CHAPTER 2

Laboratories

We could stop our enquiry where we left it at the end of the previous chapter. For a layperson, studying science and technology would then mean analysing the discourse of scientists, or counting citations, or doing various bibliometric calculations, or performing semiotic studies[1] of scientific texts and of their iconography, that is, extending literary criticism to technical literature. No matter how interesting and necessary these studies are, they are not sufficient if we want to follow scientists and engineers at work; after all, they do not draft, read and write papers twenty-four hours a day. Scientists and engineers invariably argue that there is something behind the technical texts which is much more important than anything they write.

At the end of the previous chapter, we saw how the articles forced the reader to choose between three possible issues: giving up (the most likely outcome), going along, or working again through what the author did. Using the tools we devised in Chapter 1, it is now easy to understand the first two issues, but we are as yet unable to understand the third. Later, in the second part of this book, we will see many other ways to avoid this issue and still win over in the course of a controversy. For the sake of clarity, however, I make the supposition in this part that the dissenter has no other escape but to work through what the author of the paper did. Although it is a rare outcome, it is essential for us to visit the places where the papers are said to originate. This new step in our trip through technoscience is much more difficult, because, whilst the technical literature is accessible in libraries, archives, patent offices or corporate documentation centres, it is much less easy to sneak into the few places where the papers are written and to follow the construction of facts in their most intimate details. We have no choice, however, if we want to apply our first rule of method: if the scientists we shadow go inside laboratories, then we too have to go there, no matter how difficult the journey.

Part A
From texts to things: a showdown

'You doubt what I wrote? Let me show you.' The very rare and obstinate dissenter who has *not* been convinced by the scientific text, and who has not found other ways to get rid of the author, is led from the text into the place where the text is said to come from. I will call this place the **laboratory**, which for now simply means, as the name indicates, the place where scientists *work*. Indeed, the laboratory was present in the texts we studied in the previous chapter: the articles were alluding to 'patients', to 'tumours', to 'HPLC', to 'Russian spies', to 'engines'; dates and times of experiments were provided and the names of technicians acknowledged. All these allusions however were made within a paper world; they were a set of semiotic actors presented in the text but not *present* in the flesh; they were alluded to as if they existed independently from the text; they could have been invented.

(1) Inscriptions

What do we find when we pass through the looking glass and accompany our obstinate dissenter from the text to the laboratory? Suppose that we read the following sentence in a scientific journal and, for whatever reason, do not wish to believe it:

> (1) 'Fig.1 shows a typical pattern. Biological activity of endorphin was found essentially in two zones with the activity of zone 2 being totally reversible, or statistically so, by naloxone.'

We, the dissenters, question this figure 1 so much, and are so interested in it, that we go to the author's laboratory (I will call him 'the Professor'). We are led into an air-conditioned, brightly lit room. The Professor is sitting in front of an array of devices that does not attract our attention at first. 'You doubt what I wrote? Let me show you.' This last sentence refers to an image slowly produced by one of these devices (Figure 2.1):

(2)

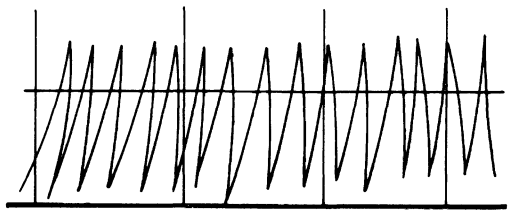

Figure 2.1

'OK. This is the base line; now, I am going to inject endorphin, what is going to happen? See?!' (Figure 2.2)

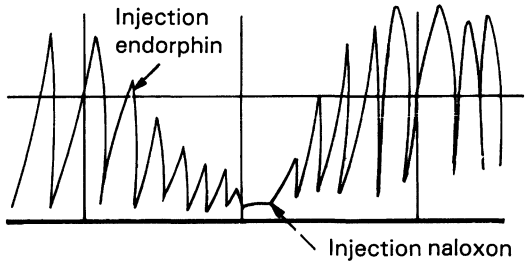

Figure 2.2

'Immediately the line drops dramatically. And now watch naloxone. See?! Back to base line levels. It is fully reversible.'

We now understand that what the Professor is asking us to watch is related to the figure in the text of sentence (1). We thus realise where this figure comes from. It has been *extracted* from the instruments in this room, *cleaned, redrawn,* and *displayed.* We now seem to have reached the source of all these images that we saw arrayed in the text as the final proofs of all the arguments in Chapter 1. We also realise, however, that the images that were the last layer in the text, are the *end result* of a long process in the laboratory that we are now starting to observe. Watching the graph paper slowly emerging out of the physiograph, we understand that we are at the junction of two worlds: a paper world that we have just left, and one of instruments that we are just entering. A hybrid is produced at the interface: a raw image, to be used later in an article, that is emerging from an instrument.

For a time we focus on the stylus pulsating regularly, inking the paper, scribbling cryptic notes. We remain fascinated by this fragile film that is in between text and laboratory. Soon, the Professor draws our attention beneath and beyond the traces on the paper, to the physiograph from which the image is slowly being emitted. Beyond the stylus a massive piece of electronic hardware records, calibrates, amplifies and regulates signals coming from another instrument, an array of glassware. The Professor points to a glass chamber in which bubbles are regularly flowing around a tiny piece of something that looks like elastic. It is indeed elastic, the Professor intones. It is a piece of gut, guinea pig gut ('myenteric plexus-longitudinal muscle of the guinea pig ileum', are his words). This gut has the property of contracting regularly if maintained alive. This regular pulsation is easily disturbed by many chemicals. If one hooks the gut up so that each contraction sends out an electric pulse, and if the pulse is made to move a stylus over graph paper, then the guinea pig gut will be induced to produce regular scribbles over a long period. If you then add a chemical to the chamber you *see* the peaks drawn by the inked stylus slow down or accelerate at the other end. This perturbation, invisible in the chamber, is visible on paper: the

chemical, no matter what it is, is given a *shape* on paper. This shape 'tells you something' about the chemical. With this set-up you may now ask new questions: if I double the dose of chemical will the peaks be doubly decreased? And if I triple it, what will happen? I can now measure the white surface left by the decreasing scribbles directly on the graph paper, thereby defining a quantitative relation between the dose and the response. What if, just after the first chemical is added, I add another one which is known to counteract it? Will the peaks go back to normal? How fast will they do so? What will be the pattern of this return to the base line level? If two chemicals, one known, the other unknown, trace the same slope on the paper, may I say, in this respect at least, that they are the same chemicals? These are some of the questions the Professor is tackling with endorphin (unknown), morphine (well known) and naloxone (known to be an antagonist of morphine).

We are no longer asked to believe the text that we read in *Nature*; we are now asked to believe *our own eyes*, which can see that endorphin is behaving exactly like morphine. The object we looked at in the text and the one we are now contemplating are identical except for one thing. The graph of sentence (1) which was the most concrete and visual element of the text, is now in (2) the most abstract and textual element in a bewildering array of equipment. Do we see more or less than before? On the one hand we can see more, since we are looking at not only the graph but also the physiograph, and the electronic hardware, and the glassware, and the electrodes, and the bubbles of oxygen, and the pulsating ileum, and the Professor who is injecting chemicals into the chamber with his syringe, and is writing down in a huge protocol book the time, amount of and reactions to the doses. We can see more, since we have before our eyes not only the image but what the image is made of.

On the other hand we see *less* because now each of the elements that makes up the final graph could be modified so as to produce a different visual outcome. Any number of incidents could blur the tiny peaks and turn the regular writing into a meaningless doodle. Just at the time when we feel comforted in our belief and start to be fully convinced by our own eyes watching the image, we suddenly feel uneasy because of the fragility of the whole set up. The Professor, for instance, is swearing at the gut saying it is a 'bad gut'. The technician who sacrificed the guinea pig is held responsible and the Professor decides to make a fresh start with a new animal. The demonstration is stopped and a new scene is set up. A guinea pig is placed on a table, under surgical floodlights, then anaesthetised, crucified and sliced open. The gut is located, a tiny section is extracted, useless tissue peeled away, and the precious fragment is delicately hooked up between two electrodes and immersed in a nutrient fluid so as to be maintained alive. Suddenly, we are much further from the paper world of the article. We are now in a puddle of blood and viscera, slightly nauseated by the extraction of the ileum from this little furry creature. In the last chapter, we admired the rhetorical abilities of the Professor as an author. Now, we realise that many other manual abilities are required in order to write a convincing paper later on. The guinea pig alone would not have been able to tell us anything

about the similarity of endorphin to morphine; it was not mobilisable into a text and would not help to convince us. Only a part of its gut, tied up in the glass chamber and hooked up to a physiograph, can be mobilised in the text and add to our conviction. Thus, the Professor's art of convincing his readers must extend beyond the paper to preparing the ileum, to calibrating the peaks, to tuning the physiograph.

After hours of waiting for the experiment to resume, for new guinea pigs to become available, for new endorphin samples to be purified, we realise that the invitation of the author ('let me show you') is not as simple as we thought. It is a slow, protracted and complicated staging of tiny images in front of an audience. 'Showing' and 'seeing' are not simple flashes of intuition. Once in the lab we are not presented outright with the real endorphin whose existence we doubted. We are presented with another world in which it is necessary to prepare, focus, fix and rehearse the vision of the real endorphin. We came to the laboratory in order to settle our doubts about the paper, but we have been led into a labyrinth.

This unexpected unfolding makes us shiver because it now dawns on us that if we disbelieve the traces obtained on the physiograph by the Professor, we will have to give up the topic altogether or go through the same experimental chores all over again. The stakes have increased enormously since we first started reading scientific articles. It is not a question of reading and writing back to the author any more. In order to argue, we would now need the manual skills required to handle the scalpels, peel away the guinea pig ileum, interpret the decreasing peaks, and so on. Keeping the controversy alive has already forced us through many difficult moments. We now realise that what we went through is nothing compared to the scale of what we have to undergo if we wish to continue. In Chapter 1, we only needed a good library in order to dispute texts. It might have been costly and not that easy, but it was still feasible. At this present point, in order to go on, we need guinea pigs, surgical lamps and tables, physiographs, electronic hardware, technicians and morphine, not to mention the scarce flasks of purified endorphin; we also need the skills to use all these elements and to turn them into a pertinent objection to the Professor's claim. As will be made clear in Chapter 4, longer and longer detours will be necessary to find a laboratory, buy the equipment, hire the technicians and become acquainted with the ileum assay. All this work just to start making a convincing counter-argument to the Professor's original paper on endorphin. (And when we have made this detour and finally come up with a credible objection, where will the Professor be?)

When we doubt a scientific text we do not go from the world of literature to Nature as it is. Nature is not directly beneath the scientific article; it is there *indirectly* at best (see Part C). Going from the paper to the laboratory is going from an array of rhetorical resources to a set of new resources devised in such a way as to provide the literature with its most powerful tool: the visual display. Moving from papers to labs is moving from literature to convoluted ways of getting this literature (or the most significant part of it).

This move through the looking glass of the paper allows me to define an **instrument**, a definition which will give us our bearings when entering any

laboratory. I will call an instrument (or **inscription device**) any set-up, no matter what its size, nature and cost, that provides a visual display of any sort in a scientific text. This definition is simple enough to let us follow scientists' moves. For instance an optical telescope is an instrument, but so is an array of several radio-telescopes even if its constituents are separated by thousands of kilometers. The guinea pig ileum assay is an instrument even if it is small and cheap compared to an array of radiotelescopes or the Stanford linear accelerator. The definition is not provided by the cost nor by the sophistication but only by this characteristic: the set-up provides an inscription that is used as the final layer in a scientific text. An instrument, in this definition, is not every set-up which ends with a little window that allows someone to take a reading. A thermometer, a watch, a Geiger counter, all provide readings but are not considered as instruments as long as these readings are not used as the final layer of technical papers (but see Chapter 6). This point is important when watching complicated contrivances with hundreds of intermediary readings taken by dozens of white-coated technicians. What will be used as visual proof in the article will be the few lines in the bubble chamber and not the piles of printout making the intermediate readings.

