence between the areas or the boundary may be a 'virtual boundary' that exists only in council records. A fence may have a practical purpose such as keeping animals in or it may be purely symbolic. It may allow people to cross the boundary but prevent animals from doing so or *vice versa*.
- Of particular interest is the question of whether the boundaries are stable or dynamic. A dynamic boundary is one that is maintained by constant boundary work. An example is a front-line in a war. The front may move very slowly or not at all but this is only because both sides maintain it continually. As a boundary, it would cease to exist as soon as the boundary work on either side ceased. In contrast, a fixed boundary is one that does not require *continual* work to exist (such as fence between two fields on a farm). Some of the boundaries between science and non-science are dynamic and some stable (though still disposed to modification).
- Two principal entities can have more than one boundary between them determined by different dependent entities or areas of common interest. (This is one of the ways in which boundaries in science differ from geographical boundaries.)

- Two principal entities can also have *no* boundary between them. Conceiving boundaries in terms of intermediate dependent entities thus vastly simplifies thinking about the constitution of science. We do not, for instance, need to ask, 'where does science stop and morris dancing start?' because there are no dependent entities that would make the question meaningful.
- In general, boundary disputes are not about the principal entities. They are about which principal entity 'owns' an intermediate entity.
- There are usually good, practical, reasons for division. (Good fences make good neighbours.)

With these points as a guide we can return to the question of boundary work and identify four activities: 1) establishing a new boundary; 2) moving a boundary; 3) changing the characteristics of a boundary; and 4) changing the rules that govern agreed intersections. Gieryn's three genres of boundary work – expulsion, expansion and protection of autonomy – can be understood within this scheme. Expulsion can involve establishing a new boundary, changing the rules that govern agreed intersections or changing the characteristics of a boundary or a combination of all three. Expansion involves moving a boundary. Protecting autonomy involves changing the characteristics of a boundary or changing the rules that govern agreed intersections. The scheme may seem elaborate but, by breaking 'boundary work' down into combinations of distinct activities, it greatly simplifies descriptions of the process of negotiation.

Another point to note about boundary work is that groups from *each* of the principal entities are involved. The demarcation of science is not necessarily driven by scientists and *their* interests. This is a point that Gieryn does not make clearly enough, for instance when he is explaining the cartographic metaphor,

> Maps of science get drawn by knowledge makers hoping to have their claims accepted as valid and influential downstream, their practices esteemed and supported financially, their culture sustained as the home of objectivity, reason, truth, or utility. Maps of science get unfolded and read by those of us not so sure about reality, or about which accounts of it we should trust and act upon[16].

Whilst this is true, it is a mistake to assume that the cartographers are *always* 'upstream' and the map users always 'downstream'. It is also a mistake to assume that scientists are always keen to expand the boundaries of science and that competing groups are

always keen to stop them. As we shall see, the BSE crisis in the United Kingdom in the 1990s is a case in point.

Dependent Entities are not 'Boundary Objects' nor 'Boundary Organisations'

Several studies of boundary work to date have concentrated on explaining how diverse social worlds can meet productively around scientific issues. They deal with the problem of 'translation' and the negotiation of mutual interests. The relevance to questions of policy of such analysis is clearly apparent as it elucidates the mechanisms by which mutually beneficial outcomes are achieved. Several accounts explain how the stability of relations between science and non-science is maintained with reference to 'boundary objects' and 'boundary organisations'. These sit between two social worlds and can be used by each for their own purposes without losing their identity. Thus, they operate as a means of translation.

However, translation is not the role of popular science texts that I am keen to explore here in relation to science policy. I concentrate instead on the role of popular texts in establishing the frame of reference for boundary negotiations. The question here is, how do we decide what is and is not 'scientific'? This issue is prior to the mechanisms for translating interests and facilitating collaboration. It is the question of how the consensus is achieved about the constitution of the boundary upon which subsequent negotiations about it are based. Because the multiplicity of boundary concepts is confusing, it is worth being clear about what 'dependent entity' means and its relation to boundary objects and boundary organisations.

