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Actor-Network Theory

Actor-Network Theory: Relational Materialism

Actor-network theory (ANT) is the name given to a framework originally developed by Michel Callon (e.g. 1986), Bruno Latour (e.g. 1987), and John Law (e.g. 1987). ANT has its origins in an attempt to understand science and technology, or rather *technoscience*, since on this account science and technology involve importantly similar processes (Latour 1987). ANT is, though, a general social theory centered on technoscience, rather than just a theory of technoscience.

ANT represents technoscience as the creation of larger and stronger networks. Just as a political actor assembles alliances that allow him or her to maintain power, so do scientists and engineers. However, the actors of ANT are heterogeneous in that they include both human and non-human entities, with no methodologically significant distinction between them. Both humans and non-humans form *associations*, linking with other actors to form networks. Both humans and non-humans have *interests* that cause them to act, that need to be accommodated, and that can be managed and used. Electrons, elections, and everything in between contribute to the building of networks.

Michel Callon (1987), for example, describes the effort of a group of engineers at Electricité de France (EDF) to introduce an electric car in France. EDF's engineers acted as "engineer-sociologists" in the sense that they articulated a vision simultaneously of fuel cells for these new cars, of French society into which electric cars would later fit, and of much between the two – engineering is never complete if it stops at the obvious boundaries of engineered artifacts. The EDF actors were not alone, though; their opponents at Renault, who were committed to internal combustion engines, criticized both the technical details and the social feasibility of EDF's plans, and so were also doing engineering-sociology. The engineering and the sociology are inseparable. Neither the technical vision nor the social vision will come into being without the other, though with enough concerted effort both may be brought into being together.

ANT's sociology, and the implicit sociology of the scientists and engineers being studied, deals with concrete actors rather than macro-level forces. Latour describes the efforts of the engineer Rudolf Diesel to build an earlier (than EDF's) new type of engine: "At the start, Diesel ties the fate of his engine to that of *any* fuel, thinking that they would all ignite at a very high pressure. . . . But then, nothing happened. Not every fuel ignited. This ally, which he had expected to be unproblematic and faithful, betrayed him. Only kerosene ignited, and then only erratically. . . . So what is happening? Diesel has to *shift his system of alliances*" (Latour 1987: 123). Diesel's alliances include entities as diverse as kerosene, pumps, other scientists and engineers, financiers and entrepreneurs, and consumers. The technoscientist needs to remain constantly aware of a shifting array of dramatically different actors in order to succeed. A stable network, and a successful piece of technoscience, is the result of managing all of these actors and their associations so that they contribute toward a goal.

Actors build networks. These networks might make machines function, when their components are made to act together to achieve a consistent effect. Or, they might turn beliefs into taken-for-granted facts, when their components are made to act as if they are in agreement. So working machines and accepted facts are the products of networks. The activity of technoscience, then, is the work of understanding the interests of a variety of actors, and *translating* those interests so that the actors work in agreement (Callon 1986; Callon and Law 1989). That is, in order to form part of a network, an actor must be brought to bear on other actors, so they must be brought together. Moreover, they must be brought together so as to work together, which may mean changing the ways in which they act. By being moved and changed, interests are translated in both place and form. In this way, actors are made to act; as originally defined, the actors of ANT are *actants*, things *made to act*.

ANT is a materialist theory. It reduces even the "social" to the material, both inside and outside of science (Latour 2005). Science and technology work by translating material actions and forces from one form into another. Scientific representations are the result of material manipulations, and are solid precisely to the extent that they are mechanized. The rigidity of translations is key here. Data, for example, is valued as a form of representation because it is supposed to be the direct result of interactions with the natural world. Visiting an ecological field site in Brazil, Latour (1999) observes researchers creating data on the colors of soil samples. So that the color of the sample can be translated into a uniform code, Munsell color charts are held against the samples (just as a painter will hold a color chart against a paint sample). As Latour jokes, the gap between representation and the world, a standard philosophical problem that gives rise to questions about realism (Chapter 6), is reduced by scientists to a few millimeters. Data-level representations are themselves juxtaposed to form new relationships that are summarized and otherwise manipulated to form higher-level representations, representations that are more general and further from their objects. Again, the translation metaphor is apt, because these operations can be seen as translations of representations into new forms, in which they will be more generally applicable. Ideally, there should be no leaps between data and theory – and between theory and application – but only a series of minute steps. There is no action at a distance, though through the many translations or linkages there may be long-distance control (see Star 1989).

