• *ABSTRACT*

This paper explores in some detail a semi-popular text written by Einstein to present his theory of relativity. Semiotic tools are used to compare what Einstein says about the activity of building spaces and times with what sociologists of science can tell us. Einstein's text is read as a contribution to the sociology of delegation. *Once the drama of Einstein's argument has been reconstructed, it is possible to learn from his theory of relativity something about the classical problem of 'relativity' in the STS field. A comparison is established between the notion of social context and that of the aether, and an argument is developed to lead us beyond 'social' explanations. The goal of such a semiotic study is twofold: to allow the adaptation of the strong programme to the peculiar conditions of the theoretical sciences; and to find a vocabulary for an activity best defined as* infra-physics.

A Relativistic Account of Einstein's Relativity

Bruno Latour

If the young field of social studies of science can be granted some degree of success in the empirical sciences and in theoretical physics, its achievements are far from impressive in the mathematical sciences. The more formalized a field of science, the less field studies there exist and the less convincing they are. Most are satisfied if they can show *some* degree of relationship between 'society' and 'content', but the bold claim of the strong programme — namely, that the content of any science is social through and through — remains a programme for future field studies.[1]

There are two ways of interpreting this relative failure. The first is to take it as the best proof that the strong programme is an empty claim. When it reaches the more abstract or formal aspects of science, it starts to lose its acumen — although not its pretence — because these aspects *are* indeed more and more remote from society and history (the word 'abstract' will be redefined below, pp. 31ff). The second way of interpreting this failure is to consider that the definition of 'society' brought into play in order to explain the sciences is unfit for the task. Given the

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apparatus familiar to sociologists, the explanation of the more abstract parts of science becomes ever more far-fetched, not because these parts of science escape from society, but because the apparatus is in itself much too crude. This in turn creates a positive feedback loop: every unconvincing explanation of the theoretical sciences offers grist to the mill of those who prefer the first interpretation. 'There is more to science than society,' says the latter, 'and the failure of the strong programme proves this clearly enough.'

In this paper, however, I want to pursue another tack: there is more to society than meets the eyes of social scientists. Instead of extending the social sciences' usual concepts to the natural sciences, I want to redefine these very social concepts in order to make them able to explain the more formal sciences. The task at hand is to keep the same strong programme, but to doubt what the social sciences have to say about society. It is in effect a two-pronged enterprise, one that treats the natural and the social sciences symmetrically.[2]

Limits of the Material

In a previous work,[3] I have shown that instead of extending our knowledge of French nineteenth-century society to Pasteur's bacteriology with very disappointing results, and with a view merely to explaining the most superficial aspects of his science, it was easier and faster to suspend our knowledge of French nineteenth-century society and to follow, in the very technical aspects of Pasteur's benchwork, how a new social link was forged. Instead of imposing a far-fetched *implicit* social interpretation of their interests on the actors, this approach displayed the *explicit* translation by the Pastorians of both a new society and a new science. The price to pay for such an approach was to give away the claim that sociologists and social historians know society well enough to explain the sciences. This price seemed to me a light one.

Pasteur, however, grounded as he was in the empirical sciences and being involved as he was in all aspects of contemporary industrial, economic, and practical activity, was an easy case. For this paper, I have chosen a more difficult case — that of Einstein's relativity theory. His reformulation of space and time is considered revolutionary, far removed from common sense and quite abstract. Social explanations of Einstein have limited themselves to his political activities and shunned the technical aspects of his theory. When they happen to deal with them, they are rather disappointing. Feuer, for instance, brings into play a whole battery of social and psychological concepts — such as upbringing, milieu, intergenerational conflicts, race, religion and culture — just to account for the choice of the *word* 'relativity'.[4] He gives no indication of how relativity theory *itself* could be said to be social. The other reason for my choice is, of course, the tantalizing link that exists between the debates surrounding relativity in physics and those in social studies of science, my own discipline.

The present paper is limited to the study of the English version of one semi-popular work written by Einstein: *Relativity, the Special and the General Theory*.[5] Such a choice is a severe limitation, even though this book was carefully rewritten by Einstein over many years. The limitation, however, is not so great for our purpose, which is the following: in what ways can we, by reformulating the concept of society, see Einstein's work as *explicitly* social? A related question is: how can we learn from Einstein how to study society? If I fail in answering these questions on the semi-popular version, I will surely fail to show it on the more mathematical texts. If I succeed, it will not be a proof that I would have succeeded on the more technical texts. It will simply show that instead of looking for laborious social explanations, there is an easier and broader way to develop the strong programme, which has no reason to be limited to the experimental sciences.

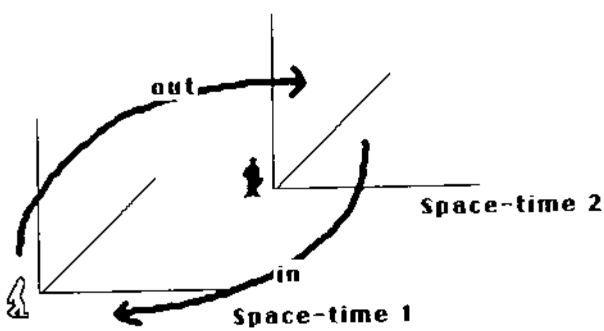
Shifting Out and Shifting In

To study Einstein's argument, we first need to define a few basic tools for analyzing texts. But in order to make the argument lighter and to allow a reader, even one unfamiliar with Einstein's book, to follow my own narration, I have gathered most of the results into six Tables at the end of the paper (pp. 37–41).

One of the most elementary operations of any narration is what semioticians call *shifting out*,[6] as, for instance, when Agatha Christie writes: 'Hercule Poirot arrived at Paddington Station at 9 o'clock on Christmas Eve.' She asks the reader to shift their attention away from her, the writer (also called the enunciator), to a new actor (Poirot), operating elsewhere (at Paddington), at a different time (9 o'clock on Christmas Eve). These three types of shifting out (*actorial*, *spatial* and *temporal*) may be repeated, separately or together, by the author as many times as necessary — as, for example, when, in a dialogue, Poirot summarizes his adventures to the rather slow Hastings. Naturally, the actors (or more exactly *actants*) which are shifted out in this way need not be human characters: they can be anything. For instance, in phrases like 'that train arrived in at seven o'clock' or 'scientific progress has always been valued everywhere', the three processes of shifting out are easily recognizable, 'train' and 'scientific progress' being actants like any other (see Table 2).

The converse operation is called *shifting in*, whereby the writer brings attention back to him or herself and gives the reader the impression — it is by definition never more than an impression — that the enunciator, the author and the 'I' who speaks in the text are one and the same character. To depict these two elementary movements, I will use the following diagram in which the two (or more) frames of reference mark different positions in space and time; the change in the little outlines from white to black signifies the shift from enunciator to actor; the two arrows to and from the enunciator, the shifting-in and shifting-out. The result of these two movements is to create characters which play the role of *delegates* for the main enunciator.

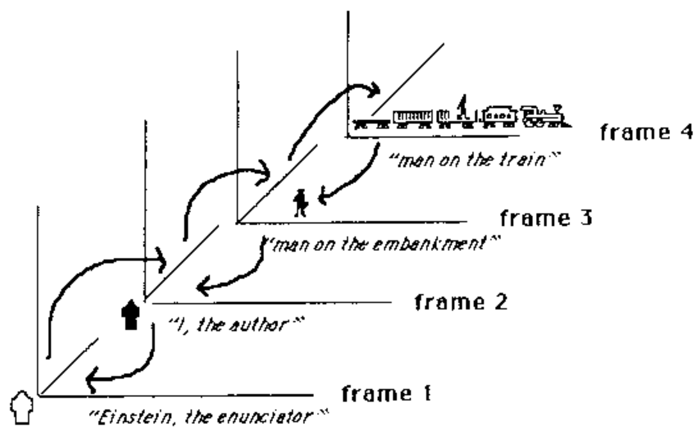
FIGURE 1
Shifting Out and In



This figure illustrates the two basic semiotic operations: shifting out and in. For further explanation see text.

Since this operation of shifting in and out is common to all narrations, it is in no way limited to 'literary' texts. Einstein, the enunciator of the book under scrutiny, for instance, shifts out a first character, the author, who says 'I' and who may be seen as a personification of Einstein, and who talks to another delegated character, 'the reader' (see Table 1). then this character shifts out again by creating a 'man on the embankment', who does various things — including among them a third shifting-out, by imagining what a 'man in the train' would do and see. Later, each of the characters shifts back in. All these operations, in which Einstein delights as much as any novelist (see Table 5), are easy to follow if we visualize them in a diagram like those in Figures 1 and 2.

FIGURE 2
Einstein's Delegation in Space and Time

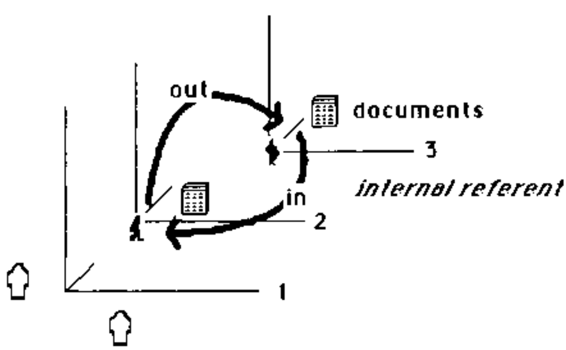


The shifting in and out of characters has one important effect on the reader. Any story — no matter how wild, bizarre and foolish — creates a certain type of *realism*, because of the constraints imposed on the actors. Even Count Dracula has to slip away safely into his coffin at dawn. The delegated characters impose constraints on one another in such a way that for a reader not everything is possible. An impression of resistance, that is of reality, is built by all stories. This built-in realism is called by semioticians the *internal referent*, to distinguish it from the *external referent* often thought to be the touchstone that allows fiction to be distinguished from accurate reporting. It is very important at this point not to push for any additional division between the various types of literature, especially between so-called 'fiction' and so-called 'science'.[7] All of them build an internal referent, but some of them choose to do so by giving the impression that the author possesses *documents* allowing him to support what he says. This realistic genre of storytelling is common to many novels, as well as to reporting and, of course, science. In such a genre, the authors offer proofs, in the text, that they have not made up the whole story, but that it is based on certain documents that can be seen or could be shown. If Hastings, in Agatha Christie's novel, says:

'I was most impressed by the list Poirot had made of all the potential suspects,' this builds an additional effect of realism into the text. This effect is reinforced if the author, shifting in one level below, actually shows the reader this impressive list, or tells us that it can be consulted in the manuscript 2345-B6H at the British Library. Thus if we actually go to the British Library and find the list of suspects, then we do not need to go any further to aver the reality of Poirot's case.

