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ABSTRACT This paper aims to enrich our understanding of the history and substance of cybernetics. It reviews the work of three British cyberneticians – W. Ross Ashby, Stafford Beer and Gordon Pask – paying attention particularly to the materiality of their practice – the strange and fascinating devices and systems that were at the heart of their work – and to the worldly projects they pursued – scientific, technological, artistic, organizational, political and spiritual. Connections are drawn between cybernetics and recent theoretical work in science and technology studies, in the hope of illuminating key features of both. The paper concludes by suggesting that the antidisciplinary impulse of contemporary science studies might find inspiration in the work of cyberneticians – that theory does not have to remain confined to the realm of theory.

Keywords artificial intelligence, cyberarts, posthumanism, robots, science & technology studies, self-organization

Cybernetics and the Mangle:

Ashby, Beer and Pask

Andrew Pickering

The historiography of the sciences since World War II has understandably paid most attention to familiar mainstream disciplines such as physics and biology. Increasingly, however, historians have found themselves drawn to an odd field that only received its name after WWII: cybernetics.[1] For obvious reasons, the American heroes of the early days of cybernetics – Norbert Wiener, John von Neumann, Warren McCulloch, Walter Pitts, Claude Shannon – have been most studied. Here, though, I want to throw some new names into the ring. I hope to show that some of the most interesting – and entertaining and occasionally uplifting – work in cybernetics, from the late 1940s and 1950s onwards, was done by a less well-known group of English cyberneticians, foremost amongst whom were W. Ross Ashby, Stafford Beer and Gordon Pask.[2] The bulk of this paper is historical, but a set of theoretical reflections weave through it, and I should start by explaining why.

Why, over the past decade or so, have historians turned to cybernetics? One reason, I am sure, is that there is something philosophically or theoretically pregnant about cybernetics. There is a kind of seductive mystery or glamour that attaches to it. And the origin of this, I think, is that cybernetics is an instantiation of a different paradigm from the one in

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which most of us grew up – the reductive, linear, Newtonian, paradigm that still characterizes most academic work in the natural and social sciences (and engineering and the humanities, too) – 'the classical sciences', as Ilya Prigogine and Isabelle Stengers (1984) call them. It appears to me, though, that historians have yet to get seriously to grips with this aspect of cybernetics, and one goal of this paper is to take us further into the heart of the mystery.[3] My route is to make some connections between cybernetics and recent theoretical work in science studies, primarily my own, and I need to say a little about this before we turn to history.

In my book, *The Mangle of Practice* (Pickering 1995b), I struggled to find the best analysis I could of what scientific practice – or just ordinary human practice in the material world – looks like. And I ended up arguing for what was, it seemed to me, a difficult and fundamental shift in how we think about what being in the world is like. Traditionally, science studies has operated in what I called the *representational idiom*, meaning that it has taken it for granted that science is, above all, about representing the world, mapping it, producing articulated knowledge of it. So science studies in this idiom is a venture into *epistemology.*

In *The Mangle*, I concluded that this is a bad way to come at the analysis of practice, and that we need to move towards *ontology* and what I called the *performative idiom* – a decentred perspective that is concerned with agency – doing things in the world – and with the emergent interplay of human and material agency. One can, of course, still be interested in epistemology and knowledge production, but my conclusion was that one should see scientific knowledge as constitutively bound up with the *dance of human and nonhuman agency*, as I romantically labelled it, rather than as a self-contained topic for enquiry in itself.[4]

And, since I wrote the book, it has slowly been dawning on me that cybernetics, too – and especially the work of the English cyberneticians – is all about this shift from epistemology to ontology, from representation to performativity, agency and emergence, not in the analysis of science but within the body of science itself. That, I think, is where at least one aspect of the singularity of cybernetics resides. To explore and clarify this idea, my strategy in what follows is, as I said, to interweave the historical and the theoretical, making connections as appropriate between the work of the cyberneticians and the work of myself and others in science studies.[5]

Ross Ashby

W. Ross Ashby was born in London in 1903 and died in 1972.[6] He was the doyen of the English cyberneticians, publishing his first recognizably cybernetic work in 1940 (Ashby 1940), long before Wiener gave the field its name. He was probably the least glamorous of my trinity; but, as often happens, he was probably philosophically the most interesting of them, certainly from my theoretical science-studies point of view. Ashby's contributions to cybernetics were many, including a great deal of theoretical work which often drew on information theory, including the famous Law

FIGURE 1
Ross Ashby

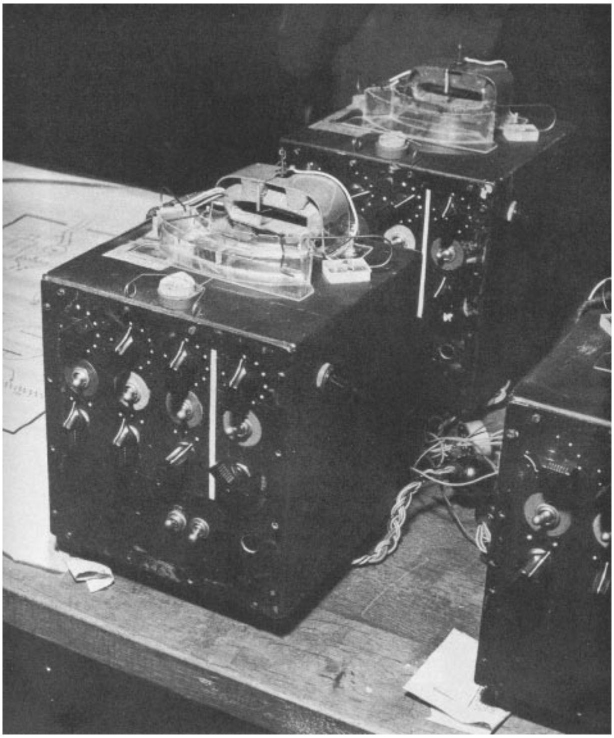
Source: I thank Ross Ashby's daughters, Jill Ashby, Sally Bannister and Ruth Pettit, for providing me with this photograph and for permission to reproduce it.

of Requisite Variety. But the aspect of his work that I need to focus on concerns a machine he built in the late 1940s, mostly from war-surplus electrical equipment, the legendary *homeostat*.[7]

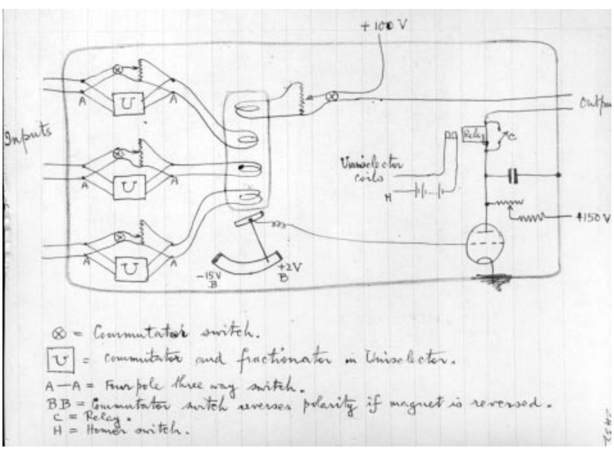
The homeostat was an electrical device, which took electrical inputs and turned them into outputs. The input current passed through a coil within the homeostat, generating a magnetic field which exerted a torque on a needle or vane on the top of the machine, causing it to rotate in one direction or the other. The needle was itself part of an electrical circuit, and the end of the needle dipped into a semicircular trough of water across which a constant voltage was maintained by a battery. Thus the varying position of the needle controlled the current that flowed through it – which, after amplification, was in turn the output current of the homeostat unit. In the configuration shown in Figure 2(a), the output of each homeostat was the input to three others. All four homeostats were thus interconnected via electrical feedback loops (Figure 2(b)).