Again, science and technology must work by translating material actions and forces from one form into another. The working of abstract theories and other general knowledge appears a miracle unless it can systematically be derived from or traced to local interactions, via hands-on manipulation and working machines, via extractions from original settings, via data, and via techniques for summarizing, grouping, and otherwise exploiting information. This is the methodological value of materialism. Universal scientific knowledge is the product of the manipulation of local accounts, a product that can supposedly be transported through time and space to a wide variety of new local circumstances. But such universal knowledge is only applicable through a new set of manipulations that adapt it once again to those local circumstances (or adapt those local circumstances to it). Sciences have to solve the problem of action at a distance, but in so doing they work toward a kind of universality of knowledge.

Seen in these terms, laboratories give scientists and engineers power that other people do not have, for "it is in the laboratories that most new sources of power are generated" (Latour 1983: 160). The laboratory contains tools, like microscopes and telescopes, that change the effective sizes of things. Such tools make objects human in scale, and hence easier to observe and manipulate. The laboratory also contains a seemingly endless variety of tools for separating parts of objects, for controlling them, and for subjecting them to tests: objects are tested to find out what they can and cannot do. This process can also be thought of as a series of tests of actors, to find out which alliances can and cannot be built. Simple tools like centrifuges, vacuum pumps, furnaces, and scales have populated laboratories for hundreds of years; these and their modern descendents tease apart, stabilize, and then quantify objects, enabling a kind of *engine science* (Carroll 2006). *Inscription devices*, or machines that "transform pieces of matter into written documents" (Latour and Woolgar 1986: 51), allow researchers to deal with nature on pieces of paper. Like the representations produced by telescopes and

Box 8.1 The Pasteurization of France

Louis Pasteur's anthrax vaccine is the subject of an early statement of actor-network theory (Latour 1983), and Pasteur's broader campaign on the microbial theory of disease is the subject of a short book (Latour 1988).

How could Pasteur be seen as the central cause of a revolution in medicine and public health, even though he, as a single actor, could do almost nothing by himself? The laboratory was probably the most important starting point. Here is Pasteur, describing the power of the laboratory:

> As soon as the physicist and chemist leave their laboratories, . . . they become incapable of the slightest discovery. The boldest conceptions, the most legitimate speculations, take on body and soul only when they are consecrated by observation and experience. Laboratory and discovery are correlative terms. Eliminate the laboratories and the physical sciences will become the image of sterility and death . . . Outside the laboratories, the physicists and chemists are unarmed soldiers in the battlefield. (in Latour 1988: 73)

Pasteur used the strengths of the laboratory to get microbes to do what he wanted. Whereas in nature microbes hide, being invisible components of messy constellations, in the laboratory they could be isolated and nurtured, allowing Pasteur and his assistants to deal with visible colonies. These could be tested, or subjected to *trials of strength*, to find their properties. In the case of microbes, Pasteur was particularly interested in finding weak versions that could serve as vaccines.

Out of the complex set of symptoms and circumstances that make a disease, Pasteur *defined* a microbe in the laboratory; his manipulations and records specified its boundaries and properties. He then was able to argue, to the wider scientific and medical community, that his microbe was responsible for the disease. This was in part done via public demonstrations that repeat laboratory experiments. Breakthroughs like the successful vaccination of sheep against anthrax were performed in carefully staged demonstrations, in which the field was turned into a laboratory, and the public was invited to witness the outcomes of already-performed experiments. Public demonstrations helped convince people of two important things: that microbes are key to their goals, whether those goals are health, the strength of armies, or public order; and that Pasteur had control over those microbes.