As I have shown elsewhere,[8] it is possible to define scientific literature stylistically by following how the authors, instead of alluding to documents, mobilize them in the text as so many *inscriptions* (tables, graphs, pictures, diagrams). It is even possible to decide if a narration pertains to a harder or a softer field of science by looking at the type of inscriptions and the way they are piled on top of one another so as to create, for the reader, the impression of a harder or softer reality.[9] To visualize this added realism in the diagram, I have chosen a symbol, ☐, that represents the type of written trace the delegated characters bring from one level of the story back to the one below. The 'adequation', or the coincidence between documents or inscriptions, is what we mean by reality, as far as semiotic theory is concerned.

FIGURE 3
The Realist Genre



The Figure illustrates how documents are brought back to the delegating frame of reference.

The shifting operations, and the building up of reality that ensues, have another important effect on the reader. While the enunciator and the reader (also called 'enunciatee') are both stuck to one portion of space and time and to one character (albeit unknown), the effect of the shifting-out operation is to delegate them elsewhere in space and time under a different guise, and then, thanks to the shifting-in operation, to bring the delegated characters *back*. If there were no shifting, there would be no way of ever escaping from the narrow confines of *hic et nunc*, and no way of ever defining who the enunciator is. There would be utter silence. No science, no politics, no art would be possible. The delegation provided by the triple shifting — actorial, spatial and temporal — is the basis of every discourse. These simple semiotic tools allow us to follow precisely practices usually subsumed under the names of 'power', 'institution' and 'domination', as well as others such as 'instruments' and 'equations' which are thought to pertain to cognition. We can now understand why every argument that touches upon this problem of delegation (whether it be in science, in politics or in art) appears to be fundamental and so triggers passions, interests and fears.

The Practical Work of Framing Events

The peculiarity of Einstein's narration is not that it puts to use shifting in and out, since every narration does the same, but that it focuses the reader's attention upon these very operations. Although he takes the reader, at the beginning, to Trafalgar Square (p. 6), he is not interested in sending him to tail Hercule Poirot on to the train at Paddington, nor in observing how he solves a murder mystery. He is interested only in the way in which we send *any* actor to *any* other frame of reference. Instead of describing laws of nature, he sets out to describe how any description is possible. He does not tell a story inside some framework to which he has taken us, his readers, but he tells the story of how you *frame* any event, how you build any frame of reference. Technically, his book is about delegation and, like those of Greimas, for example, is a book of meta-linguistics or of semiotics, one which tries to understand how any narration is constructed.

Inscriptions

While Greimas and most semioticians are content with a definition of shifting that simply sends a character to a different space and to a different time,[10] Einstein's exclusive attention is focused on how we define that it is a *different* space and a *different* time in the first place. Playing the idiot, the author-in-the-text redefines what an event is, what a space and a time are, by the practical activity of a little character holding firmly a rigid little rod (no cheap psychoanalysis intended) who superimposes the *readings* of the hands of watches and of the notches of rulers. From within the genre, common at this period, of Machian reduction of physical concepts,[11] Einstein's narration translates the abstract and given notions of space and time, in terms of a practice that locally generates spatial and temporal frames (see Table 3).

In the first chapter, 'the truth of a geometrical proposition' is translated into 'a construction with ruler and compasses' (p. 3). Then this practical construction is further translated:

> Every description of the scene of an event or of the position of an object in space is based on the specification of the point on a rigid body (body of reference) with which that event or object *coincides*. (p. 5; my emphasis)

Since this translation limits the observer to a small number of situations — the ones in which he can actually erect the scaffolding of rigid rods — he then constructs a wider scaffolding, the Cartesian coordinates:

> Referred to a system of co-ordinates, the scene of any event will be determined (for the main part) by the specification of the lengths of the three perpendiculars or co-ordinates (x, y, z) which can be dropped from the scene of the event to those three plane surfaces. The lengths of these three perpendiculars can be determined by a series of manipulations with rigid measuring rods performed according to the rules and methods laid down by Euclidean geometry. (p. 7)

The result of this transformation from abstraction into a concrete task of staging coordinates is to get rid of the notion of space:

> We entirely shun the vague word 'space', of which, we must honestly acknowledge, we cannot form the slightest conception . . . (p. 9)

Then to the hard and lowly work of building a rigid scaffolding to frame any event is added the practical management or at least *three* delegates shifted out in other frames of reference.[12] The illustration of the problem is again made in terms of a train — to which is added a falling stone, the primitive scene of physics since the Middle Ages. How can one decide whether an observation made in a train about the behaviour of a falling stone can be made to coincide with the observation made of the same falling stone from the embankment? If there are only one, or even *two*, frames of reference, no solution can be found since the man in the train claims he observes a straight line and the man on the embankment a parabola. Thus nothing tells us if it is the same stone acting according to the same law of physics. Each observer has 'its' — remember it is a semiotic character in the text — own irreducible vision of the world. The characters may be shifted out, but not shifted back in, running the risk of falling into relativism. Einstein's solution is to consider *three* actors: one in the train, one on the embankment and a third one, the author or one of its representants, who tries to superimpose the coded observations sent back by the two others. The shifting-in of superimposable written records is feasible if the delegated observers are thoroughly disciplined and are forced to stick to much simpler tasks than the ones usually required from travellers and railway employees. They are not asked to tell what they see, but to write down the 'ticks' of the clocks and the notches of rulers they have been equipped with:

> We understand by the 'time' of an event the reading (position of the hands) of that one of these clocks which is in the immediate vicinity (in space) of the event. In this manner a time-value is associated with every event which is essentially capable of observation. (p. 24)

The meaning of space, that of time and that of a description is nil, if the relation that ties the delegated observers hearing ticks and superimposing notches to others to which they send written and coded reports is not specified. Any description has meaning only 'relative to a particular body of reference'; it is meaningless if the equipment, hierarchy, task and method of documentation of the delegated observers are not specified.

Instead of considering instruments (rulers and clocks) as ways of representing abstract notions like space and time, Einstein takes the instruments to be what *generates* space and time. Instead of space and time being represented through the mediation of the instruments, it is space and time which have always been representing the humble and hidden practice of superimposing notches, hands and coordinates. It must be said that the character portrayed by Einstein does a very similar job to that of an anthropologist of science who refuses to understand what 'space' and 'time' mean, and who focuses instead on work, practices and instruments. Like any constructivist in sociology of science, Einstein's first move in this text is to bring the abstractions back to the inscriptions and to the hard work of producing them. This shift of emphasis from abstraction to inscription will allow Einstein to transform the usual frame of the traditional Newtonian narrations into actants that can be altered (shortened, slowed down, elongated, rotated). What really *counts* in framing any scene is not space and time but other activities, like shifting out a delegated observer, bringing it back in, sending signals, superimposing traces, and so on. Instead of dominating all scenes, space and time are aspects of what is set up at the beginning of any scene.

Thus, the first originality of Einstein's text is to replace the shifting-out in space and time that every other narrator (including sociologists and semioticians) took for granted, by a slightly more complicated operation that requires at least three delegated observers equipped with clocks and rulers who send light signals and who then build up the stage of coordinates inside which the usual shiftings may later operate.

> Every reference-body (co-ordinate system) has its own particular time. Unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event. (p. 26)

Meaning comes back to the story only when the metrological *work* is specified. The word 'relativity' applies whenever this former work that gives meaning back to the story is specified. (This point should be kept in mind because this is also the way we will define, below, the relativity of our own account.)

Subscriptions

Einstein, in this work, is not only obsessively interested in the staging of the very frames of references that allow spatial and temporal shifting-out, but he also focuses on the shifting-in. As I have said, it is not the former but only the latter that creates distinctions between fiction-writing and fact-writing. The confidence of the reader in the trustworthiness of the account increases if the author shows that it has the documents to guarantee what 'it' says. If these documents are inscriptions that can be superimposed on the narration, then confidence grows according to the number or quality of the documents and to the perfection of the fit. Such operations give the impression that there is an adequation between utterances, and what the utterances are about (this 'adequatio rei et intellectus' being the basis of most of our definitions of truth). Of course, this construction of an internal referent may be common to much narration. Even the scientific genre may be imitated as a literary effect by making up the inscriptions that prove that the story is not made up! This is common practice when some degree of realism is the goal.

There is, however, a final way of claiming to establish the trustworthiness of the account. This is by shifting in the *first* shifting-out — that is, by focusing the attention of the reader back to the enunciator's own setting.

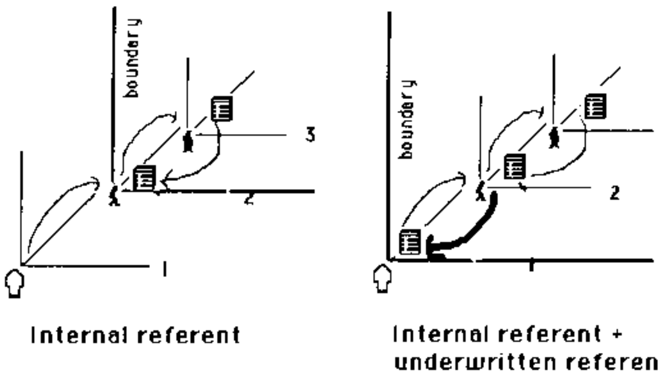
Let us illustrate this crucial point. The reader of Agatha Christie's novel is asked to travel with Hercule Poirot to a different frame of reference, much as the reader of an astronomy paper is asked to go 'out there' to the stars. When they begin to wonder whether it is a fiction or a real story, they are both asked to shift back to the many proofs that the authors have mobilized in their stories to build the internal referent. However, the reader of the novel is not supposed to go further back to Agatha Christie's office, and to see if Hercule Poirot has left traces of his passage that resemble *in some ways* what is in the novel. On the other hand, the reader of the astronomy paper is led to think that he could be permitted (although it would be a rare outcome) to come back to the astronomers' observatory and to *superimpose* the traces of the stars he has read about upon the traces present in the lab. If the reader's attention was shifted back in this way, his disappointment at finding nothing in the writer's office could not be taken against the fiction writer's craft — quite the contrary — but it would be the end of the scientific writer's credit. The internal referent of the text is complemented, asserted, evaluated by its adequation, fit, superimposition, to another referent that I will call *underwritten*[13] (or subscribed) because it is made of another set of inscriptions that establish the credibility of the ones used in the text to establish the reference of the narration.

This might be, in the end, the only distinction between 'literary' literature and scientific literature, but it is one that cannot be taken lightly. As the following diagram stresses, the possibility of this final shifting-in defines a different *boundary* for the narration. On the left-hand side of Figure 4 we have a text and the enunciator's setting is irrelevant; on the right-hand side, we have something slightly different from a text since the enunciator's setting, the laboratory, becomes essential — hence this idea that scientific papers are simply means of communicating information and do not relate to general literature.