Now, exactly how such a lash-up might behave, with each unit feeding variable currents to and thus disturbing the others, is a pretty obscure question. If one knew the exact values of all the component parts one could try to calculate the behaviour, I suppose. But think about it another way. We can imagine such an assemblage of homeostats existing in one of two overall states. It might be *stable*, meaning that the needles on all of the units might come to rest in the middle of their ranges, so that small deviations of the position of any one needle would induce small deviations of the other three (as the output current of the first unit changed a bit, and this effect propagated through the system) but that eventually all the needles would settle down to their midpoints again. Or, the configuration might be *unstable* – meaning that all the needles might be driven to the

FIGURE 2
The Homeostat: Photos and Wiring Diagram



(a)



(b)

Sources: (a) Photograph of four interconnected homeostat units (de Latil 1956: facing 275). (b) First full wiring design for the homeostat, from Ashby's personal notebook, dated 3 March 1948. Reproduced by permission of Jill Ashby, Ruth Pettit and Sally Bannister.

extremes of their ranges and just stick there. This stable/unstable contrast was what interested Ashby, and leads us to the clever bit of the homeostat's circuitry.

Each homeostat was built so that if its needle departed too much from its central position a relay would trip, and the device would *randomly reconfigure* itself. In practice, this meant that the relay would drive a Uniselector or stepping-switch to its next position, either reversing the polarity of the voltage or changing the resistance of the circuit, with the values of the possible resistances being set in advance according to a table of random numbers. And the upshot of such random reconfiguration could be one of two possibilities. Either the device would achieve a stable configuration, in which the needle now settled at the middle of its range, or it would continue to be unstable, in which case the needle and its associated current would continue to go out of whack. In that case the relay would operate again and the system would randomly reconfigure itself again, and so on and so on until the device finally achieved a stable configuration.

This property of inevitably finding some stable state was the key attribute of the homeostat. The homeostat was an example of what Ashby called an *ultrastable* system, and the demonstration of ultrastability as a real possibility was precisely why Ashby built the device. The question I need to tackle now is: so what? What's so great about ultrastability? Why bother to build a machine whose only function appears to be to stay the same? Grey Walter (1953: 123) sarcastically dubbed the homeostat *machina sopora*, the sleep machine. I want now to say first why I personally find the homeostat fascinating and suggestive, and then, more specifically, why Ashby himself was fascinated with it.

In 1954, Norbert Wiener (1967: 54) described the homeostat as 'one of the great philosophical contributions of the present day', and I believe he was right. First, think about a single homeostat unit. Ashby himself often described these units as if they were simply generic kinds of machine, but what strikes me about them is their singular *liveliness*. I can't actually think of any prior example of a real machine that would randomly – *open-endedly*, as I would say – reconfigure itself in response to its inputs. When I think of 1950s machines, I think of lathes, drilling machines and whatever – deterministic devices that either respond predictably to commands or just break down and never work again. It seems reasonable, then, to speak of the homeostat as having a kind of *agency* – it did things in the world that sprang, as it were, from inside itself, rather than having to be fully specified from outside in advance.[8]

And here I can make a direct connection back to my own theoretical work in science studies. The whole point about the performative idiom as I developed it in *The Mangle* was to see the world as a lively place full of agency – not something static and dead, sitting around waiting to be represented, as the representational idiom suggests. And it now strikes me that the homeostat is a very nice device to illustrate that ontology. The homeostat was visibly an electromechanical device situated in the material world, but it was a surprising one – one could never tell from the outside how it would reconfigure itself next, what it would *do* next.

And one can go further than that. In the four-homeostat set-up, imagine one of the units as standing for some organic being in the world – a scientist, say – and the other three units as standing for that being's material environment. Then the scientist-homeostat could be seen as open-endedly searching through spaces of the material performativity of its environment, which itself open-endedly and unpredictably unfolds, with the final stable state of the four-homeostat assemblage appearing as the emergent joint product of open-ended trial and error through states of both the scientist and the environment. *And this just is a description of the dance of agency as I described it in my book.* The multiunit homeostat set-up, then, is, I think, a true philosophical object, a thing to think with, a simple but beautiful material model of the processes of material, social and cultural extension in science which I tried in my book to analyse in their real-world complexity. It is also, of course, an extension to the world of things alone of the model I developed for thinking of the relation of people and things. To put it immodestly, the homeostat thus shows that I might have been right in suggesting that the mangle was a Theory of Everything.

We can come back to Ashby in just a moment, but I want to add one more theoretical remark. I need to make clear that the homeostat can indeed be seen as a model of the mangle, but only to a limited extent. The homeostats that Ashby built had 25 settings on their stepping switches; a four-unit set-up thus had a total of $25^4 = 390{,}625$ possible states. That is a big number, which is why I felt justified just now to speak of the homeostat making open-ended searches. But it is still a finite number. In *The Mangle*, I wanted to conjure up a picture of both human and material agency as *indefinitely* open-ended, bounded by no such finite range of possibilities. There is thus a disanalogy here. Also, one needs to note that there was a principle of stability hard-wired into the homeostat – the requirement that the needle positions remained close to the middle of their ranges, otherwise the relays would trip. I do not believe there is any such principle of stability to be found in human practice: all of the principles of interactive stabilization that I have come across there are local ones, themselves liable to transformation in practice.

So, from my point of view, the homeostat can help us think about the mangle, and even to see how to extend the range of its application, but the homeostat is not itself the end of the story. The mangle is in at least two ways on the wild side of the homeostat – involving indefinitely open-ended searches of spaces of agency, and with no fixed principle of assemblage. I mention this in the hope of clarifying the singularity of both the homeostat and of my analysis of practice, but also as a way of exemplifying the possibility of a more general kind of discourse that I would like to encourage – a discourse that would explore differences as well as similarities between instantiations of the non-classical paradigm. There is space for a lot of interesting, constructive work to be done here.

That was my longest theoretical interlude; now back to history. If Ashby did not build homeostats to exemplify the theory of practice that I came up with 50 years later, why did he build them? It is time to reveal that the homeostat is the centrepiece of Ashby's first book, the amazing *Design for a Brain*, subtitle, *The Origin of Adaptive Behaviour*, first published in 1952 and much revised in 1960. The homeostat was an electromechanical proto-brain, and both Ashby and Beer took it very seriously as such.[9] Beer especially, I think, had visions of actually building superbrains – artificial brains that were better than human. A few remarks on this are in order.

First, we need to get clear how something like the homeostat could possibly be seen as a brain. The answer might not be obvious, but it is pretty simple when you see it. Running through *Design for a Brain*, from beginning to end, is a simple observation on feline behaviour: 'the burnt kitten avoids the fire'. According to Ashby, kittens have no instinctive fear of fire. They like to dab at red sparkly things. Until, that is, they have singed their paws a few times, when they learn never to do it again. Growing up, they learn to sit a certain range from the fire, further or closer as the fire flares up or dies down. Kittens, that is, learn to *adapt* to the material environment through their interaction with it. We think of that as 'knowing', and associate it with the brain and the nervous system. And, of course, that kind of adaptation is just what the homeostat did. If we think of its needle positions as measures of pain (Ashby admitted he didn't know how to talk scientifically about pleasure), then the homeostat learned how to minimize pain in its interactions with the environment, just like kittens do. Hence the homeostat as brain.

