The Materials of STS

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Introduction

> ‘Whatever resists trials is real.
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> The verb “resist” is not a privileged word. I use it to represent the whole collection of verbs and adjectives, tools and instruments, which together define the ways of being real. We could equally well say “curdle”, “fold”, “obscure”, “sharpen”, “slide.” There are dozens of alternatives.’[2]

Matter matters. But how does this happen? This is the issue I explore in this chapter: how Science, Technology and Society (STS) imagines that matter matters.

Latour’s words above point to the shape of the argument. In STS materiality is usually understood as relational effect. Something becomes material because it makes a difference: because somehow or other it is detectable. It depends, then, on a relation between that which is detected and that which does the detecting. Matter that does not make a difference does not matter. It is not matter since there is no relation between.

Inevitably there are complications. First, if matter is not given, then neither are relations. They too are relational and they have to be done. So in STS materiality cannot be prised apart from the enactment of relations or, more generally, the practices that do these. Here there is a methodological proposal. If you want to understand mattering of the material, then you need to go and look at practices, and to see how they do reals relationally. And, a vitally important coda: you don’t take anything for granted.

This leads to the second complication. I’ve just said: ‘you don’t take anything for granted.’ This is because relations and the matters that they do may shift in shape. The implication is that if we assume too much about their form we may not be able to detect the character of that shape-shifting and so the way that reals get materialised. But there are two further issues here. First, in practice we always and necessarily take all sorts of things for granted. As Pierre Duhem pointed out many years ago, a raft can be disassembled and rebuilt, but not all at the same time. Indeed, more strongly, what we take for granted is mostly invisible, below the waterline. This is a general and inescapable predicament. There is nothing to be done except to be aware of it. Second, we may want to say that practices are more or less patterned. If we say this then it follows that materials are also more or less patterned, for instance culturally. They keep on being re-done.

Can we talk, then, of relative stability? Can we talk of relatively stable relations and relatively stable materials? STS divides on this question. Some say yes, that indeed matters and their practices are relatively stable. This means that modes of mattering extend through time and space. Others are more sceptical. In this second view mattering gets done and redone in ways that shift unpredictably. The jury is out, and it is most unlikely to return a verdict in the foreseeable future. STS is, as I just said, divided. So in this chapter I start with patterned practices and relative stability and show how

[2] Latour (1988a, 158-159).

STS imagines these. Here the story takes two forms – humanist and material semiotic. Then I move to talk about instabilities in practice, and consider the shape-shifting that might be implied in mobile mattering, and the politics that are implied in mattering

Social Construction

Imagine a material technology. It might be an electricity generating plant, a bicycle, an electric vehicle, a print technology, a missile guidance system, or a sailing ship[3]. Then ask: why does this technology take the form that it does? Common sense suggests an answer. Its form reflects its environment, together with the task for which it is intended. So the shape of a sailing ship reflects the winds and the sea, the raw materials from which it is built, its environment. It reflects its social environment too – for instance the skills that are available in the culture. And then, again socially, it reflects the task for which it is built. Cargo carrying, fighting, or conspicuous consumption – the reason for which it is constructed is reflected in the build. Note that environment and task overlap. Vessels that need to sail close to the shore – or close to the wind – get shaped in one way. Those that don't, in another. And both task and environment may change too. Wood becomes scarce, and steam power gets invented, so the sailing ship gets consigned to history, and is replaced by the steam packet.

The discipline of STS works through case studies. Some describe the social shaping of technologies. How did the bicycle come to take the form that it now does? The answer is that it was shaped by economic and social interests, the cultural skills available, and, of course, by the laws of momentum. STS scholar Wiebe Bijker tells us that the penny-farthing was an excellent bicycle for young men who wanted to display their masculinity, but it wasn't very stable. That, of course, was precisely the point: in the culture of the time in western Europe, stability and virtuoso displays of masculinity were taken to be mutually exclusive. At the same time, this meant that it wasn't suitable for anyone else – and especially for women, constrained in the Victorian period by particular and gendered ideas about modesty. More culture. The regular safety bike with smaller wheels of the same size was much more stable and much more 'suitable' (especially in the version without the crossbar). It therefore had a much larger potential buying public, and was much more profitable. The consequence was that it replaced the penny-farthing. Here's the argument: the bike was shaped (and shaped quite literally) by a combination of economic and social interests and cultural capacities – not to forget the laws of momentum.

This is the social shaping of technology at work. Materials – technologies – are moulded by the intersection of natural and social factors. They are shaped. There isn't much difference between this and what is often called the social construction of technology. Both phrases are current in STS. If there is a distinction perhaps it's this. To talk of social shaping draws our attention to

[3] For electric power see Hughes (1971; 1979), the bicycle see Bijker (1995), electric vehicles see Callon (1980), on missile guidance systems see MacKenzie (1990), on print technologies see Cockburn (1983; 1999) and on sailing ships see Law (1986). For edited collections on the social shaping of technology see Bijker, Hughes and Pinch (1987), Bijker and Law (1992), and MacKenzie and Wajcman (1999).

the larger factors (economic conditions, cultural assumptions) that pattern materials. By contrast, to talk of social construction differentially draws our attention to the people doing the patterning, the act of creating and building, and their uses of culture. But the difference is a nuance and in practice in STS the terms are used more or less interchangeably.

