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The Couch, the Cathedral, and the Laboratory: On the Relationship between Experiment and Laboratory in Science

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Introduction

Scientific laboratories have become a popular subject in social studies of contemporary science. From a status of nearly complete neglect only one decade ago they have risen to the center of analysts' attention and have given their name to a whole approach in the new sociology of science. Part of the reason for this surely lies in the general reorientation of the field in the early seventies, as a consequence of which sociologists have begun to include in their study the technical content of science and the "hard core" of scientific activity, the process of knowledge production. But this is not the whole story. In many ways the notion of a scientific laboratory in sociology of science stands for what in history and methodology of science has long been the notion of "experiment." Why should sociologists, latecomers to the study of science, choose a focus that is so clearly different from the one that earlier fields have found useful? And is there a theoretically interesting difference between the notion of an experiment and the notion of a laboratory? Or have the different fields merely chosen different labels for what is basically an orientation to the same phenomenon, knowledge production?

I shall seek an answer to this question by drawing upon the literature on laboratories and upon my own recent research in particle physics and molecular genetics.[1] My strategy in developing an answer will be twofold. I shall first summarize the theoretical relevance of the notion of a laboratory as compared to received notions of experiment. I shall argue that far from being just the physical space in which experiments are conducted, laboratories have

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1. This work is summarized in Amann 1990 and Knorr Cetina 1992.

emerged as carrying a systematic "weight" in our understanding of science.[2] This weight can be linked to the reconfiguration of the natural and social order which in my opinion constitutes a laboratory. In the second part of the paper I shall show how the instrumental shape of laboratories differs across areas of investigation in connection with these reconfigurations, and how this is associated with the "technology" employed in experimentation. As a consequence of this situation, laboratories and experiments combine differently in different fields: for example, each may be the principal agent that defines the situation, or both may be equals in a segmentary organization.

The Theoretical Relevance of Laboratories: The Malleability of Natural Objects

Why should the study of laboratories be important to the study of science, and what do laboratories account for that is not accounted for by experiment? It seems that experiments have until recently carried much of the epistemological burden in explaining the validity of scientific results and rational belief in science. This has been largely unquestioned, and it is founded upon methodology rather than upon the history or sociology of experimentation. The advantages attributed to experiments on methodological grounds include the fact that experiments disentangle variables and test them in isolation, that they use comparison and justify results through replication, or that they exclude, through blind or double-blind designs, experimenter bias and subjective expectations. As a result, experiments were thought to be capable of establishing or disestablishing hypotheses and of deciding, as crucial experiments, between competing theories. With this methodological rationale in place, the real-time processes of experimentation in different fields and at different times remained largely unexamined.[3]

When the first laboratory studies turned to the notion of a laboratory, they opened up a new field of investigation not covered by the methodology of experimentation. For them the notion of a laboratory played a role which the notion of experiment, given its methodological entrenchment, could not fulfill: it shifted the focus away from methodology and toward the study of the cultural activity of science. The focus upon laboratories has allowed us to consider experimental activity within the wider context of equipment and symbolic practices within which the conduct of science is located without reverting to the traditional concerns of the study of scientific organizations. In other words, the study of laboratories has brought to the fore the full spectrum of activities involved in the production of knowledge. It showed that scientific objects are not only "technically" manufactured in laboratories but are also inextricably symbolically or politically construed, for example, through literary techniques of persuasion such as one finds embodied in scientific papers, through the political stratagems of scientists in forming alliances and mobilizing resources, or through the selections and decision translations which "build" scientific findings from within.[4] An implication of this has been the awareness that in reaching its goals, research "intervenes" (to use Hacking's terminology)[5] not only in the natural world but also—and deeply—in the social world. Another implication is that the products of science themselves have come to be seen as cultural entities rather than as natural givens discovered by science. If the practices observed in laboratories were cultural in the sense that they could not be reduced to the application of methodological rules, the facts which were the consequence of these practices also had to be seen as shaped by culture.

Thus the laboratory has served as the place in which the separate concerns of methodology and other areas such as organizational sociology could be seen as dissolved in cultural practices which were neither methodological nor social-organizational but something else that needed to be conceptualized and that encompassed an abundance of activities and aspects that social studies of science had not previously concerned themselves with. But the significance of the

2. This weight has not been systematically spelled out in recent surveys of the field. For examples of such surveys, see Knorr Cetina and Mulkay 1983, Giere 1988, and Cole 1990.