Einstein is obsessed by the risk that the last shifting-in that creates the only final distinction between fiction-writing and fact-writing, becomes impossible. The dramatic intensity of his text depends in large part on the following dilemma: either we believe that there is a space and a time to which we can shift-out our delegated observers, but then, when we shift them back in, their reports are no longer superimposable; or we require that all their reports be superimposable, but then we have to abandon the idea that characters can be delegated in an unproblematic space and time (see Table 6).

The first branch of the dilemma leads to what is commonly referred to as 'relativism': each observer sees according to its own point of *view*; when the man on the embankment adds up velocities, the total is not the same as for the man in the train; each actor has its own irreducibly

FIGURE 4
The Underwritten Referent



When the underwritten referent is added to the discourse, the divide between fiction and science is moved down one level.

subjective point of view, which means that all points of view are equally privileged, which means that the enunciator cannot prove that what he says is based on superimposable inscriptions. Of taste and colours, one does not discuss. Texts are always, in the end, points of views, opinions, interpretations — that is to say, fictions.

It is the second branch of the dilemma that will lead to relativity, which is the exact opposite of relativism, as many commentators of Einstein have pointed out. The delegated actor has no personal point of view; when the man on the embankment adds up velocities the total adds up exactly to what the man in the train has summed up, at least in the hands of the third observer, the narrator of this text; there is no privileged point of view; which means that no matter how far away I delegate the observers, they all send back superimposable reports that establish my credibility; which means that it is possible to escape from fiction. We understand the intensity of the efforts, of the reflection, even of the passions triggered by this meta-scientific text: what is at stake here is the final boundary between fact and fiction. The ability of semiotics to be extended to science depends on its ability to deal with this reference that underwrites the inscriptions commented in a text.[14]

Transcriptions

The frequent confusion of relativism and relativity is amusing because it is the fierce fight between the two that gives Einstein's text much of its impetus (see Table 6). To understand this point, we should turn our attention not to temporal or spatial shifting, as we have just done, but to the third kind, called 'actorial' shifting. The question is to decide if the shifted-out actors have personal points of view or not. If yes, then you can't shift them back in, since they will all present unequivalent versions of the scenes they have observed. If no, then you are indeed able to shift all of them back in. They will all come back with equivalent versions of the scenes they have been delegated to observe. In the first case, they are shifted out and independent; in the other, they are also shifted out but are completely dependent.

However, it is only when the enunciator's *gain* is taken into account that the difference between relativism and relativity reveals its deeper meaning. If the actors are all independent, each with its own irreducible point of view, the enunciator has no privilege. What is the consequence if the actors have no personality, are all dependent, if they have points of view that can be easily reduced to the enunciator's? It is the enunciator that has the privilege of accumulating all the descriptions of all the scenes he has delegated observers to. The above dilemma boils down to a struggle for the control of privileges, for the disciplining of docile bodies, as Foucault would have said.

What appears confusing in Einstein's text, as well as in the opposition between relativism and relativity, is this apparent paradox: if there exist many points of view each claiming to be privileged, no one of them can get an edge over all the others; if, on the contrary, there are no privileged points of view, this means that there is nothing to prevent one of them getting an edge over all the others. We are, in our daily practice, quite clever at handling this seeming paradox — not in physics, to be sure, but in economics. It is the same paradox as that of liberalism. As long as any movement of goods, money or people is interrupted by many local franchises, protections, tariffs, feudal systems, particular regulations, traditions, irreducible cultures, it is impossible to capitalize on any large scale. 'Laissez-faire laissez-passer' is a necessary precondition for large-scale capitalization. Of course there is a price to pay — abandonment of protection, of tariffs, of special ad hoc regulations — but the payoff is worth it for those who can profit from the weakening of others' barriers.

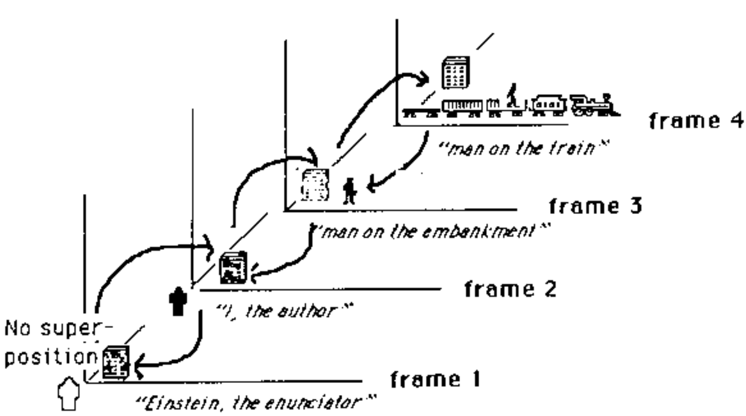
In Einstein's text, we also have to grasp the same relation between two seemingly contradictory slogans: no privileged point of view; no independent observer. The choice given us by Einstein is between the *deformation* of the reports sent by the observers — relativism — or the *transformation* of these reports — relativity. The same attention Einstein

FIGURE 5
Relativism *versus* Relativity

Relativism	**Relativity**
Privileged points of view	No privileged points of view
Independent observers	Dependent observers
Unequivalence of observations	Equivalence of observations
No superimposition of traces	Superimposition of traces
Enunciator has no privilege	Enunciator gains in the end
No large-scale privilege	Large-scale privileges
No possible omniscience	Omniscience is possible

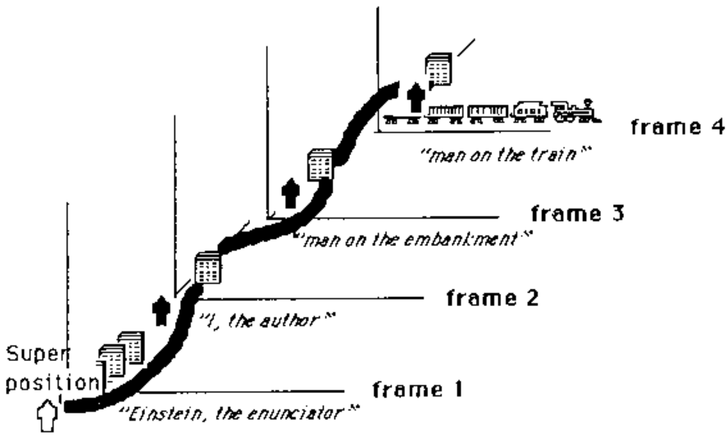
paid to setting up the instruments (clocks and rulers) is now paid to the *transcription* of the reports sent by the delegated actors. Either the reports are sent without retranscription and they cannot be superimposed once they are all gathered back in the enunciator's lab; or they are retranscribed and they are then fully superimposable. Either each report is deformed and it seems that each observer has its own view of the scene; or each report is transformed and it appears that no observer has its own peculiar point of view. In the first case, the enunciator is just one among many other observers, stuck as much as they are in one frame of reference since no frame is equivalent to any other; in the second, it is *as if* he was freely travelling from one frame to another, since all frames have been rendered equivalent. I have portrayed the two branches of the dilemma thus:

FIGURE 6
Relativism



With relativism, each frame of reference has its own definition of its actions; the enunciator thus cannot gather any superimposable document.

FIGURE 7
Relativity



With relativity, a transversal path is established in between frames of reference which no longer have their own irreducible points of view; thus it is possible for the enunciator to capitalize on superimposable reports.

In the first solution, shifting in and out may be interrupted at any point, since the man in the train and the man on the embankment send different messages about what happens in their frame of reference. In the second solution, the enunciator cannot be betrayed by anyone. The impersonal delegated observers work for him and for him only, sending perfectly superimposable documents. As stressed in the pictures, what counts in the first solution is the series of shifted frames of reference, whereas, in the second, what counts above all is the *transversal* path established in between frames. Nothing interrupts the free movement of the enunciator — he can expand from one frame to another. There is no longer any one frame that might be used as a rigid and stable reference, into which confidence is vested; confidence is now put into the transversal link that allows all frames, no matter how unstable and pliable, to be *aligned*. Instead of a complicated gear to shift every frame of reference out and in, there is only one transformation. To take a still simpler metaphor, the first solution is like going on foot through bumpy and unknown fields that have no beaten path; the second is like following a highway. To the constant negotiations through inequivalent and irreducible frames, relativity leads us to a non-negotiated travel from one equivalence to the next.

Given the importance of the gain, the *paperwork* imposed by the retranscription of each document appears quite light. Given any set of coordinates, x, y, z and t sent by any one of the delegated observers, it is possible for the enunciator to shift them back in his own frame of reference by substituting each coordinate with another, through the set of equations known as a 'Lorentz transformation'.

FIGURE 8
The Lorentz Transformation

$$x' = \frac{x - ut}{\sqrt{1 - \frac{u^2}{c^2}}}$$

$$y' = y$$

$$z' = z$$

$$t' = \frac{t - \frac{u^2}{c^2}x}{\sqrt{1 - \frac{u^2}{c^2}}}$$

The Lorentz transformation defines the paperwork necessary to move documents from one frame to the other and still maintain superimposition of traces at the end.

In the case, at least, of observers sent to unaccelerated frames of reference, the Lorentz transformation is a way of shifting out and in without having to lose, in the jump, the documents gathered by the delegated actors. What semioticians call without further ado 'shifting out and in', because they mostly consider narrations that are content to be read as text and fiction, is offered a precise meaning by Einstein because he studies narrations that he wants to *distinguish* from texts and fictions. The choice between deformation without transformation — relativism — or transformation and stability of the form — relativity — is nicely summed up on p. 47:

> Every general law of nature must be so constituted that it is *transformed* into a law of exactly *the same form* when, instead of the space-time variables x, y, z, t of the original co-ordinate system k, we introduce new space-time variables x', y', z', t' of a co-ordinate system k'. In this connection the relation between the ordinary and the accented magnitudes is given by the Lorentz transformation. Or in brief: General laws of nature are co-variant with respect to Lorentz transformation. (My stress)

Later in the text, when the problem will be to send accounts of observations from accelerated frames of reference, more transformations than this simple paperwork will be required, but the goal will be the same (see Table 6): in order to maintain the stable equivalent form of all observations, more and more transformations and retranscriptions are necessary. The rigid Cartesian coordinates used so far to control the behaviour of delegates is replaced by a less rigid but much finer mesh, the Gaussian coordinates, of which the Cartesian are only a particular case.