It is important to note that the use of this definition of instrument is a relative one. It depends on time. Thermometers *were* instruments and very important ones in the eighteenth century, so were Geiger counters between the First and Second World Wars. These devices provided crucial resources in papers of the time. But now they are only parts of larger set-ups and are only used so that a new visual proof can be displayed at the end. Since the definition is relative to the use made of the 'window' in a technical paper, it is also relative to the intensity and nature of the associated controversy. For instance, in the guinea pig ileum assay there is a box of electronic hardware with many readings that I will call 'intermediate' because they do not constitute the visual display eventually put to use in the article. It is unlikely that anyone will quibble about this because the calibration of electronic signals is now made through a black box produced industrially and sold by the thousand. It is a different matter with the huge tank built in an old gold mine in South Dakota at a cost of $600,000 (1964 dollars!) by Raymond Davis[2] to detect solar neutrinos. In a sense the whole set-up may be considered as *one* instrument providing one final window in which astrophysicists can read the number of neutrinos emitted by the sun. In this case all the other readings are intermediate ones. If the controversy is fiercer, however, the set-up is broken down into *several* instruments, each providing a specific visual display which has to be independently evaluated. If the controversy heats up a bit we do not see neutrinos coming out of the sun. We see and hear a Geiger counter that clicks when $Argon^{37}$ decays. In this case the Geiger counter, which gave only an intermediate reading when there was no dispute, becomes an instrument in its own right when the dispute is raging.

The definition I use has another advantage. It does not make presuppositions about what the instrument is made of. It can be a piece of hardware like a telescope, but it can also be made of softer material. A statistical institution that

employs hundreds of pollsters, sociologists and computer scientists gather all sorts of data on the economy *is* an instrument if it yields inscriptions for papers written in economic journals with, for instance, a graph of the inflation rate by month and by branch of industry. No matter how many people were made to participate in the construction of the image, no matter how long it took, no matter how much it cost, the whole institution is used as *one* instrument (as long as there is no controversy that calls its intermediate readings into question).

At the other end of the scale, a young primatologist who is watching baboons in the savannah and is equipped only with binoculars, a pencil and a sheet of white paper may be seen as an instrument if her coding of baboon behaviour is summed up in a graph. If you want to deny her statements, you might (everything else being equal) have to go through the same ordeals and walk through the savannah taking notes with similar constraints. It is the same if you wish to deny the inflation rate by month and industry, or the detection of endorphin with the ileum assay. The instrument, whatever its nature, is what leads you from the paper to what supports the paper, from the many resources mobilised in the text to the many more resources mobilised to create the visual displays of the texts. With this definition of an instrument, we are able to ask many questions and to make comparisons: how expensive they are, how old they are, how many intermediate readings compose one instrument, how long it takes to get one reading, how many people are mobilised to activate them, how many authors are using the inscriptions they provide in their papers, how controversial are those readings . . . Using this notion we can define more precisely than earlier the laboratory as any place that gathers one or several instruments together.

What is behind a scientific text? Inscriptions. How are these inscriptions obtained? By setting up instruments. This other world just beneath the text is invisible as long as there is no controversy. A picture of moon valleys and mountains is presented to us as if we could see them directly. The telescope that makes them visible is invisible and so are the fierce controversies that Galileo had to wage centuries ago to produce an image of the Moon. Similarly, in Chapter 1, the accuracy of Soviet missiles was just an *obvious* statement; it became the outcome of a complex system of satellites, spies, Kremlinologists and computer simulation, only *after* the controversy got started. Once the fact is constructed, there is no instrument to take into account and this is why the painstaking work necessary to tune the instruments often disappears from popular science. On the contrary, when science in action is followed, instruments become the crucial elements, immediately after the technical texts; they are where the dissenter is inevitably led.

There is a corollary to this change of relevance on the inscription devices depending on the strength of the controversy, a corollary that will become more important in the next chapter. If you consider only fully-fledged facts it seems that everyone could accept or contest them equally. It does not cost anything to contradict or accept them. If you dispute further and reach the frontier where facts are made, instruments become visible and with them the cost of continuing the discussion rises. It appears that *arguing is costly*. The equal world of citizens

having opinions about things becomes an unequal world in which dissent or consent is not possible without a huge accumulation of resources which permits the collection of relevant inscriptions. What makes the differences between author and reader is not only the ability to utilise all the rhetorical resources studied in the last chapter, but also to gather the many devices, people and animals necessary to produce a visual display usable in a text.

(2) Spokesmen and women

It is important to scrutinise the exact settings in which encounters between authors and dissenters take place. When we disbelieve the scientific literature, we are led from the many libraries around to the *very few* places where this literature is produced. Here we are welcomed by the author who shows us where the figure in the text comes from. Once presented with the instruments, who does the talking during these visits? At first, the authors: they *tell* the visitor what to *see*: 'see the endorphin effect?', 'look at the neutrinos!' However, the authors are not lecturing the visitor. The visitors have their faces turned towards the instrument and are watching the place where the thing is writing itself down (inscription in the form of collection of specimens, graphs, photographs, maps – you name it). When the dissenter was reading the scientific text it was difficult for him or her to doubt, but with imagination, shrewdness and downright awkwardness it was always possible. Once in the lab, it is much more difficult because the dissenters see with their own eyes. If we leave aside the many other ways to avoid going through the laboratory that we will study later, the dissenter does not have to believe the paper nor even the scientist's word since in a self-effacing gesture the author has stepped aside. 'See for yourself' the scientist says with a subdued and maybe ironic smile. 'Are you convinced now?' Faced with the thing itself that the technical paper was alluding to, the dissenters now have a choice between either accepting the fact or doubting their own sanity – the latter is much more painful.

We now seem to have reached the end of all possible controversies since there is nothing left for the dissenter to dispute. He or she is right in front of the thing he or she is asked to believe. There is almost no human intermediary between thing and person; the dissenter is in the very place where the thing is said to happen and at the very moment when it happens. When such a point is reached it seems that there is no further need to talk of confidence': the thing impresses itself directly on us. Undoubtedly, controversies are settled once and for all when such a situation is set up – which again is very rarely the case. The dissenter becomes a believer, goes out of the lab, borrowing the author's claim and confessing that 'X' has incontrovertibly shown that A is B'. A new fact has been made which will be used to modify the outcome of some other controversies (see Part B, Section 3).

If this were enough to settle the debate, it would be the end of this book. But... there is someone saying 'but, wait a minute . . .' and the controversy resumes!

What was imprinted on us when we were watching the guinea pig ileum assay? 'Endorphin of course,' the Professor *said*. But what did we *see*? This

(3)

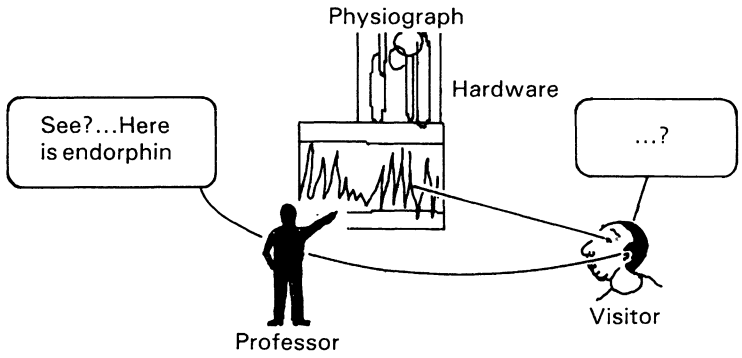

Figure 2.3

With a minimum of training we see peaks; we gather there is a base line, and we see a depression in relation to one coordinate that we understand to indicate the time. This is not endorphin yet. The same thing occurred when we paid a visit to Davis's gold and neutrino mine in South Dakota. We saw, he said, neutrinos counted straight out of the huge tank capturing them from the sun. But what *did* we see? Splurges on paper representing clicks from a Geiger counter. Not neutrinos, yet.

When we are confronted with the instrument, we are attending an 'audio-visual' spectacle. There is a *visual* set of inscriptions produced by the instrument and a *verbal* commentary uttered by the scientist. We get both together. The effect on conviction is striking, but its cause is mixed because we cannot differentiate what is coming from the thing inscribed, and what is coming from the author. To be sure, the scientist is not trying to influence us. He or she is simply commenting, underlining, pointing out, dotting the i's and crossing the t's, not adding anything. But it is also certain that the graphs and the clicks by themselves would not have been enough to form the image of endorphin coming out of the brain or neutrinos coming out of the sun. Is this not a strange situation? The scientists do not say anything more than what is inscribed, but without their commentaries the inscriptions say considerably less! There is a word to describe this strange situation, a very important word for everything that follows, that is the word **spokesman** (or **spokeswoman**, or **spokesperson**, or mouthpiece). The author behaves as if he or she were the mouthpiece of what is inscribed on the window of the instrument.

The spokesperson is someone who speaks for others who, or which, do not speak. For instance a shop steward is a spokesman. If the workers were gathered

together and they all spoke at the same time there would be a jarring cacophony. No more meaning could be retrieved from the tumult than if they had remained silent. This is why they designate (or are given) a delegate who speaks on their behalf, and in their name. The delegate – let us call him Bill – does not speak in *his* name and when confronted with the manager does not speak 'as Bill' but as the 'workers' voice'. So Bill's longing for a new Japanese car or his note to get a pizza for his old mother on his way home, are not the right topics for the meeting. The voice of the floor, articulated by Bill, wants a '3 per cent pay rise—and they are deadly serious about it, sir, they are ready to strike for it,' he tells the manager. The manager has his doubts: 'Is this really what they want? Are they really so adamant?' 'If you do not believe me,' replies Bill, 'I'll show you, but don't ask for a quick settlement. I told you they are ready to strike and you will see more than you want!' What does the manager see? He does not see what Bill said. Through the office window he simply sees an assembled crowd gathered in the aisles. Maybe it is because of Bill's interpretation that he reads anger and determination on their faces.

For everything that follows, it is very important not to limit this notion of spokesperson and not to impose any clear distinction between 'things' and 'people' in advance. Bill, for instance, represents people who could talk, but who, in fact, cannot all talk at once. Davis represents neutrinos that cannot talk, in principle, but which are made to write, scribble and sign thanks to the device set up by Davis. So in practice, there is not much difference between people and things: they both need someone to talk for them. From the spokesperson's point of view there is thus no distinction to be made between representing people and representing things. In each case the spokesperson literally does the talking for who or what cannot talk. The Professor in the laboratory speaks for endorphin like Davis for the neutrinos and Bill for the shopfloor. In our definition the crucial element is not the quality of the represented but only their number and the unity of the representative. The point is that confronting a spokesperson is not like confronting any average man or woman. You are confronted not with Bill or the Professor, but with Bill and the Professor *plus* the many things or people on behalf of whom they are talking. You do not address Mr Anybody or Mr Nobody but Mr or Messrs Manybodies. As we saw in the chapter on literature, it may be easy to doubt one person's word. Doubting a spokesperson's word requires a much more strenuous effort however because it is now one person – the dissenter – against a crowd – the author.