3. While this has recently changed on a noticeable scale, it has changed in the wake of laboratory studies and the turn toward the cultural study of scientific work which they promoted, and in the wake of other approaches within the new sociology of science. For an example of recent studies of experimentation, sec Gooding et al. 1989. For some earlier cultural studies of experimentation see Collins 1975, Pickering 1984, and Shapin and Schaffer 1985.

4. The laboratory studies which have argued these points most forcefully arc by Latour and Woolgar (1979), Knorr (1977); Knorr Cetina (1981), Zenzen and Rcstivo (1982), and Lynch (1985). For an illustration of the political nature of science see also Shapin 1979 and Wade 1981. For a more anthropological study of scientific laboratories see Traweek 1988.

5. Hacking (1983) draws a distinction between experiments which "intervene" and scientific theories which "represent." This distinction, however, does not give adequate weight to the instrumental use of theories in experimentation or to the fact that some experiments, as we shall see later, focus upon representation rather than intervention.

notion of a laboratory lies not only in the fact that it has opened up this field of investigation and offered a cultural framework for plowing this field. It lies also in the fact that the laboratory itself has become a theoretical notion in our understanding of science. According to this perspective, the laboratory is itself an important agent of scientific development. In relevant studies, the laboratory is the locus of mechanisms and processes which can be taken to account for the success of science. Characteristically, these mechanisms and processes are nonmethodological and mundane. They appear to have nothing to do with a special scientific logic of procedure, with rationality, or with what is generally meant by "validation." The hallmark of these mechanisms and processes is that they imply, to use Merleau-Ponty's terminology, a reconfiguration of the system of "self-others-things," of the "phenomenal field" in which experience is made in science.[6] As a consequence of these reconfigurations, the structure of symmetry relationships which obtains between the social order and the natural order, between actors and environments, is changed. To be sure, it is changed only temporarily and within the walls of the laboratory. But it appears to be changed in ways which yield epistemic profit for science.

What do I mean by the reconfiguration of the system of "self-others-things," and how does this reconfiguration come about? The system of self-others-things for Merleau-Ponty is not the objective world independent of human actors or the inner world of subjective impressions, but the world-experienced-by or the world-related-to agents.[7] What laboratory studies suggest is that the laboratory is a means of changing the world-related-to-agents in ways which allow scientists to capitalize on their human constraints and sociocultural restrictions. The laboratory is an enhanced environment which improves upon the natural order in relation to the social order. How does this improvement come about? Laboratory studies suggest that it rests upon the *malleability* of natural objects. Laboratories use the phenomenon that objects are not fixed entities which have to be taken as they are or left to themselves. In fact, laboratories rarely work with objects as they occur in nature. Rather they work with object images or with their visual, auditory, electrical, etc., traces, with their components, their extractions, their purified versions.

6. Merleau-Ponty's original notion in the French version of his book is "le system 'Moi-Autrui-les choses'" (1945, 69). For the English translation and the exposition of this concept see Merleau-Ponty (1962, chap. 5, and p. 57).

7. For example, a culture in which artificial light is available will have a means of extending the day and as a consequence will experience the world differently than a culture without artificial light.

There are at least three features of natural objects which a laboratory science does not need to accomodate: First, it does not need to put up with the object *as it is;* it can substitute all of its less literal or partial versions, as illustrated above. Second, it does not need to accommodate the natural object *where it is,* anchored in a natural environment; laboratory sciences bring objects *home* and manipulate them on their own terms in the laboratory. Third, a laboratory science does not need to accomodate an event *when it happens;* it docs not need to put up with natural cycles of occurrence but can try to make them happen frequently enough for continuous study. Of course the history of science is also a history of varying opportunities and successes in accomplishing these transitions. But it should be clear that it is escaping the need to accommodate objects within the natural order which laboratory studies suggest is epistemically advantageous; it is the detachment of the objects from a natural environment and their installation in a new phenomenal field defined by social agents.

Consider an example. Astronomy by common definition used to be something like a field science. For a long time, astronomers were restricted to observation, even though since Galileo it was observation aided by a telescope. Now for more than a century astronomers have also used an imaging technology, the photographic plate, with the help of which photons of light emitted by stellar bodies can be captured and analyzed. Astronomy therefore appears to have been transformed from a science which surveys natural phenomena into a science which processes images of phenomena. Further developments of imaging technology since 1976 have resulted in a replacement of the photographic plate by CCD (charge-coupled device) chips.[8] For example, the light of Halley's comet in 1982 was collected by the gigantic two-hundred-inch mirror of the Hale telescope on Mount Palomar and was focused on CCDs. CCD chips constitute a major change in imaging technology. They have digitalized outputs and thus enable astronomers to transfer and process their data electronically. If CCDs are used with space telescopes, they not only improve astronomers' data but they render astronomy completely independent of the direct observation of its field. Once the transition is complete, astronomy will have been transformed from an observational field science to an image-processing laboratory science.[9]