Susan Leigh Star and James R. Griesemer introduced the idea of boundary objects in an account of how the various interests of scientists, trappers, amateur collectors, university administrators, and others came together in establishing a natural history museum in California. Boundary objects are the results of collaborations for the production of representations of nature[17]. In the case of the natural history museum, boundary objects include specimens, field notes and California itself. Each contributing group has partial jurisdiction over the boundary object but it will be meaningful for each group in very different ways.

Joan H. Fujimura develops the idea of boundary objects in an account of the development of cancer research. The task she sets herself is to explain both collaboration across divergent social worlds and the stabilization of allies behind 'facts' which she does by introducing a new boundary concept: the standardized package[18]. Because boundary objects and standardized packages do not, by themselves, explain all the dynamics of policy creation, David H. Guston adds a broader concept – the 'boundary organisation' – an organisation that

facilitates the creation of boundary objects and standardised packages and has distinct lines of accountability to each of two different social worlds[19].

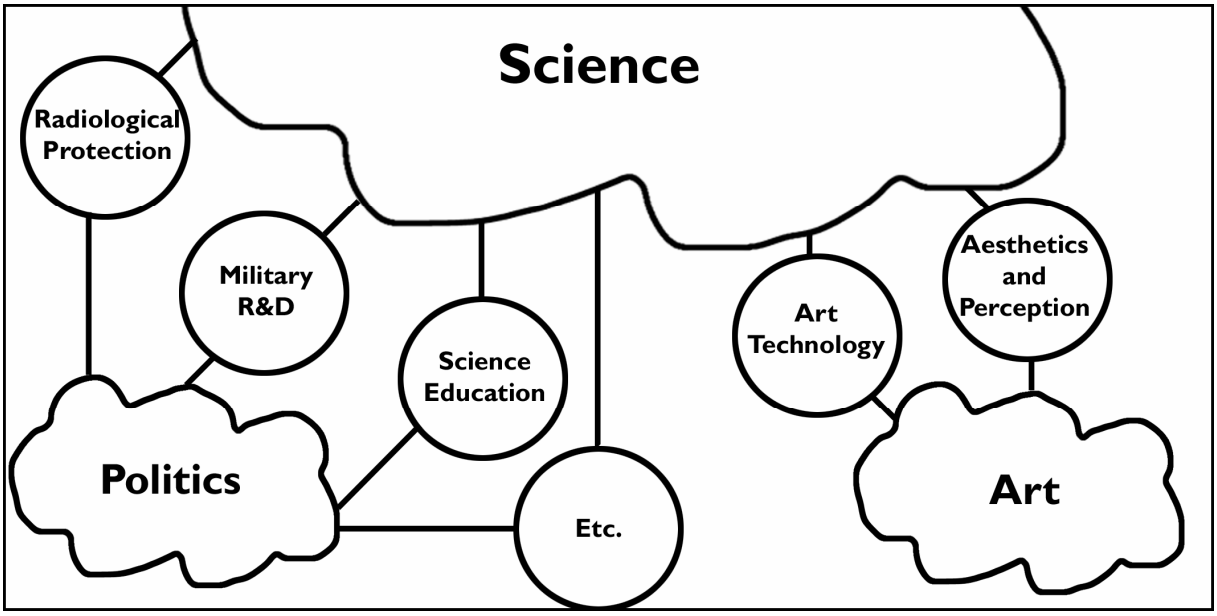
Boundary objects in particular are prone to be confused with dependent entities though they are quite different concepts. The idea of dependent entities is a broader concept than a boundary object. In some senses it is even more vague than a boundary object. Although both can be described as places where different social worlds meet, there are two levels of interaction involved. The dependent entity is the overarching concept. Boundary objects enable some types of negotiation over the 'rules' associated with the dependent entity. Thus, we can think of a dependent entity as including or encompassing several boundary objects that assist in the process of translation.

A boundary object, and even a boundary organisation is local; its meaning is not contested because there is no need for consensus. Indeed, part of the function of a boundary object is to remove the need for consensus over meanings – boundary objects have different meanings for each group. This flexibility over meaning is in contrast to the clearly delimited 'jurisdiction' each group has over various aspects of the boundary object. In contrast, dependent entities are necessarily non-local – their constitution has to be apparent to all and are thus characterised by consensus over their meaning. The establishment and maintenance of that consensus is the goal of boundary work as it is understood here. Although the jurisdiction over boundary objects is shared, jurisdiction over a whole dependent entity is generally understood to belong to one group or another. In general, a dependent entity is either 'part of science' or 'part of government' or whatever.