On the other hand, the strength of a spokesperson is not so great since he or she is by definition *one* man or woman whose word could be dismissed – one Bill, one Professor, one Davis. The strength comes from the representatives' word when they do not talk by and for themselves but *in the presence of* what they represent. Then, and only then, the dissenter is confronted simultaneously with the spokespersons and what they speak for: the Professor and the endorphin made visible in the guinea pig assay; Bill and the assembled workers; Davis and his solar neutrinos. The solidity of what the representative says is directly supported

by the silent but eloquent presence of the represented. The result of such a set-up is that it seems as though the mouthpiece does not 'really talk', but that he or she is just commenting on what you yourself directly see, 'simply' providing you with the words you would have used anyway.

This situation, however, is the source of a major weakness. Who is speaking? The things or the people *through* the representative's voice? What does she (or he, or they, or it) say? Only what the things they represent would say if they could talk directly. But the point is that they cannot. So what the dissenter sees is, in practice, rather different from what the speaker says. Bill, for instance, says his workers want to strike, but this might be Bill's own desire or a union decision relayed by him. The manager looking through the window may see a crowd of assembled workers who are just passing the time and can be dispersed at the smallest threat. At any rate do they really want 3 per cent and not 4 per cent or 2 per cent? And even so, is it not possible to offer Bill this Japanese car he so dearly wants? Is the 'voice of the worker' not going to change his/its mind if the manager offers a new car to Bill? Take endorphin as another instance. What we really saw was a tiny depression in the regular spikes forming the base line. Is this the same as the one triggered by morphine? Yes it is, but what does that prove? It may be that all sorts of chemicals give the same shape in this peculiar assay. Or maybe the Professor so dearly wishes his substance to be morphine-like that he unwittingly confused two syringes and injected the same morphine twice, thus producing two shapes that indeed look identical.

What is happening? The controversy flares even after the spokesperson has spoken and displayed to the dissenter what he or she was talking about. How can the debate be stopped from proliferating again in all directions? How can all the strength that a spokesman musters be retrieved? The answer is easy: by letting the things and persons represented *say for themselves the same thing that the representatives claimed they wanted to say.* Of course, this never happens since they are designated because, by definition, such direct communication is impossible. Such a situation however may be convincingly staged.

Bill is not believed by the manager, so he leaves the office, climbs onto a podium, seizes a loudspeaker and asks the crowd, 'Do you want the 3 per cent rise?' A roaring 'Yes, our 3 per cent! Our 3 per cent!' deafens the manager's ears even through the window pane of his office. 'Hear them?' asks Bill with a modest but triumphant tone when they are sitting down again at the negotiating table. Since the workers themselves said exactly what the 'workers' voice' had said, the manager cannot dissociate Bill from those he represents and is really confronted with a crowd acting as one single man.

The same is true for the endorphin assay when the dissenter, losing his temper, accuses the Professor of fabricating facts. 'Do it yourself,' the Professor says, irritated but eager to play fair. 'Take the syringe and see for yourself what the assay reaction will be .' The visitor accepts the challenge, carefully checks the labels on the two vials and first injects morphine into the tiny glass chamber. Sure enough, a few seconds later the spikes start decreasing and after a minute or so

they return to the base line. With the vial labelled endorphin, the very same result is achieved with the same timing. A unanimous, incontrovertible answer is thus obtained by the dissenter himself. What the Professor said the endorphin assay will answer, if asked directly, is answered by the assay. The Professor cannot be dissociated from his claims. So the visitor has to go back to the 'negotiating table' confronted not with the Professor's own wishes but with a Professor simply transmitting what endorphin really is.

No matter how many resources the scientific paper might mobilise, they carry little weight compared with this rare demonstration of power: the author of the claim steps aside and the doubter sees, hears and touches the inscribed things or the assembled people that reveal to him or to her exactly the same claim as the author.

(3) Trials of strength

For us who are simply following scientists at work there is no exit from such a set-up, no back door through which to escape the incontrovertible evidence. We have already exhausted all sources of dissent; indeed we might have no energy left to maintain the mere idea that controversy might still be open. For us laymen, the file is now closed. Surely, the dissenter we have shadowed since the beginning of Chapter 1 will give up. If the things say the same as the scientist, who can deny the claim any longer? How can you go any further?

The dissenter goes on, however, with more tenacity than the laymen. The identical tenor of the representative's words and the answers provided by the represented were the result of a carefully staged situation. The instruments needed to be working and finely tuned, the questions to be asked at the right time and in the right format. What would happen, asks the dissenter, if we stayed longer than the show and went backstage; or were to alter any of the many elements which, everyone agrees, are necessary to make up the whole instrument? The unanimity between represented and constituency is like what an inspector sees of a hospital or of a prison camp when his inspection is announced in advance. What if he steps outside his itinerary and tests the solid ties that link the represented and their spokesmen?

The manager, for instance, heard the roaring applause that Bill received, but he later obtains the foremen's opinion: 'The men are not for the strike at all, they would settle for 2 per cent. It is a union order; they applauded Bill because that's the way to behave on the shopfloor, but distribute a few pay rises and lay off a few ringleaders and they will sing an altogether different song.' In place of the unanimous answer given by the assembled workers, the manager is now faced with an *aggregate* of possible answers. He is now aware that the answer he got earlier through Bill was extracted from a complex setting which was at first invisible. He also realises that there is room for action and that each worker may be made to behave differently if pressures other than Bill's are exerted on them.

The next time Bill screams 'You want the 3 per cent don't you?' only a few half-hearted calls of agreement will interrupt a deafening silence.

Let us take another example, this time from the history of science. At the turn of the century, Blondlot, a physicist from Nancy, in France, made a major discovery like that of X-rays.[3] Out of devotion to his city he called them 'N-rays'. For a few years, N-rays had all sorts of theoretical developments and many practical applications, curing diseases and putting Nancy on the map of international science. A dissenter from the United States, Robert W. Wood, did not believe Blondlot's papers even though they were published in reputable journals, and decided to visit the laboratory. For a time Wood was confronted with incontrovertible evidence in the laboratory at Nancy. Blondlot stepped aside and let the N-rays inscribe themselves straight onto a screen in front of Wood. This, however, was not enough to get rid of Wood who obstinately stayed in the lab asking for more experiments and himself manipulating the N-ray detector. At one point he even surreptitiously removed the aluminium prism which was generating the N-rays. To his surprise, Blondlot on the other side of the dimly lit room kept obtaining the same result on his screen even though what was deemed the most crucial element had been removed. The direct signatures made by the N-rays on the screen were thus made by something else. The unanimous support became a cacophony of dissent. By removing the prism, Wood severed the solid links that attached Blondlot to the N-rays. Wood's interpretation was that Blondlot so much wished to discover rays (at a time when almost every lab in Europe was christening new rays) that he unwittingly made up not only the N-rays, but also the instrument to inscribe them. Like the manager above, Wood realised that the coherent whole he was presented with was an aggregate of many elements that could be induced to go in many different directions. After Wood's action (and that of other dissenters) no one 'saw' N-rays any more but only smudges on photographic plates when Blondlot presented his N-rays. Instead of enquiring about the place of N-rays in physics, people started enquiring about the role of auto-suggestion in experimentation! The new fact had been turned into an artefact. Instead of going down the ladder of Figure 1.9, it went up the ladder and vanished from view.

The way out, for the dissenter, is not only to dissociate and disaggregate the many supporters the technical papers were able to muster. It is also to shake up the complicated set-up that provides graphs and traces in the author's laboratory in order to see how resistant the array is which has been mobilised in order to convince everyone. The work of disbelieving the literature has now been turned into the difficult job of manipulating the hardware. We have now reached another stage in the escalation between the author of a claim and the disbeliever, one that leads them further and further into the details of what makes up the inscriptions used in technical literature.

Let us continue the question-and-answer session staged above between the Professor and the dissenter. The visitor was asked to inject morphine and endorphin himself in order to check that there was no foul play. But the visitor is

now more devious and does not make any effort to be polite. He wants to check where the vial labelled endorphin comes from. The Professor, unruffled, shows him the protocol book with the same code number as on the vial, a code that corresponds to a purified sample of brain extract. But this is a text, another piece of literature, simply an account book that could have been either falsified or accidentally mislabelled.

By now, we have to imagine a dissenter boorish enough to behave like a police inspector suspecting everyone and believing no one and finally wanting to see the real endorphin with his own eyes. He then asks, 'Where do I go from this label in the book to where the contents of the vial comes from?' Exasperated, the author leads him towards another part of the laboratory and into a small room occupied by glass columns of various sizes, filled with a white substance, through which a liquid is slowly percolating. Underneath the columns, a small piece of apparatus moves a rack of tiny flasks in which the percolated liquid is collected every few minutes. The continous flow at the top of the columns is collected, at the bottom, into a discrete set of flasks, each of which contains the part of the liquid that took the same given amount of time to travel through the column.

(4)–Here it is, says the guide, here is your endorphin.

–Are you kidding, replies the dissenter, where is endorphin? I don't see a thing?

–Hypothalamic brain extract is deposited on the top of the Sephadex column. It is a soup. Depending on what we fill it with, the column disassociates the mixture, sieves it; it may be done by gravity, or electrical charge, anything. At the end you get racks that collect samples which have behaved similarly in the column. This is called a fraction collector. Each fraction is then checked for purity. *Your* vial of endorphin came from *this* rack two days ago, no. 23/16/456.

–And this is what you call pure? How do I know it is pure? Maybe there are hundreds of brain extracts that travel through the column at the same pace exactly and end up in the same fraction.

The pressure is mounting. Everyone in the lab is expecting an outburst of rage, but the Professor politely leads the visitor towards another part of the laboratory.

(5)–Here is our new High Pressure Liquid Chromatograph (HPLC). See these tiny columns? They are like the ones you just saw, but each fraction collected there is submitted to an enormous pressure here. The column delays the passage and at this pressure it strongly differentiates the molecules. The ones that arrive at the same time at the end are *the same* molecules, the same, my dear colleague. Each fraction is read through an optical device that measures its optical spectrum. Here is the chart that you get . . .. See? Now, when you get a single peak it means the material is pure, so pure that a substance with only one different amino-acid in a hundred will give you *another* peak. Is not that quite convincing?

–(silence from the dissenter)

–Oh, I know! Maybe you are uncertain that I did the experiment with *your* vial of endorphin? Look here in the HPLC book. Same code, same time. Maybe you claim that I asked this gentleman here to fake the books, and obtain this peak for me with another substance? Or maybe you doubt the measurement of optical spectra. Maybe

you think it is an obsolete piece of physics. No such luck, my dear colleague, Newton described this phenomenon quite accurately – but maybe he's not good enough for you.

The Professor's voice is quivering with hardly suppressed rage but he still behaves. Of course the dissenter could start doubting the HPLC or the fraction collector as he did with the guinea pig ileum assay, converting them from black boxes into a field of contention. He *could* in principle, but he *cannot* in practice since time is running out and he is sensitive to the exasperation in everyone's voice. And who is he anyway to mount a dispute against Water Associates, the company who devised this HPLC prototype? Is he ready to cast doubt on a result that has been accepted unquestioningly for the past 300 years, one that has been embedded in thousands of contemporary instruments? What he wants is to see endorphin. The rest, he must face it, cannot be disputed. He has to compromise and to admit that the Sephadex column, and the HPLC, are indisputable. In a conciliatory tone he says:

(6)–This is very impressive; however I must confess a slight disappointment. What I see here is a peak which, I admit, means that the brain extract is now pure. But how do I know that this pure substance is endorphin?

With a sigh, the visitor is led back to the assay room where the little guinea pig gut is still regularly contracting.