Microbes were not merely entities that Pasteur studied, but agents with whom Pasteur built an alliance. The alliance was ultimately very successful.

It created enormous interest in Pasteur's methods of inquiry, reshaped public health measures, and brought prestige and power to Pasteur. We might see Pasteur's work as having introduced a new element into society, an element of which other people have to take account if they are to achieve their goals.

When doctors, hygienists, regulators, and others put in place measures oriented around Pasteur's purified microbe, it became a taken-for-granted truth that the microbe was the real cause of the disease, and that Pasteur was the cause of a revolution in medicine and public health.

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microscopes these are also medium-sized, but perhaps more importantly they are durable, transportable, and relatively easy to compare to each other. Such *immutable mobiles* can be circulated and manipulated independently of the contexts from which they derive. Nature brought to a human scale, teased into components, made stable in the laboratory, and turned into marks on paper or in a computer, is manipulable, and manipulable at leisure in *centers of calculation* (Latour 1987) where inscriptions can be combined and analyzed to produce abstract and general representations. When they become accepted, those representations are often taken to be Nature, rather than products of or interpretations of nature.

We can see that, while ANT is a general theory, it is one that explains the centrality of science and technology to the idea of modernity (Latour 1993). Technologies reshape the field of agency, because people delegate agency to them. Science and technology explicitly engage in crossing back and forth between objects and representations, creating more situations in which humans and non-humans affect each other. Science and technology are responsible for the contemporary world, because more than any other activities they have mixed humans and non-humans together, allowing a dramatic expansion of the social world. Science and technology have brought non-humans into the human world, to shape, replace, and enlarge social organizations, and have brought human meanings and organizations to the non-human world, to create new alignments of forces (Latour 1994).

But although the material processes by which facts and machines are produced may be very complex, science and engineering's networks often stabilize and become part of the background or invisible. Configurations become *black boxes*, objects that are taken for granted as completed projects, not as messy constellations. The accumulation of black boxes is crucial for what is considered progress in science and engineering. As philosopher Alfred

North Whitehead (1992 [1911]) wrote, "Civilization advances by extending the number of important operations which we can perform without thinking about them."

While actor-network theory is thoroughly materialist, it is also built on a relational ontology; it is based on a *relational materiality* (Law 1999). Objects are defined by their places in networks, and their properties appear in the context of tests, not in isolation. Perhaps most prominently, not only technoscientific objects but also social groups are products of network-building. Social interests are not fixed and internal to actors, but are changeable external objects. The French military of 1880 was interested in recruiting better soldiers, but Louis Pasteur translated that interest, via rhetorical

Box 8.2 Ecological thinking

Science and technology are done in rich contexts that include material circumstances, social ties, established practices, and bodies of knowledge. Scientific and technological work is performed in complex ecological circumstances; to be successful, that work must fit into or reshape its environment.

An ecological approach to the study of science and technology emphasizes that multiple and varying elements contribute to the success of an idea or artifact – and any element in an idea or artifact's environment may be responsible for failure. An idea does not by itself solve a problem, but needs to be combined with time to develop it, skilled work to provide evidence for it, rhetorical work to make it plausible to others, and the support to put all of those in place. If some of the evidential work is empirical, then it will also demand materials, and the tinkering to make the materials behave properly. Solutions to problems, therefore, need nurturing to succeed.