The emphasis in the work of Star and Griesemer, Fujimura and Guston is on the fourth type of boundary activity listed above: changing the rules that govern agreed intersections. 'Boundary objects', 'standardized packages' and 'boundary organizations' help explain how different social worlds collaborate when there is consensus that an issue is 'scientific'. That consensus is achieved through a different type of boundary work, which takes place at the level of the intermediate dependent entity itself rather than at the level of boundary objects that operate within it.

When it is not clear that a dependent entity is part of science or part of, say, government, then it is necessary to clarify the situation in order to locate power, attribute blame, control resources, etc. Unlike the more local case of establishing boundary objects, the process of negotiation by which this happens does *not* involve 'translation'. Rather, it is a process of 'naturalisation' – an ideological struggle. An important site for this type of

boundary work is popular/mass culture. We see this in the example of the BSE crisis in the United Kingdom.



The boundaries between science and adjacent fields (in this case, politics and art). There is no single boundary between science and politics. Rather, science and adjacent fields meet at a variety of 'intermediate dependent entities' – entities that depend on both science and an adjacent field to be meaningful. Science, politics and art are portrayed as being nebulous in contrast to the well defined dependent entities. The type of boundary work described by Star and Griesemer[20] takes place within dependent entities. The dependent entities encompass 'boundary objects' and 'boundary organisations'. In contrast, the boundary work described in this paper involves establishing the consensus about issues such as 'ownership' of the dependent entity – is radiological protection owned by science or government?

The BSE crisis as a boundary dispute

The major 'scientific' issues that have featured in public discourse over the past decade have involved 'cultural cartography' or boundary work from many different groups. Scientists *qua* scientists often had little either to lose or gain from boundary work associated with, for instance, controversies over the management of BSE and the safety and value of GMOs. As a result, it was often not 'knowledge makers' involved in drawing up 'maps of science' but other interested groups for whom the way the maps were drawn made a material difference.

After the announcement of a probable link between BSE (also known as 'mad cow disease') and 10 cases of a new variant of Creutzfeldt-Jakob disease (CJD) in March 1996, Stephen Dorrell (then the British minister for health) sought to distance his government from the controversy and panic that followed[21]. One way to do this was to redraw the boundaries between science and politics in such a way that both the cause of the problem and responsibility for its solution became 'scientific'. Dorrell deflected difficult questions by explaining that they were questions for scientists, not questions for him as a minister. This

response was applied even to questions about restoring confidence in foreign markets and whether the government was considering slaughtering the entire national herd and compensating farmers.

Deflecting questions this way represents boundary work on very specific boundaries between politics and science. The dependent entities involved were agriculture and public health policy. Previously these had 'belonged' to politics even though scientists have an interest in each of them and they require both entities to have meaning. Dorrell's response was, essentially, a proposal to expand the boundaries of science in these two areas at the expense of politics. In many areas scientists already have important advisory and arbitration roles and occasionally some real power, so extending the boundaries of science in this case is not a *particularly* radical proposal.

Even though the realm of science is expanded in this proposal, scientists themselves stood to lose rather than gain from the move. However, scientists did not stand to lose as much as the government had to gain so their defence of the existing boundaries was not very forceful and certainly not very co-ordinated. One response was from biologist and populariser Lewis Wolpert who was invited to comment on the affair in the week after the initial announcement[22]. Wolpert explicitly criticised Stephen Dorrell's concept of science and forcefully rejected (on behalf of his colleagues) any responsibility for the tough decisions that needed to be made. His rejection of Dorrell's boundary work was summed up in a slogan that he repeated several times: "science is descriptive, not prescriptive". This slogan serves as a pithy definition of science that suggests that a competing conception of science is *logically* flawed and can thus be rejected without reference to any merits it may have[23]. However, it was not Lewis Wolpert or other scientists who were important when it came to maintaining the existing boundaries of science in this instance.