(7)–Each of the fractions deemed pure by the HPLC is tried out here, in this assay. Of all the pure fractions only two display any activity, I repeat only two. When the whole process is repeated in order to get purer material, this activity dramatically increases. The shape may be exactly superimposed onto that of commercially available morphine. Is that insignificant? We did it thirty-two times! Is that nothing? Each modification of the spikes has been tested for statistical significance. Only endorphin and morphine have any significant effect. Does all of that count for nothing? If you are so clever, can you give me an alternative explanation why morphine and this pure substance X would behave identically? Can you even imagine another explanation?

–No, I must admit, whispers the believer, I am very impressed. This really looks like genuine endorphin. Thank you so much for the visit. Don't trouble yourselves, I will find my own way out . . .. (exit the dissenter)

This exit is not the same as that of the semiotic character of Chapter 1, p.53. This time it is for good. The dissenter tried to disassociate the Professor from his endorphin, and he failed. Why did he fail? Because the endorphin constructed in the Professor's lab *resisted* all his efforts at modification. Every time the visitor followed a lead he reached a point where he had either to quit or start a new controversy about a still older and more generally accepted fact. The Professor's claim was tied to the brain, to the HPLC, to the guinea pig ileum assay. There is something in his claim that is connected to classic claims in physiology, pharmacology, peptide chemistry, optics, etc. This means that when the doubter tries out the connections, all these other facts, sciences and black boxes come to

the Professor's rescue. The dissenter, if he doubts endorphin, has also to doubt Sephadex columns, HPLC technics, gut physiology, the Professor's honesty, that of his whole lab, etc. Although 'enough is never enough' – see the introduction – there is a point where no matter how pig-headed the dissenter could be, enough is enough. The dissenter would need so much more time, so many more allies and resources to continue to dissent that he has to quit, accepting the Professor's claim as an established fact.

Wood, who did not believe in N-rays, also tried to shake the connection between Blondlot and his rays. Unlike the former dissenter he succeeded. To dislocate the black boxes assembled by Blondlot, Wood did not have to confront the whole of physics, only the whole of one laboratory. The manager who suspected the workers' determination tried out the connections between them and their union boss. These connections did not resist a few classic clever tricks for long. In the three cases the dissenters imposed a showdown running from the claim to what supports the claim. When imposing such a **trial of strength** they are faced with spokespersons and what (or whom) these persons speak for. In some cases the dissenters isolate the representative from his or her 'constituency', so to speak; in other cases such a separation is impossible to obtain. It cannot be obtained without a trial of strength, any more than a boxer can claim to be a world champion without convincingly defeating the previous world champion. When the dissenter succeeds, the spokesperson is transformed from someone who speaks for others into someone who speaks for him or herself, who represents only him or herself, his or her wishes and fancies. When the dissenter fails, the spokesperson is seen not really as an individual but as the mouthpiece of many other mute phenomena. Depending on the trials of strength, spokespersons are turned into **subjective** individuals or into **objective** representatives. Being objective means that no matter how great the efforts of the disbelievers to sever the links between you and what you speak for, the links resist. Being subjective means that when you talk *in the name* of people or things, the listeners understand that you represent only yourself. From Mr Manybodies you are back to being Mr. Anybody.

It is crucial to grasp that these two adjectives ('objective', 'subjective') are *relative* to trials of strength in specific settings. They cannot be used to qualify a spokesperson or the things he or she is talking about once and for all. As we saw in Chapter 1, each dissenter tries to transform a statement from objective to subjective status, to transform, for instance, an interest in N-rays inside physics into an interest in self-suggestion in provincial laboratories. In the endorphin example, the dissenter seemed to be trying very hard to convert the Professor's claim into a subjective flight of fancy. In the end it was the lonely dissenter who saw his naive questioning turned into a trivial flight of fancy, if not an obsessive drive to seek fraud and find fault everywhere. In the trial of strength the Professor's endorphin was made *more objective* – going down the ladder – and the dissenter's counter-claim was made *more subjective* – pushed up the ladder. 'Objectivity' and 'subjectivity' are relative to trials of strength and they can shift

gradually, moving from one to the other, much like the balance of power between two armies. A dissenter accused by the author of being subjective must now wage another struggle if he or she wishes to go on dissenting without being isolated, ridiculed and abandoned.

Part B
Building up counter-laboratories

Let me summarise our trip from the discussion at the beginning of Chapter 1 up to this point. What is behind the claims? Texts. And behind the texts? More texts, becoming more and more technical because they bring in more and more papers. Behind these articles? Graphs, inscriptions, labels, tables, maps, arrayed in tiers. Behind these inscriptions? Instruments, whatever their shape, age and cost that end up scribbling, registering and jotting down various traces. Behind the instruments? Mouthpieces of all sorts and manners commenting on the graphs and 'simply' saying what they mean. Behind them? Arrays of instruments. Behind those? Trials of strength to evaluate the resistance of the ties that link the representatives to what they speak for. It is not only words that are now lined up to confront the dissenter, not only graphs to support the words and references to support the whole assembly of allies, not only instruments to generate endless numbers of newer and clearer inscriptions, but, behind the instruments, new objects are lined up which are defined by their resistance to trials. Dissenters have now done all they can do to disbelieve, disaggregate and disassociate what is mustered behind the claim. They have come a long way since barging into the first discussion at the beginning of Chapter 1. They became readers of technical literature, then visitors to the few laboratories from which the papers were coming, then impolite inspectors manipulating the instruments to check how faithful they were to the author.

At this point they have to take another step – either give up, or find other resources to overcome the author's claim. In the second part of this book we will see that there exist many ways to reject the laboratory results (Chapter 4); but for this chapter we will concentrate on the rarest outcome, when, all else being equal, there is no other way open to the dissenters than to *building another laboratory.* The price of dissent increases dramatically and the number of people able to continue decreases accordingly. This price is entirely determined by the authors whose claims one wishes to dispute. The dissenters cannot do less than the authors. They have to gather more forces in order to untie what attaches the spokesmen and their claims. This is why all laboratorries are *counter-laboratories* just as all technical articles are counter-articles. So the dissenters do not simply have to get a laboratorry; they have to get a *better* laboratory. This makes the price still higher and the conditions to be met still more unusual.

(1) Borrowing more black boxes

How is it possible to obtain a better laboratory, that is a laboratory producing less disputable claims and allowing the dissenter – now head of a lab – to disagree and be believed? Remember what happened to the visitor to the Professor's laboratory. Every time a new flaw appeared which the disbeliever tried to exploit, the Professor presented him with a new and seemingly incontrovertible black box: a Sephadex column, an HPLC machine, basic physics, or classic physiology, etc. It might have been possible to dispute each of these, but it was not practical because the same energy would have been needed to reopen each of these black boxes. Indeed, *more* energy would have been applied because each of these facts in turn would have led to more tightly sealed black boxes: the microprocessors treating the data from the HPLC, the fabrication of the gel in the columns, the raising of guinea pigs in the animal quarters, the production of morphine at an Ely-Lily factory, etc. Each fact could be made the departure point of a new controversy that would have led to many more accepted facts, and so on *ad infinitum*.

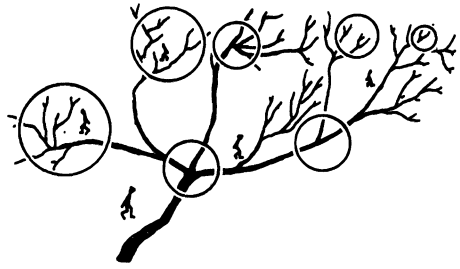

Figure 2.4

The dissenter was thus confronted by an exponential curve, a slope similar to the one drawn in Figure 1.8. Now that he has become the head of a brand new laboratory, one of the ways to make it a better counter-lab is to discover ways either of levelling the slope or of confronting his opponents with an even steeper one.

For instance Schally, in order to back up his ill-fated GHRH, see Chapter 1, statement (5) – used a bioassay called the rat tibia cartilage assay. Guillemin, who disagreed with GHRH, started to try out the tibia assay in exactly the way our dissenter tried out his guinea pig ileum assay.[4] In the face of this challenge, Schally's tibia assay was made to say quite different things by Guillemin. The growth of tibia cartilage in the rat might be caused by a growth hormone substance but might just *as well* have been caused by a variety of other chemicals, or

indeed not have occurred at all. In several harsh papers, Guillemin said the 'results were so erratic that Schally's claims should be taken with the most extreme precaution'. Thus Schally was cut off from his supply line. He claimed the existence of GHRH, but nothing followed. Isolated, his claim was made more subjective by the dissenter's action.

Why should anyone believe Guillemin's counter-claim rather than Schally's claim? One obvious way to strengthen this belief is to modify the bioassay to make it impossible for anyone to make it say different things from Guillemin. Guillemin discarded the rat tibia assay and shifted to a rat pituitary cell culture. Instead of seeing the growth of cartilage with the naked eye, what is 'seen' is the amount of hormone released by the few pituitary cells maintained in a culture; this amount is measured by an instrument – in the sense I gave this term earlier – called radio-immunoassay. The new assay is much *more* complicated than Schally's older ones – in itself the radio-immunoassay requires several technicians and takes up to a week to complete – but it gives inscriptions at the end that may be said to be more clear-cut, that is they literally cut shapes out of the background. In other words, even without understanding a word of the issue, the perceptive judgment to be made on one is easier than on the other.

The answers are less equivocal than the 'erratic' ones given by the tibia assay – that is, they leave less room for the dissenter to quibble – and the whole instrument is *less* easily disputable. Although it is complicated, the cell culture assay can be taken as *a single black box* which provides a single window from which to read the amount of GHRH. Naturally, it can be disputed in principle. It is just that it's harder to do so in practice. A physiologist with a little training may nitpick at the cartilage assay, may quibble about the length from growth in the tibia. He or she needs much more than a little training to dispute Guillemin's new figures. The assay is now tied to basic advances in molecular biology, immunology and the physics of radioactivity. Nitpicking at the inscriptions is possible but less reasonable, the heckler needing more resources and becoming more isolated. The gain in conviction is clear: from Schally's first words a fierce dispute ensues about the assay which is supposed to reveal the very existence of GHRH. In Guillemin's counter-paper this part of the discussion *at least* has been sealed off since his detection system is made indisputable, and the range of possible disputes has *shifted to other* aspects of the same claims.

Another example is provided by the controversy about the detection of gravitational waves.[5] One physicist, Weber, built a massive antenna made of a large aluminium alloy bar weighing several tons that vibrated at a certain frequency. To detect a gravitational wave the antenna must be insulated from all other influences – ideally it should be in a vacuum, free from seismic vibrations and radio interference, at a temperature at or near absolute zero, etc. Taken as an instrument, the whole set-up provides a window which allows one to read the presence of gravitational waves. The problem is that the peaks above the noise threshold are so tiny that any passing physicist could dispute Weber's claim. Indeed, any passing physicist could set the instrument off! Weber argues that

they represent gravitation but every dissenter may claim that they represent many other things *as well.* This little expression 'as well' is what kills most solid claims. As long as it is possible to say 'as well', there is no established line from the gravitation waves to Weber via the antenna. The figure offered by Weber may represent either 'gravitational waves' or meaningless scribbles registering terrestrial noise. To be sure, there are many ways out of the controversy so as to shrug off Weber's claim as a mere opinion. But the way out of the controversy that interests us here is to build *another* antenna, one, for instance, that is a thousand million times more sensitive than Weber's so that this part of the detection at least is not disputed. The aim of this new antenna is to confront the sceptic with an incontrovertible black box *earlier* in the process. After this, sceptics may still discuss the amount of gravitation, and what it does to the relativity theory or to astrophysics, but they will not argue that there are peaks that cannot be explained by terrestrial interferences. With the first antenna alone, Weber might be the freak and the dissenters the sensible professionals. With the new antenna, those who deny the presence of the peaks are the isolated sceptics and it is Weber who is the sensible professional. All other things being equal the balance of power would have been tipped. (In this case, however, it did not make the slightest difference because many other avenues for dissent were opened.)