For those who prefer more horrible analogies, Ashby offered many in his book. He talked about nasty physiological experiments involving surgically reversing the connections of the muscles that control monkeys' eyeballs. You would imagine that that would cause their eyes to point in the opposite direction from what they intended. It turns out, however, that monkeys can adapt to this kind of surgery, quickly learning how to restore binocular vision when just one eye has been mutilated, for example. Again, the implication is that monkeys' *brains* adapt themselves to the new physiological situation. Another experiment that Ashby invoked involved similarly crossing the muscles that flex monkeys' arms, to which, it turns out, they can also adapt. In a less traumatic version, Ashby noted that if one inverted the connections of a normal autopilot to the plane's wings, the autopilot would make the plane radically unstable, causing it to flip over, rather than keeping it level. A homeostatic autopilot, in contrast, would not care – however you swapped its connections to the control surfaces around, its Uniselectors would spin until it learned how to keep the plane level.

So, the homeostat was a model of the brain as an adaptive controller of behaviour, and Ashby took this idea very far. He noted, for instance, that, as so far described, the homeostat might be a brain, but that it would be hopelessly inefficient in complex situations. He estimated, for example, that such a device trying to control 100 variables and changing its state once per second would take about 10^{22} years to come to equilibrium, longer than the age of the universe. He then suggested ways to speed things up, which interestingly depended on both the interconnectivity of homeostatic units and on what the terrestrial environment is actually like. Ashby argued that if the environment needs to be described as a densely interconnected system of heterogeneous variables, then both the homeostat and biological brains would take forever, literally, to come to terms with it. If, on the other hand, and as seems to be the case, the connection between environmental variables was sparse, then a sparsely connected homeostatic brain could adapt to it in a realistic time. These ideas still look clever today.

I want to end this section by talking more generally about approaches to the mind and brain. The late 1940s and early 1950s were a very rich and complex period in scientific thinking on the brain, in which all sorts of ideas from cybernetics and information theory mingled with the new technology of the digital electronic computer. This complexity was resolved from the mid-1950s onwards, and what emerged triumphant is now known as symbolic AI, exemplified in the work of Alan Newell and Herbert Simon, with Ashby-style cybernetic approaches to the brain increasingly exiled to the margins and beyond.[10] And here I want to make one simple philosophical point concerning the paradigmatic divergence of these two approaches. If, as I have argued, the homeostat exemplifies an understanding of the brain in the performative idiom – as a seat of agency immediately engaged with the agency of its environment – then symbolic AI is a perfect exemplification of intelligence construed in the representational idiom. Symbolic AI just takes for granted an image of the cognitive as the manipulation of representations, with embodied connections to the material world – inputs to and outputs from the symbolic world – treated as trivial add-ons.

It is fascinating to find the dispute between the representational and the performative idioms thus played out in the world of engineering – something which one might otherwise imagine to be purely a matter of interpretive theory in science studies. This connects, of course, directly to Kathryn Hayles's discussion of embodiment and disembodiment in the postwar cognitive sciences in her book, *How We Became Posthuman* (1999). And it complicates nicely those arguments that surface from time to time in science studies between symbolic AI enthusiasts and the social constructivists (for example, Slezak et al. 1989). The homeostat proves to be an engineering ally, not an antagonist, of approaches to science studies like the mangle, the actor-network and Donna Haraway's cyborgs.

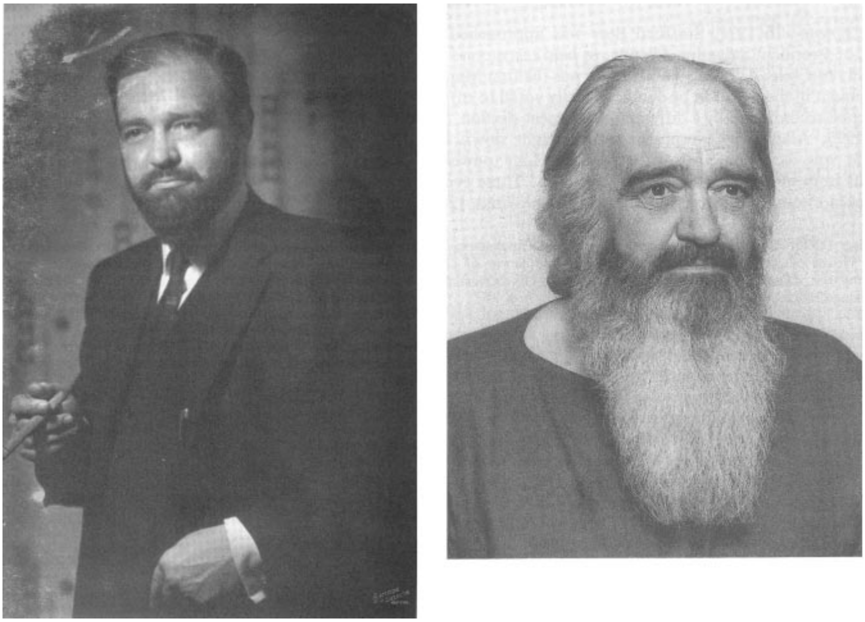
All of this is worth pondering upon, but I want to move on to my other two cyberneticians, Beer and Pask. Ashby did his early work in private (in a padded cell of the mental hospitals where he worked as a psychiatrist) and his later work in the electrical engineering department of the University of Illinois. What fascinates me about Beer and Pask, in contrast, is that they did their cybernetics out there in the real world. I want now to sketch out what that practical cybernetics looked like.

Stafford Beer

Stafford Beer was born in London in 1926.[11] He served in India during and after World War II, where he developed an interest in the new field of operations research. At United Steel between 1949 and 1961 he created and led their Operations Research Group, later renamed the Operations Research and Cybernetics Group, and one of his primary concerns from then on has been the application of cybernetics to the real world of managing organizations of all scales. From 1961 to the present he has operated as a management consultant in the broadest sense of the term, except for the period 1966–70, when he was Development Director of IPC, the International Publishing Corporation. He was the founder of a field called 'management cybernetics', the author of 10 books on the topic – 10 pints of beer, as he calls them – beginning with a wonderful book, *Cybernetics and Management*, in 1959. I can talk more specifically about management in a moment; but I want to begin with some weird and wonderful material devices that figured in Beer's early work.