There is a large body of excellent STS work on the social shaping or the social construction of technologies. It tells us a great deal about particular kinds of materials, and the forms that they take. It is a basic resource in any study of material culture. But its explanatory form runs us into the second complication that I mentioned above. This approach, the social construction of technology (I'll call it by its common acronym, SCOT) is certainly relational, but it also makes strong assumptions about the overall shape or pattern taken by those relations. I'll mention three. One: it makes assumptions about people, endowing them with special and creative powers: for instance, the ability to acquire culturally transmitted skills, to design, and to use tools. Two: it assumes that the natural world is pretty much a given: that, for instance, the laws of momentum are unlikely to change. And three: it assumes that the social world has a particular somewhat stable, albeit possibly ultimately revisable, shape too. Ideas about safety, modesty, and the economic interests of bicycle manufacturers, these provide an third part of the explanatory backcloth for the form taken by materias. In SCOT it is the relations between the three that give shape to the matter at hand: the safety bicycle or the sailing ship.

These assumptions reflect a common understanding of the character of proper social science explanation. In part this is a commitment to theoretical humanism. It is assumed that people are special because they are active agents. They are taken, for instance, to be language users, or they're endowed, as I noted above, with the capacity to use tools and acquire and deploy cultural skills. Probably they count as moral beings too, and appropriately exercise ethical and political judgements. At the same time, as I also mentioned, it is taken for granted that the natural world is relatively stable, and that, at least for the purposes of understanding the shaping of materials, so too is the social and cultural context. This is a metaphysics that generates a particular and highly productive understanding of materiality. In practice, in this way of thinking, the material world acquires its significance in relation to human activity and human purposes or needs. It may do so in the form of an environmental resource where materiality is treated as some kind of standing reserve. Alternatively, materials may be understood as objects that have been given a shape like a tool, something that is of functional use such as a penny-farthing or a safety bicycle, or perhaps something to be appreciated aesthetically such as an art object. Materials, then, express, inter-alia, sets of cultural practices and prejudices. If we stick with the safety bicycle these have, for instance, to do with metallurgy and metal working, the organisation of labour, and the proper role of women in society. This is material culture at work in the vision offered by SCOT. It is embedded in patterns of working and living, and in the objects that are implicated in such patterns.

Much of STS works this way, but parts do not. 'Material semiotics' – a blanket term that I use in this chapter to cover a range of approaches from so-called

actor-network theory through parts of feminist technoscience studies, to work in governmentality influenced by the work of Michel Foucault – takes none of these categories for granted[4]. In principle in these non-humanist approaches, everything – people, the natural world, and social and cultural context – are all shaped in relations. So what happens to materiality if we think this way?

The Laboratory According to the Sociology of Scientific Knowledge

Imagine a laboratory. It might be an historically important laboratory from the English seventeenth century, or SLAC, the Stanford Linear Accelerator, the Salk Laboratory in San Diego, CERN near Geneva, or a small laboratory in a provincial British university.[5] Here is a core question for STS. Why and how do the ideas created in such laboratories take the form that they do?

There are different answers to this question. But if you track and trace the day-to-day work in a scientific laboratory you find a lot of practical work. People are handling objects, instruments, animals, cell-lines, detectors. That's what an experiment is: a whole set of bits and pieces assembled together. You find a series of instruments, from rulers, through scanning electron microscopes, to PCR machines and neutrino detectors. There are lots of texts and inscriptions too. A scientist's desk is covered with notes, papers, books, reports, graphs, photographs, and arrays of figures, electronic or otherwise. And then there is talk. There is gossip, of course, but also science talk, though the two may be impossible to disentangle. So there are rumours about new experimental results, guesses about what a rival laboratory is up to, and reports of seminar presentations.

STS grew up in debate with philosophers. Whilst epistemologists usually argue that scientific method is philosophically special (though they debate how this might be between themselves), STS ethnographers and sociologically inclined historians of science are more impressed by the messy mundanity of laboratories. In the STS way of thinking laboratory work (or science practice in general) often looks more like cookery than cogitation. Or it looks like light industry, since some of it is being done in warehouse-sized buildings or holes in the ground filled with fancy machinery. Then again, for STS the conduct of science is also a matter of more or less large-scale organisation – both experimental and social (assuming that it is possible to separate the two in the first place.) So what should be made of this?

The sociology of scientific knowledge (SSK), in an approach that owes much to the writing of historian of science Thomas Kuhn[6], influentially argues that the ideas generated in laboratories reflect the interaction between the natural, social and cultural environments on the one hand, and the task of solving

[4] On actor-network theory see Callon (1986), Latour (1998) and Law (1992), on feminist technoscience studies see Haraway (1989; 1991b) and Barad (1999), and on STS-influenced work on governmentality see Barry (2001).
[5] On SLAC see Traweek (1988), on the Salk laboratory see Latour and Woolgar (1986), on CERN see Knorr Cetina (1999), on a British biochemistry laboratory see the chapters by Law in Callon, Law and Rip (1986), and on the creation of the laboratory in restoration England by Robert Boyle see Shapin and Schaffer (1985).
[6] Kuhn (1970).

scientific and technical problems on the other[7]. It argues that in laboratory work is messy, practical, and materially heterogeneous. In this way of thinking knowledge may be theoretical, but it is also embodied in skills and ways of seeing, and in the relations between people, machines and experimental objects. It is shaped or constructed by human beings who deploy cultural and material tools to solve puzzles. Their solutions thus reflect their creativity, those tools, and a relatively stable natural, social and cultural environment. The argument is similar to that of SCOT – though SSK preceded SCOT, and is much more controversial since it undermines the epistemological version of the scientific method.