Borrowing more black boxes and situating them earlier in the process is the first obvious strategy for building a better counter-laboratory. The discussion is diffracted and shunted away. Any one laboratory gets an edge on all the others if it finds a way to delay the possible discussions until later. In the early days of microbe cultures, for example, the microbes were grown in a liquid like urine. They were visible in the flasks but you needed keen and trained eyesight to detect them. Dissent could ensue because the construction of the fact was interrupted from the start by a preliminary discussion on whether or not microbes were present in the flask. When Koch invented the solid milieu culture, acute eyesight was no longer needed to see the little microbes: they made nice little coloured patches which contrasted clearly with the white background. The visibility was dramatically enhanced when specific dyes coloured certain microbes or their parts. The laboratory endowed with these techniques made dissent more difficult: a slope was deepened, a trench was dug. Although many other aspects were still open to dispute, the presence of the microbes was made indisputable.

At this point, it is easy to imagine the growing differences between good and bad (counter-) laboratories. Imagine a lab that starts making claims based on the cartilage tibia assay, Weber's first antenna and the liquid microbe culture. If the head of this laboratory wanted to be believed he would have an endless task. Every time he opened his mouth, any number of his dear colleagues would start shaking their heads, and suggesting many alternatives just as plausible as the first. To do so, they would only need a bit of imagination. Like Achilles in Zeno's paradox, the challenger will never reach the end of his argument since each point will be the start of an indefinite regression. In contrast, claims produced by the good laboratory cannot be opposed simply with a bit of imagination. The cost of

disputing the claims increases proportionally with the number of black boxes assembled by the author. Faced with the pituitary culture assay, the new antenna which is one thousand million times more sensitive and the solid milieu culture, the dissenters are forced to assent or, at least, *to redirect* their dissent toward some other aspect of the claims. They can still mount a controversy but the magnitude of the mobilisation needed to do so has increased. They need an even better equipped laboratory with more and more black boxes, thus delaying the dispute still further. The vicious (or virtuous) circle of lab construction is now launched and there is no way to stop it – apart from giving up the production of credible arguments altogether, or recruiting more powerful allies elsewhere.

(2) Making actors betray their representatives

The competition between scientists – whom I will treat in this section as alternately authors and dissenters – to turn one another's claims into subjective opinion leads to expensive laboratories equipped with more and more black boxes introduced as early as possible into the discussion. This game, however, would soon stop if only existing black boxes were mobilised. After a time dissenters and authors – all things remaining equal – would have access to the *same* equipment, would tie their claims to the same harder, colder and older facts and none would be able to get an edge on the other: their claims would be thus left in limbo, in intermediary stages between fact and artefact, objectivity and subjectivity. The only way to break this stalemate is to find either new and unexpected resources (see the next section) or, more simply, to force the opponent's allies to *change camp.*

This would happen, for instance, if the manager of our little vignette above could organise a secret ballot to decide about the continuation of the strike. Remember that Bill, the shop steward, claimed that 'all the workers want a 3 per cent pay rise'. This claim was confirmed at meetings during which the represented said the same things as their mouthpiece. Even if the manager suspects that the workers are not so unanimous, each public meeting loudly confirms Bill's claim. However, in organising a secret ballot, the manager tests the same actors in a different way, by exerting a new set of pressures on them: isolation, secrecy, recounting of the ballots, surveillance. Submitted to these new trials, only 9 per cent of the same workers voted for the continuation of the strike, and 80 per cent were ready to settle for 2 per cent. The represented have changed camp. They now say what the manager said they would say. They have a new spokesperson. This, naturally, does not stop the controversy, but the dispute will now bear on the election process itself. Bill and his union accuse the manager of intimidation, unfair pressure, of having stuffed the ballot boxes and so on. This shows that even the most faithful supporters of a spokesman may be made to *betray.*

As I showed above, both people able to talk and things unable to talk have

spokesmen (Part A, section 2). I propose to call whoever and whatever is represented **actant.** What the manager did to Bill, a dissenter may do for the ally of his opponent's laboratory. Pouchet, engaged in a bitter struggle against Louis Pasteur's claim that there is no spontaneous generation, built a nice counter-experiment.[6] Pasteur argued that it is always germs introduced from the outside that generate micro-organisms. Long swan-necked open glass flasks containing sterilised infusion were contaminated at low altitude but stayed sterile in the High Alps. This impressive series of demonstrations established an incontrovertible link between a new actor, the micro-organisms, and what Pasteur said they could do: microbes could not come from *within* the infusion but only from *outside.* Pouchet, who rejected Pasteur's conclusion, tried out the connection and forced the micro-organisms to emerge from within. Repeating Pasteur's experiment Pouchet showed that glass flasks containing a sterile hay infusion were very soon swarming with micro-organisms even in the 'germ-free' air of the Pyrenees Mountains. The micro-organisms on which Pasteur depended were made to betray him: they appeared spontaneously thus supporting Pouchet's position. In this case, the actants change camps and two spokesmen are supported at once. This change of camp does not stop the controversy, because it is possible to accuse Pouchet of having unknowingly introduced micro-organisms from outside even though he sterilised everything. The meaning of 'sterile' becomes ambiguous and has to be renegotiated. Pasteur, now in the role of dissenter, showed that the mercury used by Pouchet was contaminated. As a result Pouchet was cut off from his supply lines, betrayed by his spontaneous micro-organisms, and Pasteur becomes the triumphant spokesman, aligning 'his' micro-organisms which act on command. Pouchet failed in his dissent and ended up isolated, his 'spontaneous generation' reduced by Pasteur to a *subjective* idea, to be explained not by the behaviour of microbes but by the influence of 'ideology' and 'religion'.[7]

The same luring of allies away from their spokesperson occurred among the Samoans. As mobilised in the 1930s by Margaret Mead to act on North American ideals of education and sexual behaviour, Samoan girls were more liberated than Western ones and free from the crises of adolescence.[8] This well-established fact was attributed not to Mead – acting as the anthropologist mouthpiece of the Samoans – but to the Samoans. Recently another anthropologist, Derek Freeman, attacked Mead, severing all links between the Samoan girls and Margaret Mead. She was turned into an isolated liberal American lady without any serious contact with Samoa and writing a 'noble savage' fiction off the top of her head. Freeman, the new spokesman of the Samoans, said the girls there were sexually repressed, assaulted and often raped and that they went through a terrible adolescence. Naturally, this 'kidnapping', so to speak, of Samoan teenagers by a new representative does not bring the controversy to an end any more than in our other examples. The question is now to decide if Freeman is a boorish and insensitive male influenced by sociobiology, and if he has more Samoan allies on his side than Margaret Mead, a highly thought of female

anthropologist, sensitive to all the subtle cues of her Samoan informants. The point for us is that the most sudden reversal in the trials of strength between authors and dissenters may be obtained simply by cutting the links tying them to their supporters.

A subtler strategy than Freeman's to cut these links was employed by Karl Pearson in his dispute with George Yule's statistics.[9] Yule had devised a coefficient to measure the strength of an association between two *discrete* variables. This crude but robust coefficient allowed him to decide whether or not there was an association between, for instance, vaccination and the death rate. Yule was not interested in defining links more precisely. All he wanted to be able to determine was whether vaccination decreased the death rate. Pearson, on the other hand, objected to Yule's coefficient because when you wanted to decide *how close* the links were, it offered a wide range of possible solutions. With Yule's coefficient you would never know, in Pearson's opinion, if you had your data all safely arrayed behind your claims. Yule did not bother because he was treating only discrete entities. Pearson, however, had a much more ambitious project and wanted to be able to mobilise a large number of *continuous* variables such as height, colour of skin, intelligence . . . With Yule's coefficient he would have been able to define only weak associations between genetic variables. This meant that any dissenter could easily have severed him from his data and turned one of the most impressive arrays on genetic determinism ever compiled into a mixed and disorderly crowd of unclear relations. Pearson devised a correlation coefficient which made any discrete variable the outcome of a continuous distribution. Yule was left with only weak associations and Pearson, tying his data together with his 'tetrachoric coefficient of correlation', could transform any continuous variable into a strongly associated whole of discrete variables and so *solidly* attach intelligence to heredity. This of course did not mark the end of the controversy. Yule tried out the Pearson coefficient showing that it arbitrarily transformed continuous variables into discrete ones. If successful, Yule would have deprived Pearson of the support of his data. Although this controversy has been continuing for nearly a hundred years, the lesson for us is that, with the same equipment and data, the stalemate between dissenting authors may be broken by a simple modification of what it is that ties the data together (we shall see more of this phenomenon in Chapter 6).

In each of the examples above I showed how allies were enticed away from their representative in order to tip the balance, but I also indicated that this need not settle the debate. Often it modifies the field of contention enough to buy time – not enough to win. This strategy must in general be combined with that of section 1 in order to succeed – borrowing more black boxes and positioning them earlier in the process – and with that of the third section, which is the most daring and the most difficult to grasp for the visiting layperson.

(3) Shaping up new allies

The dissenter, now the head of a (counter-) laboratory, has imported as many black-boxed instruments as possible and has tried to entice his opponent's supporters away. Even combining these two strategies he or she will not fare very well since all scientists are playing with a *limited set* of instruments and actants. After a few moves the controversy will reach a new stalemate with the supporters continually changing camp: for and against the manager, for and against Pasteur, for and against Margaret Mead, for and against Pearson, with no end in sight. No credible fact will be produced in such confusion since no third party will be able to borrow any statement as a black box to put it to use elsewhere. In order to break the stalemate, other allies which are *not yet* defined have to be brought in.

Let me go back to the example of GHRH discovered by Schally using his rat tibia cartilage assay. We saw how Guillemin, rejecting this 'discovery' – now in quotation marks – devised a new, less controvertible assay, the pituitary cell culture (Chapter 1, section 2). With it, he induced the GHRH supporting Schally's claim to shift alliances. Remember that when Schally thought he had found a new important hormone, Guillemin intervened and showed that this 'new important hormone' was a contaminant, a piece of haemoglobin. By following the two strategies we have just defined, Guillemin won but only *negatively*. Although he overcame his competitor, his own claims about GHRH – which he calls GRF – are not made more credible. For a third party the whole topic is simply a mess from which no credible fact emerges. In the search for the final *coup de grâce,* the dissenter needs something more, a supplement, a little 'je ne sais quoi' that, everything being equal, will ensure victory and convince the third party that the controversy has indeed been settled.

In the (counter-) laboratory the purified extracts of GRF are injected into the cell culture. The result is appalling: nothing happens. Worse than nothing, because the results are negative: instead of being triggered by GRF the growth hormone is decreased. Guillemin gives his collaborator, Paul Brazeau, who has done the experiment, a good dressing down.[10] The whole instrument, supposed to be a perfect black box, is called into doubt, and the whole career of Brazeau, supposed to be a skilled and honest worker, is jeopardised. The dissenter/author struggle has now shifted inside the laboratory and they are both trying out the assay, the purification scheme and the radio-immunoassay exactly as the visitor did above for endorphin (In Part A, section 3). At the third trial Brazeau still obtained the same result. That is, no matter how much effort he was making, the same negative results were produced. No matter how strongly Guillemin attacked him, he was led every time to the same sort of quandary with which I finished Part A: either to quit the game or to start discussing so many basic, old and accepted black boxes that the whole lab would have to be dismantled. Since the negative results resisted all trials of strength, since the cell culture assay was left indisputable, and since Brazeau's honesty and skill were withstanding the shock, some other weak point had to give way. The hormone they were looking for

released growth hormone; in their hands it *decreased* growth hormone. Since they could no longer doubt that their 'hands' were good, they had to doubt the first definition or quit the game altogether: they had got their hands on a hormone that *decreased* the production of growth hormone. They had, in other words, tried out a *new* hormone, a new, unexpected and still undefined ally to support another claim. Within a few months they had obtained a decisive advantage over Schally. Not only had he confused GHRH with a piece of haemoglobin, but he had sought the wrong substance all along.