Undoubtedly, the key cybernetic device as far as Beer was concerned was Ashby's homeostat. Beer, perhaps more than anyone else, believed that the homeostat held out the promise of constructing superhuman brains, and I first want to emphasize the variety of materializations of homeostat-type set-ups that Beer contemplated, and often built, in the 1950s and

FIGURE 3
Stafford Beer



(a) Director, SIGMA, 1961–66; (b) Wales, 1975.
Source: Beer (1994: xii, 315). Reproduced by permission of John Wiley & Sons, and Stafford Beer.

early 1960s. In 1956, for example, he devised a game for solving simultaneous linear equations in two dimensions (Beer 1994 [1962a]: 28). The key feature of this game was that it could be played by *children* who did not know the relevant mathematics. The children would make selections from various alternative moves, and their choices would be encouraged or discouraged by what Beer called *algedonic feedback* – in this case, coloured lights signifying pleasure or pain at whatever moves the children made. In effect, the children were the material basis of an *adaptive* or *self-organizing* system that could be trained to perform the relevant calculations without having to be explicitly 'programmed' to do so. Beer then moved on from children to mice, thinking that mice could be trained to solve simultaneous equations, too. It is not clear whether this worked or not, but I do believe this mouse-computer eventually moved into popular culture, having a rôle in Douglas Adams's book *The Hitch-Hiker's Guide to the Universe*. It certainly features in a recent novel in Terry Pratchett's *Discworld* series. A rather general point here, I suppose, is that cybernetics had a sense of humour – one of its many differences from the classical science paradigm.

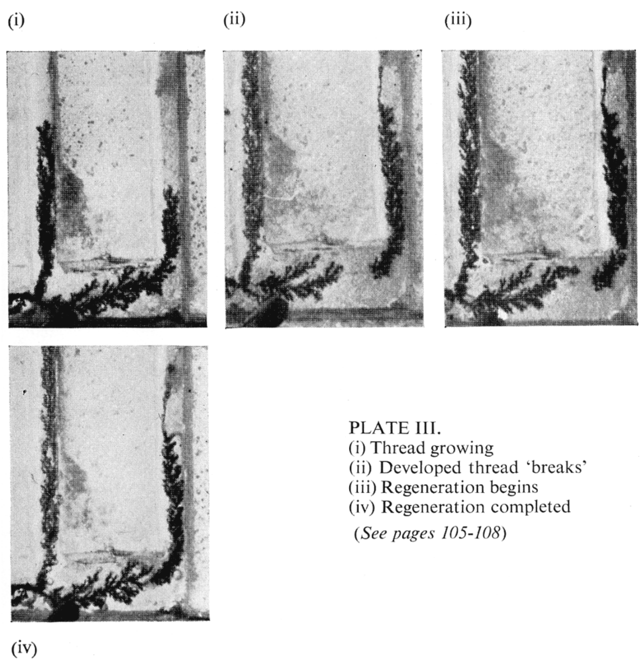
Beer did not stop with children and mice. He experimented with the use of colonies of *Daphnia*, a freshwater crustacean, which had been induced to ingest iron filings and could thus be coupled to external environments via electromagnets, and he also tried light-sensitive amoebas known as *Euglena*. When the *Euglena* refused to function as a homeostatic system, he switched to entire ponds as homeostatic ecosystems. Yet again, in the second half of the 1950s, Beer and Gordon Pask collaborated on the production of what Beer called 'fungoid' or 'whisker' systems (Figure 4). These were electrochemical set-ups with three electrodes, in which patterns of metal deposition between the electrodes – the 'whiskers' – displayed a nonlinear sensitivity to changes in the distribution of voltages over the electrodes over time. These systems proved to be sensitive to an indefinite variety of environmental influences, and Beer and Pask hoped to be able to *train* them to perform all sorts of functions. Beer and Pask, for example, succeeded in training such a device, dangled from the window of Pask's flat in Baker Street in London, to distinguish different segments of the noise spectrum – 'evolving an ear', as it has been described (interview, 23 June 1999; Cariani 1993). These whisker systems were conceived of as *artificial neurons*, as elements for some future artificial brain. And again, we can note a contrast with mainstream developments in computer technology; the whisker systems just grew, without having to be designed and fabricated in detail, unlike electronic valve circuits or silicon chips – they were, again, adaptive or self-organizing systems.

A point worth stressing about these wonderful gadgets and assemblages is that, like Ashby's homeostat, they illustrate the paradigmatic singularity of cybernetics at the material level. Once one starts thinking about adaptive systems exploring the complexity of their environments, it is perhaps not utterly surprising to find Beer thinking about control systems made from children, mice, magnetic crustaceans or electrochemical fungoids (though I still admire his imagination enormously). On the other hand, it is *extremely* hard to imagine anyone outside cybernetics making the same explorations of the field of material performativity.

Now I should move on to Beer's technical practice. As I said, unlike Ashby, Beer's central concern was with real-world applications of cybernetics, especially in the management of industries and organizations, though Beer's approach to management looked little like either the standard social-scientific approach or the hardware-oriented approach of computer enthusiasts. From the 1950s onwards (for example, Beer 1959), Beer was consistently a critic of the usual uses of electronic computers and information technology in management, arguing that computers were being used simply to replace paper – in the construction of large databases, and so on – in an unimaginative way that left the traditional social structure of organizations intact. Beer felt that this was to ignore the real problem of managing organizations, which was the following.

The success or failure of organizations, Beer felt, was a function of their adequacy in coping with their environment, the outside world of suppliers and consumers. And, still according to Beer, the outside world was what he classified as an 'exceedingly complex system' – meaning that it was not exhaustively knowable; however much one mapped it and theorized it, one would always be surprised by it. (And here I can interject

FIGURE 4
Whiskers/Artificial Neurons



Source: Pask (1961: facing 64). Reproduced by permission of Amanda Heitler.

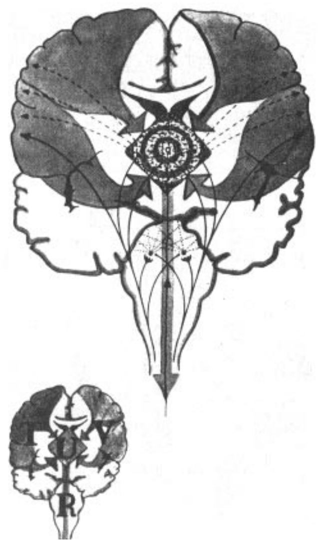
that this is precisely the ontology I argued for in *The Mangle of Practice*.) The fundamental problem of management, then, lay not in constructing and manipulating bigger databases, but, first, in the artful design of information flows – so that the firm could be quickly and adequately informed of what the outside world was actually doing. Ashby's 'Law of Requisite Variety' was the key here. The second true problem of management was to act on those flows, and this is where the homeostat loomed large in Beer's thinking. Just as Ashby's homeostats were always in the thick of things – responding to changing inputs in real-time; reconfiguring themselves internally to change their outputs; monitoring what came back at them from the world – so Beer's idea was that organizations, too, needed homeostatic controllers, capable of open-ended responses to unpredictable inputs, to keep them steady in an unknowable world. Whether these controllers should be electronic computers, ponds full of *Daphnia*, or, in the end, just good, old-fashioned humans, connected up to an appropriately designed information system, Beer was prepared to find out, in experimentation with the weird systems I mentioned before, and others.