> According to the special theory of relativity, the equations which express the general laws of nature *pass over* into equations of the *same forms* when, by making use of the Lorentz transformation, we replace the space-time variables x, y, z, t, of a (Galilean) reference-body by the space-time variables x', y', z', t', of a new reference body K'. According to the general theory of relativity, on the other hand, by application of *arbitrary substitutions* of the Gauss variables x_1, x_2, x_3, x_4, the equations must *pass over* into equations of the *same form*. (p. 98, my stress)

The devil take the rigidity and stability of the frames of reference, provided the delegated observers have no privileged point of view and send in*form*ation which is not de*form*ed. At the end of his text Einstein, abandoning any sort of rigidity of the frames, devises what he calls a 'mollusc of reference'. It is this mollusc that allows the enunciator to send delegates anywhere at any speed and still get back usable observation that maintains the forms of the description intact and stable:

> Every point on the mollusc is treated as a space-point, and every material point which is at rest relatively to it is at rest, so long as the mollusc is considered as reference body. The general principle of relativity requires that all these molluscs can be used as reference-bodies with equal right and equal success in the formulation of the general laws of nature; the laws themselves must be quite independent of the choice of the mollusc. (p. 99)

Either the laws are dependent on the choice of independent observers, or the observers are made dependent, thus rendering the laws independent. The ability of the delegated observers to send superimposable reports is made possible by their utter dependence and even stupidity. The only thing required of them is to watch the hands of their clocks closely and obstinately:

> These clocks satisfy only one condition, that the 'readings' which are observed simultaneously on adjacent clocks (in space) differ from each other by an indefinitely small amount. (p. 99)

That is the price to pay for the freedom and credibility of the enunciator.

In this book, Einstein's fiddling with time and space does not lead, as we can now see, to the metaphysics often triggered by his writings, but to an *infra-physics* of crucial importance for the sociology of science. Instead of frames of reference, we are presented with the practical work of setting up frames; instead of characters, we now see the hard work of disciplining and managing delegated observers and instruments; instead of taking information for granted, the encoding and decoding of information are now made visible. Inscriptions, subscriptions, transcriptions: the word 'relativity' refers to this lowly work of building and relating frames to one another in such a way that some kind of stable form can be maintained which can, then, be cumulated, combined and superimposed at some point.

The Limits of a Social Explanation

What does it mean to offer a social and political explanation of Einstein's definition of relativity? If, by political and social, we mean that the technical work of Einstein should be translated into *another* language in which words such as 'groups', 'classes', 'interests', 'cultures' are said to be what is really present *beneath* the words 'trains', 'embankment', 'stars', 'Gaussian coordinates', or 'Minkowski four-dimensional space', a social explanation would be meaningless. Einstein's work is not reducible to the work done, in other domains, by economists, historians, sociologists and ideologists. Nothing is hidden beneath, reflected by, represented through, mirrored in, alluded to by his technical work. Should we thus conclude that his work is so technical and abstract that it escapes from our world and pertains only to physics with no relation to anything else? Certainly not. This alternative between two technical languages for two scientific professions — social scientists and physicists — is precisely what this paper aims to avoid.

On the other hand, if, by a social explanation, we mean that we can learn from the technical part of Einstein's argument something about the way society is built, we might start to approach such an explanation. It is clear, for a start, that the various ways of shifting, the management of delegates, the question of their faithfulness, the difference between fact-writing and fiction-writing, the displacement without deformation, the building of equivalences, the keeping up of metrological chains — all these problems are *common* to many disciplines and activities, and cut across what is abstract and what is concrete, what is scientific and what is daily practice, what is political and what is technical. For instance, the Smithsonian Institution, in the middle of the nineteenth century, had similar problems in building up meteorological phenomena. How to obtain in Washington a map of tornadoes?[15] By recruiting 600 correspondents spread around the country. This recruitment drive is only one little part of the task, because it is then necessary to discipline them in such a way that they fill in usable forms that make sense once gathered in the Washington office. It is especially important to make sure that they make their readings at the same time every day, at the same place. 'Weather missionaries' are sent around to make sure correspondents are dedicated and faithful. This is not an easy task, especially if one bears in mind that the same people are often asked to send to the same Institution stuffed animals, plants, specimens of all sorts, which means that they have to roam around the country as much as possible.[16] The practical question of obtaining at the same time fixed dedicated weathermen and mobile dedicated naturalists is enormous, and is as much part of the building of an institution as is Einstein's meta-discourse on how to discipline any observer sent to any frame of reference.

It is to accommodate many examples of such a problem that I have proposed considering history of science as the history of centres which are growing through the management of traces that have three main characteristics: they are as mobile, as immutable and faithful, and as combinable as possible. The circulation back and forth of these 'immutable mobiles' trace *networks* — that is to say, two-way paths leading from the centre to the now-dominated frames. These networks are constantly repaired against interruption by maintaining *metrological chains* that keep the frames equivalent. To define these centres in the most general way, I have called them *centres of calculation*.[17] The main point of their history is that no distinction has to be made between economics, science, technics or even the arts, when we follow how each of their three characteristics is enforced. Contributions to this common history may be made by historians of perspective, of print, of art, of technics, of expeditions, of economics, and so on. From this point of view, no distinction has to be made, either, between 'abstract' thinking and 'practical' activities. The immutability of the mobilized traces is as much enhanced when a naturalist imagines a new way of naturalizing killed bears, as when Laplace invents a new way of calculating error variations in astronomers' readings. The mobility of the traces is as much favoured when a new satellite link is established between two data banks as when Linnaeus devises a new way of coding any plant with two Latin words. The combinability of the traces is as much enhanced when a Computer Assisted Design engineer fuses on the same screen the shapes of a car's parts and their price, as when Monge invents a way of merging descriptive geometry and fortress defilading. It is because of the links between these innovations in various domains that centres may also be called 'centres of capitalization'.

Obviously, Einstein is both a latecomer in this long history and a significant contributor to it. His obsession with transporting *in*formation through *trans*formations without *de*formation; his passion for the precise superimposition of readings; his panic at the idea that observers sent away might betray, might retain privileges, and send reports that could not be used to expand our knowledge; his desire to discipline the delegated observers and to turn them into dependent pieces of apparatus that do nothing but watch the coincidence of hands and notches; even his readiness to jettison what common sense cherishes provided the equivalence of all metrological chains be saved. Thus it is easy to see in what way Einstein's work pertains to this general history.

To assess his role in this history of centres of calculation, there might be another and more straightforward way than to dig in his cultural milieu, or to see if the economic infrastructure of turn-of-the-century capitalism could in some distorted and far-fetched way be 'mirrored' in what he does. What Einstein does for the centres he does directly and without mediation. He says in this text that, if the special and general relativity are not accepted, there is a risk. The risk is that the reports sent by observers delegated to frames of reference which are closer to the speed of light, or violently accelerated, be made useless. What he proposes is a series of 'minor' innovations in the way we delegate observers, discipline their information, decode their messages and translate their representations. They are minor innovations since they are inserted in a vast and long history of centres of calculation, and remain meaningless without it. Still, they are innovations that are to be taken seriously if these centres decide to resume their travels to frames that are accelerated or close to the speed of light. Einstein's invention may not be new and important enough to trigger the great organ of metaphysics, but it is not insignificant enough to be simply reduced to the earlier solutions offered by the centres to 'long-distance travel'. We should strike a precise balance between overstating his solution (revolution in space and time 'out there') and underrating it (conservation of the centres 'down here'). The balance should be something like this: provided the two relativities are accepted, more frames of reference with less privilege can be accessed, reduced, accumulated and combined, observers can be delegated to a few more places in the infinitely large (the cosmos) and the infinitely small (electrons), and the readings they send will be understandable. His book could well be titled: 'New Instructions for Bringing Back Long-Distance Scientific Travellers'.

To weigh the importance of centres of calculation, there is no better way than to measure what Einstein is ready to jettison in order for them to go on at an expanded rate and scale. Why does maintaining equivalent observers have such paramount importance that everything else should be made subservient to it? (See Table 6). I indicated above the solution to this question by the comparison with liberalism. This comparison was simply a metaphor to help grasp the seeming paradox that ties the fight against privileges with the increase of privileges. It is time to see how these fights against privileges in economics or in physics are literally, and not metaphorically, the same. If the man in the train sees different things than the man on the embankment — this difference being made visible by the lack of fit when superimposing the two reports — it means that there is no gain to be made for the second by dealing with the first. Each has its own autonomous life, its own view of the world, its own evaluation of quantities. Each, in other words, is as weak or as strong as any other. There is no delegation, no agreed chain of command, but a democracy of points of view where every one sees the others as so many undisciplined and intractable bodies. If, on the other hand, the man in the train describes scenes according to instruments which, after a few transformations, are made equivalent to the ones seen by the man on the embankment, this means that the latter will gain something. Without being on the train, the man on the embankment will have 'its' point of view *plus* another one compatible and addable to the first. Of course, it is not the man on the embankment that we care about, but the enunciator, the last one in the list, for whom the others are cat's paws. In other words, if it is possible to make all frames of reference equivalent (with respect to a few transformations) it is possible to *accumulate* all the others in the last frame.

Who is going to benefit from sending all these delegated observers to the embankment, trains, rays of light, sun, nearby stars, accelerated lifts, the confines of cosmos? If relativism is right, each one of them will benefit as much as any other. If relativity is right, only *one* of them (that is, the enunciator, Einstein or some other physicist) will be able to accumulate in one place (his laboratory, his office) the documents, reports and measurements sent back by all his delegates. Relativity draws the design of a centre of calculation from which, and to which, paths lead. It is not his privileged point of view that gives a centre any superiority over other locations, but its rejection of any privilege to any local point of view including its own, thus permitting the gathering in one point of all the superimposable traces. It is not because it has a better view of the clouds from its windows that the Smithsonian is better able to build up meteorological maps, but because, instead of looking through the windows, they look at the weathermen's reports inside dark offices.

This rejection of some privileges in order to shore up some others, throws a rather new light on the usual argument that Einstein is a revolutionary. Scientific revolutionaries are often portrayed as bold thinkers who break away from common sense. In Einstein's case, the breaking away from Galilean frames of reference, from Newtonian absolute space and time, the audacity with which he shortens rulers, slows down clocks, curves space and gets rid of gravity, makes him indeed the epitome of a revolutionary in science. It is because of this audacity that social and contextual explanations try to sneak into the physics. Einstein, it is said, was an outcast immersed in a revolutionary culture and milieu, and his flamboyant political views do nothing to contradict these social explanations. The notion of scientific revolutions should, however, be taken with a grain of salt; so, for that matter, should that of political revolutions.[18] Instead of marvelling at how revolutionaries become latter-day conservatives, it would be better to see first if there is such a thing as a revolutionary breaking away from orthodoxy.