We have reached a point which is one of the most delicate of this book, because, by following dissenting scientists, we have access to their most decisive arguments, to their ultimate source of strength. Behind the texts, they have mobilised inscriptions, and sometimes huge and costly instruments to obtain these inscriptions. But something else resists the trials of strength behind the instruments, something that I will call provisionally a **new object**. To understand what this is, we should stick more carefully than ever to our method of following only scientists' practice, deaf to every other opinion, to tradition, to philosophers, and even to what scientists say about what they do (see why in the last part of this chapter).

What is a new object in the hands of a scientist? Consider the GRF that Guillemin and Brazeau were expecting to find: it was defined by its effect on tibia cartilage assay and in cell cultures. The effect was uncertain in the first assay, certain and negative in the second. The definition had to change. The new object, at the time of its inception, is still undefined. More exactly, it is defined by what it does in the laboratory trials, *nothing more, nothing less*: its tendency to decrease the release of growth hormone in the pituitary cells culture. The etymology of 'definition' will help us here since defining something means providing it with limits or edges (*finis*), giving it a shape. GRF had a shape; this shape was formed by the answers it gave to a series of trials inscribed on the window of an instrument. When the answers changed and could not be ignored a new shape was provided, a new thing emerged, a something, still unnamed, that did exactly the opposite of GRF. Observe that in the laboratory, the new object is *named after what it does*: 'something that inhibits the release of growth hormone'. Guillemin then invents a new word that summarises the actions defining the thing. He calls it 'somatostatin' – that which blocks the body (implying body growth).

Now that somatostatin is named and accepted, its properties have changed and are not of interest to us at this point. What counts for us is to understand the new object just at the moment of its emergence. Inside the laboratory the new object is *a list of written answers to trials*. Everyone today talks for instance of 'enzymes' which are well-known objects. When the strange things later called 'enzymes' were emerging among competing laboratories, scientists spoke of them in very different terms:[11]

> (8) From the liquid produced by macerating malt, Payen and Persoz are learning to extract, through the action of alcohol, a solid, white, amorphous, neutral, more or

> less tasteless substance that is insoluble in alcohol, soluble in water and weak alcohol, and which cannot be precipitated by sub-lead acetate. Warmed from 65° to 75° with starch in the presence of water, it separates off a soluble substance, which is dextrin.

At the time of its emergence, you cannot do better than explain what the new object is by repeating the list of its constitutive actions: 'with A it does this, with C it does that.' It has *no other shape than this list.* The proof is that if you add an item to the list you *redefine the object*, that is, you give it a new shape. 'Somatostatin' for instance was defined by the now well-established fact that, coming from the hypothalamus, it inhibited the release of growth hormone. The discovery I summarised above was described in this way for a few months after its construction. When another laboratory added that somatostatin was also found in the pancreas and inhibited not only growth hormone but also glucagon and insulin production, the definition of somatostatin had to be changed, in the same way as the definition of GRF had to be altered when Brazeau failed to get positive results in his assay. The new object is completeley defined by the list of answers in laboratory trials. To repeat this essential point in a lighter way, the new object is always called after a name of actions summarising the trials it withstood like the old Red Indian appellations 'Bear Killer' or 'Dread Nothing' or 'Stronger than a Bison'!

In the strategies we have analysed so far, the spokesperson and the actants he or she represented were already present, arrayed and well drilled. In this new strategy the representatives are looking for actants they do not know and the only thing they can say is to list the answers the actants make under trials.

Pierre and Marie Curie originally had no name for the 'substance x' they tried out. In the laboratory of the Ecole de Chimie the only way to shape this new object is to multiply the trials it undergoes, to attack it by all sorts of terrible ordeals (acids, heat, cold, presure).[12] Will something resist all these trials and tribulations? If so, then here it is, the new object. At the end of their long list of 'sufferings' undergone by the new substance (and also by the unfortunate Curies attacked by the deadly rays so carelessly handled) the authors propose a new name – 'polonium'. Today polonium is one of the radioactive elements; at the time of its inception it was the long list of trials successfully withstood in the Curies' laboratory:

> (9) Pierre and Marie Curie: –Here is the new substance emerging from this mixture, pitchblende, see? It makes the air become conductive. You can even measure its activity with the instrument that Pierre devised, a quartz electrometer, right here. This is how we follow our hero's fate through all his ordeals and tribulations.
>
> Scientific Objector: This is far from new, uranium and thorium are also active.
>
> –Yes, but when you attack the mixture with acids, you get a liquor. Then, when you treat this liquor with sulphurated hydrogen, uranium and thorium stay with the liquor, while our young hero is precipitated as a sulphuride.
>
> – What does that prove? Lead, bismuth copper, arsenic and antimony all pass this

trial as well, they too are precipitated!

–But if you try to make all of them soluble in ammonium sulphate, the active something resists . . .

– Okay, I admit it is not arsenic, nor antimony, but it might be one of the well-known heroes of the past, lead, copper or bismuth.

–Impossible, dear, since lead is precipitated by sulphuric acid while the substance stays in solution; as for copper, ammoniac precipitates it.

–So what? This means that your so-called 'active substance' is simply bismuth. It adds a property to good old bismuth, that of activity. It does not define a new substance.

–It does not? Well, tell us what will make you accept that there is a substance?

– Simply show me one trial in which bismuth reacts differently from your 'hero'.

– Try heating it in a Boheme tube, under vacuum, at 700° centigrade. And what happens? Bismuth stays in the hottest area of the tube, while a strange black soot gathers in the cooler areas. This is more active than the material with which we started. And you know what? If you do this several times, the 'something' that you confuse with bismuth ends up being four hundred times more active than uranium!

–. . ..

–Ah, you remain silent . . .. We therefore believe that the substance we have extracted from pitchblende is a hitherto unknown metal. If the existence of this new metal is confirmed we propose to name it polonium after Marie's native country.

What are these famous things which are said to be behind the texts made of? They are made of a list of victories: it defeated uranium and thorium at the sulphurated hydrogen game; it defeated antimony and arsenic at the ammonium sulphur game; and then it forced lead and copper to throw in the sponge, only bismuth went all the way to the semi-final, but it too got beaten down during the final game of heat and cold! At the beginning of its definition the 'thing' is a *score list* for a series of trials. Some of these trials are imposed on it either by the scientific objector and tradition – for instance to define what is a metal – or tailored by the authors – like the trial by heat. The 'things' behind the scientific texts are thus similar to the heroes of the stories we saw at the end of Chapter 1: they are all defined by their **performances**. Some in fairy tales defeat the ugliest seven-headed dragons or against all odds they save the king's daughter; other inside laboratories resist precipitation or they triumph over bismuth . . .. At first, there is no other way to know the essence of the hero. This does not last long however, because each performance presupposes a **competence**[13] which retrospectively explains why the hero withstood all the ordeals. The hero is no longer a score list of actions; he, she or it is an essence slowly unveiled through each of his, her or its manifestations.

It is clear by now to the reader why I introduced the word 'actant' earlier to describe what the spokesperson represents. Behind the texts, behind the instruments, inside the laboratory, we do not have Nature – not yet, the reader will have to wait for the next part. What we have is an array allowing new extreme constraints to be imposed on 'something'. This 'something' is progressively shaped by its re-actions to these conditions. This is what is behind all the

arguments we have analysed so far. What was the endorphin tried out by the dissenter in Part A, section 3? The superimposition of the traces obtained by: a sacrificed guinea pig whose gut was then hooked up to electric wires and regularly stimulated; a hypothalamus soup extracted after many trials from slaughtered sheep and then forced through HPLC columns under a very high pressure.

Endorphin, before being named and for as long as it is a new object, *is* this list *readable* on the instruments *in* the Professor's laboratory. So is a microbe long before being called such. At first it is something that transforms sugar into alcohol in Pasteur's lab. This something is narrowed down by the multiplication of feats it is asked to do. Fermentation still occurs in the absence of air but stops when air is reintroduced. This exploit defines a new hero that is killed by air but breaks down sugar in its absence, a hero that will be called, like the Indians above, 'Anaerobic' or 'Survivor in the Absence of Air'. Laboratories generate so many new objects because they are able to create extreme conditions and because each of these actions is obsessively inscribed.

This naming after what the new object does is in no way limited to actants like hormones or radioactive substances, that is to the laboratories of what are often called 'experimental sciences'. Mathematics also defines its subjects by what they *do*. When Cantor, the German mathematician, gave a shape to his transfinite numbers, the shape of his new objects was obtained by having them undergo the simplest and most radical trial:[14] is it possible to establish a one-to-one connection between, for instance, the set of points comprising a unit square and the set of real numbers between 0 and 1? It seems absurd at first since it would mean that there are as many numbers on one side of a square as in the whole square. The trial is devised so as to see if two different numbers in the square have different images on the side or not (thus forming a one-to-one correspondence) or if they have only one image (thus forming a two-to-one correspondence). The written answer on the white sheet of paper is incredible: 'I see it but I don't believe it,' wrote Cantor to Dedekind. There are as many numbers on the side as in the square. Cantor creates his transfinites from their performance in these extreme, scarcely conceivable conditions.

The act of defining a new object by the answers it inscribes on the window of an instrument provides scientists and engineers with their final source of strength. It constitutes our **second basic principle**, as important as the first in order to understand science in the making: scientists and engineers speak in the name of new allies that they have shaped and enrolled; representatives among other representatives, they add these unexpected resources to tip the balance of force in their favour. Guillemin now speaks for endorphin and somatostatin, Pasteur for visible microbes, the Curies for polonium, Payen and Persoz for enzymes, Cantor for transfinites. When they are challenged, they cannot be isolated, but on the contrary their constituency stands behind them arrayed in tiers and ready to say the same thing.

(4) Laboratories against laboratories

Our good friend, the dissenter, has now come a long way. He or she is no longer the shy listener to a technical lecture, the timid onlooker of a scientific experiment, the polite contradictor. He or she is now the head of a powerful laboratory utilising all available instruments, forcing the phenomena supporting the competitors to support him or her instead, and shaping all sorts of unexpected objects by imposing harsher and longer trials. The power of this laboratory is measured by the extreme conditions it is able to create: huge accelerators of millions of electron volts; temperatures approaching absolute zero; arrays of radio-telescopes spanning kilometres; furnaces heating up to thousands of degrees; pressures exerted at thousands of atmospheres; animal quarters with thousands of rats or guinea pigs; gigantic number crunchers able to do thousands of operations per millisecond. Each modification of these conditions allows the dissenter to mobilise one more actant. A change from micro to phentogram, from million to billion electron volts; lenses going from metres to tens of metres; tests going from hundreds to thousands of animals; and the shape of a new actant is thus redefined. All else being equal, the power of the laboratory is thus proportionate to the number of actants it can mobilise on its behalf. At this point, statements are not borrowed, transformed or disputed by empty-handed laypeople, but by scientists with whole laboratories *behind* them.

However, to gain the final edge on the opposing laboratory, the dissenter must carry out a fourth strategy: he or she must be able to transform the new objects into, so to speak, older objects and feed them back into his or her lab.