The Laboratory According to Material Semiotics

Material semiotics attends to much the same messy laboratory realities. It starts, like SSK, with a story about the assembly of heterogeneous materials. Then it notes, again like SSK, that this is often, indeed perhaps usually, a process beset by uncertainty. In most labs and most of the time, at the experimental cutting edge entropy is constantly threatening. Experiments don't work. The signal to noise ratio is too low, a vital input isn't available, the software has crashed, or the experimental rats are anomalous. Then it says (and again this is close to SSK) that laboratory science is all about ordering (in) an uncertain environment. It is about lining materials up for long enough to get them to hold in a particular way. It is about creating assemblages that will hold sufficiently well to allow an experiment to take place. But at this point it starts to part company from SSK.

First, and absolutely crucially for any understanding of materiality, it argues that scientific experimenting is about lining heterogeneous components up for long enough to enact materials that can be detected, inscribed, and transcribed. Note that: to enact materials. This claim of radical relationality represents a radical break from both SSK, and common sense. To repeat, it is being argued that whatever emerges from an experiment is an effect of the relations that are assembled and held together in it. Natural, social and human materials and realities, all of these are understood as effects rather than causes. This means that there are no essential or foundational differences between such realities. The differences that there are (and these are often deep) are taken to be consequences, not causes. It also means that they cannot be treated as explanatory resources. The natural, the social and the human do not explain anything. Rather, it is they that are in need of explanation[8].

The STS laboratory ethnographers arrived at this radical position by looking at the messy laboratory practices that generate representations through more or less post-structuralist lenses. What they found is that at the start of a complex and cutting edge experiment representations, realities, and contexts are usually almost indistinguishable.[9] Talk is likely to combine ideas about natural realities, or hints from data sources, with gossip about the reliability of the experimental setup, the sources of materials, or training of the technicians or the track record of the scientists doing the work. Here methodological

[7] See, for instance, Barnes (1977) and Collins (1975).
[8] The point is developed in Latour's recent (2005).
[9] See Latour and Woolgar (1986) and Law (2004).

concerns, ideas about the natural world and assessments of the social are freely mixed up in the network of relations. The plausibility of a possible empirical result may be inextricably linked to the reputation of a laboratory. Different versions of the real with very short lives are being circulated.

Most putative versions of natural reality never make it past this stage of visibly messy heterogeneity. A few, however, start to become more robust. Doubts about the context in which they were generated, worries about noise in the detectors, or the reliability and integrity of the scientists involved, start to disappear. More data appears because the experimental rig holds together. Then data resonates with a theoretical hunch, or rumours about findings coming from another laboratory. And as this goes on and the network of relations reconfigures itself, particular representations of the real start to lose their qualifications. And if the process goes all the way, then the those representations of reality are purified of all their qualifications. They come to stand not for the messy and heterogeneous social-cum-natural-cum-organisational-cum-methodological process out of which they emerged with all the built-in qualifications and doubts. The relations are reconfigured so they come to stand, instead, for a reality that by virtue of this process, has become a feature of the natural world. But only afterwards. Only at the end of the process.

So material semiotics counter-intuitively assumes that laboratory realities do not exist outside the relations that produce them. But this leads to a second point. Thus it also distances itself from SSK by insisting that realities and knowledges are not made but done.[10] Thus in SSK it is usually said that knowledge is 'constructed'. The SSK assumption, perhaps more often tacit than explicit, is that once construction has taken place, something has been made that achieves a status somewhat like that of the bicycle.[11] Once the bits and pieces have been successfully assembled and bolted together it is taken to have a form, and everything else being equal it will continue to hold that form. But material semiotics does not share this assumption. Instead it assumes that knowledge and realities are being continuously enacted or performed. This talk of performance does not lead us to Goffman, for Goffman assumes that people are resourceful actors on a stage with more or less fixed props. Instead it takes us to the kind of non-humanist and post-structuralist world imagined by Michel Foucault or Judith Butler in which human subjects are being enacted and given form in relational practices just as much as anything else[12]. And if the practices stop? Then so do the realities they are performing. For realities only exist in the practices that materialise them. Which leads to a third important consequence. If the realities materialised by science are practice-dependent, then it also follows that they cannot be universal. This means that science and its realities govern, but only in very specific practices and locations.[13] And this means in turn that it becomes

[10] The distinction is most clearly developed in Mol (2002).
[11] SSK often attended to controversies and their 'closure'. The assumption was that one might expect a single solution to controversies in science, the construction of a single reality. See Collins (1975)
[12] See, for instance, Foucault (1979) and Butler (1990).
[13] The argument is made explicit in Latour and Woolgar (1986) and, Latour (1988a). See also Law and Mol (2001).

important to ask geographical questions about where the practices materialising realities are located, how they link together, and how materialisations circulate – if indeed they do.

All of this is counter-intuitive and controversial, but it is also STS's most distinctive general insight into the character of materiality. And it is what Latour was pointing to in the epigram with which I started this chapter. In saying that the object is to explore 'the whole collection of verbs and adjectives, tools and instruments, which together define the ways of being real', he is pointing to the relational character of materialisation, and the way in which this is embedded in practices. In short, in its material semiotic versions, STS is precisely about the processes of realising or mattering. And it is telling us that such processes of realising or mattering do not simply apply at the cutting edge of science – or indeed in the context of technological innovation. Rather it is suggesting that they are ubiquitous. Materialising, inseparable from practices as it is, is being done everywhere.