In the text under scrutiny, the author never presents us with a break from the usual ways of thinking, but with a choice between two ills: either we maintain absolute space and time and the laws of nature become different in different places; or we maintain the equivalence of the laws of nature, and we 'discard' (p. 27) absolute space and time. The question is not how to revolutionize our thinking but how to maintain, to conserve, to stabilize, to rigidify, one thing that appears more important than anything else. The author is not calling us to an upheaval of physics, but to get rid of a few minor points — aether, simultaneity — so as to let physics go on its ancient way on an expanded scale. The drama he unfolds is not that of a revolution but that of the testing and selection of the *weakest point* that should give way for everything else to be maintained (see Table 6).

In view of this dilemma there appears to be nothing else for it than to abandon either the principle of relativity or the simple law of the propagation of light *in vacuo*. Those of you who have carefully followed the preceding discussion are almost sure to expect that we should retain the principle of relativity, which appeals so convincingly to the intellect because it is so natural and simple. The law of propagation of light *in vacuo* would then have to be replaced by a more complicated law conformable to the principle of relativity. The development of theoretical physics shows, however, that we cannot pursue this course. . . Prominent theoretical physicists were therefore more inclined

> to reject the principle of relativity, in spite of the fact that no empirical data had been found which were contradictory to this principle.
>
> At this juncture the theory of relativity entered the arena. As a result of an analysis of time and space, it became evident that *in reality there is not the least incompatibility between the principle of relativity and the law of propagation of light* [E.'s italics] and that by systematically *holding fast* to both these laws a logically *rigid* theory could be arrived at. (p. 19, my stress)

Strange revolutionary indeed that sacrifices a belief in order to build a rigid theory that maintains two of the physicists' most cherished beliefs intact! If Einstein is a revolutionary, it is in the same way as the Prince Salina, who wished to change everything so that everything remained the same. If Einstein appears to breach an important principle, this simply means that something *more* important is thereby conserved. The question to be asked is this: given what Einstein wishes to maintain, what should rather be sacrificed? Hence in this case, it is no use trying to distinguish revolutionaries from conservatives — and thus it might be a waste of time to search Einstein's Swiss milieu for revolutionary influences. In the trial of forces displayed in the above quotation, one weaker link is going to break; the stronger links which are thus fortified and expanded are what need watching.

An argument is not social because it deals with society and groups; it is social when it tries out which ties are stronger and which ones are weaker. This is why the more meta-linguistic, the more abstract, the more theoretical is a study, the closer we are to the *explicit* analysis of the three characters of immutability, mobility and combinability, and the easier it is to offer an explanation of it in terms of centres of calculation. I started by saying that empirical sciences appeared easier for sociologists than more theoretical ones. We can now see that the case is exactly the opposite. Social studies of science, far from being limited to the empirical disciplines, are better equipped for the more formal ones because these disciplines offer, in a way, a simpler, more direct, and more explicit case. When we get to texts, such as Einstein's, which talk about the ways of describing any possible experience, we are *closer* to our sociology, not farther from it. That closeness depends, of course, on the previous work of redefinition done on sociology itself.

It is now clear that we no longer call 'social' some translation that would replace the vocabulary of physicists by the vocabulary of sociologists, but rather one that forges a hybrid vocabulary that makes the speed of light *c*, or the Lorentz transformation, part of the normal business of building a society, while it makes the rôle of the enunciator and of centres of calculation part of the normal business of elaborating a scientific revolution in physics. This means, of course, that we, sociologists, do not know in advance what society is made of. As Mike Lynch has demonstrated,[19] this admission of ignorance is the only way of getting further inside the sciences.

A Relativistic Solution to the Problem of Social Context

The main consequences of Einstein's infra-physics, and of the peculiar explanation in terms of immutable mobiles I have provided of it, is to raise anew two related problems: what does it mean to talk about the social context of a science? What does it mean to 'socially explain' a science? The second question, which is easier, will be used to solve the first, more tricky one. Explaining a science means that we should be able to establish with it more *equal* relations in such a way that we learn from it about society and use our own discipline to teach a few things to the science we are dealing with.[20] This more equal status should be our touchstone even though, in the case of physics, such a programme may appear ludicrous. The fecundity of an account in this newly redefined strong programme will be assessed by our ability to transform the definition of social until it is *on a par* with the very content of the science studied, and exchanges properties with it. One example of such an exchange is to formulate questions like this one: can we, sociologists, learn about our relativism from Einstein's relativity?

The principle of relativity (Galileo's argument that movement is as nothing), the special and the general theories of relativity, are various ways of giving back *meanings* to descriptions. The *work* of setting up instruments, taking readings, framing coordinates, shifting out and in, transcribing messages, establishing equivalences is what offers meaning. This is what Einstein calls 'relativity', and what he opposes to 'relativism'. Absolutism and relativism are tied to one another, while relativity reestablishes reality by giving up absolutism.

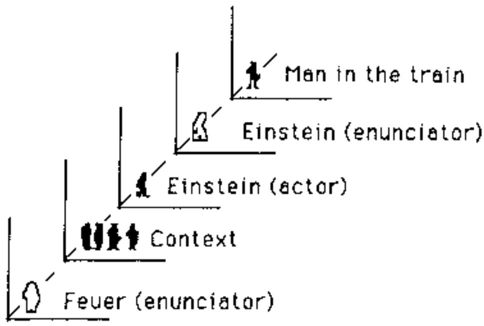
What is the case in social studies of science? It is exactly parallel. We fight against absolute definitions of science; we refuse meaning to any description that does not portray the *work* of setting up laboratories, inscription devices, networks; we always relate the word 'reality' to the specific trials inside specific laboratories and specific networks that measure up the resistance of some actants. Is this a weakening of the concept of reality? Is this relativism in the sense that all accounts would be irreducible, untranslatable, and unrelated? No, in spite of our critiques — and to be fair, in spite of a few of our early claims[21] — it is not. We are no more relativist that Einstein, and for the same reason. By fighting absolute definitions of observations that do not specify the practical work and material networks that give them meaning, we take as seriously as everyone else the construction of reality — indeed, we might be the only one to take it seriously *enough*.

Is it then possible to use Einstein's argument to reformulate our relativity in such a way that it is made as clearly different from relativism as Einstein's? To tackle this most difficult point we have to go back to the actorial shift described above, and to what creates the distinction between fact-writing and fiction-writing. Einstein, in his text, populates his world with many actants: ravens, trains, clouds, men with rigid rods, lifts, marble tables, *c*, molluscs, and of course clocks and rulers — see Table 2. Although we are dealing with what is called the 'content' of Einstein's book we, the readers, are meeting a great many figures who do all sorts of actions. Semiotics is the study of these figures and actions. What happens if we go *outside* of Einstein's text — let's say to Feuer's? We find new characters like Einstein's parents, the Olympia Academy, Ernst Mach, fin-de-siècle Europe, conflicts of generation, and so on. We also find Albert Einstein. Instead of being the enunciator and author of the text under study, he is now the object of Feuer's explanation, a real man in his social and cultural context. Sociology, social history or psycho-sociology are some of the names of the disciplines which study such characters and social contexts.

Now, let us ponder what the relation is between the inside characters and the outside ones. This amounts to following up Einstein's question, 'What is the relation between the man on the train and the man on the embankment?', with this question: 'What is the relation between Einstein, enunciator of his text, and Albert Einstein in Feuer's story?' The two relations are precisely the same. No matter how 'outside' and 'contextual' and 'historical' Feuer may wish it to be, his Albert Einstein is a shifted-out character *inside* his text exactly as the man in the train is in Einstein's text. No matter how sociologists and historians love to put texts, ideas, and events *in* their context, this context is always made up of shifted characters inside another text. They can *add* one text to another, but not *escape* from it. We have access to co-texts not to context.

This is the basis of what has been called 'the semiotic turn': nothing can be said of the enunciator of a narration if not in a narration where the enunciator becomes a shifted-out character. In consequence, there is no difference to be made in principle, between internal sociology — how to manage the population of actants that make up the *content* of a text — and external sociology — how to manage the population of actants that make up the *context* of a text. This is not to say that many

FIGURE 9
Co-Texts, not Context



The creation of a context in which Einstein is put follows the same rules as those by which Einstein creates delegated characters in his own account.

distinctions of style, genre, richness, conviction, quality, cannot be drawn between texts. It simply means that a statement about 'the pragmatic context of an utterance' is as devoid of meaning as the statement of a state of motion without specification of the coordinates.

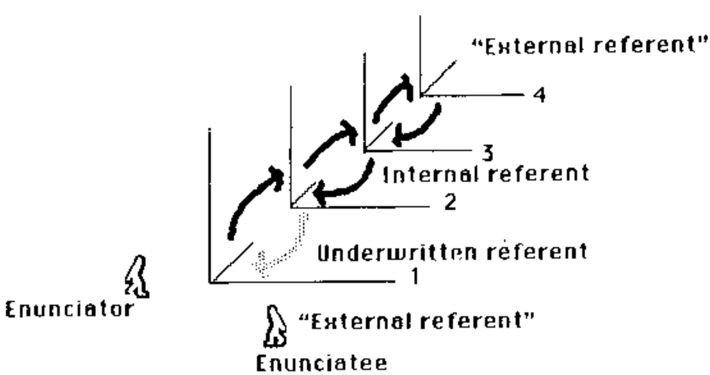
The two principles, that of Einstein's relativity and that of semiotics, are one and the same. They both state that to talk of an *external* referent independently of the structure of the report is devoid of meaning. They both state that we are always in between at least two frames and that the deeper we go into physics and cosmology the more we should examine the conditions of the narration that stage these frames. They both state that an effect of reality is built in by the superimposition of reports sent from at least two frames of reference to a third one.

Why is the first one accepted with gratitude while the other is greeted with horror, by natural as well as by social scientists? It is simply that the opposition between relativism and relativity which is so clear in the case of Einstein has not been made as clear in the case of semiotics. The reason for this lack of clarity is to be sought through the question of the referent.

The introduction of relativity is not a way for Einstein to weaken reality — that is adequation with a referent — but the only way to strengthen it. Why? Because, as I have shown above, when you shift in, it allows you to obtain a new fit between superimposed reports that you would not get were you to reject relativity. The internal referent is then assessed by what I called above the 'underwritten referent'. Of course, the price to pay for this added realism is the abandonment of the external referent, which is an effect of the discourse on the reader.

Now, when we, social students of science, say that there is no distinction of principle between context and content, we do not mean to say that all narrations pertain to the genre of fiction-writing, or even that all descriptions are simply 'texts' — as French deconstructionists are often prone to claim. We simply say that by shifting out and in, sociologists, historians, and social scientists in general, build up *internal* referents as much as any other realist writers. We only repeat that the external referent is an effect of these discourses over their readers. When Feuer creates Albert Einstein by shifting out a character of that name, he mobilizes documents of all sorts to give the impression that his story is not made up. Is this an impression only? It is impossible to go beyond narration and beyond some superimposition of documents in order to answer the question. Does this mean that there is no touchstone to decide if Feuer's book fits in any way the reality of Einstein's youth and background? No. Any more than relativity means a breakdown of communications between the man in the train and the man in the embankment — quite the contrary.