8. See Smith and Tatarewicz 1985 for a summary of this development.

9. I leave open the question, which cannot be answered at this point, of whether all of scientific astronomy will switch to space telescopes. It is likely that, as with

What reconfiguration of the phenomenal field of astronomy is achieved in this process of transformation? At least the following changes are apparent:

1. Through being imaged, the objects of investigation become detached from their natural environment and are made to be continually present and available for inquiry in the laboratory; through digitalization and computer networks, the availability of the same data is extended to potentially the whole of the scientific community;

2. Through the transition to a literary technology, the processes of interest to astronomers become miniaturized;

3. Planetary and stellar time scales become social-order time scales. Astronomers all over the world who are connected to the electronic networks can now process and analyze stellar and planetary responses in parallel and continually.

The point is that with all these changes, astronomy still has not become an experimental science. The processes described all pertain to laboratories; they enable investigations to be performed in one place, without regard to natural conditions (e.g., weather, seasonal changes, regional differences in visibility, etc.), subject only to the contingencies of local situations (e.g., to the speed and the local resources that scientists can bring to bear on the work). In other words, laboratories allow for some kind of homing in of natural processes,- the processes are "brought home" and made subject only to the local conditions of the social order. The power of the laboratory (but of course also its restrictions) resides precisely in its enculturation of natural objects. The laboratory subjects natural conditions to a social overhaul and derives epistemic effects from the new situation.

Playing upon the Social Order: Enhanced Agents

But laboratories not only improve upon the natural order; they also upgrade the social order in the laboratory, in a sense which has been neglected in the literature on laboratories. Received notions of science conceived of the social as extraneous and possibly averse to science. As Bloor (1976, 141) points out, social factors were brought into the picture only to explain incorrect scientific results but never to explain correct ones. The new sociology of science has eliminated this "asymmetry" in favor of models which stress the interweaving of social and scientific interests (e.g., MacKenzie 1981; Pickering 1984) and generally consider social and political strategies as part and parcel of scientists' conduct (e.g., Latour 1987). Yet studies of laboratory science have failed to specify how features of the social world, and more generally of everyday life, become played upon and turned into epistemic devices in the production of knowledge. Phrased differently, the social is not merely "also there" in science. Rather, it is capitalized upon and upgraded to become an instrument of scientific work. If we see laboratory processes as processes which align the natural order with the social order by creating reconfigured, "workable" objects in relation to agents of a given time and place, we also have to see how laboratories install "reconfigured" scientists who become workable (feasible) in relation to these objects. In the laboratory, it is not the scientist who is the counterpart of these objects. Rather it is agents enhanced in various ways so as to fit a particular emerging order of self-other-things, a particular ethnomethodology of a phenomenal field. Not only objects but also scientists are malleable with respect to a spectrum of behavioral possibilities. In the laboratory, scientists are "methods" of going about inquiry; they are part of a field's research strategy and a technical device in the production of knowledge.

How arc aspects of the social order being reconfigured? Consider the scientist turned into a measurement device. By common assent, consciousness and perhaps also intentionality are defining characteristics of human beings. For example, many of the demarcationist battles waged against the programs and promises of artificial intelligence rest upon arguments from human consciousness and intentionality and draw out their manifold implications (e.g., Searle 1983). Since the computer is not a conscious, intentional actor—or so the argument goes—it will never develop the full mental capacities of human agents. Or consider one of the most basic concepts in the social sciences, the concept of action. There appears to be no definition of action which does not presuppose (conscious) intentions. In fact, meaningful intentions serve as the distinguishing characteristic which differentiates action from behavior, and which thereby delimits what is of interest to social science and what is not. Yet in molecular biology laboratories, scientists are often featured in ways which contradict these assumptions. For example, scientists figure prominently as *repositories of unconscious experience* whose responsibility it is to develop an embodied sense for resolving certain problem situations. These situations obtain when a circular relationship between procedure and outcome arises such that to op-

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older observational technologies, photographic-plate astronomy, just **like** observation through hand-manipulated telescopes, will become a "backyard" astronomy.

timize a methodological procedure one would have to know its outcome, but of course to get to know the outcome is the whole point oi optimizing the procedure.