If this basic insight is correct then it has profound implications for locations and topics that are far removed from experimental science.

Patterning

Now we reach a location of debate in material semiotics. This has to do with the patterning of practices. For unless we want to say that practices and the realities that they materialise are utterly idiosyncratic, then we need to attend to how – and the extent to which – those patterns repeat themselves. And even if we ignore sociological theories of practice (on the grounds that they are socially reductionist and therefore don't consider how it is that the social is being redone along with all the other forms of the real[14]) material semiotics has generated at least four different ways of thinking about such patterning.

First, it has been argued that once practices with specific patterns become established they tend to reproduce themselves and spread. Philosopher and historian of science Ian Hacking catches what is at stake here in the title of his article on 'the self-vindication of the laboratory sciences.'[15] His assumption is that the different practices in the laboratory sciences are so interlinked and mutually dependent that practices and realities at one site are likely to be picked up and incorporated in experimental practice at other sites. In the abstract alternative realities and forms of experimental practice are perfectly conceivable, but in practice they are unlikely. Analogous arguments about what one might think of as the path-dependency of scientific practice and its materialisations are explored by sociologist of science Andrew Pickering.[16] Particular versions of the real, particular experimental practices, and particular theories and finding emerge from periodic moments of upheaval in the natural sciences, and then they tend, at least for a time, to become stable. It isn't worthwhile – and probably not possible – to articulate alternative sets of practices

Second, and only somewhat differently, it has been argued that practices may be extended – but only with considerable effort. So, for instance, Bruno Latour

[14] The argument is made in Callon and Latour (1981), and at length in Latour (2005).
[15] Hacking (1990).
[16] Pickering (1993; 1995).

and Steve Woolgar, while arguing like Pickering that it is too expensive literally and metaphorically to undermine the interrelated scientific and instrumental practices of materialisation, also explore how particular realities-and-representations may move from site to site in specific material forms that don't get distorted, but rather hold their shape (Latour calls these 'immutable mobiles'). Immutable mobiles may include texts, for instance in the guise of scientific papers or reports, and people such as scientists and technicians who may carry particular skills. They also, and possibly in the long run most important, include instruments, devices and technologies which also hold their structure as they are shipped from one location to another. The suggestion is that these get embedded in, and tend to have patterning effects on, other sites of practice.[17] Indeed, Latour has argued that 'technology is society made durable.'[18] But the argument is a bit tricky – or at least it cannot be applied mechanically. Immutable mobiles may get distorted or lost along they way, and whether they will work, or work in the way that was originally intended when they arrive at their destination is always an open question. For the argument about immutable mobiles to work, the new site of practice has to reflect the pattern of relations. So, for instance, as Latour shows, to Pasteurize France it was first necessary to reshape French farms as mini-laboratories. It was only then that the vaccines took the proper material form of protecting cattle from disease.[19]

The notion of the network is a crucial metaphor in this second version of relational mattering. Scientific practices and the realities that they enact, only exist within specific sites and networks of relations, and, crucially, it takes a lot of effort to organise these. Latour catches what is at stake when he writes:

> 'We say that the laws of Newton may be found in Gabon and that this is quite remarkable since that is a long way from England. But I have seen Lepetit camemberts in the supermarkets of California. This is also quite remarkable, since Lisieux is a long way from Los Angeles. Either there are two miracles that have to be admired together in the same way, or there are none.'[20]

The miracle is the creation of networks which carry camemberts or the laws of Newton without melting or otherwise distorting their relational structure.

A third way of thinking about shared patterning attends to styles of materialisation rather than to specific objects. So, for instance, it is well known that in his writing (surely interpretable as a particular version of material semiotics!) Michel Foucault is preoccupied with the character of epochal epistemes. In particular, he is interested in the way in which what he calls the modern episteme percolated in and through the practices of the social, starting in the late eighteenth century. But what is the modern episteme? One answer is that it is a particular strategy, often and perhaps usually implicit, that orders the materially heterogeneous relations of the social to generate particular and distinctive patterns of subjectivities and objectivities. Foucault's interest in the processes of decomposition, recomposition, normalisation and

[17] See Latour and Woolgar (1986), and Pickering (1995).
[18] I place this in citation marks since it is the title of a paper by Latour. See his (1991).
[19] Latour (1988b).
[20] Latour, 1988 #182, 227}.

self-monitoring that enact modern subjectivities is well known. However, the modern episteme can also be seen as a strategy that tends to generate specific versions of materiality. For like subject, objects, may also be decomposed, recomposed, and normalised. The rationalisation of the subjectivities implied in military drill is only possible if the devices caught up in these practices are also rationalised and standardised. In the absence of a standardised weapon – or industrial machinery – drilling human beings to turn them into docile subjects makes little sense. Perhaps, indeed, it is not even possible. This, then, is a strategy or a style that tends to pattern matter. It is a mode of mattering. And it may be that rationalisation is not the only style of materialisation enacted in the modern episteme. Another that that might fit with Foucault's account would be the technologies of surveillance that precede and accompany reflexive self-monitoring. And yet another might be the materialisations appropriate to the pleasures embedded in the modern self.