FIGURE 10
Three Types of Referent



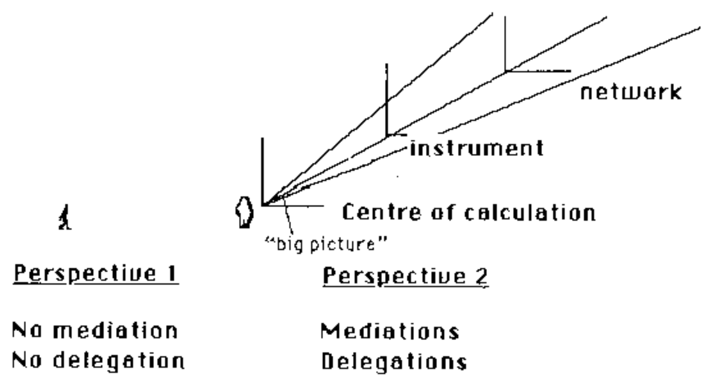
Three types of referent can be distinguished; the impression of an external referent 'out there' is obtained 'down there' by the superimposition of the underwritten referent with the internal referent.

In both cases the only path that is left open is that of the underwritten referent. Can you shift in all the way back to Feuer's office and superimpose in some way the documents he mobilizes in his text with others? If no, then the boundary of the narration is such that you have only a text; from the text to the enunciator there is a *non sequitur*, a gap. If yes, then what happens? The boundary of the text is stretched further in; there is continuity, a network is in place. But who does such a verification? Who goes to the office of the writer to check this ultimate superimposition? *Another scientist*, another writer who is busy expanding still another network by establishing a continuous link between the inscriptions mobilized in his text and what a potential reader could wish to see in his office, were he to check, and so on. In other words, there are three things we cannot escape from: discourses, inscription devices and networks — that is, infra-physics. This argument is common to Einstein's theory and to our 'social' explanation of it.

In other words, 'social context' in current social studies of science plays the same sort of role as 'aether' for turn-of-the-century physics.[22] This vast social structure that would somehow surround networks and seems necessary to provide a firm foundation to sociologists' explanations is no more provable and no more necessary than this subtle and infinitely elastic milieu that physicists firmly defended for over a generation to establish the firm foundation of *their* explanations. Sociologists always want to add the social context, and they think that in a case study something is amiss if there is no larger-scale entity to explain the whole thing. In practice, however, the characters presented in their accounts, and which bear the name of 'social structure' 'longue durée', 'large-scale influences', 'overarching interests', and the like, are not bigger than the little ones they try to explain. A giant in a story is not a bigger character than a dwarf, it just does different things. The same two-metre-square painting may represent a battlefield or an apple; no one will say that the first is bigger and more encompassing than the second. *Size is not a property of characters, only of networks and of their relations.* Society, in the accounts of sociologists, might not be much bigger than a pumpkin — at least if we judge from the evocative gestures they make when they talk of the 'big picture'!

We can gather that this 'aether' is entirely unnecessary for sociologists from this simple argument: were we really to step outside of accounts related to one another in a manner of a network, we would be limited to the narrowest of all possible point of views, our own *hic et nunc* vision of the world. If we want to see the 'big picture', we have to be in touch with some sort of an inscription device that, through many mediations, elaborates locally and *inside* a network, a projected picture. If we step outside to be in touch with the real context — the reality outside of any narration, any network, and any discourse — this is to be *limited* to one point of view, to the smallest picture, to what we see from our own unaided and unmediated body. Either the 'big picture' is very tiny but related to a long network that makes it really big, or the 'big picture' is unrelated to any instrument and is really very, very small (see Figure 11). Away from the work of inscriptions, subscriptions and transcriptions, no shifting in and out would be possible. We would be limited to a point. Are the social scientists who want us to place things *in* the bigger framework not asking us to commit suicide? Is it not the same as forcing us to eat and drink only aether, under the pretext that it is the staple of the universe?

FIGURE 11
The Relative Sizes of the 'Big Picture'



Either one abandons networks and is limited to one's own unmediated point of view, or one wishes to look at a bigger picture but then has to consider the end point of a network made up of long series of mediators.

The reason why this simple infra-physical argument is so hard for social scientists to grasp has to do with another belief, the belief in abstraction. When they claim that the 'big picture' includes the smaller ones, they do not take the word 'picture' literally but metaphorically. It means, for them, a view of the world, an abstraction that cannot be reduced to the lowly practices of building inscription devices.

It is one of the great powers of Einstein's text that it also throws light on the very process of abstraction. He is not only a master at managing spatial and temporal shifting, he is also very good at the third shifting, which is called, as the reader may recall, the actorial one. For instance, Einstein replaces coordinates by train and embankment, or walking men by beams of light, or trains and embankment by earth and sun (see Tables 2 and 4). The process by which abstract notions are replaced by characters is usually called, in semiotics, *figurativity*, or figuration. It is often said that one can tell a popular article from a scientific one by the number of figures (human or animal-like characters) that play parts in the stories. At face value, it seems that Einstein is writing a popular book, because he slowly takes us from trains and walking men all the way to abstract mathematics, thus following a strict hierarchy from concrete to abstract actants. One could claim that Einstein, like the Lord, masters the abstract structure but, knowing the weakness of his readers, feeds them figures, stories and parables instead.

However, Einstein's innovation for the third kind of shifting is as essential as for the two others. *There is no clearly recognizable hierarchy* in his text from one level of simple concrete metaphors to another more abstract one. The most abstract argument, about Gaussian coordinates, is also the one where the mollusc is introduced (p. 99). When he builds up a spacious chest in the middle of nowhere that is lifted by 'a being' through a constant force with a 'rope', this abstract thought experiment is supplemented with very concrete notations concerning what the man in the chest feels in his leg muscles (p. 66). These notations are not added for realism so as to make an ignorant reader swallow the pill of an abstract thought: they are crucial for the argument about the similarity between feeling acceleration and feeling gravitation. Even when he introduces four-dimensional Minkowski space (p. 57), it is to make its coordinates 'play exactly the same role as the Euclidean coordinates', reversing again the order between levels of abstraction.

The word 'abstraction' in Einstein's text does not refer to a certain type of figure, but to the very common activity of selecting in and out those details which are convenient. For instance, he starts with trains and embankment mirrors and clocks. Then (p. 31) the embankment is 'supplemented laterally and in a vertical direction by means of a framework of rods, so that an event which takes place anywhere can be localized with reference to this framework'. As to the train, it is elongated 'across the whole of space, so that every event, no matter how far off it may be, could also be localized with respect to the second framework'. Although the description of the embankment and of the train has already lost some realism, the author continues and 'disregard[s] the fact that in reality these frameworks would continually interfere with each other, owing to the impenetrability of solid bodies'. After these three transformations, the figures of the train and of the embankment have become geometric coordinates. Are these coordinates less figurative than the train and embankment? Are they more abstract? No, they simply have different details and keep only some of the elements of the train — the first story of the train having already retained but the barest details of the railway system of turn-of-the-century Switzerland. To find positions from one system of coordinates to another, the author again modifies the figuration and replaces the geometric coordinates by an algebraic notation — by Galilean transformation, which is a subset of the Lorentz one when the velocity of light is infinite. Are these equations more abstract or less figurative than the two or three earlier ones? No. They lose details which were considered irrelevant — like the colour of the curtains in the wagon or the price of the ticket — and add new details deemed more important — like the possibility of calculating for any value of x the corresponding value of x'.

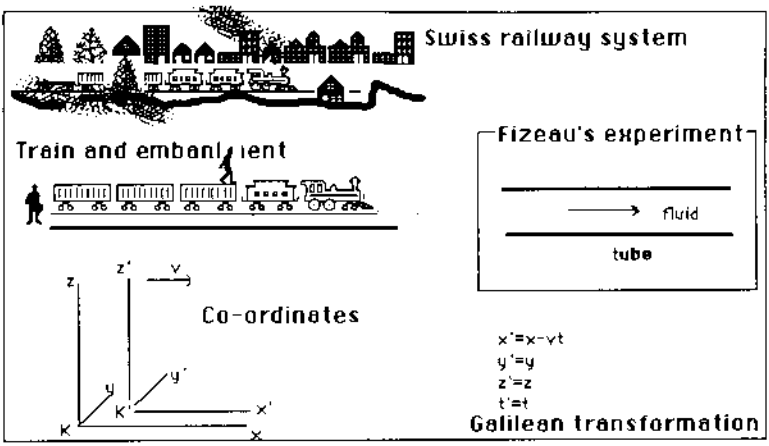
The most striking aspect of this reworking of the meaning of abstraction is offered by the confusion between thought-experiment and the experiments which, he says, have taken place in a laboratory. As a rule, the real experiments have *fewer* details and look more like what we would call a thought-experiment than the latter, which are, on the contrary, vividly described! For instance, Einstein moves from the equations of Maxwell's transformation to the experimental scenography, that of Fizeau:

> The tube *plays the part* of the railway embankment or of the co-ordinate system K, the liquid *plays the part* of the carriage or of the co-ordinate system K', and finally the light *plays the part* of the man walking along the carriage, or of the moving point in the present section. If we denote the velocity of the light relative to the tube by W, then this is given by the equation (A) or (B), according as the Galileo transformation [where c is infinite] or the Lorentz transformation [where c is finite] corresponds to the fact. Experiment decides in favor of equation (B) derived from the theory of relativity, and the *agreement* is indeed very exact. (p. 40, my stress)

Is this new experimental scene more figurative than the thought experiment of an elongated train, or the writing down of the equations? No, and the drawing that displays this real experimental laboratory is the most abstract of all!

Hierarchies between degrees of figuration, distinctions between actual and thought-experiments, shifts from popular accounts to more abstract ones, divides between theory and experiment — all this does not interest Einstein much. In Figure 12, Einstein does not try to order them on a scale from concrete figures to abstract ones. So what is it that interests him in shifting from one repertoire of figures to another one?

FIGURE 12
Non-Hierarchical Series of Figurations



Abstraction does not refer to one particular type of human or non-human-like figures, but to what is maintained through the non-hierarchical movement through various types of figures.

What counts for him is *what is maintained* through all these transformations from one figuration to the next. Going from train to embankment, from this story to coordinates, from them to equations, from these to thought-experiments, from these to real experiments, and maybe back to the circulation of trains — the only place where we ever experience non-accelerated regular translation — this is what is of paramount importance. The freedom of the enunciator counts, not the order of the figuration. But this problem of freedom is also the very question tackled in the text: how can one maintain everywhere in the same form the laws of Nature, so as practically to build some degree of universality for the centre's networks to expand? If we remember that the word 'metaphore' means displacement or transportation, we understand how fascinating is Einstein's use of these metaphors that manage to transport so much without deformation.