Let me *give an* example.[10] *In* molecular genetics, *gel* electrophoresis is a method for separating DNA and RNA fragments of different lengths in a gel on which an X-ray film is exposed. As a result of the procedure, one gets blackish and whitish bands which are most clearly distinguishable in the middle of the matrix which the film represents; at the bottom of the film, bands tend to be drawn apart, and on top they tend to stick together and may in fact become indistinguishable. Thus, to obtain a good resolution and highly analyzable and publishable results, one should place the bands of interest in the middle of the matrix. And to achieve this, the gel run must be stopped exactly when the fragments of interest appear in the right place—which, however, is possible only if one knows the length of the expected fragments (and bands) in advance. But this, of course, is never the case, since it is precisely the goal of the gel run to determine the length of the fragments one is interested in. Thus the circular relationship between gel run and its outcome results from the fact that the optics of the gel can only be optimized through knowledge of the expected bands, while at the same time the optics is already presupposed in any attempt to determine the bands.

There arc several ways in which we can deal with this situation. For example, we can break up the circle by dividing it into its components and then run several subtests simultaneously in order to place limits around what will be a likely outcome; to know the range of likely outcomes is often sufficient to adequately fine-tune a method. Thus scientists can try to identify the procedure most likely to yield optimum results by varying the crucial ingredients and running many tests in parallel before choosing a final method. Alternatively to the breakup strategy, we can choose a framing strategy to deal with the problem, for example, by turning to theory or computer simulation to discover the likely range of the results of interest. Molecular biologists mostly do not do simulations, and there are no phenomenological theories closely linked to experiments such that they would be helpful for molecular biologists. Hence the framing strategy is not an option. On the other hand, molecular biologists do not want to use the circle breakup strategy either. Their reluctance is based on the shared assumption that systematic breakup strategies are too time-consuming. For example, running several subtests simultaneously to determine an optimum procedure usually means not only that there are more tests to be performed but also that the number of preparatory steps needed to obtain the reaction mixes for the subtests grows by a factor x, and depending on how many steps are involved in preparing a reaction mix, the total number of tasks can be large. Molecular biologists reason that it is not only the number of tasks that grows proportionately with such a strategy. Also each step in a multiply layered procedure would be affected by the difficulty and uncertainty of having to work in the absence of appropriately delimited expectations, and thus each step would be subject to the same sources of error as the original problem. The susceptibility to error multiplies with the number of steps.

Given such reasoning, molecular biologists situate themselves somewhere between what they perceive as the methodical-systematic strategy of breaking up the circle and the framing strategy which I described above. The intermediate method which they turn to is that of the *holistic gloss:* they leave it to individual scientists to develop a sense for a reasonable strategy in response to the challenge. Scientists are expected to make a good guess about what procedure might work best and to thereby optimize procedures holistically (without attempting systematic optimization of substeps) and locally (without recourse to procedurally external sources like theory or simulation). The required sense of successful procedure draws heavily upon an individual's experience: upon the prognostic knowledge which individuals must somehow synthesize from features of their previous experience, and which remains implicit, embodied, and encapsulated within the person. It is a knowledge which draws upon scientists' *bodies* rather than their minds. Consciousness and even intentionality are left out of the picture. And there is no native theory as to what this body without mind is doing, or should be doing, when it develops sense.

My point is that we have to be prepared to encounter scientists who function as instruments or objects in the laboratory, or as illustrated elsewhere, as collective organisms, just as we have to be prepared to encounter organisms that have been transformed into images, extractions, or agents. By the time the reconfigurations of self-others-things which constitute laboratories have taken place, we are confronted with a new emerging order that is neither social nor natural, an order whose components have mixed genealogies and continue to change shape as laboratory work goes on.

10. For a full ethnography of the molecular biology laboratory from which this and other examples in this paper are derived, see **Amann** 1990.

Types of Reconfigurations: From Laboratory to Experiment

What I have said so far refers to laboratory processes in general. I have neglected the phenomenon whereby concrete laboratory reconfigurations are shaped in relation to the kind of work which goes on within the laboratory. This is where experiments come into the picture; through the technology they use, experiments embody and respond to reconfigurations of the natural and social order. In this section, I will draw attention to three different types of laboratories and experiment in the contemporary sciences of particle physics, molecular biology, and the social sciences. In distinguishing between these types, I shall take as my starting point the constructions placed upon natural objects in these different areas of science and their embodiment in the respective technologies of experimentation. I want to show how, in connection with these different constructions, laboratories and experiments become very different entities and enter very different kinds of relationships with each other. For one thing, laboratories and experiments can encompass more-or-less distinctive, more-or-less independent activities: they can be assembled into separate characters which confront and play upon each other, or disassembled to the degree to which they appear to be mere aspects of one another.[11] For another thing, the relationship between local scientific practice and environment also changes as laboratories and experiments are differently assembled. In other words, reconfigurations of the natural and social order can in fact *not* be entirely contained in the laboratory space. Scientific fields are composed of more than one laboratory and more than one experiment; the reconfigurations established in local units have implications for the kind of relationship which emerges between these units, and beyond.