What makes a laboratory difficult to understand is not what is presently going on in it, but what *has been* going on in it and in other labs. Especially difficult to grasp is the way in which new objects are immediately transformed into something else. As long as somatostatin, polonium, transfinite numbers, or anaerobic microbes are shaped by the list of trials I summarised above, it is easy to relate to them: tell me what you go through and I will tell you what you are. This situation, however, does not last. New objects become **things**: 'somatostatin', 'polonium', 'anaerobic microbes', 'transfinite numbers', 'double helix' or '*Eagle* computers', things isolated from the laboratory conditions that shaped them, things with a name that now seem independent from the trials in which they proved their mettle. This process of transformation is a very common one and occurs constantly both for laypeople and for the scientist. All biologists now take 'protein' for an object; they do not remember the time, in the 1920s, when protein was a whitish stuff that was separated by a new ultracentrifuge in Svedberg's laboratory.[15] At the time protein was nothing but the action of differentiating cell contents by a centrifuge. Routine use however transforms the naming of an actant after what it does into a common name. This process is not mysterious or special to science. It is the same with the can opener we routinely use in our kitchen. We consider the opener and the skill to handle it as one black box which means that it is unproblematic and does not require planning and

attention. We forget the many trials we had to go through (blood, scars, spilled beans and ravioli, shouting parent) before we handled it properly, anticipating the weight of the can, the reactions of the opener, the resistance of the tin. It is only when watching our own kids still learning it the hard way that we might remember how it was when the can opener was a 'new object' for us, defined by a list of trials so long that it could delay dinner for ever.

This process of routinisation is common enough. What is less common is the way the same people who constantly generate new objects to win in a controversy are also constantly transforming them into relatively older ones in order to win still faster and irreversibly. As soon as somatostatin has taken shape, a new bioassay is devised in which sosmatostatin takes the role of a stable, unproblematic substance in a trial set up for tracking down a new problematic substance, GRF. As soon as Svedberg has defined protein, the ultracentrifuge is made a routine tool of the laboratory bench and is employed to define the constituents of proteins. No sooner has polonium emerged from what it did in the list of ordeals above than it is turned into one of the well-know radioactive elements with which one can design an experiment to isolate a new radioactive substance further down in Mendeleev's table. The list of trials becomes a thing; it is literally *reified.*

This process of reification is visible when going from new objects to older ones, but it is also reversible although less visible when going from younger to older ones. All the new objects we analysed in the section above were framed and defined by stable black boxes which had *earlier* been new objects before being similarly reified. Endorphin was made visible in part because the ileum was known to go on pulsating long after guinea pigs are sacrificed: what was a new object several decades earlier in physiology was one of the black boxes participating in the endorphin assay, as was morphine itself. How could the new unknown substance have been compared if morphine had not been known? Morphine, which had been a new object defined by its trials in Seguin's laboratory sometime in 1804, was used by Guillemin in conjunction with the guinea pig ileum to set up the conditions defining endorphin. This also applies to the physiograph, invented by the French physiologist Marey at the end of the nineteenth century. Without it, the transformation of gut pulsation would not have been made graphically visible. Similarly for the electronic hardware that enhanced the signals and made them strong enough to activate the physiograph stylus. Decades of advanced electronics during which many new phenomena had been devised were mobilised here by Guillemin to make up another part of the assay for endorphin. Any new object is thus shaped by simultaneously importing many older ones in their reified form. Some of the imported objects are from young or old disciplines or pertain to harder or softer ones. The point is that the new object emerges from a complex set-up of sedimented elements each of which has been a new object at some point in time and space. The genealogy and the archaeology of this sedimented past is always possible in theory but becomes more and more difficult as time goes by and the number of elements mustered increases.

It is just as difficult to go back to the time of their emergence *as it is to contest them.* The reader will have certainly noticed that we have gone full circle from the first section of this part (borrowing more black boxes) to this section (blackboxing more objects). It is indeed a circle with a feedback mechanism that creates better and better laboratories by bringing in as many new objects as possible in as reified a form as possible. If the dissenter quickly re-imports somatostatin, endorphin, polonium, transfinite numbers as so many incontrovertible black boxes, his or her opponent will be made all the weaker. His or her ability to dispute will be decreased since he or she will now be faced with piles of black boxes, obliged to untie the links between more and more elements coming from a more and more remote past, from harder disciplines, and presented in a more reified form. Has the shift been noticed? It is now the author who is weaker and the dissenter stronger. The author must now either build a better laboratory in order to dispute the dissenter's claim and tip the balance of power back again, or quit the game – or apply one of the many tactics to escape the problem altogether that we will see in the second part of this book. The endless spiral has travelled one more loop. Laboratories grow because of the number of elements fed back into them, and this growth is irreversible since no dissenter/author is able to enter into the fray later with fewer resources at his or her disposal – everything else being equal. Beginning with a few cheap elements borrowed from common practice, laboratories end up after several cycles of contest with costly and enormously complex set-ups very remote from common practice.

The difficulty of grasping what goes on inside their walls thus comes from the sediment of what has been going on in other laboratories earlier in time and elsewhere in space. The trials currently being undergone by the new object they give shape to are probably easy to explain to the layperson – and we are all laypeople so far as disciplines other than our own are concerned – but the older objects capitalised in the many instruments are not. The layman is awed by the laboratory set-up, and rightly so. There are not many places under the sun where so many and such hard resources are gathered in so great numbers, sedimented in so many layers, capitalised on such a large scale. When confronted earlier by the technical literature we could brush it aside; confronted by laboratories we are simply and literally impressed. We are left without power, that is, without resource to contest, to reopen the black boxes, to generate new objects, to dispute the spokesmen's authority.

Laboratories are now powerful enough to define **reality**. To make sure that our travel through technoscience is not stifled by complicated definitions of reality, we need a simple and sturdy one able to withstand the journey: reality as the latin word *res* indicates, is what *resists*. What does it resist? *Trials of strength.* If, in a given situation, no dissenter is able to modify the shape of a new object, then that's it, it *is* reality, at least for as long as the trials of strength are not modified. In the examples above so many resources have been mobilised in the last two chapters by the dissenters to support these claims that, we must admit, resistance will be vain: the claim has to be true. The minute the contest stops, the minute I

write the word 'true', a new, formidable ally suddenly appears in the winner's camp, an ally invisible until then, but behaving now as if it had been there all along: Nature.

Part C
Appealing (to) Nature

Some readers will think that it is about time I talked of Nature and the real objects *behind* the texts and behind the labs. But it is not I who am late in finally talking about reality. Rather, it is Nature who always arrives late, too late to explain the rhetoric of scientific texts and the building of laboratories. This belated, sometimes faithful and sometimes fickle ally has complicated the study of technoscience until now so much that we need to understand it if we wish to continue our travel through the construction of facts and artefacts.

(1) 'Natur mit uns'

'Belated?' 'Fickle?' I can hear the scientists I have shadowed so far becoming incensed by what I have just written. 'All this is ludicrous because the reading and the writing, the style and the black boxes, the laboratory set-ups – indeed all existing phenomena – are simply *means* to express something, vehicles for conveying this formidable ally. We might accept these ideas of 'inscriptions', your emphasis on controversies, and also perhaps the notions of 'ally', 'new object', 'actant' and 'supporter', but you have omitted the only important one, the only supporter who really counts, Nature herself. Her presence or absence explains it all. Whoever has Nature in their camp wins, no matter what the odds against them are. Remember Galileo's sentence, '1000 Demosthenes and 1000 Aristotles may be routed by any average man who brings Nature in.' All the flowers of rhetoric, all the clever contraptions set up in the laboratories you describe, all will be dismantled once we go from controversies about Nature to what Nature is. The Goliath of rhetoric with his laboratory set-up and all his attendant Philistines will be put to flight by one David alone using simple truths about Nature in his slingshot! So let us forget all about what you have been writing for a hundred pages – even if you claim to have been simply following us – and let us see Nature face to face!'

Is this not a refreshing objection? It means that Galileo was right after all. The dreadnoughts I studied in Chapters 1 and 2 may be easily defeated in spite of the many associations they knit, weave and knot. Any dissenter has got a chance. When faced with so much scientific literature and such huge laboratories, he or she has just to look at Nature in order to win. It means that there is a *supplement*, something more which is nowhere in the scientific papers and nowhere in the labs which is able to settle all matters of dispute. This objection is all the more

refreshing since it is made by the scientists themselves, although it is clear that this rehabilitation of the average woman or man, of Ms or Mr Anybody, is also an indictment of these crowds of allies mustered by the same scientists.

Let us accept this pleasant objection and see how the appeal to Nature helps us to distinguish between, for instance, Schally's claim about GHRH and Guillemin's claim about GRF. They both wrote convincing papers, arraying many resources with talent. One is supported by Nature – so his claim will be made a fact – and the other is not – it ensues that his claim will be turned into an artefact by the others. According to the above objections, readers will find it easy to give the casting vote. They simply have to see who has got Nature on his side.

It is just as easy to separate the future of fuel cells from that of batteries. They both contend for a slice of the market; they both claim to be the best and most efficient. The potential buyer, the investor, the analyst are lost in the mist of a controversy, reading stacks of specialised literature. According to the above objection, their life will now be easier. Just watch to see on whose behalf Nature will talk. It is as simple as in the struggles sung in the Iliad: wait for the goddess to tip the balance in favour of one camp or the other.

A fierce controversy divides the astrophysicists who calculate the number of neutrinos coming out of the sun and Davis, the experimentalist who obtains a much smaller figure. It is easy to distinguish them and put the controversy to rest. Just let us see for ourselves in which camp the sun is really to be found. Somewhere the natural sun with its true number of neutrinos will close the mouths of dissenters and force them to accept the facts no matter how well written these papers were.

Another violent dispute divides those who believe dinosaurs to have been cold-blooded (lazy, heavy, stupid and sprawling creatures) and those who think that dinosaurs were warm-blooded (swift, light, cunning and running animals).[16] If we support the objection, there would be no need for the 'average man' to read the piles of specialised articles that make up this debate. It is enough to wait for Nature to sort them out. Nature would be like God, who in medieval times judged between two disputants by letting the innocent win.

In these four cases of controversy generating more and more technical papers and bigger and bigger laboratories or collections, Nature's voice is enough to stop the noise. Then the obvious question to ask, if I want to do justice to the objection above, is 'what does Nature say?'

Schally knows the answer pretty well. He told us in his paper, GHRH *is* this amino-acid sequence, not because he imagined it, or made it up, or confused a piece of haemoglobin for this long-sought-after hormone, but because this is what the molecule is in Nature, independently of his wishes. This is also what Guillemin says, not of Schally's sequence which is a mere artefact, but of his substance, GRF. There is still doubt as to the exact nature of the real hypothalamic GRF compared with that of the pancreas, but on the whole it is certain that GRF is indeed the amino-acid sequence cited in Chapter 1. Now, we have got a problem. Both contenders have Nature in their camp and say what it

says. Hold it! The challengers are supposed to be refereed by Nature, and not to start another dispute about what Nature's voice really said.

We are not going to be able to stop this new dispute about the referee, however, since the same confusion arises when fuel cells and batteries are opposed. 'The technical difficulties are not insurmountable,' say the fuel cell's supporters. It's just that an infinitesimal amount has been spent on their resolution compared to the internal combustion engine's. Fuel cells are Nature's way of storing energy; give us more money and you'll see.' Wait, wait! We were supposed to judge the technical literature by taking another outsider's point of view, not to be driven back *inside* the literature and *deeper* into laboratories.