Abstraction, in this text, does not designate a list of non-human-like figures, but a reversible movement from any one list to any other that keeps some meaning intact in the process. More exactly, what we call 'meaning' is whatever is preserved in the movement through stories, and not *one* of the repertoires obtained after reaching at last one final story. This semiotic innovation is as important for our sociology of science as the other one on the spatial and temporal shifting. The 'big picture' is not given in one frame of reference, but in going from one frame to all the others through a network. Operations like thinking, abstracting, building pictures, are not *above* other practical operations like setting up instruments, arraying devices, laying rods, but are *in between* them. The vocabulary often used by cognitive and social sciences to describe mental operations is misleading. Abstraction does not designate a higher level of figuration but a fast *circulation* from one repertoire to another. It is not a property of the mind, it is a property of the networks. By reworking also the notion of abstraction, Einstein, in the present text, shows us a way of never leaving the firm ground of infra-physics, even when we enter the realm of abstraction.

Conclusion

Have we succeeded, as foreshadowed in the introduction, in opening, through the semiotic study of one semi-popular book by Einstein, a more direct and less laborious way to resume the strong programme? Although the answer is to be left to the reader, it should be made clear that this question has now taken the following form: have we succeeded in establishing a different, more equal, relation between social studies of science and Einstein's physics? To be sure, we learned a lot *from* Einstein for clarifying our own definition of society, of relativity, of context and of abstraction; but did we teach Einstein anything? No matter how presumptuous the question seems to be, it is the necessary counterpart of this more equal status the method requests. My claim would be that, without the enunciator's position (hidden in Einstein's account), and without the notion of centres of calculation, Einstein's own technical argument is ununderstandable; so is the reason why he prefers *above all* to maintain the forms of the natural laws against all transformations of space, time and characters. The forces that hold his argument together and that account for the passion generated in and by his arguments, need to be put back in place for the physics to make sense at all. To push the claim to its extremity, the metrological chains vastly expanded, accelerated, transformed and recombined by Einstein are in *our* social[23] space and not ours in *his*...

To demonstrate that this argument is not so presumptuous, we could show how simple is the solution it offers to some problems of interpretation that have plagued Einstein scholars. Einstein later recanted the Machian interpretation of special relativity, and took up a realist and absolutist metaphysics once he had reached general relativity. Did he change his mind? Had he disguised later his interest for Mach, or pretended earlier to be one of his disciples? Psychological or tactical interpretations are not necessary if my argument on capitalization is right: once obedient delegates flow effortlessly back and forth to the centre of calculation a new semiotic position is designed for a character that is an Einstein-God reaching without any problem the essence of physical reality. Once delegates are totally disciplined they count as nothing. Relativity and absolutism merge again, in the same way as we can reach someone else through long distance phone calls, no matter how many delegates we have in between, provided they are at once present, aligned and faithful. The same clarification occurs when we turn to this other commonplace of Einstein scholarship — that is, his rejection of quantum mechanics' philosophy. How come that this revolutionary joined the traditionalists' camp? Did he become less flexible with age? Again, psychological interpretations are too shallow. If the above argument is right, revolution and flexibility mean nothing when you want to discipline delegates once and for all. The philosophy of quantum mechanics re-introduced what Einstein had fought all along: independent and active observers, so active indeed that they influenced what they observe. . . This revival of relativism had to be opposed.

TABLE 1
List of the Marks of Enunciation in Einstein's Text
(only the marks that *personify* the author-in-the-text or the reader-in-the-text are noted below)

ENUNCIATOR (Author)		ENUNCIATEE (Reader)
		'you read' p.1
		'you remember with more respect'
		'you were chased by conscientious teachers'
		'you would regard with disdain' p.1
	'we feel constrained' p.2	
'If I analyse' p.5		
'I load my conscience with grave sin' p.9		
'I stand at the window'		
'I ask' 'we shun...we replace... we must honestly acknowledge'		
	'we must specify' p.10	
	'who would imagine' p.17	
'the thoughtful physicist plunged into the greatest difficulties'		
'If I ask you' p.21		'you will answer 'yes''
'If I now approach you'	'you find it not so easy'	
'I cannot be satisfied'		
'I allow myself to be deceived as a physicist' p.22		
'I would ask the reader not to proceed further'		
		'after thinking the matter you offer'
'I am very pleased'		'you cast a disdainful glance at me' p.23
		'these results must strike you' p.38
		'seized by a shuddering' p.55
	'every intellect must feel the temptation' p.61	
	'ought we to smile at the man?' p.67	
'I must warn the reader against a misconception' p.69		
	'no person can rest satisfied' p.71	
'I am standing in front of a gas range' p.72		
'I dare not withold it from the reader' p.78		
'I am guilty of a certain slovenliness' p.79		
		'this lays no small claims on the patience of the reader'id.
		'the reader will appreciate' p.83
		'if he is not too pedantic'
'I am thankfully surprised' p.84		
		'The reader may be anxious' p.94
		'After mature consideration the reader will admit' p.95

TABLE 2
List of Some of the Important Actants

Important objects
'Rods' chapter I and II
'Trafalgar Square, London' 'Earth' 'Clouds' 'Poles' p.6
'Train', 'embankment' 'falling stone'p.9
'trajectory' 'clocks'p.10
'the law of inertia' 'fixed stars' p.11
'a raven' p.12
'the note emitted by an organ pipe' p.11
'our old friend the railway carriage' p.16
'Lightning' p.21
'arrangement of two mirrors inclined at 90°' p.22
'Lorentz transformations' 'Galilei transformation' p.33
'world' p.55
'our old friend the railway carriage' has 'brakes' p.62
'stones' 'magnetic fields' 'gravitation' p.63
'earth' p64
'a spacious chest resembling a room' 'hook' 'ropes' p.67
'a gas range' 'a fire' 'a pan' p.72
'a plane circular disk which rotates' p.79
'a marble table' p.83
'a large number of little rods of equal lengths' p.83
a heated marble table p.85
'Gaussian co-ordinates' p.87
'mollusc of reference'

Human like actants
'I in the train' 'pedestrian on the embankment' p.9
'a man in the train'
'the Dutch astronomer De Sitter' p.17
'H.A. Lorentz' p.19
'an able meteorologist' p.21
'people travelling in the train' p.25
'an observer in the train' p.28
'the brilliant physicist Fizeau' p.39
'Minkowski' p.55
'an observer' 'a being' p.66
'opponents of the theory of relativity' p.76
'an observer who is sitting eccentrically' p79
'an observer who is at rest' p.80

Authorities
'As is well known' p.11
'The most careful observations have never revealed such anisotropic properties' 'This is a powerful argument in favour of the principle of relativity'p.15
'Every child at school knows' 'We know with great exactness that this velocity' p.17
'The epoch making theoretical investigations of H.A Lorentz... show that' 'Prominent theoretical physicists were therefore more inclined to reject...'p.19
Fizeau's measurement 'has been repeated since then by some of the best experimental physicists so that there can be no doubt about its result' p.39
'Experiment decides in favour of equation B' p. 40

TABLE 3
Work of Inscribing, Subscribing, Transcribing

'The practice of seeing in a 'distance' two marked positions on a practically rigid body' p.3
'we understand its validity for a construction with ruler and compasses'
'We can mark off the distance S time after time' p.5
'erecting a pole' p.7
'attaching', 'dropping', 'manipulating' p.7
'If I were to be commissioned to determine by observations whether in the actual case two events took place simultaneously' p.21
'This observer should be supplied with an arrangement of mirrors' p.22
'We understand by the 'time' of an event the reading... In this manner a time-value is associated with every event' p.24
'An observer...marking off his measuring rod in a straight lines many times as is necessary to take him from the one marked point to the other. Then the number which tells us how often the rod has to be laid down is the required distance' p.28
'The magnitudes $x,y,z,t,$ are nothing more nor less than the results of measurements obtainable by means of measuring-rods and clocks' p.36
'The four dimensional continuum...shows a prounounced relationship to the three dimensional continuum of Euclidean geometrical space....We must replace the usual time co-ordinate t by an imaginary magnitude ...' p.57
'an observer equipped with apparatus' p.66
'tension of a rope' p.67
Building up squares with ropes on marble table p.83
'To every point of a continuum are assigned as many numbers...as the continuum has dimensions. This is done in such a way, that only one meaning can be attached to the assignment' p.90
'Every physical description resolves itself into a number of statements, each of which refers to the space-time coincidence of two events A and B' p.95
'Thus in reality the description of the time-space continuum by means of Gauss co-ordinates completely replaces the descriptions with the aid of a body of reference' p.96
'We learn the behaviour of measuring-rods and clocks and also of freely-moving material points ...simply by mathematical transformation' p.100

TABLE 4
Figurativity

'we see that it will be advantageous if, in the description of a position, it should be possible by means of numerical measures to make ourselves independent of the existence of marked positions (possessing names) on the rigid body of reference' p.7
the flying raven :'Expressed in an abstract manner we may say: If a mass m is moving uniformly...' p.12
'Now in virtue of its motion in an orbit around the sun our earth is comparable with a railway carriage travelling with a velocity of about 30 km per second' p.15
train and embankment 'We shall imagine that the air above it to have been removed... The ray of light <u>plays the part</u> of the man walking along relatively to the carriage' p.18
'Up to the present we have only considered events taking place along the embankment,..we can imagine this reference body suppplemented laterally by means of a framework of rods' 'we can imagine the train ..continued across the whole of space' we can disregard the fact that in reality these framework would continually interfere' p.31
'<u>In place of</u> the man walking inside the carriage we <u>introduce</u> a point moving relatively to the co-ordinate systems' p.38
'The tube <u>plays the part</u> of the railway embankment or of the co-ordinate system K, the liquid <u>plays the part</u> of the carriage or of the co-ordinate system K', and finally the light <u>plays the part</u> of the man walking along the carriage, or of the moving point in the present section. ' p.40
'The natural laws satisfying the demands of the special theory of relativity assume mathematical forms, in which the time <u>plays exactly the same role</u> as the three space co-ordinates' p.57
'By means of purely theoretical operations (i.e. simply by calculation) we are then able to find...' p.74

TABLE 5

Main Shiftings Out and In Associated with a Scenography

p.4 et seq. : sequence at Trafalgar Square of a man equipped with a rod building up the scaffold necessary for any event to be transformed in readings;
p.9 et seq. : sequence of the author throwing a stone from a train while a pedestrian on the embankment observes; the two characters then try to make their observations coincide (*shifting in*).
p.10. : sequence which makes either the stars or the earth move into a circle depending on the point of reference chosen.
p.12: sequence of the flying raven above a train observed by the man in the train.
p.16: sequence of the man walking in the train while the man on the embankment tries to measure his velocity relative to the train and relative to the embankment.
p.21 et seq.: sequence of the heated discussions between the author, meteorologists, man in the train, and man on the embankment, to decide if events are simultaneous
p.26.: same sequence but with beams of light
p.27.: sequence of the man measuring the train with a rod while the man on the embankment tries to superimpose his own measurement of the train.
p.31: sequence of the transformation of a train embankment scene into a co-ordinate system.
p.40: sequence of Fizeau's experiment which is superimposed to the train embankment earlier scenes.
p.66 et seq.: sequence of the accelerated chest and of the experiments imagined in it by the man and out of it by another observer at rest; the author and the readers are making comments on the errors they both make.
p.72: sequence of the author puzzling over a gas range.
p.75: sequence of a planned experiment to be done with a solar eclipse.