In the following, I shall only document some of these issues in a most cursory manner. My point is to draw attention to and to illustrate some of these matters rather than to provide a full analysis of a complex issue.[12] What I want to draw attention to in this section are the diverse *meanings* of "experiment" and "laboratory" which are indicated in different reconfigurations, and which have been generally ignored in recent empirical studies of science.[13] I want to indicate the differential significance and the mutual relationship of laboratories and experiments in three situations, which I distinguish in terms of whether they use a technology of representation, a technology of treatments and interventions, or a technology of signification. The construction placed upon the objects of research varies accordingly,- in the first case, objects in the laboratory are *representations,* of real-world phenomena; in the second, they are *processed partial versions* of these phenomena; in the third, they are *signatures* of the events of interest to science. Note that the distinctions drawn are not meant to point to some essential differences between fields but rather attempt to capture how objects are primarily featured and attended to in different areas of research. To illustrate the differences, and to emphasize the continuity between mechanisms at work within science and outside of it, I shall first draw upon examples of laboratories and experimentation invoked outside natural science, those of the psychoanalyst's couch, the twelfth-and-thirteenth century cathedral, and the military war game.

11. It is clear that we can have laboratories without experiments as traditionally understood, as in the science of astronomy or in the many cases of nonresearch laboratories in which specimens are merely tested. And we know that experiments may occur in nonlaboratory settings, for example, as natural experiments. Rut even when laboratories and experiments tend to go together, as in the examples to be discussed, there can be different matches and combinations.

12. For a detailed analysis and documentation of these issues, see Knorr Cetina 1992.

Experiments (almost) without laboratory: construing objects as representations

I begin with the war game. The hallmark of a war game in the past was that it took place on a sand table, a kind of sandbox on legs in which the geographic features of a potential battle area were built out of sand and whole battles were fought between hostile toy armies. The setup and the action were similar to the actual terrain and the likely movements of soldiers. The landscape made of sand had to be modeled on the supposed spot of a real enemy engagement in all relevant respects, and the movements made by the toy armies had to correspond as closely as possible to the expected moves of real soldiers. The war game in the sandbox was an invention of the eighteenth century which was developed further by Prussian generals. Its modern equivalent is the computer simulation. This has become widely used not only in the military but in many areas of science in which real tryouts are impracticable for one reason or another. Computer simulations are also increasingly used in laboratory sciences to simulate experiments,- indeed, the computer has been called a laboratory in descriptions of this development (e.g., Hut and Sussman 1987).

13. Philosophers have started to devote some attention to the issue. See, among others, Hacking 1983.

The point here is that many real-time laboratory experiments bear exactly the same kind of relationship to the reality they deal with as the war game on the sand table bears to the real engagement, or the computer simulation bears to the action that is simulated: they *represent* the action. As an example, consider most experiments in the social sciences, particularly in social psychology, in economics, in research on problem-solving, and the like. To illustrate, experimental research on jury decision making uses mock juries; in these experiments, participants (mostly college students) are asked to reach judgments on a simulated trial.[14] Research on the heuristics of problem solving sets up simulated problem situations and asks participants to search for a solution to the problem.[15] Social science experiments, as is well known, characteristically get the same criticism as computer simulations: what is usually questioned is whether generalizable results can be reached by studying mock reality behaviors when the factors distinguishing this mock reality from real-time events are not known or have not been assessed.

Aware of this criticism, researchers in these areas take great care to design experimental reality so that in all relevant respects they come close to perceived real-time processes. In other words, they exemplify and deploy *a technology of representation.* For example, they set up a system of assurances through which correct correspondence with the world is monitored, and they set up procedures designed to implement the proper performance simulation of the world. One outstanding characteristic of this system of assurances is that it is based on a theory of nonintervention. In blind and double-blind designs, researchers attempt to eradicate the very possibility that the researcher will influence the outcomes of the experiments. In fact experimental design consists in, on the one hand, implementing a world simulation and, on the other hand, implementing a thorough separation between the action of experimental subjects, which is to take its natural course, and the action, interests, and interpretations of the researchers.