Foucault cannot be claimed for STS, but his work is important because it suggests the possible importance of styles in the relational or ontological patterning of practices. Unsurprisingly, some material semiotic authors have followed his lead. In particular, however, they have suggested that multiple styles or modes of mattering may be practised alongside – or in interaction with – one another[21]. To take one example, in a study of the ordering processes in a large scientific laboratory, John Law (the present author) argued that managers, management systems, meetings, technologies and texts all performed a series of different but recurrent patterns or styles. [22] One of these was 'administrative'. It enacted rational-legal versions of due process in Weberian mode. This pattern could be found in the laboratory accounting system, in paperwork such as agendas and minutes, and in versions of management subjectivity that emphasised the importance of rule following. But there was another quite different 'entrepreneurial' mode of ordering. This was carried in a new management accounting system, in publicity materials, and in the organisational insistence on personal responsibility and delivery. The relations between these were contingent. Sometimes they clashed, and on other occasions they dovetailed together. Both, for instance, were materialised in the design of large-scale scientific instruments which needed to enact both the health and safety regulations (a version of administrative patterning) and the needs of possible customers (which reflected a version of entrepreneurial patterning). In these instruments, then, mattering was being done in at least two modes simultaneously – and there was no longer a single ordering episteme, but instead there were several interacting with one another.

But there is a fourth way of thinking of the relations between practices. Instead of looking for common patterns it is also possible to look for differences and disjunctions. Perhaps Law's emphasis on different modes of ordering or matters starts to do this. But the argument can be made much more emphatically.

[21] See, for instance, Latour and Venn (2002) on regimes of enunciation, and Boltanski and Thévenot (2006) on 'cités' or commonwealths.
[22] This is discussed at length in Law (1994).

Ontological Difference

Imagine a set of practices. They might have to do with an aircraft, or Alzheimer's disease, or, say, lower limb atherosclerosis[23]. So, for instance, and sticking with the last of these, a textbook on atherosclerosis may tell us that changes in the blood, perhaps associated with diet and lack of exercise lead to disease in the form of atherosclerotic plaque. Then it may tell us that this builds up on the interior walls of blood vessels. If this plaque builds up beyond a certain level then it begins to restrict the flow of blood through the vessel to the extremities of the body – for instance to the calves and feet. The result is pain on walking because the muscles need more oxygen than they are getting if they are exercised.

Pause for a moment. Lower limb atherosclerosis is a nasty and not uncommon condition. But is it one thing or is it many? The textbook says that it is single condition. But what happens if we attend to practice rather than to theory? The answer turns out to be surprising. This is because what we discover is a high degree of variability: mattering is being done in a large number of different ways. So, for instance, in the doctor's surgery the patient's presenting symptom for the lower limb atherosclerosis is likely to be pain on walking. This is called claudication. In the radiography department the condition appears in the form of an angiogram – that is, as an x-ray that is taken to reveal the position and size of the blood vessels after a radio-opaque dye has been injected into the patient's circulatory system. In an angiogram the narrowing in the patterns that appear on the plate are taken to show stenoses in the blood vessels. In the ultrasound department the disease appears as an inscription that is assumed to represent the speed of the blood flow. Here the idea is that blood passes more quickly through the diseased and therefore constricted parts of a vessel. Blood flow is measured with a device that emits an ultrasound signal and is moved over the gelled skin of the patient following the line of the suspect vessel. The frequency of the signal reflected back into the probe indicates the speed at which the blood is flowing. And then, on the operating table, with the leg opened up and the vessel revealed in a surgical intervention, the disease appears in the form of a thick white paste that may be scraped from the vessel's interior.

So here is the paradox. If we attend strictly to practice, then lower limb atherosclerosis is being materialised in four or five quite different ways, even though everyone also assumes they are dealing with a single body. The issue comes to a head in the practice of the case conference where the professionals meet to decide what to do about a particular patient. Sometimes everything fits together. The different materialisations and their practices are successfully co-ordinated to form a consistent whole. Sometimes, then, the textbook account works. But often this is not the case. Perhaps the Doppler investigation doesn't fit with the angiography, or the patient doesn't report claudication even though the angiograph shows precious little blood flow to the leg. This is a major practical problem for health-care professionals, but is also crucial if we want to understand the character of mattering in practice. The conclusion is that if we consistently attend to practice and how materials

[23] On an aircraft see Law (2002), on Alzheimer's disease see Moser (2008), and on lower limb atherosclerosis, see Mol (2002).

are done, then mattering is multiple. Mol indexes this by talking, oxymoronically, of 'the body multiple'.

Ontology, Complexity, and Politics

What happens if we take this argument seriously? The first consequence is that mattering becomes complex. A second is that we need to try to find new ways of thinking that complexity. Here the question becomes: how do the multiple realities hold together? But a third is that it opens a new space for what might be called an 'ontological politics'.

Mol explores the relations between practices and materialisations empirically. Sometimes practices are consistent (the nicely-running case conference). Sometimes they contradict one another (the case-conference with contra-indications). Sometimes practices and their realities are separate from one another. (Epidemiology indicates that physiotherapy may be effective in treating lower limb atherosclerosis, but this reality does not appear at the case conference.) Sometimes realities that don't really cohere are added together in a form of syncretism. (A single score to test a disease is derived from quite different components). Sometimes one practice is included in another. (Clinical diagnosis indirectly includes epidemiological realities because medical practitioners look for likely conditions, but epidemiological realities conversely include practitioners' clinical observations). But if mattering is empirically complex, then this also suggests a novel way of thinking about politics. Thus if the feminists told us that biology is not destiny, then material semiotics is now telling us that reality is not destiny. This is because if we attend to consistently practices, then we start to discover alternative forms of materialisation. And if we discover alternative forms of materialisation, then it is not surprising that some may be better than others from one point of view or another. And it is this that is the space of an ontological politics. But/and the promise of such a politics is being hidden in a widespread assumption of ontological consistency. Most of the time, in theory, the differences between practices are being effaced – which means that matter is being made singular. It is being turned into destiny by sleight of hand. And the textbook is just one example.