Even though scientists did not have a strong interest in the outcome of the boundary work, other groups did and *they* ensured that the government was held to account. It was important to farmers for instance to prevent questions in which they had a direct interest being dubbed 'scientific' and therefore totally out of their control. Thus it was farmers, grocers, consumers, and opposition parties who maintained the boundaries of science rather than scientists. They had a material interest in doing so that was greater than scientists' own interest in the particular boundaries in question. As the controversy developed it became clear that Dorrell's proposal was not going to be accepted by anybody. The newspaper journalists continued to address their questions to the government.

Returning briefly to essentialist conceptions of science – it may be the case that there is a 'right' answer to the question of whether Stephen Dorrell acted reasonably or not. That is, there may be a way to arbitrate on such matters unequivocally much as Wolpert tried to do. The important point is that it does not matter whether there is a right answer or not. A true (essentialist) definition of science would not be sufficient to explain the outcome of the BSE controversy and the division of responsibility that emerged. The explanation lies instead in the *interests* that different groups had in maintaining or moving the conventional boundaries. The putative true boundary was irrelevant.

What is also important in this example is the question of where and how the boundary work took place. It was not a 'local' negotiation involving just two social worlds at a time. Rather, it was an attempt to change the meaning of agriculture and health policy universally; an attempt to present this construction of agriculture as 'natural', as if it had always been thus. Also, this process did not take place in elite forums. All the boundary work – the proposal and its rejection – took place in popular contexts such as news media. That is, we should understand this negotiation not as this process of translation but as an ideological process. Understanding such boundary processes involves attending to the available readings of texts in which ideological conceptions of science are rehearsed.

A Victorian Vision: Physicists as Torturers

The following example is even more directly related to questions of science policy yet extreme enough to amply illustrate the point I have been making about the boundaries of science being dynamic and subject to negotiation. At any moment, the terms of the negotiation appear to be entirely natural; whether one resists or supports change, shifts in the boundaries rarely seem *radical*. What it means to be a scientist changes *gradually* even if, in a Kuhnian sense, scientific knowledge is subject to revolutionary change from time to time. However, proposals that seem natural in one context can seem bizarre in another. With the passage of time, a proposal that would have been unremarkable to contemporaries is revealed as a major transgression of boundaries and redefinition of 'scientist'. One such proposal from the late nineteenth-century is that the civic duty of physicists should include torturing criminals. Bizarre as this suggestion seems today, it serves as reminder of the social contingency of science policy decisions, an aspect of science policy that frequently goes unnoticed because of the 'naturalising' effect of science itself. Though the suggestion was not embraced enthusiastically in the 1880s, it would not have been considered completely wide of the mark as it is today. A warning, perhaps, that our grandchildren may be equally bemused

about science policy debates that seem entirely straightforward to us at the beginning of the twenty-first century.

The proposal was made in a book entitled *The Unseen Universe*, which deals simultaneously with question of social organisation, economics, theology and thermodynamics[24]. *The Unseen Universe* (originally published anonymously) presents a physical argument for a belief in the immortality of the soul based on thermodynamics. The book attracted critical acclaim from such prominent physicists as James Clerk Maxwell and went through fourteen editions in thirteen years[25]. The authors revealed themselves by the time the fourth edition was published. Balfour Stewart and Peter Guthrie Tait were both famous physicists and popularisers. Two years earlier, Stewart had published a textbook on thermodynamics[26]. Before that he had, with Norman Lockyer (the first editor of *Nature*) published popular articles on thermodynamics and theology[27].

The Unseen Universe is an interesting example to look at from the point of view of boundary work because it makes claims about theology, social order, economics and thermodynamics all at once. To modern readers, the text strays a long way beyond the expertise of the authors. Indeed, the way their authority over questions of thermodynamics (which we grant them because they are physicists) seems to be conflated with the authoritative tone with which they address questions of social order (which has no foundation in their professional status) looks distinctly disingenuous to twenty-first century readers. But this is what makes the book interesting. How do we account for the difference between its reception amongst its contemporaries and the way (we can speculate) it would be read today?