There is no *a priori* ordering of such elements. That is, no one of them is crucial in advance. With enough effort, and with enough willingness to make changes elsewhere in the environment, anything can be changed, moved, or made irrelevant. (This is a generalized version of the Duhem–Quine thesis, Box 1.2.) As a result, there is no *a priori* definition of good and bad ideas or good and bad technologies. Success stories are built out of many distinct elements. They are typically the result of many different innovations, some of which might normally be considered technical, some economic, some social, and some political. The "niche" of a technological artifact or a scientific fact is a multi-dimensional development.

work, into support for his program of research. After Pasteur's work, the military had a new interest in basic research on microbes. Translation in ANT's sense is not neutral.

Whereas the strong programme was "symmetric" in its analysis of truth and falsity and in its application of the same social explanation for, say, both true and false beliefs, ANT is "supersymmetric," treating both the social and material worlds as the products of networks (Callon and Latour 1992; Callon and Law 1995). Representing both human and non-human actors, and treating them in the same relational terms, is one way of prompting full analyses, analyses that do not discriminate against any part of the ecologies of scientific facts and technological objects. It does not privilege any particular set of variables, because every variable depends upon others. Networks confront each other as wholes, and to understand their successes and failures STS has to study the wholes (and the parts) of those networks.

Some Objections to Actor-Network Theory

Actor-network theory, especially in the form articulated by Bruno Latour in his widely read book *Science in Action* (1987), has become a constant touchstone in STS, and is increasingly being exported into other domains. The theory is easy to apply to, and can offer insights on, an apparently limitless number of cases. Its focus on the materiality of relations creates research problems that can be solved, through analyses of the components and linkages of any given network. Yet its broad application of materialism, and the fact that its materialism is relational, means that its applications are often counter-intuitive. This success does not, though, mean that STS has uncritically accepted ANT. The remainder of this chapter is devoted to criticisms of the theory. This discussion of problems that ANT faces is not supposed to indicate the theory's failure, but instead should contribute to further explaining the theory and demonstrating its scope.

1 Practices and cultures

Actor-network theory, and for that matter almost every other approach in STS, portrays science and engineering as rational in a means–end sense: technoscientists use the resources that are available – rhetorical resources, established power, facts, and machines – to achieve their goals. Of course, rational choices are not made in a vacuum, or even only in a field of simple material and conceptual resources. They are made in the context of

Box 8.3 The Mathematical Tripos and the Cambridge culture of mathematical physics

For much of the nineteenth century, placing highly on Cambridge University's Mathematical Tripos exam was a mark of the successful Cambridge undergraduate, even among those not intending to go on in mathematized fields. The pressure to perform well spawned systems of private tutoring, intense study, and athletic activity, in which students mastered problems, techniques, heuristics, and bodily discipline – university athletics as a whole arose in part because of the exam (Warwick 2003). Students hoping to score among the top group had little choice but to hire the top tutors and submit to their highly regimented plans of study; those tutors, some of them brilliant at both mathematical physics and pedagogy, taught many of the most important physicists of the century. The increasing ability of the undergraduates, and competition in the relatively closed world of those setting the exam, led to the Tripos's increasing difficulty, and also fame: lists of those in the order of merit, with special attention on those placed as "Wranglers" at the top, were printed in the *Times* of London from 1825 to 1909.

All of this activity created a distinctive culture of mathematical physics at Cambridge, one centered on a particular array of skills and examination-sized problems. Even James Clerk Maxwell's 1873 *Treatise on Electricity and Magnetism*, one of the key works of physics of the nineteenth century, was partly written as a textbook for Cambridge undergraduates, and featured case-by-case solutions to problems. That difficult work, in turn, became important to pedagogy, through its consistent and careful interpretation by other physicists, at Cambridge and elsewhere in Britain. The result was a distinctive style of classical physics in Britain, that was, for example, practically incommensurable with the new styles of physics that arose in Germany in the twentieth century, because its core mathematical practices were different (Warwick 2003).

existing technoscientific cultures and practices. Practices can be thought of as the accepted patterns of action and styles of work; cultures define the scope of available resources (Pickering 1992). Opportunistic work, even work that transforms cultures and practices, is an attempt to appropriately combine and recombine cultural resources to achieve particular goals. Practices and cultures provide the context and structure for technoscientific opportunism. But because ANT treats humans and non-humans on the same footing, and because it adopts an externalized view of actors, it does not pay attention to such distinctively human and apparently subjective factors as cultures and practices.