So what is the scope of an ontological politics? How might this be done? There can be no general rules. If the general strategy is to bust (the appearance of) ontological monopoly, there are many plausible tactics.

One is to introduce subversive tropes that bend material-semiotic matterings in novel ways. Technoscience writer Donna Haraway works in this way when she mobilises the radical, anti-racist, feminist trope of the cyborg to interfere with its militaristic and masculinist predecessor project – and more recently, she does something similar by re-imagining human-animal relations in her notion of 'companion species'.[24] Postcolonial STS theorist Helen Verran works, somewhat differently, to soften and multiply reality-enacting practices in her work on encounters between white Australians and aborigines[25]. What is at issue here are the materialisations of land in a context of legal disputes

[24] Haraway(1991a; 2003; 2008).
[25] Verran (1998). For related work on the enactment of number in a Nigerian classroom see Verran (2001).

about its ownership and use. Is land a fixed reality in a Euclidean space-time box (which is how white people tend to experience and enact it in their practices)? Or is it rather something that is done, and done again, and then done again, within practices and rituals, (which would be closer to aboriginal experience)? Verran intervenes to try to undo what she thinks of as the hardening of the categories in white practices and its imagination. Land, she suggests, is being done in legal practices just as much as in aboriginal rituals. As a part of this she explores the multiple enactments that are taken for granted in aboriginal cosmology, which treats the world as a continuing performative expression of practice.[26]

A second strategy is to discover multiplicity within practices that appear to be producing ontological monopoly. This is the tactic adopted by Mol in her work on lower limb atherosclerosis. She might have mounted arguments against the domination of biomedicine and the patriarchal character of the medical profession. No doubt many such complaints would be justified. But what she actually did was to generate differences and so potential tensions between the practices of different professionals and the materialities that they enact. This is an ontological politics because it makes it possible to propose, for instance, that in particular circumstances, the realities enacted in walking therapy may be better than those of surgery.[27]

A third related tactic is to discover practices that are materialising alternative but marginalised realities. So, for instance, biomedical enactments of Alzheimer's disease are common and powerful. But there are also alternative non-biomedical enactments of dementia. STS scholar Ingunn Moser describes the Marte Meo Method which is a technique that analyses patterns of interactions between carers and patients to detect and enact otherwise unrecognised competences in the latter. Moser writes that:

> '[Alzheimer's] is object and relation, and the object is made in and through relations. When the nurses work on the relations of Alzheimer's, they also transform the object. For instance, if they slow down verbal communications and interaction, the person with dementia may be able to act and participate competently.'[28]

These are practices that materialise dementia quite differently. Moser is showing that biomedical Alzheimer's is not destiny. There are plausible alternatives that matter too.

Another fourth option is to attend more carefully to the character of circulation – and to what it is that circulates. How seriously, for instance, should we take Latour's suggestion that technoscientific mattering is co-ordinated in the circulation of immutable mobiles? That practices are tightly aligned when objects that hold their shape circulate from site to site? The answer is: not necessarily seriously at all. For instance, Marianne de Laet and Annemarie Mol describe an object that changes it shape as it moves. This is a water pump that is widely distributed in Zimbabwe.[29] Manufactured in Harare, it is found in many villages. It is mechanically simple and contextually

[26] See also Law (2004).
[27] Mol (1999)
[28] Moser (2008, 104).
[29] de Laet and Mol (2000).

undemanding since it needs a borehole and a concrete platform that are supposedly created by the village collective – but not much else. And the pump itself is flexible, so that when it breaks down it is usually repaired with whatever comes to hand – tree branches or pieces of worn-out tyres. And sometimes it isn't a collective that looks after the pump, but just a few families. Even its manufacturer is agreeably surprised its degree of flexibility. The lesson is this. Rather than being immutable, the pump is better understood as a mutable mobile, a fluid object. It is being materialised in subtly and not so subtly different practices in different locations. And this has a knock-on political consequence, because what we might think of as the 'watering of Zimbabwe' is quite unlike the 'Pasteurization of France'. Pasteur set up a rigid network which turned every farm into a laboratory, and located the Institut Pasteur as the central node, the obligatory point of passage. The manufacturer in Harare produces the pump, but once this is done it drops out of the picture. The fluid materialisations of the pump in practice also means that the centre no longer matters – or, better, that it isn't a centre at all.[30]

Conclusion

In this chapter I have explored how STS imagines materials by considering two major story-lines. Both take it for granted that objects are relational effects. The first, SCOT, whose intellectual origins and inspiration are historical and sociological, explores the cultural, social, and human shaping of materiality. It explains why materials take the form that they do by drawing on assumptions about the relative stability of the social, economic and natural environments on the one hand, and the creative character of human action on the other. Its dominant metaphors talk of construction and the making of materials. The second, material semiotics, which draws on post-structuralism and post-humanism, treats everything – materials, but also culture, social arrangements and human subjectivities – as the relationally variable effects of practices. Its metaphors emphasise the enactment and doing of materials or objects. Using verbs rather than nouns, and exploring how it is that processes work, it talks more of mattering or materialising, than of matter or materiality. Since different practices materialise in different ways, its understanding of materiality is complex. How do materials hold together, if they do? This is its analytical and empirical question.