Our initial reaction, might be to try to explain the difference thus: the late nineteenth-century was still early days as far as modern science is concerned and since then we have edged closer to the 'proper' relations of science, theology, economics, etc. So, our failure to respond to the rhetoric of *The Unseen Universe* reflects our superior understanding. This 'explanation' fits our intuitive sense of the boundaries of science being fixed and the constitution of science being external to society and culture, but closer examination reveals it to be logically flawed and empirically inadequate. Nevertheless, it remains compelling and this fact alone helps to explain why discussion of boundary work in science can be counterintuitive.

It may well be the case that the present relations between these fields represent a metaphysical improvement, but this has no bearing *by itself* on whether *The Unseen Universe* is perceived as scientific or not. What is important is our *belief* that our conception of the constitution of science is better than Stewart and Tait's. Being right is not enough by itself.

We also need to *believe* we are right (and believe that Stewart and Tait are wrong) before *The Unseen Universe* looks 'unscientific' to us. This means that we need to explain where the belief comes from, which our putative explanation (superiority) does not do and this is its logical flaw.

Interestingly, a modern book addresses many of Stewart and Tait's themes. *The Unseen Universe* has a great deal in common with Frank J. Tipler's *The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead* which argues that modern physics provides proof of an afterlife[28]. In both cases, the authors' status as scientists allowed them to be taken seriously. While Stewart and Tait had support from Norman Lockyer of *Nature*, Tipler received favourable mention in *Science*! V A Raman said of the book,

> Tipler has written a masterpiece conferring much craved scientific respectability on what we have always wanted to believe[29].

We can conclude that the explanation for the difference in reception of *The Unseen Universe* by its contemporaries and by modern readers is *not* the subject matter. The two books are different at the level of rhetoric rather than the substantive claim made. Somehow, Tipler frames his discussion in such a way that modern audiences can engage with the argument. Both books explore the very latest results of physics. Tipler, like Stewart and Tait before him, can then engage in boundary work over the 'ownership' of dependent entities such as morality and its rewards after death.

While it is true that neither book had much impact on the way physicists think about the physical world, they both offer accounts that both scientists and non-scientists could recognise as 'physical' or 'scientific'. The difference between them is that Stewart and Tait's book no longer seems scientific. This indicates that, in the intervening years, the meaning of the adjective 'scientific' has changed. It is not necessarily 'science' itself that has changed (whatever this may mean) but the intermediate dependent entities. If the 'ownership' of these or the rules governing them shifts then so does the *meaning* of 'science'.

In *The Unseen Universe*, imagery from one field is employed to naturalise a description in another field and the boundaries are transformed in the process. Greg Myers has traced the way commonplaces of social rhetoric were reified in the language of thermodynamics as physicists struggled to articulate the new theory in the early nineteenth-century. Later, after thermodynamics was well established, the theory itself appeared to support the ideology that gave rise to the commonplaces employed in its formulation[30]. The

section of *The Unseen Universe* examined here is just one extract that is itself an aside and does not deal with the main subjects of the book[31].

The extract speaks both about the role of physics in providing technological solutions to social problems and the role of the physicists generally. That is, it establishes physics as a subject that is valuable to society and proposes an extension of the role of the physicist. The authors are addressing the rising levels of violent crime and lamenting the transition from "merry England" with its "jolly and chivalrous wrestlers and boxers" to the modern "hell of running-kicks, garrotting, gouging and stabbing". The subject is raised as if it owes its place in the book not so much to its relevance as to its importance. The rise of violent crime seems to be a problem that demands immediate attention and this is why it is allowed to interrupt the flow of the argument. The subject and the way it is invoked look very much like a 'moral panic'[32].

> *Now* creatures in the likeness of men vent their despicable passions in murderous assaults upon women and children. But science hints at an effectual cure. It is probable that before many years have passed, electricity...will be called upon by an enlightened legislature to solve this desperate social problem. Imprisonment has been tried in vain, and, besides, it involves great and needless expense. The 'cat' though thoroughly appropriate, is objected to as tending to brutalise the patient and render murder not unlikely. No such objections can be urged against the use of electricity...For it can easily be applied so as to produce for the requisite time, *and for that only*, and under the direction of skilled physicists and physiologists, absolutely indescribable torture (unaccompanied by wound or even bruise), thrilling through every fibre of the frame of such miscreants[33]. [Italics in original.]