Consider the laboratory in these situations. It does not as a rule involve a richly elaborated space, a place densely stacked with instruments and materials and populated by researchers. In many social sciences, the laboratory reduces to the provision of a one-way mirror in a room that includes perhaps a table and some seating

14. **Ail** example of this kind of research can be found in MacCoun 1989.

15. For a review of the literature in this area, see, for example, **Kahneman,** Slovic, and Tversky 1982.

facilities. In fact, experiments may be conducted in researchers' offices when a one-way mirror is not essential. But even when a separate laboratory space exists, it tends to become activated only when an experiment is conducted, which, given the short duration and special "entitivity" of such experiments, happens only rarely. The laboratory is a virtual space and in most respects coextensive with the experiment. Like a stage on which plays are performed from time to time, the laboratory is a storage room for the stage props that are needed when social life is instantiated through experiments. The objects which are featured on the stage are players of the social form. The hallmark of their reconfiguration seems to be that they are called upon to be performers of everyday life, to be competent to behave under laboratory conditions true to the practice of real-time members of daily life.

Laboratories come of age: the construal of objects as processing materials

Consider now a second example from outside the sciences. In the twelfth and thirteenth centuries, cathedrals were built in Paris, Canterbury, Saint Denis (an abbey church), and later in Chartres, Bourges and other places, that were modeled upon earlier, smaller churches. Between them they demonstrate a rapid transmission of design innovations, manifest, for example, in the spread of the flying buttress.[16] After structural analyses of these churches, Mark and Clark argue that "cathedral builders learned from experience, using the actual buildings in the way today's engineer relies on instrumental prototypes" (1984, 144). The builders seemed to have observed wind pressure damage and cracking in the mortar of older churches, flaws in the original buttressing scheme, the flow of light, and generally how a particular design held up in relation to its purpose and usage.

The point about learning from wind pressure damage to cathedral towers by changing the structure of the buildings in response to their observed deficiencies is that on the one hand a system of surveillance must have existed which permitted those participating in the observational circuit to build upon (rather than to deplore, find who was guilty of, ignore, or otherwise deal with) mistakes. Since there were at the time no design drawings which were circulated, the system of surveillance must have depended on travel between

16. For a detailed analysis of buttressing patterns and apparent spread of information between building sites, see Mark and Clark 1984.

cathedrals and on communication of orally transmitted observations. The observation circuit together with the actual buildings acted as a kind of laboratory (Mark and Clark 1984) in which builders experimented. But the second point is that experimenting in this laboratory consisted of changing architectural designs and building cathedrals accordingly. In other words, it involved *manipulation* of the object under study, a sequence of cures classified today as architectural innovations. Consider now a typical experimental setup in a molecular genetics bench laboratory which focuses on gene transcription and translation. Like the work of twelfth-century cathedral building, the work in this laboratory is not concerned with stage playing a reality from somewhere else. The most notable feature of experimentation in this laboratory is that it subjects specimens and substances to procedural manipulations. In other words, experimentation deploys and implements a technology of intervention. For example, a routine procedure in such a laboratory is DNA hybridization, in which genes are isolated and then used to identify other genes of the same kind. In this procedure, scientists chemically cut double-stranded DNA from a particular species into fragments, then separate the fragments by size, and clone them on a lawn of bacteria. Once the clones have multiplied, the plaques which form are transferred to a filter, and the DNA. on the filter is chemically separated into single strands and exposed to a radioaetively labeled probe which contains single-stranded DNA from the gene through which the DNA on the filter is supposed to be identified. Then the unbound probe is removed and a photographic film exposed on the dish with the plaques to determine whether the probe did in fact bind, that is, identify the probed DNA as structurally similar. Finally, dark spots on the film which indicate binding sites are aligned with the corresponding plaques to show which of the plaques on the dish contain the targeted genes.

With a view to the reconfiguration of objects, the hallmark of this experimental technology is that it treats natural objects as *processing materials,* as *transitory object states* which correspond to no more than a temporary pause in a series of transformations. Objects are decomposable entities from which effects can be extracted through appropriate treatment; they are ingredients for processing *programs* which are the real threads running through the laboratory.[17] Objects are subject to tens, and often hundreds, of separately attended to *interferences* with their "natural" makeup, and so are