Perhaps the most interesting feature of Beer's cybernetic vision of organizational design was that he modelled it on the human nervous system. Information flows and autonomous homeostatic control systems were supposed to mimic those within the human body, with all sorts of filters, redundant flows and feedback loops leading to and from the board of directors, which Beer thought of as the 'brain of the firm', the title of Beer (1972). Again, the resonance with theory in science studies is obvious and striking. For Beer, ontologically, the firm was, or should be, a literal *cyborg*, in Donna Haraway's sense (1991), a decentred, posthuman, assemblage of human and nonhuman parts, cybernetically coupled to one another and the outside world (Figure 5).[12]

Beer and his followers have attempted to put this Viable System Model, as it is known, into operation in many organizations over the years (Espejo & Harnden 1989), but the showpiece was Beer's attempt to cybernetize Chile in the period 1971–73, under the socialist regime of Salvador Allende (Beer 1972, 2nd edn 1981). This project sought to convert the entire Chilean economy into the kind of cyborg assemblage I just described, with real-time information flows running from individual factories (and so on) to a central control-room – the brain – and back again (Figure 6). The project went a long way in a short time, before it was cut off by the Pinochet coup. Many of the principals (though not Beer) found themselves in jail; others fled to the USA. Nobody, alas, has offered Beer an entire nation-state to work on since.

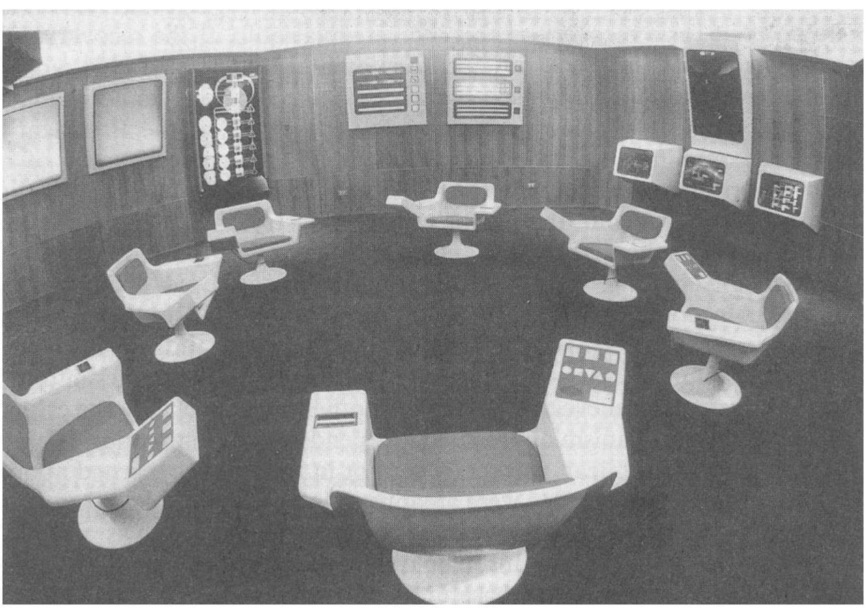
Beer's work, then, offers us a sketch of what cybernetics has looked like, when put to work in the real world of 'exceedingly complex systems'. And to stay with Beer for a moment longer, I should note that Beer's real-world cybernetic engagements have been even richer and more interesting than so far indicated. It turns out, for example, that his experience in India during World War II had a double impact on him. On the one hand, his management work there drew him into operations research and thence into

FIGURE 5
The Cybernetic Factory



Source: Beer (1994 [1962b]: 198). Reproduced by permission of John Wiley & Sons, and Stafford Beer.

FIGURE 6
Control Room of the Chile Project



Source: Beer (1994 [1974]: 330 [Fig. 12.1]) Reproduced by permission of John Wiley & Sons, and Stafford Beer.

cybernetics. On the other hand, in India Beer was also drawn to all sorts of Eastern religious and spiritual practices, which later themselves inflected his cybernetics (and no doubt *vice versa*). During the Chile project, for instance, Beer met a Buddhist monk who formally bestowed upon Beer a mandala embodying a mystical figure known as an enneagram, and the enneagram in turn became a key geometry in Beer's subsequent work in management (Beer 1994b: 202–05). This connection to Eastern mysticism points to the social as well as the material and conceptual singularity of cybernetics – and to resonances between cybernetics and New Age philosophy which it would be very interesting to explore further. I might also mention that Beer's vision of cybernetics included a kind of global politics. His 1975 book, *Platform for Change* – subtitle, *A Message from Stafford Beer* – was his manifesto, printed on paper of four different colours (white, blue, pink and yellow).

The overall point I want to emphasize from this discussion of Stafford Beer's work is, then, that homeostatic cybernetics was by no means necessarily a self-enclosed academic project. In Beer's hands, Ashby's electromechanical proto-brains turned into projects in the reorganization of social structures large and small, running from individual companies through nation-states to the world itself, skimming through the arts and latching on to distinctive non-Western spiritualities. I am reminded of the antidisciplinary theme I developed in *The Mangle*, and of my reference at the end of the book to nonmodern cultures. It turns out that Beer has lived such ideas, while I was content to lay them out theoretically. . . .

Gordon Pask

Now for my third character. Gordon Pask was born in Derby, England in 1928, and died in London in 1996.[13] He was definitely a 'character' – often dressed as an Edwardian Dandy, with dicky-bow and cape. A Festschrift in his honour published in 1993 testified to his position in the cybernetic pantheon and, incidentally, contains more affirmations of love and affection than I have ever seen before in a scholarly work (Glanville 1993). Festschrifts in physics certainly do not look like that. This outpouring of human emotion is yet another angle on the human and social singularity of cybernetics.

To understand Pask's cybernetics one has to start, as usual, with objects. Pask's involvement with cybernetics began in the theatre. As Cambridge undergraduates in the early 1950s, he and Robin McKinnon-Wood formed a company called 'Sirenelle' dedicated to staging musical comedies. Both men were fascinated with the technology of such performances: 'Gordon used to come back [to Cambridge] with bits of Calliope organ, I would come back. . . with bits of bomb sight computer' (McKinnon-Wood 1993: 129). From such pieces, they constructed a succession of odd and interesting machines, running from a Musical Typewriter, through a self-adapting metronome to the so-called 'Musicolour machine', which is worth describing. Musicolour used a microphone pickup to convert the