During the period that *The Unseen Universe* was enjoying popularity, physics itself was undergoing a process of professionalisation. This required support from society at large, which meant physicists had to present their discipline as worth funding. As Myers points out however, the value of physics was not immediately apparent. It had not been employed in natural theology as much as natural history or geology, and, unlike mathematics, it had no long tradition in the university. (Indeed, the subject was still often called 'natural philosophy', so lacking was 'physics' in heritage.) In particular, though, physics had not yet proved its practical value in the way chemistry had[34].

Electricity was something of a watershed for physics – its first unequivocal triumph. It was the first time that theory had pre-empted any technological applications. Nobody knew what would come from the development of electricity or how physics would be transformed.

In giving *their* assessment of the potential for electricity, the authors were going much further than an objective description. They were suggesting an extension of the areas where physicists' expertise is applicable and presenting this as a natural development.

As it turned out, the authority of the physicist was not extended into the field of correctional policy and, far from being seen as the protectors of public morality, torturers are universally despised. Electricity is used in torture today (Amnesty International reports the use of cattle prods and similar tools on victims) but nobody would feel that physicists *qua* physicists have any special interest in the matter. The punishment of offenders, especially their torture can no longer be considered even remotely relevant to physicists. A similar proposal to extend the role of physicists in this way would not and *could not* be made today.

At the time Stewart and Tait were writing, special circumstances made such a suggestion reasonable. Firstly, a moral panic demanded attention from all sections of society because it was treated as a priority. Secondly, electricity was a new technology and it was impossible to predict the social relations of its application. Thirdly, electricity was the first technology to emerge wholly from pure science and it was reasonable to assume that physicists would *keep control* of all its applications (or, rather, it was hard to imagine them losing control). Finally, there was still much more overlap between science and morality, economics, theology etc. than there is now. The border regions (or 'common ground') were broader in the 1870s because the Scientific Naturalist movement (led by the likes of Huxley and Tyndall) had not fully disrupted what Robert M. Young has described as a 'common cultural context' linking scientists, clerics and lay people[35]. Stewart's writing, in particular, fits into a 'natural theology' tradition rather than reflecting the ethos of Scientific Naturalism. However, the hegemony of Scientific Naturalism is reflected in his insistence that his arguments are *physical arguments* as here in an article in *Macmillan's* magazine written with Norman Lockyer:

> It is desirable to state clearly, and once for all, that our standpoint in what follows is that of students of physical science. (Stewart and Lockyer 1868, Quoted in Myers 1985: 52)[36]

The circumstances outlined above notwithstanding, the *only place* where a proposal such as Stewart and Tait's could make sense is in a popularisation. Suggesting that physicists involve themselves in the punishment of offenders is a proposal to move the boundaries of physicists' authority into a new area. (It is a claim to ownership of a dependent entity.) Within the confines of *existing* disciplinary boundaries, there was no scope to discuss such a

proposal. In professional scientific literature, the authors would have had enormous trouble demonstrating the relevance of their point. In a popularisation however, (especially one like Stewart and Tait 1886) the scope is much greater. Special circumstances such as a moral panic can legitimately make an impact in a popularisation but generally not in professional discourse (though moral panics could under some circumstances influence funding). This explains the special role of popular science texts in the process of demarcation.

Conclusion

What counts as science; who counts as a scientist; where to place the boundaries of scientists' responsibility and authority (for instance where science stops and politics or theology begins)? These are all matters of continual negotiation between scientists and the rest of society. One, often overlooked, function of popular science is to provide a forum in which the negotiation can take place – perhaps the most important forum.

The concept of intermediate dependent entities improves the concept of boundary work enormously. It allows us to deal with more than one boundary between principal entities and also allows us to recognise when there are none (for instance there are no boundaries between science an morris dancing!) Intermediate dependent entities give us a handle on the type of boundary work that goes on in popular texts and provides insight into the role of popular culture in framing science policy.