17. For an elaboration of the role of treatment programs in a medical field, see Hirschauer 1991.

the natural sequences of events in which objects take part. Through these interferences, natural objects are smashed into fragments, made to evaporate into gases, dissolved in acids, reduced to extractions, mixed up with countless substances, shaken, heated and frozen, reconstituted, and rebred into workable agents. In short, they are fashioned as working materials subject to almost any imaginable intrusion and usurpation, never more than a stage in a transition from one material state to another. The transitions effected during experimentation are not intended to imitate similar transitions in nature. Rather, they are intended to generate or explore a particular effect. There is no assumption that the transitory object states obtained in the laboratory and the manipulations which generate these objects correspond to or are supposed to correspond to natural events. Consequently the conclusions derived from such experiments are not justified in terms of the equivalence of the experiments to real-world processes.[18] And the assurances installed with such experiments do not set up a separation between experimentor and experiment. They are not based on a doctrine of noninterference by the experimenter and object integrity, which sees objects of experiments as not-to-be-tampered-with performances of natural courses of events. And how could such a doctrine be warranted if the whole point of experimentation is to influence the materials of the experiment through direct or indirect manipulation by the researcher.

If we now turn to the laboratories within which the manipulation takes place, it comes as no surprise that they are not, as in the first case, storage rooms for stage props. It seems that it is precisely with the above-mentioned processing approach and object configuration that laboratories *come of age* and are established as distinctive and separate entities. What kind of entities? Take the classical case of a bench laboratory as exemplified in molecular genetics. This bench laboratory is always activated; it is an actual space in which research tasks are performed continuously and simultaneously. The laboratory has become a *workshop* and a *nursery* with which specific goals and activities are associated. In the laboratory, different plant and animal materials are maintained, bred, nourished, kept warm, observed, prepared for experimental manipulation, and generally tended and cared for. They are surrounded by equipment and apparatus and are used themselves as technical devices to producing experimental effects. The laboratory is a repository of processing

18. Though of course there are such experiments in the biological sciences, like the ones which attempt to simulate the origin of life.

materials and devices which continuously feed into experimentation. More generally, laboratories are objects of work and attention over and above experiments. Laboratories employ caretaking personnel for the sole purpose of tending to the waste, the used glassware, the test animals, the apparatus, the preparatory and maintenance tasks of the lab. Scientists are not only researchers but spend part of their time as caretakers of the laboratory. Certain kinds of work *on* the laboratory becomes focused in laboratory leaders who tend to spend much of their time representing, promoting, and recruiting for "their" laboratory. In fact, laboratories are also social and political structures which "belong" to leaders and provide for the career goal of "heading one's own laboratory." Laboratories become identified in terms of their leaders; they are the outfits installed for senior scientists and a measure of successful scientific careers. Thus the proliferation of laboratories as objects of work is associated with the emergence of a two-tier system of laboratory-level and experiment-level social organization of agents and activities. Experiments, however, tend to have little entitivity. In fact, they appear to be dissolved into processing activities parts of which are occasionally pulled together for the purpose of publication. As laboratories gain symbolic distinctiveness and become a focus of activities, experiments lose some of the wholeness and unity they display in social science fields. When the laboratory becomes a permanent facility, experiments can be conducted continuously and in parallel, and begin to blend into each other. Thus experiments dissolve into experimental work, which in turn is continuous with laboratory-level work.

But there is also a further aspect which is of interest in regard to the permanent installation of laboratories as internal processing environments. This has to do with the phenomenon that laboratories now arc collective units which encapsulate within themselves a traffic of substances, materials and equipment, and observations. In other words, the laboratory houses within itself the circuits of observation and the traffic of experience which twelfth- and thirtccnth-century cathedral builders brought about through travel, and it includes an exchange of specimens, tools, and materials. Through this traffic, researchers participate in each other's experimental procedures, and outcomes arc watched, noticed, and learned from by a number of researchers. If the existence of such a traffic can be associated with acceleration effects, such effects are now appropriated by laboratories. Nonetheless, they are not limited to laboratories; it appears, and this is a last point I want to consider in regard to the present type of laboratory, neither the traffic of specimens and materials nor the system of surveillance are wholly contained in the laboratory. In fact, if the laboratory has come of age as a continuous and bounded unit that encapsulates *internal environments,* it has also become a *link between internal and external environments,* a *border* in a *wider* traffic of objects and observations. For example, experiments are not as a rule conducted completely and exclusively by the scientist in charge (with the help of technicians). Rather researchers draw upon other researchers from whom components of the work are extracted and obtained. These pieces of work may come from inside the laboratory, but they also often come from other laboratories. In contrast to work that deploys a technology of representation, the present type of work tends to produce composite and assembled outcomes. With the reconfiguration of objects as material states in successive transitions, experiments become composable in chunks, and the chunks correspond to the results of processing stages. Chunks of work are transferable like written or visual records, they travel between and within laboratories. Since the respective pieces of work are often obtained through gift exchange rather than through formal collaborations indicated by joint authorship, the degree of "assemblage" embodied in research products and the degree of traffic upon which these products are built is not apparent from publications.