If two approaches differ analytically, they also differ politically. SCOT identifies social agendas, for instance to do with gender, class, or ethnicity, that are built into or shape materials. It has often been effectively used in the service of social critique. Material semiotics may also explore how social agendas are enacted in practices, but it is distinctive for its sensitivity to the political potential of multiplicity. Its ontological politics talks up and explores different matterings, or modes of mattering. This is a politically performative intervention since it erodes the monopolistic assumption that reality is destiny. It is doubly performative when it is deployed to interfere in particular locations

[30] Explorations of the fluidity of the pump point to the possibility that modes of materialisation may be understood topologically as expressions of different spatial systems with different versions of what is to count as a stable object. See Law and Mol (2001) and Law and Singleton (2005).

and practices to strengthen or weaken specific materialisations or forms of reality.

What we learn in all this work is that in a dozen subtle ways, mattering is simultaneously about the real, what there is in the world, and about the good and the bad, about values and politics. It is sometimes possible and temporarily desirable to tease these apart and talk, for instance, of matters of fact on the one hand, and matters of concern on the other. But they can only be held apart for so long and in particular and specific relations. Again there can be no general rule. However, such is the complexity and the multiplicity of mattering that located interventions may hold most analytical and political promise. For Helen Verran the question is: how to go on together. How to go on well. The answer, always enacted anew, will depend on time and place and practice.

References

Barad, Karen (1999), 'Agential Realism: Feminist Interventions in Understanding Scientific Practices', in Mario Biagioli (ed.), The Science Studies Reader, New York: Routledge.

Barnes, Barry (1977), Interests and the Growth of Knowledge, London: Routledge and Kegan Paul.

Barry, Andrew (2001), Political Machines: Governing a Technological Society, London and New York: The Athlone Press.

Bijker, Wiebe E. (1995), Of Bicycles, Bakelite and Bulbs: Toward a Theory of Sociotechnical Change, Inside Technology, Cambridge, Mass: MIT Press.

Bijker, Wiebe E., Thomas P. Hughes, and Trevor J. Pinch (eds) (1987), The Social Construction of Technical Systems: New Directions in the Sociology and History of Technology, Cambridge, Mass: MIT Press.

Bijker, Wiebe, and John Law (eds) (1992), Shaping Technology, Building Society: Studies in Sociotechnical Change, Cambridge, Mass: MIT Press.

Boltanski, Luc, and Laurent Thévenot (2006), On Justification: Economies of Worth, Princeton and Oxford.: Princeton University Press.

Butler, Judith (1990), Gender Trouble: Feminism and the Subversion of Identity, Thinking Gender, ed. Linda J. Nicholson, New York and London: Routledge.

Callon, Michel (1980), 'The State and Technical Innovation: a Case Study of the Electric Vehicle in France', Research Policy, 9, 358-376.

Callon, Michel (1986), 'Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of Saint Brieuc Bay', pages 196-233 in John Law (ed.), Power, Action and Belief: a new Sociology of Knowledge? Sociological Review Monograph, 32, London: Routledge and Kegan Paul.

Callon, Michel, and Bruno Latour (1981), 'Unscrewing the Big Leviathan: how actors macrostructure reality and how sociologists help them to do so', pages 277-303 in Karin D. Knorr-Cetina and Aaron V. Cicourel (eds), Advances in

Social Theory and Methodology: Toward an Integration of Micro- and Macro-Sociologies, Boston, Mass: Routledge and Kegan Paul.

Callon, Michel, John Law, and Arie Rip (eds) (1986), Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World, London: Macmillan.

Cockburn, Cynthia (1983), Brothers: Male Dominance and Technological Change, London: Pluto.

Cockburn, Cynthia (1999), 'The Material of Male Power', pages 177-198 in Donald MacKenzie and Judy Wajcman (eds), The Social Shaping of Technology, Buckingham, Philadelphia: Open University Press.

Collins, H.M. (1975), 'The Seven Sexes: a Study in the Sociology of a Phenomenon, or the Replication of Experiments in Physics', Sociology, 9, 205-224.

de Laet, Marianne, and Annemarie Mol (2000), 'The Zimbabwe Bush Pump: Mechanics of a Fluid Technology', Social Studies of Science, 30: (2), 225-263.

Foucault, Michel (1979), Discipline and Punish: the Birth of the Prison, Harmondsworth: Penguin.

Hacking, Ian (1990), The Taming of Chance, Cambridge: Cambridge University Press.

Haraway, Donna J. (1989), Primate Visions: Gender, Race and Nature in the World of Modern Science, London: Routledge and Chapman Hall.

Haraway, Donna J. (1991a), 'A Cyborg Manifesto: Science, Technology and Socialist Feminism in the Late Twentieth Century', pages 149-181 in Donna Haraway (ed.), Simians, Cyborgs and Women: the Reinvention of Nature, London: Free Association Books, also available at http://216.239.59.104/search?q=cache:FXGOe-wsmCgJ:www.stanford.edu/dept/HPS/Haraway/CyborgManifesto.html+Haraway+cyborg&hl=en&ct=clnk&cd=1&gl=uk&client=firefox-a.

Haraway, Donna J. (1991b), Simians, Cyborgs and Women: the Reinvention of Nature, London: Free Association Books.