FIGURE 7
Gordon Pask

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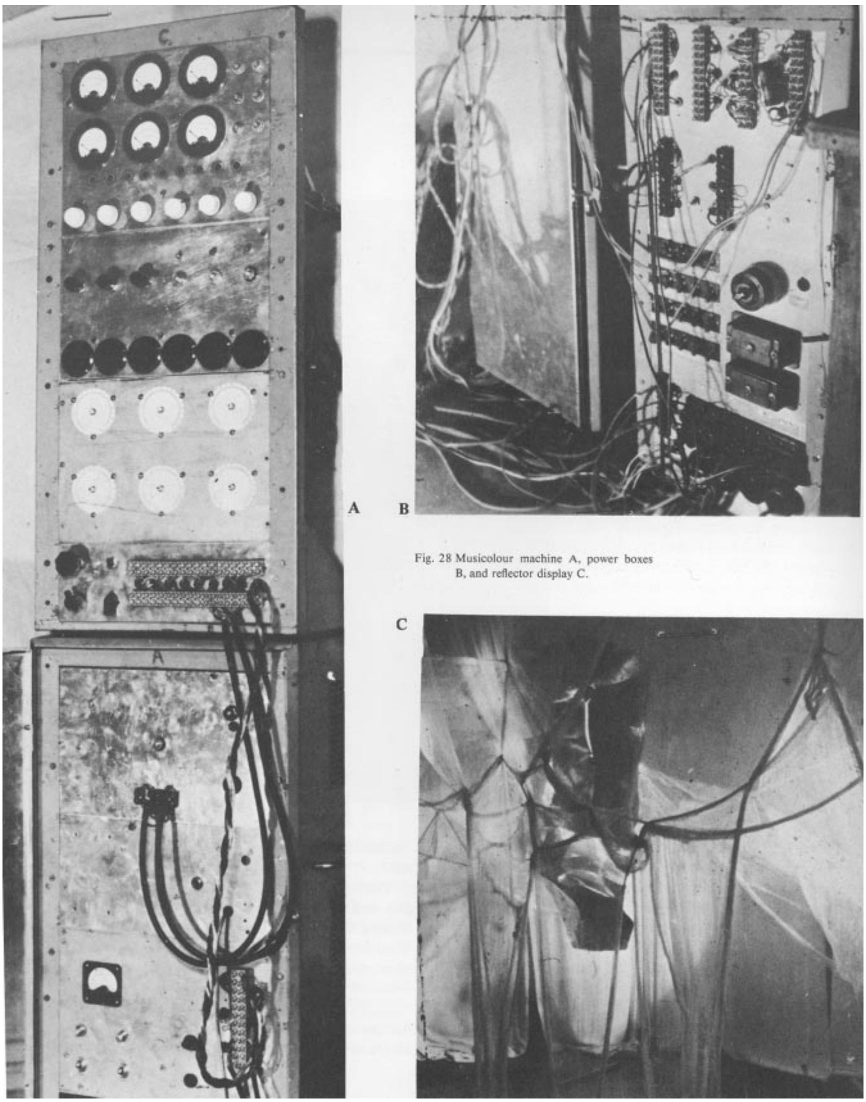
sound output from a musical instrument into an electrical signal, which was then processed electrically through some more Heath-Robinson-ish circuitry and used to control a light-show (Figure 8). Importantly, the processing was designed to vary unpredictably in time, and thus to be opaque and inscrutable to the musical performer. If the performance became too repetitive, the machine would 'get bored' and cease to respond, encouraging the performer to try something new. The system could also detect lags in the musical performance (relative to a regular beat) and amplify them in the light display, and so on (Pangaro 1993).

Musicolour, we can note, was a cybernetic device in much the same sense as the homeostat, though even more lively: a Musicolour performance centred on a feedback loop running from the human performer through the musical instrument and the machine itself into the environment (the light show), and thence back to the performer. A Musicolour performance might, in fact, be a better model of my analysis of scientific practice than the homeostat. In place of the homeostat's finite number of states, the human part of a Musicolour performance could explore the space of performative possibilities of the machine in a truly open-ended fashion, and the only criterion of stability was itself a locally emergent one, not given in advance; it was just whatever pleased the performer and the audience on some occasion. And, just as I argued about scientific practice in *The Mangle*, a Musicolour show was precisely a decentred joint performance of the human and the nonhuman. As Pask put it: 'He [the performer] trained the machine, and it played a game with him. In this sense, the system acted as an extension of the performer with which he could cooperate to achieve effects that he could not achieve on his own' (Pask

1971: 78). As nice an exemplification of the dance of agency as one might wish.

Pask's most advanced machine in this category was his 'Colloquy of Mobiles', displayed at an exhibition called 'Cybernetic Serendipity' at the Institute for Contemporary Arts in London in the summer of 1968 (where Beer's Stochastic Analogue Machine was also on display: Reichardt 1968, 1971; Pask 1971). The mobiles were complicated electro-mechanical robots, designated male and female, which would search for one another and

FIGURE 8
The Musicolour Machine



Source: Pask (1971: 82). Reproduced by permission of Amanda Heitler.

engage in uncertain and complicated *matings* (Figure 9). The males would emit light beams from their upper parts, which the females would try to reflect back at them. When the reflected beam struck a particular spot on the lower parts of the males, they would be 'satisfied' and go quiescent – until charges started to build up again on their capacitors, when the dance would begin all over again. Spectators were issued with mirrors so that they could interfere with these hesitant and difficult couplings by redirecting the light rays – a rather cruel thing to do.

Pask's cybernetics, then, had its first home in the worlds of the arts and entertainment. But the construction of machines like Musicolour and the Colloquy of Mobiles led Pask also into the world of business. 'We met [Christopher Bailey], by chance... at an exhibition.... Gordon talked to him about Grey Walter's tortoise, and Christopher took us aside and said, "You don't want to buy something – you want to sell something".... [Bailey] was then Technical Director of the Solartron Electronic Group, which was expanding into the field of AI. He was interested in Gordon and his ideas, and prepared to support them. With him we designed Eucrates' (McKinnon-Wood 1993: 131–32). Eucrates was a self-adaptive teaching and learning machine which, like Musicolour, responded to the performance of the trainee, speeding up or slowing down in response to the trainee's emergent performance, identifying weaknesses and harping upon them (Pask 1961: 67–70; Figure 10). Pask later moved from Eucrates to the development of SAKI (Self Adaptive Keyboard Instructor), which was widely copied in commercial typing trainers. Pask's involvement with the stage and entertainment technology thus fed directly and materially into a more lucrative career in educational technology.

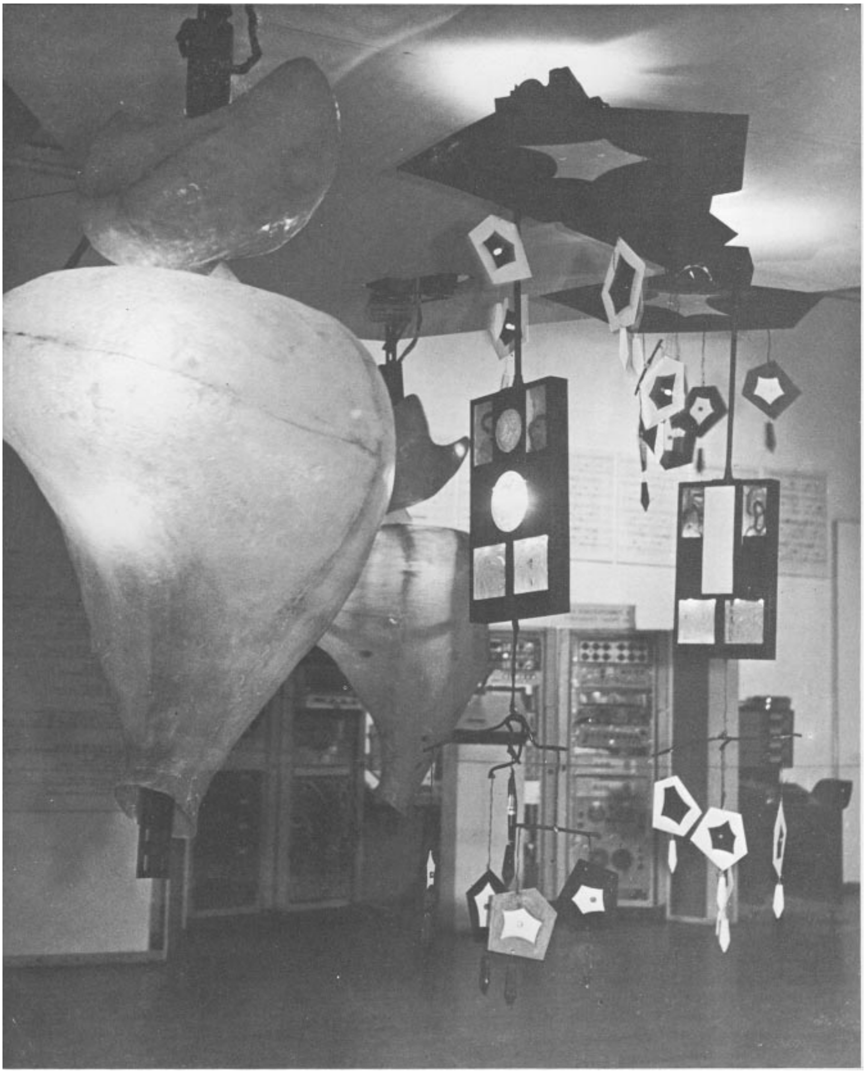
The construction of all of these material devices, artistic and commercial, I should add, was informed by, and fed into, Pask's theoretical work, which began with his conviction that 'an aesthetically potent environment should... respond to a man, engage him in conversation and adapt its characteristics to the prevailing mode of discourse' (Pask 1971: 76). This posthuman image of 'conversation' – between people and things or between people and people – was a key one for Pask, and he eventually elaborated his understanding of it into a rather daunting formalism that he called 'conversation theory'.