Cultures and cultural networks do not fit neatly into the network framework offered by ANT. For example, mathematical physicists at Cambridge University developed a particular style of work and theorizing (Warwick 2003; see Box 8.3). The result was a generalized culture of physics that shaped and was shaped by pedagogy, skills, and networks. To take another example, trust is an essential feature of scientific and technological work, in that researchers rely upon findings and arguments made by people they have never met, and about whom they may know almost nothing. But trust is often established through faith in a common culture. The structure of trust in science was laid down by being transferred from the structure of gentlemanly trust in the seventeenth century; gentlemen could trust each other, and could not easily challenge each other's truthfulness (Shapin 1994). Similarly, trust in technical judgment often resides in cultural affiliations. Engineers educated in the École Polytechnique in nineteenth-century France trusted each other's judgments (Porter 1995), just as did engineers educated at the Massachusetts Institute of Technology in the twentieth century (e.g. MacKenzie 1990).

To account for even rational choices we need to invoke practices and cultures. Yet the world of ANT is culturally flat. Within the terms of the theory practices and cultures need be understood in terms of arrangements of actors that produce them. Macro-level features of the social world have to be reducible to micro-level ones, without action at a distance. While that is possibly very attractive, the reduction represents a large promissory note.

2 Problems of agency

Actor-network theory has been criticized for its distribution of agency. On the one hand, it may encourage analyses centered on key figures, and perhaps as a result many of the most prominent examples are of heroic scientists and engineers, or of failed heroes. The resulting stories miss work done by other actors, miss structures that prevent others from participating, and miss non-central perspectives. Marginal, and particularly marginalized, perspectives may provide dramatically different insights; for example, women who are sidelined from scientific or technical work may see the activities of science and technology quite differently (e.g. Star 1991). With ANT's focus on agency, positions from which it is difficult to act make for less interesting positions from which to tell stories. So ANT may encourage the following of heroes and would-be heroes.

On the other hand, actor-network analyses can be centered on any perspective, or on multiple perspectives. Michel Callon even famously uses the perspective of the scallops of St. Brieuc Bay for a portion of one important statement of ANT (Callon 1986). This positing of non-human agents is one of the more controversial features of the theory, attracting a great deal of criticism (see, e.g., Collins and Yearley 1992).

In principle, ANT is entirely symmetrical around the human/non-human divide. Non-humans can appear to act in exactly the same way as do humans – they can have interests, they can enroll others. (Because ANT's actors are *actants*, things made to act, agency is an effect of networks, not prior to them. This is a difficult distinction to sustain, and the ends of ANT's analyses seem to rest on the agency of non-humans.) Critics, though, argue that humans and non-humans are crucially different. Humans have, and most non-humans do not have, intentionality, which is necessary for action on traditional accounts of agency. To treat humans and non-humans symmetrically, ANT has to deny that intentionality is necessary for action, and thus deny that the differences between humans and non-humans are important for the theory overall.

In practice, though, actor-network analyses tend to downplay any agency that non-humans might have (e.g. Miettinen 1998). Humans appear to have richer repertoires of strategies and interests than do non-humans, and so tend to make more fruitful subjects of study. The subtitle of Latour's popular *Science in Action* is *How to Follow Scientists and Engineers through Society*, suggesting that however symmetric ANT is, of particular interest are the actions of scientists and engineers.