Rather than being a rival to philosophical approaches to science, the concept of boundary work offers a way around the problems of addressing an essentially social activity metaphysically. It does this by providing a clear way to distinguish the question, 'what is science?' from 'what is science taken to be?' However, we need to proceed with caution as there are philosophical implications of which we need to remain aware. The conception of science presented here is impoverished in the sense that emphasis is placed exclusively on the relations of science with other fields. (This is the reason that science and adjacent fields are represented as clouds in the diagram whilst the intermediate dependent entities are well defined and geometric.) In effect, science is thus defined as the sum of these dependent entities and the rules that govern them. Whether such a move is justified philosophically as well as sociologically is another matter.

Notes

[1] This perhaps should not be surprising in the context of the distinctly sociological turn in the philosophy of science since the publication of Thomas Kuhn's , *The Structure of Scientific Revolutions*, 2nd Edn., (Chicago and London: University of Chicago Press, 1970) . For a discussion of some of the problems of essentialist accounts of science and the insight afforded by 'deflationary' metaphysics see Sismondo, Sergio, 'Deflationary Metaphysics and the Construction of Laboratory Mice', *Metaphilosophy*, Vol. 28, No. 3 (July 1997), 219-232.

[2] The idea of a spectrum of science texts with specialist audiences at one end and mass audiences at the other with texts moving 'downstream' from one end to the other comes from Hilgartner, Stephen , 'The Dominant View of Popularization: Conceptual Problems, Political Uses', *Social Studies of Science*, Vol. 20 (1990), 519-539. In Lewenstein, Bruce V 'From Fax to Facts: Communication in the Cold Fusion Saga', *Social Studies of Science*, Vol. 25 (1995), 403-436, this stream metaphor is replaced with a 'web' model, which explains the various and changing roles different media in the scientific enterprise. My own analysis of popular contexts for science has revealed the role popular science texts play in boundary work. Even though the process of negotiation is rarely explicit, popular texts provide one of the most important forums in which boundaries of science are negotiated.

[3] The modern clarity about the status of phrenology is the result of significant 'boundary work' often in the context of popular science. See Cooter, Roger, *The Cultural Meaning of Popular Science: Phrenology and the Organisation of Consent in Nineteenth-Century Britain*, (Cambridge: Cambridge University Press, 1984) and Gieryn, Thomas F., 'Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists', *American Sociological Review*, Vol. 48 (Dec. 1983) , 781-795, 787-789. For a lucid account of the development of the apparent coherence of the two categories 'science' and 'the public' see Shapin, Steven, 'Science and the Public', Olby, R. C. *et al* (Eds.) *Companion to the History of Modern Science* (Chap. 65) 990-1007, (London: Routledge, 1989).

[4] Barthes, Roland, *Mythologies*, Annette Lavers (trans.), (London: Paladin, 1973)

[5] Sismondo, Sergio, op. cit. note 1, 221.

[6] Ibid., 220.

[7] Gieryn, Thomas F., 'Boundaries of Science', Jasanoff, Sheila *et al* (Eds.) *Handbook of Science and Technology Studies* (Chap. 18) 393-443, (Thousand Oaks (CA), London, New Delhi: Sage, 1994), 424. This is presumably a

reference to Barnes, Barry, *Scientific Knowledge and Sociological Theory*, (London and Boston: Routledge and Kegan Paul, 1974), Chap. 5 – *'Internal' and 'External' Factors in the History of Science*.

[8] Barnes, Barry, *T. S. Kuhn and Social Science*, (New York: Columbia University Press, 1982), 93.

[9] Gieryn, Thomas F. op. cit. note 7.

[10] Ibid., 424.

[11] Gieryn, Thomas F., *Cultural Boundaries of Science: Credibility on the Line*, (Chicago and London: University of Chicago Press, 1999), 15-17.

[12] Shapin, Steven and Schaffer, Simon, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*, (Princeton and Oxford: Princeton University Press, 1985), 333.

[13] Gieryn tells us that he has always been fond of maps and has a collection of over 300 of them, op. cit. note 11., vii.

[14] Gieryn, Thomas F., op. cit. note 11, x.

[15] Gieryn, Thomas F., op. cit. note 7, 424-425.