TABLE 6

List of the Main Trials and Structure of the Text

Eliminated through trials	Dilemmas	Maintained through trials
absolute truth is out (p.3)		
absolute space is out (p.8)		
		natural phenomena run their courses according to the same general laws: principle of relativity p.13
	either we reject the principle of relativity or the experiments that detect no rôle for the direction of motion p.15	
		principle of relativity disproven by no experiment p.15 p.19
	Dramatisation: either we reject the principle of relativity or we reject the well established speed of light p.19 **Resolution of the drama**: 'Enter the ***theory*** of relativity... No incompatibility between the principle of rel. and the speed of light'	
absolute time is out p.26		
		what is kept is simultaneity relative to a reference body p.26
absolute distance is out p.27		
let's drop independence from the condition of motion p.30		

How should we modify the theorem of the addition of velocities to keep the principle of rel.? p.30

what is kept is Lorentz's transformation p.33

Let's keep Fizeau's result about speed of light p.41

Classical mechanics is transformed p.42
Principle of relativity is out

Object of value:
'General laws of nature are co-variant with respect to Lorentz transformation' p.43

Aether and specially favoured co-ordinates are out p.53
'*Time* is robbed of its independence' p.56

What is kept in practice is Minkowski's formulation p.57

Relativity without him 'would not have got farther than its long clothes' p.57

Let's go further than uniform rectilinear and non rotary motions p.61

New trial: Can we do it for ***all*** bodies of reference? p.61
We seem forced to discard the theory of rel. and grant absolute physical reality to non-uniform motions p.62

Distinction between inertia and gravitation is discarded p.69
Classical mechanics and theory of rel. are unsatisfactory p.72

Dramatisation: Is the theory of relativity laid in the dust? p.76

The special theory is not overthrown but survives in the other as a limiting case p.77

It seems that general relativity itself is called into question p.82

Cartesian co-ordinates are out p.85

Gaussian co-ordinates are kept p.87

The law of the constancy of the velocity of light cannot be maintained p.93
What lead us in the special theory of rel. is invalidated p.93
Exit the Euclidean continuum

Description with Gaussian co-ordinates replaces Euclidean continua p.96

Final dramatisation: the general theory has to be reformulated without rigid reference bodies p.97

Rigid reference bodies out

Object of value:
'All Gaussian co-ordinate systems are essentially equivalent for the formulation of the general laws of nature' p. 97

Final heroes who passed through all trials:
Molluscs who have equal rights and equal success,
laws which are independent of the choice of the mollusc,
the great power of relativity which lies in its comprehensive limitation p.99

• NOTES

I apologize to all Einstein scholars for this 'underrealist' portrayal of their hero. The main ideas of this paper have been obtained through discussions with Michel Callon, Isabelle Stengers and François Bastide. I am also grateful to Mannar Hammad for his insights on delegated observers, and to Jim Griesemer for his spirited defence of realism. Mike Lynch, Trevor Pinch and Leigh Star provided useful comments on the final draft. I thank Geoffrey Bowker for correcting the English. He was so entirely unconvinced by the argument against social context that he simply muttered 'appure si muove. . .'!

1. See the pioneering work of David Bloor, *Knowledge and Social Imagery* (London: Routledge & Kegan Paul, 1976); Sal Restivo, 'The Social Roots of Pure Mathematics: A Contribution to the Sociology of Ideas and Minds' (mimeo, 1986); and the field study of Eric Livingstone, *The Ethnomethodological Foundations of Mathematics* (London: Routledge & Kegan Paul, 1985). A different but more complete, much more empirically grounded argument is to be found in J. Lave, *Culture, Cognition and Practice* (Cambridge: Cambridge University Press, in press).

2. For this redefinition of the principle of symmetry, see B. Latour, *Science in Action* (Milton Keynes, Bucks.: Open University Press, 1987).

3. B. Latour, *The Pasteurization of France*, followed by *Irreductions: A Politico-Scientific Essay* (Cambridge, MA: Harvard University Press, in press).

4. See L. S. Feuer, *Einstein and the Generations of Science* (New York: Basic Books, 1974). There are many other interesting aspects in Feuer's book about the notion of revolution, and conflicts between generations, that I have no room to do justice to here.

5. I use throughout the following edition: A. Einstein, *Relativity: The Special and the General Theory* (London: Methuen, first edn 1920, paperback 1960). All page numbers refer to this edition.

6. For an introduction to the semiotics of scientific texts, see F. Bastide, 'Introduction to Semiotics of Scientific Texts' (Paris: Centre de Sociologie de l'Innovation, mimeo, 1985). For the definition of the terms used in this paper, see A. Greimas and J. Courtès, trans. L. Chris et al., *Semiotics and Language: Analytical Dictionary* (Bloomington, IN: Indiana University Press, 1983).

7. A large body of literature now exists on the scientific literature. Apart from Bastide, op. cit. note 6, see M. Callon, J. Law and A. Rip (eds), *Mapping the Dynamics of Science and Technology* (London: Macmillan, 1986).

8. B. Latour, 'Visualisation and Cognition', in H. Kuklick (ed.), *Knowledge and Society: Studies in the Sociology of Culture Past and Present*, Vol. 6 (1986), 1–40.

9. For an extensive collection of the work done at the time on visualization and cognition, see B. Latour and J. de Noblet (eds), *Les 'Vues' de l'esprit*, Visualisation et connaissance scientifique, *Culture technique*, No. 14 (1985); see also M. Lynch, 'Discipline and the Material Form of Images: An Analysis of Scientific Visibility', *Social Studies of Science*, Vol. 15 (1985), 37–66.

10. Greimas & Courtès, op. cit. note 6.

11. I am perfectly well aware that this paper depends on a Machian interpretation by Einstein of his own work, an interpretation that he later recanted: see G. Holton, *Thematic Origins of Scientific Thought: Kepler to Einstein* (Cambridge, MA: Harvard University Press, 1973). Once again, semiotics is concerned with what the text does, not with what the enunciator thinks.

12. On the semiotic reason why this third frame is always necessary, see M. Hammad, 'Le petit bonhomme d'Ampere', in *Actes sémiotiques*, Vol. 7, No. 33 (1985), 37–45. Most of the difficulties related to the ancient history of the inertia principle are related to the existence of two frames only; the solution is always to add a third frame that collects the information sent by the two others: see M. A. Tonnelat, *Histoire du principe de relativité* (Paris: Flammarion, 1971).

13. Literally, what is written under another writing. 'Underwritten', like the French word 'souscription', also means the pledge that other subscribers or underwriters make to support someone's credit.

14. This is not what semioticians, obsessed by literary texts, usually do, but it is one of the extensions that it is necessary to make to Greimas's semiotics in order to be true to his own claims (see, below, the related argument about context).

15. I am following here James R. Fleming, 'Meteorology at the Smithsonian, 1847–1874: The Natural History Connection', paper presented at the 1986 HSS/SHOT/PSA/4S Meeting (Pittsburgh, PA, October 1986).

16. See the marvellous paper by L. Star, J. Griesemer and E. Gerson, 'Linking Concepts with Work Organization: Natural History and Ecological Theory', presented at the 1986 HSS/SHOT/PSA/4S Meeting (Pittsburgh, PA, October 1986), on the problem of disciplining naturalists and trappers. Classic examples of the necessity to discipline observers in order to build long-distance networks may be found in A. Chandler, *The Visible Hand* (Cambridge, MA: The Belknap Press of Harvard University Press, 1977). As expected, the very building of railroads required a complete reworking of inscriptions, subscriptions and transcriptions: 'By an arrangement now perfected,' quotes Chandler (104), 'the superintendent [of the railroad] can tell at any hour in the day, the precise location of every car and engine on the line of the road, and the duty it is performing.'

17. See Latour, op. cit. note 2. See also J. Law, 'On the Methods of Long-Distance Control' in Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge, Sociological Review Monograph* No. 32 (London: Routledge & Kegan Paul, 1986), 234–63; and Star, Griesemer & Gerson, op. cit. note 16.

18. For a critique of the political notion, see F. Furet, *Penser la Révolution Française* (Paris: Gallimard, 1978), translated as *Interpreting the French Revolution* (Cambridge: Cambridge University Press, 1981); about the scientific notion, see Holton, op. cit. note 11.

19. M. Lynch, in his *Art and Artifact in Laboratory Science: A Study of Shop Work and Shop Talk in a Research Laboratory* (London: Routledge & Kegan Paul, 1985), has presented the most radical critique so far of the 'social science' used to implement social studies of science. His main argument is that there is nothing social in the content of science but its very technical content itself. Imposing sociological notions is thus either a trivial repetition of the sociologists' prejudices, or an ignorance of the specific technical content.

20. This appears to me, at the moment, to be the only solution to the various difficulties raised by the problem of reflexivity (see S. Woolgar [ed.], *Knowledge and Reflexivity* [London: Sage, in press]), and by the symmetry between nature and society. Since we should offer neither a repetition of the tribe's language, nor a metalinguistic explanation, some sort of hybridization is necessary.

21. See especially H. Collins's asymmetric argument that Nature plays no role, but society a major one, in the settlement of scientific controversy, in his *Changing Order: Replication and Induction in Scientific Practice* (London: Sage, 1985). The classic version remains Bloor, op. cit. note 1. This presentation of relativity should not be confused with the principle of irreducibility I have offered earlier (op. cit. note 3, second Part, 2.1.1).

The building up of equivalences is what interested me there. Here, the main metrological chains that keep equivalence aligned are already in place.

22. For a recent presentation of the 'aether' argument about the necessary (macro and Marxist) context of all social studies of science, see S. Russell, 'The Social Construction of Artefacts: A Response to Pinch and Bijker', *Social Studies of Science*, Vol. 16, No. 2 (May 1986), 331–46.

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