3 Problems of realism

Running parallel to problems of agency are problems of realism. On the one hand, ANT's relationalism would seem to turn everything into an outcome of network-building. Before their definition and public circulation through laboratory and rhetorical work, natural objects cannot be said to have any real scientific properties. Before their public circulation and use, artifacts cannot be said to have any real technical properties, to do anything. For this reason, ANT is often seen, despite protests by actor-network theorists, as a blunt version of constructivism: what is, is constructed by networks of actors. This constructivism flies in the face of strong intuitions that scientists discover, rather than help create, the properties of natural things. It flies in the face of strong intuitions that technological ideas have or lack force of their own accord, whether or not they turn out to be successful. And this constructivism runs against the arguments of realists that (at least some) things have real and intrinsic properties, no matter where in any network they sit.

On the other hand, positing non-human agents appears to commit ANT to realism. Even if ANT assumes that scientists in some sense define or construct the properties of the so-called natural world, it takes their interests seriously. That is, even if an object's interests can be manipulated, they resist that manipulation, and hence push back against the network. This type of picture assumes a reality that is prior to the work of scientists, engineers, and any other actors. Latour says, "A little bit of constructivism takes you far away from realism; a complete constructivism brings you back to it" (Latour 1990: 71).

Theorists working outside the ANT tradition are faced with similar problems. For example, Karen Barad (2007) articulates a position she calls *agential realism*: human encounters with the world take the form of *phenomena*, which are ontologically basic. Material-discursive practices create intra-actions within these phenomena. These parcel out features of the world and define them as natural or human. Similarly, Andrew Pickering's pragmatic realism (1995) describes a *mangle of practice* in which humans encounter *resistances* to which they respond. Technologies and facts about nature result from a dialectic of resistance and accommodation. Barad's and Pickering's frameworks, which share features with ANT and with each other, are designed to bridge constructivist and realist views.

The implicit realism of ANT has been both criticized, as a step backwards from the successes of methodological relativism (e.g. Collins and Yearley 1992), and praised as a way of integrating the social and natural world into STS (Sismondo 1996). For the purposes of this book, whether ANT makes realist assumptions, and whether they might move the field forwards or backwards are left as open questions, much as they have been in STS itself.

4 Problems of the stability of objects and actions

A further problem facing ANT will be made more salient in later chapters. According to the theory, the power of science and technology rests in the arrangement of actors so that they form literal and metaphorical machines, combining and multiplying their powers. That machining is made possible by the power of laboratories and laboratory-like settings (such as field sites) that are made to mimic labs (Latour 1999). As noted above, the power of laboratories depends upon material observations and manipulations that we presume to be repeatable and stable. Once an object has been defined and characterized, it can be trusted to behave similarly in all similar situations, and actions can be delegated to that object.

Science and technology gain power from the translation of forces from context to context, translations that can only be consistently achieved by formal rules. However, rules have to be interpreted, and Wittgenstein's problem of rule following shows that no statement of a rule can determine its interpretations (Box 3.2). As we will see, STS has shown how tinkering is crucial to science and technology, how the work of making observations and manipulations is difficult, how much routine science and engineering involves expert judgment, and how that judgment is not reducible to formulas (Chapter 10). ANT, while it recognizes the provisional and challengeable nature of laboratory work, glides over these issues. It presents science and technology as powerful because of the rigidity of their translations, or the objectivity – in the sense that they capture objects – of their procedures. Yet rigidity of translation may be a fiction, hiding many layers of expert judgment.

Conclusions

Especially since the publication of Latour's *Science in Action* (1987), ANT has dominated theoretical discussions in STS, and has served as a framework for an enormous number of studies. Its successes, as a theory of science, technology, and everything else, have been mostly bound up in its relational materialism. As a materialist theory it explains intuitively the successes and failures of facts and artifacts: they are the effects of the successful translation of actions, forces, and interests. As a relationalist theory it suggests novel results and promotes ecological analyses: humans and non-humans are bound up with each other, and features on neither side of that apparent divide can be understood without reference to features on the other. Whether actor-network theorists can answer all the questions people have of it remains to be seen, but it stands as the best known of STS's theoretical achievements so far.