One last thought on Pask. I would be intrigued to find out just how far his work fed into popular culture. One can note, for example, that the early development of the Musicolour machine took place in London at a Dadaist association known as the Pomegranate Club, and it might be significant that Pask himself referred to goings-on there as 'happenings' – those archetypical 1960s events (Pask 1971: 78). I like to think, therefore, that cybernetics was at the heart of much that was good about the sixties.

Discussion

In this paper, I have taken up two inter-related tasks. One is an exploration of the theoretical allure of cybernetics – what is it that continues to draw scholars to its history? My suggestion is that cybernetics grabs on to the world differently from the classical sciences. While the latter seek to pin the world down in timeless representations, cybernetics directly thematizes the unpredictable liveliness of the world, and processes of open-ended becoming. While classical science has thus been an epistemological project aimed explicitly at knowledge production, cybernetics is an ontological project, aimed variously at displaying, grasping, controlling, exploiting and

FIGURE 9
The Colloquy of Mobiles
The balloon-shaped objects are the females, the dangling rectangular shapes are the males.

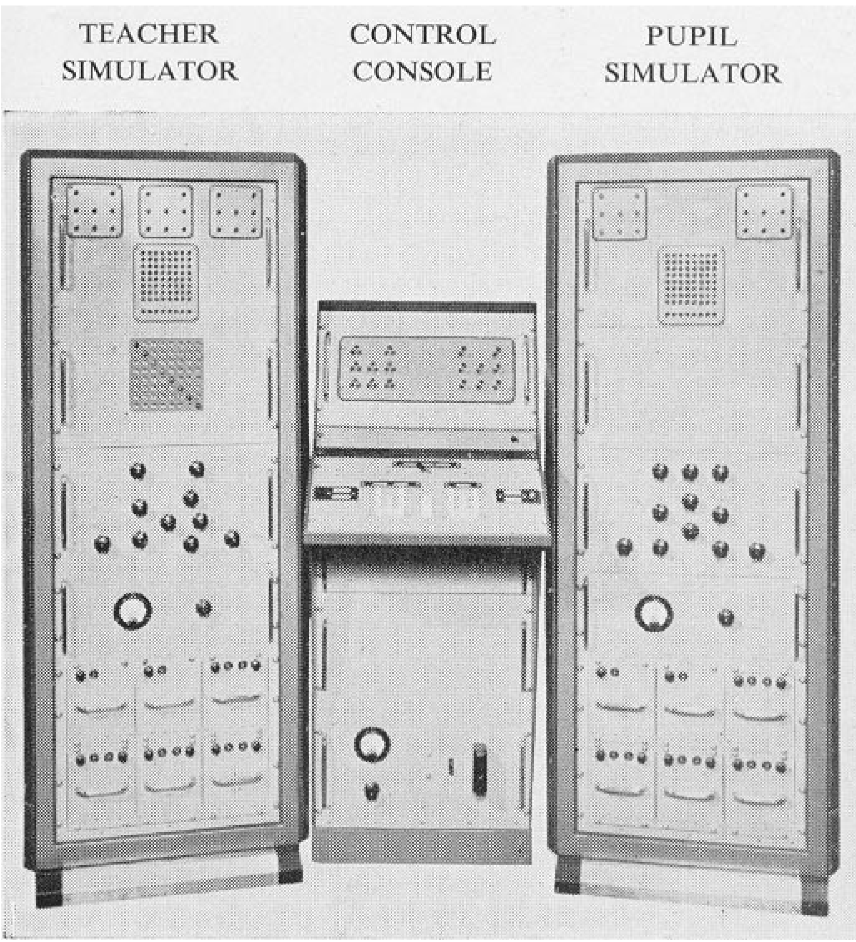


Source: Pask (1971: 97). Reproduced by permission of Amanda Heitler.

exploring the liveliness of the world. The juxtaposition of Ashby's material homeostat-as-brain endlessly searching spaces of agency and symbolic AI's disconnected representation-processing exemplifies this contrast very clearly.[14] To recycle another old formulation from Thomas Kuhn, it is as if the cyberneticians have lived in a different world from the classical scientists. That is one reason, at least, why people find cybernetics fascinating.

My second task has been to explore intersections between cybernetics and contemporary theoretical work in science studies, including my own – with an eye to the first task, of course, and in the hope of clarifying some of the features of both fields of practice. Recognizing the homeostat and the Musicolour machine as material models of the mangle of practice makes the required connection. At the same time, it helps clarify the divergence between, on the one hand, the mangle and ontological approaches to

FIGURE 10
Eucrates



Source: Pask (1961: facing 32). Reproduced by permission of Amanda Heitler.

science studies more generally, and, on the other, more traditional, epistemologically inclined approaches.[15]

Beyond that, from a science-studies perspective, the history of cybernetics can help us to break still further away from the representational idiom. In writing this paper (as in writing *The Mangle*) I have been, of course, engaging in the business of representation. Like most scholarly authors, I have grown accustomed to think that representation is what we do. But the history of cybernetics shows us that such need not be exclusively the case. Theory in science and technology studies need not rest at the level of theory. Taking my cue from the homeostat, for example, I can now see that there can be a mangle-ish style of engineering, distinctively different in approach from the classical approaches to engineering most of us are familiar with – and likewise, following Beer and Pask, there can be a mangle-ish approach to management, the arts, politics and spirituality. At the very least, even if one stops short of doing, there is an evident prospect that engineers, artists and New Age gurus can get some inspiration from us in science studies, and that we can genuinely get some inspiration from them. Over the years, many of us in science studies have bemoaned the difficulty of making an impression on the mainstream academic disciplines with which we have thought to affiliate ourselves. Perhaps we were looking in the wrong direction. Perhaps it is time for the long march through the institutions: the laboratory (as creative scientists, not just observers), politics, art galleries and the ashram.