[16] Gieryn, Thomas F., op. cit. note 11, x.

[17] Star, Susan Leigh and Griesemer, James R., 'Institutional Ecology, "Translations," and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39', Biagioli, Mario (Ed.) *The Science Studies Reader* (Chap. 33), 505-524, (London: Routledge, 1999), 517 (Reprinted with revisions from *Social Studies of Science* Vol. 19 (1989), 387-420).

[18] Fujimura, Joan H., 'Crafting Science: Standardized Packages, Boundary Objects, and "Translation"' in Andrew Pickering (Ed.) *Science as Practice and Culture* (London and Chicago: University of Chicago Press, 1992) Chapter 6, 168-211, 169.

[19] Guston, David H., 'Boundary Organizations in Environmental Policy and Science: An Introduction', *Science, Technology & Human Values* Vol. 26, No. 4 (Autumn 2001), 399-408, 400-401. See also Guston, David H., 'Stabilizing the Boundary between US Politics and Science: The Rôle of the Office of Technology Transfer as a Boundary Organization' *Social Studies of Science*, Vol. 29, No. 1 (February 1999), 87-111.

[20] Star, Susan Leigh and Griesemer, James R. op. cit. note 17.

[21] The degree of panic is illustrated well by the fact that McDondalds stopped serving beef for several days! Jasanoff, Sheila, 'Civilisation and Madness: The Great BSE Scare of 1996', *Public Understanding of Science*, Vol. 6 (1997), 221-232 provides a good account of the controversy.

[22] *The World This Weekend*, BBC Radio 4, Sunday 26 March 1996.

[23] The rhetorical role of 'pithy definitions of science' is explored further in Nieman, Adam *The Popularisation of Physics: Boundaries of Authority and the Visual Culture of Science* (Unpublished PhD Thesis, University of the West of England, 2000), 159-167.

[24] Stewart, Balfour and Tait, Peter Guthrie, *The Unseen Universe; or, Physical Speculations on a Future State*, 8th Edn., (London: Macmillan, 1886).

[25] Myers, Greg, 'Nineteenth-Century Popularisers of Thermodynamics and the Rhetoric of Social Prophecy', *Victorian Studies*, Vol. 29 (1985), 35-66, 50, 55.

[26] Stewart, Balfour, *The Conservation of Energy: An Elementary Treatise on Energy and Its Laws*, (London: Henry S. King, 1873).

[27] Stewart, Balfour and Lockyer, J. Norman, 'The Place of Life in a Universe of Energy', *Macmillan's*, Vol. 20 (August 1868), 319. For further discussion of Stewart's oeuvre see Myers, Greg op. cit. note 25.

[28] Tipler, Frank J. 1995, *The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead* (Anchor).

[29] Raman, V. A., 'The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead – Tipler, FJ' *Science* Vol. 267 (17 February 1995), 1042-1043.

[30] Myers, Greg, op. cit. note 25.

[31] For a more detailed account of *The Unseen Universe* see Heimann, P. M., 'The Unseen Universe: Physics and the Philosophy of Nature in Victorian Britain', *British Journal for the History of Science*, Vol. 6 (1972), 73-79.

[32] For an account of the concept of 'moral panics' see Stuart Hall, Charles Critcher, Tony Jefferson, John Clarke and Brian Robert, *Policing the Crisis: Mugging, the State, and Law and Order* (Palgrave, 1978). For further discussion of the concept see Barker, Martin, 'Stuart Hall, Policing the Crisis' in Barker, Martin and Beezer, Anne (Eds.) *Readings into Cultural Studies* (London & New York: Routledge, 1992).

[33] Stewart and Tait, op. cit. note 24, 143-144.

[34] Myers, Greg, op. cit. note 25, 40.

[35] Young, Robert, *Darwin's Metaphor: Nature's Place in Victorian Culture*, (Cambridge: Cambridge University Press, 1985), Chaps. 2 & 5.

[36] The reference provided by Myers is incorrect. The correct issue is: Stewart, Balfour and Lockyer, J. Norman, 'The Place of Life in a Universe of Energy', *Macmillan's*, Vol. 20 (August 1868), 319.