Yet it is not possible to wait outside, because in the third example also, more and more papers are pouring in, disputing the model of the sun and modifying the number of neutrinos emitted. The real sun is alternately on the side of the theoreticians when they accuse the experimentalists of being mistaken and on the side of the latter when they accuse the former of having set up a fictional model of the sun's behaviour. This is too unfair. The real sun was asked to tell the two contenders apart, not to become yet another bone of contention.

More bones are to be found in the paleontologists' dispute where the real dinosaur has problems about giving the casting vote. No one knows for sure what it was. The ordeal might end, but is the winner really innocent or simply stronger or luckier? Is the warm-blooded dinosaur more like the real dinosaur, or is it just that its proponents are stronger than those of the cold-blooded one? We expected a final answer by using Nature's voice. What we got was a new fight over the composition, content, expression and meaning of that voice. That is, we get *more* technical literature and *larger* collections in bigger Natural History Museums, not less; *more* debates and not less.

I interrupt the exercise here. It is clear by now that applying the scientists' objection to any controversy is like pouring oil on a fire, it makes it flare anew. Nature is not outside the fighting camps. She is, much like God in not-so-ancient wars, asked to support all the enemies at once. 'Natur mit uns' is embroidered on all the banners and is not sufficient to provide one camp with the winning edge. So what is sufficient?

(2) The double-talk of the two-faced Janus

I could be accused of having been a bit disingenuous when applying scientists' objections. When they said that something more than association and numbers is needed to settle a debate, something outside all our human conflicts and interpretations, something they call 'Nature' for want of a better term, something that eventually will distinguish the winners and the losers, they did not mean to say that we know what it is. This supplement beyond the literature and laboratory trials is unknown and this is why they look for it, call themselves 'researchers', write so many papers and mobilise so many instruments.

'It is ludicrous,' I hear them arguing, 'to imagine that Nature's voice could stop Guillemin and Schally from fighting, could reveal whether fuel cells are superior to batteries or whether Watson and Crick's model is better than that of Pauling. It is absurd to imagine that Nature, like a goddess, will visibly tip the scale in favour of one camp or that the Sun God will barge into an astrophysics meeting to drive a wedge between theoreticians and experimentalists; and still more ridiculous to imagine real dinosaurs invading a Natural History Museum in order to be compared with their plaster models! What we meant, when contesting your obsession with rhetoric and mobilisation of black boxes, was that *once the controversy is settled, it is Nature the final ally that has settled it* and not any rhetorical tricks and tools or any laboratory contraptions.'

If we still wish to follow scientists and engineers in their construction of technoscience, we have got a major problem here. On the one hand scientists herald Nature as the only possible adjudicator of a dispute, on the other they recruit countless allies while waiting for Nature to declare herself. Sometimes David is able to defeat all the Philistines with only one slingshot; at other times, it is better to have swords, chariots and many more, better-drilled soldiers than the Philistines!

It is crucial for us, laypeople who want to understand technoscience, to decide which version is right, because in the first version, as Nature is enough to settle all disputes, we have nothing to do since no matter how large the resources of the scientists are, they do not matter in the end – only Nature matters. Our chapters may not be all wrong, but they become useless since they merely look at trifles and addenda and it is certainly no use going on for four other chapters to find still more trivia. In the second version, however, we have a lot of work to do since, by analysing the allies and resources that settle a controversy we understand *everything* that there is to understand in technoscience. If the first version is correct, there is nothing for us to do apart from catching the most superficial aspects of science; if the second version is maintained, there is everything to understand except perhaps the most superfluous and flashy aspects of science. Given the stakes, the reader will realise why this problem should be tackled with caution. The whole book is in jeopardy here. The problem is made all the more tricky since scientists *simultaneously* assert the two contradictory versions, displaying an ambivalence which could paralyse all our efforts to follow them.

We would indeed be paralysed, like most of our predecessors, if we were not used to this double-talk or the two-faced Janus (see introduction). The two versions are contradictory but they are not uttered by the same face of Janus. There is again a clear-cut distinction between what scientists say about the cold settled part and about the warm unsettled part of the research front. As long as controversies are rife, Nature is never used as the final arbiter since no one knows what she is and says. But *once the controversy is settled*, Nature is the ultimate referee.

This sudden inversion of what counts as referee and what counts as being refereed, although counter-intuitive at first, is as easy to grasp as the rapid

passage from the 'name of action' given to a new object to when it is given its name as a thing (see above). As long as there is a debate among endocrinologists about GRF or GHRH, no one can intervene in the debates by saying, 'I know what it is, Nature told me so. It is that amino-acid sequence.' Such a claim would be greeted with derisive shouts, unless the proponent of such a sequence is able to show his figures, cite his references, and quote his sources of support, in brief, write another scientific paper and equip a new laboratory, as in the case we have studied. However, once the collective decision is taken to turn Schally's GHRH into an artefact and Guillemin's GRF into an incontrovertible fact, the reason for this decision is not imputed to Guillemin, but is immediately attributed to the independent existence of GRF in Nature. As long as the controversy lasted, no appeal to Nature could bring any extra strength to one side in the debate (it was at best an invocation, at worst a bluff). As soon as the debate is stopped, the supplement of force offered by Nature is made the explanation as to why the debate did stop (and why the bluffs, the frauds and the mistakes were at last unmasked).

So we are confronted with two almost simultaneous suppositions:

Nature is the final cause of the settlement of all controversies, *once controversies are settled.*

As long as they last *Nature will appear simply as the final consequence of the controversies.*

When you wish to attack a colleague's claim, criticise a world-view, modalise a statement you cannot *just* say that Nature is with you; 'just' will never be enough. You are bound to use other allies besides Nature. If you succeed, then Nature will be enough and all the other allies and resources will be made redundant. A political analogy may be of some help at this point. Nature, in scientists' hands, is a constitutional monarch, much like Queen Elizabeth the Second. From the throne she reads with the same tone, majesty and conviction, a speech written by Conservative or Labour prime ministers depending on the election outcome. Indeed she *adds* something to the dispute, but only after the dispute has ended; as long as the election is going on she does nothing but wait.

This sudden reversal of scientists' relations to Nature and to one another is one of the most puzzling phenomena we encounter when following their trails. I believe that it is the difficulty of grasping this simple reversal that has made technoscience so hard to probe until now.

The two faces of Janus talking together make, we must admit, a startling spectacle. On the left side Nature is cause, on the right side consequence of the end of controversy. On the left side scientists are *realists*, that is they believe that representations are sorted out by what really is outside, by the only independent referee there is, Nature. On the right side, the same scientists are *relativists*, that is, they believe representations to be sorted out among themselves and the actants they represent, without independent and impartial referees lending their weight to any one of them. We know why they talk two languages at once: the left mouth speaks about settled parts of science, whereas the right mouth talks about

unsettled parts. On the left side polonium was discovered long ago by the Curies; on the right side there is a long list of actions effected by an unknown actant in Paris at the Ecole de Chimie which the Curies propose to call 'polonium'. On the left side all scientists agree, and we hear only Nature's voice, plain and clear; on the right side scientists disagree and no voice can be heard over theirs.

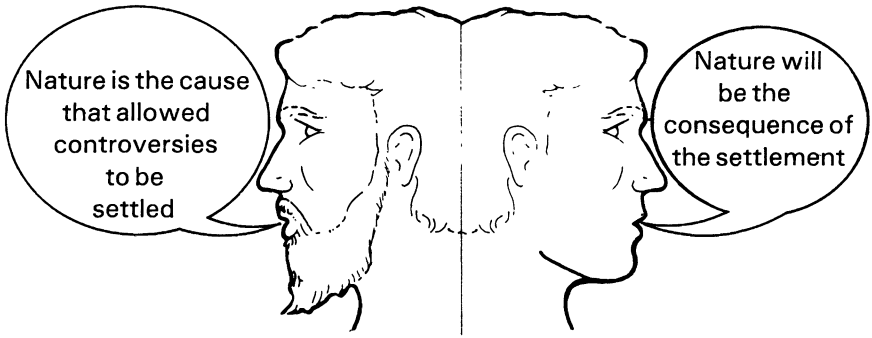

Figure 2.5

(3) The third rule of method

If we wish to continue our journey through the construction of facts, we have to adapt our method to scientists' double-talk. If not, we will always be caught on the wrong foot: unable to withstand either their first (realist) or their second (relativist) objection. We will then need to have two different discourses depending on whether we consider a settled or an unsettled part of technoscience. We too will be relativists in the latter case and realists in the former. When studying controversy – as we have so far – we cannot be *less* relativist than the very scientists and engineers we accompany; they do not *use* Nature as the external referee, and we have no reason to imagine that we are more clever than they are. For these parts of science our **third rule of method** will read: since the settlement of a controversy is *the cause* of Nature's representation not the consequence, we *can never use the outcome – Nature – to explain how and why a controversy has been settled.*

This principle is easy to apply as long as the dispute lasts, but is difficult to bear in mind once it has ended, since the other face of Janus takes over and does the talking. This is what makes the study of the past of technoscience so difficult and unrewarding. You have to hang onto the words of the right face of Janus – now barely audible – and ignore the clamours of the left side. It turned out for instance that the N-rays were slowly transformed into artefacts much like Schally's GHRH. How are we going to study this innocent expression 'it turned out'?

Using the physics of the present day there is unanimity that Blondlot was badly mistaken. It would be easy enough for historians to say that Blondlot failed because there was 'nothing really behind his N-rays' to support his claims. This way of analysing the past is called Whig history, that is, a history that crowns the winners, calling them the best and the brightest and which says the losers like Blondlot lost simply *because* they were wrong. We recognise here the left side of Janus' way of talking where Nature herself discriminates between the bad guys and the good guys. But, is it possible to use this as the reason why in Paris, in London, in the United States, people slowly turned N-rays into an artefact? Of course not, since at that time today's physics obviously could not be used as the touchstone, or more exactly since today's state is, in part, the *consequence* of settling many controversies such as the N-rays!

Whig historians had an easy life. They came after the battle and needed only one reason to explain Blondlot's demise. He was wrong all along. This reason is precisely what does not make the slightest difference while you are searching for truth in the midst of a polemic. We need, not one, but *many* reasons to explain how a dispute stopped and a black box was closed.[17]

However, when talking about a cold part of technoscience we should shift our method like the scientists themselves who, from hard-core relativists, have turned into dyed-in-the-wool realists. Nature is now taken as the cause of accurate descriptions of herself. We cannot be more relativist than scientists about these parts and keep on denying evidence where no one else does. Why? Because the cost of dispute is too high for an average citizen, even if he or she is a historian and sociologist of science. If there is no controversy among scientists as to the status of facts, then it is useless to go on talking about interpretation, representation, a biased or distorted world-view, weak and fragile pictures of the world, unfaithful spokesmen. Nature talks straight, facts are facts. Full stop. There is nothing to add and nothing to subtract.

This division between relativists and realist interpretation of science has caused analysts of science to be put off balance. Either they went on being relativists even about the settled parts of science – which made them look ludicrous; or they continued being realists even about the warm uncertain parts – and they made fools of themselves. The third rule of method stated above should help us in our study because it offers us a good balance. We do not try to undermine the solidity of the accepted parts of science. We are realists as much as the people we travel with and as much as the left side of Janus. But as soon as a controversy starts we become as relativist as our informants. However we do not follow them passively because our method allows us to document both the construction of fact and of artefact, the cold and the warm, the demodalised and the modalised statements, and, in particular, it allows us to trace with accuracy the sudden shifts from one face of Janus to the other. This method offers us, so to speak, a stereophonic rendering of fact-making instead of its monophonic predecessors!