Notes

This paper was written for a colloquium held at the Centre Koyré in Paris in May 2000, and it will appear in French translation in Amy Dahan and Dominique Pestre (eds), *La reconfiguration des sciences pour l'action dans les années 1950* (Paris: Presses de l'EHESS). Various versions of it have been presented in seminars at Northwestern University, Johns Hopkins University, Virginia Tech (as the annual Mullins Lecture) and Rice University, and I am grateful for feedback received on all those occasions. For entertaining and enlightening discussions of the history of cybernetics more generally, I thank Peter Asaro, Stafford Beer, Cornelius Borck, Geoffrey Bowker, Peter Cariani, Adrian Cussins, Fernando Elichirigoity, Peter Galison, Slava Gerovitch, Rhodri Hayward, Steve Heims, Amanda Heitler, Jonathan Heitler, the late Lily Kay, Evelyn Fox Keller, Philip Mirowski, Paul Pangaro, Jérôme Segal, Isabelle Stengers and Heinz von Foerster. For her help with the illustrations for this article, I am very grateful to Shari Day.

1. See, for example: Borck (2000), Bowker (1993), Dupuy (2000), Galison (1994, 1998), Gerovitch (1999), Haraway (1991), Hayles (1999), Hayward (1998, forthcoming), Heims (1980, 1991), Kay (1997, forthcoming), Keller (1995), Mindell, Segal & Gerovitch (forthcoming), Mirowski (2001), Pickering (1995a, 1998, forthcoming), Richardson (1991), Segal (2000).
2. Many different bodies of work were grouped under the heading of 'cybernetics' in the postwar period (for a standard categorization, see note 5, below), and scholars tend to latch on to one or the other. I focus on these three Englishmen because (a) their work is extremely interesting in itself, and (b) one can see how an examination of it might inform current work in science studies (and beyond). I can add that I focus here on those aspects of the work of Ashby, Beer and Pask that relate most closely to my theoretical interests; I do not claim to present a balanced coverage of all that they did. Other cyberneticians would also need to be discussed if one wanted to round out the

picture of cybernetics in Britain in this period, especially Grey Walter (Walter 1953; Hayward 1998; Hayward forthcoming; Pickering forthcoming).

3. Standard introductions to cybernetics tend to revolve around notions of negative feedback and purposive behaviour exemplified by the domestic thermostat, and do not get very far in this direction. In Pickering (1998) I tried to get at the singularity of work in cybernetics (and in the sciences of self-organization more generally) by pointing to the 'monstrous' character of its material referents. This monstrosity is very evident in the history that follows. A certain social singularity of cybernetics is also apparent below – linking different areas of social life in novel ways; a decentring relative to the university – but I will not attempt to thematize that. I can, however, note that this creates interesting historiographic problems. One cannot track the history of cybernetics by following patterns of academic reproduction and filiation the way one readily tracks physics, for example.
4. The view of science as primarily a representational practice is very familiar in science studies: think of mainstream analytic philosophy, the history of science written as a history of ideas (contextualized or not), canonical sociology of scientific knowledge as aiming at social explanations for scientific beliefs. In all of these approaches, scientific representations of the world (theories, models, facts) are the central topics of discussion and the *terminus ad quem* of scholarly interpretation and explanation. Embodied, performative, understandings of science are less familiar. One can trace an ancestry in continental philosophy, with Heidegger (1977) as one point of entry. In contemporary science studies, see, for example, Gooding (1990), Hacking (1983), Haraway (1991), Hayles (1999), Latour (1999) and Stengers (1997), with Fleck (1979) as an important forerunner. Several of these authors have made their own connections from the history of cybernetics to contemporary theory (though not the same connections as those made here): Hacking (1998), Haraway (1991) and Stengers on a wide variety of topics concerning self-organization (Prigogine & Stengers 1984; more specifically, see the citations to her work on the history of cybernetics in Dupuy 2000). Cybernetic influences can be detected in Bruno Latour's work, too – 'black box', for example, one of his key terms of art, belongs to the cybernetic lexicon. Heims (1980) discusses the early history of cybernetics in the social sciences (again, developing in different directions from those set out below). Galison (1994) takes Haraway (1991) and Lyotard (1984) to task for their enthusiasm for cybernetic ideas.
5. As defined by Norbert Wiener (1948), cybernetics was born in the confluence of three lines of work, in (i) information theory, (ii) neural networks and (iii) connections between negative feedback and purposive behaviour; (i) and (ii) resonate most strongly, of course, with the representational idiom. The Ur-referent for (iii) was the autonomous anti-aircraft gun that Wiener sought unsuccessfully to construct in the early years of World War II (Galison 1994). Reference to such robotic weapons carries us in the direction of the performative idiom; my judgement is that the English cyberneticians went much further in their material and conceptual explorations of performativity than Wiener, which is why I do not dwell on Wiener himself here.
6. For some obituaries, see: *Artorga* (1973), Conant (1974), Pask (1973). For more on Ashby, see Asaro (1998).
7. The following account is based on the 1960 second edition of Ashby (1952), the most extensive published account of the homeostat. I can note that I am concerned in this paper with the substance of British cybernetics, not with its antecedents, but I do not wish to give the impression that cybernetics emerged *ex nihilo* in the postwar period. Standard histories of cybernetics reach back into the history of servomechanisms and control engineering, with Watt's steam engine governor (and Maxwell's theoretical analysis of it) looming large (as, for example, in Wiener 1948; for a broader perspective on the 'control revolution' of the 19th and 20th centuries, see Beniger 1986). However, Ashby worked in psychiatry (until he moved to the United States in 1960), and the homeostat has to be undertood in relation to his behaviourist perspective on the brain (see below). Ashby's experiences in World War II would presumably shed light on the origins of the homeostat, but I have so far been unable to discover much about them.

(On Wiener's wartime work and the relations between his cybernetics and behaviourism, see Galison 1994; likewise for Grey Walter, see Pickering forthcoming; on relations between Walter and Ashby, see Hayward 1998).

8. A key contrast between the homeostat and Wiener's paradigmatic weapons systems is that the latter relied upon 'pre-programmed' electronic circuitry (rather than open-ended search) to minimize a single variable, the gap between where shells exploded and the position of the target plane. For more on the contrasts between Ashby's and Wiener's cybernetics, see Pickering (1998).
9. See also note 7 (above) for references to Grey Walter's interest in the brain.
10. In the 1980s, symbolic AI began to run out of steam, and the neural network (connectionist) wing of cybernetics came back into favour. In the 1990s, cybernetic approaches more akin to those discussed here began to attract increasing interest: see van Gelder (1995).
11. I thank Stafford Beer for providing me with biographical materials on which this paragraph is based.
12. One referee remarks: 'I don't see why Beer's firm was "decentred", when the "brain of the firm" (the board of directors) occupies such a central rôle – What could be more centred than boards of directors and central nervous systems?'. This is a nice point, and it would require going into the details of Beer's scheme to respond to it properly. The point I need to emphasize is that Beer saw the 'brain of the firm' as just one control system enmeshed with others (human or nonhuman, lower down the 'spinal column'), with all of these control systems homeostatically engaged with their environments. This is a very different image from, for example, a standard idea of the directors as a one-way source of orders based on a panoptic command of the firm and its performance.
13. For biographical details, see the obituaries by Pangaro (n.d.) and Rocha (1996).
14. This contrast is played out in the present in the engineering and philosophical tensions between symbol-processing approaches to robotics and new-wave 'situated' or 'autonomous' robotics (see Brooks 1999), though the immediate cybernetic antecedents to situated robotics appear to have been Grey Walter's 'tortoises' of the 1950s, rather than Ashby's homeostats.
15. This divergence was first explicitly addressed in the so-called 'chicken debate', between Harry Collins and Steven Yearley, and Michel Callon and Bruno Latour, in Pickering (1992).

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