Haraway, Donna J. (2003), The Companion Species Manifesto: Dogs, People, and Significant Otherness, Chicago: Prickly Paradigm Press.

Haraway, Donna J. (2008), When Species Meet, Minneapolis and London: University fo Minneapolis Press.

Hughes, Everett C. (1971), The Sociological Eye: Selected Papers on Work, Self and the Study of Society, Chicago and New York: Aldine Atherton.

Hughes, Thomas P. (1979), 'The Electrification of America: the System Builders', Technology and Culture, 20, 124-161.

Knorr Cetina, Karin D. (1999), Epistemic Cultures: How the Sciences Make Knowledge, Cambridge, Mass. and London: Harvard University Press.

Kuhn, Thomas S. (1970), The Structure of Scientific Revolutions, Chicago: Chicago University Press.

Latour, Bruno (1988a), Irréductions, published with The Pasteurisation of France, Cambridge Mass.: Harvard.

Latour, Bruno (1988b), The Pasteurization of France, Cambridge Mass.: Harvard.

Latour, Bruno (1991), 'Technology is Society Made Durable', pages 103-131 in John Law (ed.), A Sociology of Monsters? Essays on Power, Technology and Domination, Sociological Review Monograph, 38, London: Routledge.

Latour, Bruno (1998), Pandora's Hope: Essays on the Reality of Science Studies, Cambridge, Mass.: Harvard University Press.

Latour, Bruno (2005), Reassembling the Social: An Introduction to Actor-Network-Theory, Oxford: Oxford University Press.

Latour, Bruno, and Couze Venn (2002), 'Morality and Technology: The End of the Means', Theory, Culture and Society, 19: (2), 247-260.

Latour, Bruno, and Steve Woolgar (1986), Laboratory Life: the Construction of Scientific Facts, Second Edition, Princeton, New Jersey: Princeton University Press.

Law, John (1986), 'On the Methods of Long Distance Control: Vessels, Navigation and the Portuguese Route to India', pages 234-263 in John Law (ed.), Power, Action and Belief: a new Sociology of Knowledge? Sociological Review Monograph, 32, London: Routledge and Kegan Paul.

Law, John (1992), 'Notes on the Theory of the Actor-Network: Ordering, Strategy and Heterogeneity', Systems Practice, 5, 379-393.

Law, John (1994), Organizing Modernity, Oxford: Blackwell.

Law, John (2002), Aircraft Stories: Decentering the Object in Technoscience, Durham, N.Ca.: Duke University Press.

Law, John (2004), After Method: Mess in Social Science Research, London: Routledge.

Law, John, and Annemarie Mol (2001), 'Situating Technoscience: an Inquiry into Spatialities', Society and Space, 19, 609-621.

Law, John, and Vicky Singleton (2005), 'Object Lessons', Organization, 12: (3), 331-355.

MacKenzie, Donald (1990), Inventing Accuracy: a Historical Sociology of Nuclear Missile Guidance, Cambridge, Mass.: MIT Press.

MacKenzie, Donald, and Judy Wajcman (eds) (1999), The Social Shaping of Technology: How the Refrigerator Got Its Hum,, Milton Keynes: Open University Press.

Mol, Annemarie (1999), 'Ontological Politics: a Word and Some Questions', pages 74-89 in John Law and John Hassard (eds), Actor Network Theory and After, Oxford and Keele: Blackwell and the Sociological Review.

Mol, Annemarie (2002), The Body Multiple: Ontology in Medical Practice, Durham, N. Ca., and London: Duke University Press.

Moser, Ingunn (2008), 'Making Alzheimer's Disease Matter: Enacting, Interfering and Doing Politics of Nature', Geoforum, 39, 98-110.

Pickering, Andrew (1993), 'The Mangle of Practice: Agency and Emergence in the Sociology of Science', American Journal of Sociology, 99, 559-589.

Pickering, Andrew (1995), The Mangle of Practice: Time, Agency and Science, Chicago and London: University of Chicago Press.

Shapin, Steven, and Simon Schaffer (1985), Leviathan and the Air Pump: Hobbes, Boyle and the Experimental Life, Princeton: Princeton University Press.

Traweek, Sharon (1988), Beamtimes and Lifetimes: the World of High Energy Physics, Cambridge, Mass.: Harvard University Press.

Verran, Helen (1998), 'Re-Imagining Land Ownership in Australia', Postcolonial Studies, 1: (2), 237-254.

Verran, Helen (2001), Science and an African Logic, Chicago and London: Chicago University Press.

Sometimes the material choice is the solution. Other times, the design must accommodate the limitations of materials properties. The design of the Space Shuttle systems encountered many material challenges, such as weight savings, reusability, and operating in the space environment. NASA also faced manufacturing challenges, such as evolving federal regulations, the limited production of the systems, and maintaining flight certification. These constraints drove many innovative materials solutions.Â during STS-121 (2006). Extravehicular activity infrared ight camera. Engineering Innovations. In STS, materiality is usually understood as relational effect. Something becomes material because it makes a difference, because somehow or other it is detectable. It depends, then, on a relation between that which is detected and that which does the detecting. Matter that does not make a difference does not matter. It is not matter since there is no relation.Â Abstract and Keywords. Matter matters â€" this is the issue which is explored in this article. How science, technology, and society (STS) imagines that matter matters. In STS, materiality is usually understood as relational effect. Something becomes material because it makes a difference, because somehow or other it is detectable. It depends, then, on a relation between that which is detected and that which does the detecting.