The continuation of laboratory-internal processes of exchange through external processes is just one indication that the reconfiguration of objects (and agents) has implications beyond the borders of a lab. It is clear that single laboratories in benchwork sciences are situated in a landscape of other laboratories, and it appears that it is this landscape upon which they imprint their design. The laboratory in the present situation *focuses a life world* within which single laboratories are locales, but which extends much further than the boundaries of single laboratories.

Laboratories vs. experiments: when objects are signs

The phenomenon of the laboratory as a (internally elaborated) locale of a more extended life world is interesting in that it contrasts sharply with the third case to be considered, in which much of this life world appears to be drawn into experiments which are no longer merely streams of work conducted under the umbrella of a laboratory, but which "confront" and play upon the latter. This is also a situation in which objects are reconfigured neither as not-to-be-interfered-with players of natural events nor as decomposable material ingredients to processing programs, but as *signs.* The example from outside the natural sciences is psychoanalysis.[19] Freud repeatedly referred to psychoanalysis as analogous to chemistry and physics, and he likened the method of stimulating patient recollection through hypnosis with laboratory experimentation.[20] He also compared psychoanalysts to surgeons, whom he envied because they could operate on patients removed from everyday social and physical environments under clinical conditions—a situation Freud emulated by what he called the special "ceremonial" of the treatment situation (1947, vol. 11, 477ff., and vol. 8, 467). In a nutshell, this ceremonial consisted in the patient being put "to rest" on a couch while the analyst took his seat behind the facility in such a way that the patient could not see the analyst. The patient was not supposed to be influenced by the analyst's nonverbal behavior, and the analyst was supposed to remain emotionless during the encounter. This ceremonial, together with certain rules of behavior which the patient was asked to observe in everyday life during the analysis, helped patients in "disengaging" from everyday situations and in sustaining a new system of self-others relationships which the analyst set up in his office. One could say that Freud went some length to turn psychoanalysis into a laboratory science. But my point refers to the kind of activity performed in this setup rather than to the setup itself. In essence the analyst starts from a scries of pathological symptoms. These s/he tries to associate with basic drives which, by means of complicated detours having to do with events in the patient's biography, are thought to motivate the symptoms. Analysis is the progress from outward signs (the patient's symptoms) to the motivating forces which are the elements of psychic activity. Unlike the previous type of science, psychoanalysis is not processing material objects but processing signs; it is *reconstructing the meaning and origin of representations.*

Now consider contemporary particle physics, a science that indubitably involves laboratories and experiments, and in fact the largest and most complex ones in all of the sciences. In the collider experiment (called UA2J[21] we observe at the European Center for

19. I am grateful to Stefan Hirschauer for alerting me to this example.

20. For Freud's likening psychoanalysis to chemistry, sec, for example Freud's *Gesammelte Werke (1947),* vol. 10, 320; or vol. 12, 5, **184,** 186. For a reference to laboratory experimentation, see vol. 10, 131.

21. "UA2" stands for underground area 2, the site of the UA2 detector along the beam pipe several miles from CERN. UA2 is the sister experiment of **UAL** In both experiments were discovered the W and Z intermediate bosons which are thought to carry the weak electromagnetic force. Experiment UA2 has been studied since **1987.**

Particle Physics (CERN) in Geneva, protons and antiprotons are accelerated in a $p\bar{p}$ collider and hurled against each other, thereafter decaying into secondary and tertiary particles which travel through different detector materials before they get "stuck" in the outer shell of a calorimeter. Detectors can "see" the traces left by these particles, which may consist of "holes" from electrons knocked out of orbit by incoming particles in a silicon detector, optical images (scintillation light) converted into electrical pulses in a scintillating fiber detector, etc. Detectors announce the presence of these signals to "readout chains" through which signals are amplified, multiplexed, and converted from analog into digital values, and written on tape by an on-line computer. Events and particle tracks are reconstructed off-line, through the application of data production and track reconstruction programs. These construct—and extract—those signals which count as data and are to be analyzed for their physics content. Analysis continues the process of reconstruction in that it is concerned, in the case observed, with, (statistically) differentiating "interesting" signals (e.g., candidates for top quarks) from background events and with placing confidence limits around the estimates. In reality the chain of conversions, transformations, evaluations, selections, and combinations which leads from particle "footprints" to the supposed footprint-generating "real" events, that is, to specific particles and their properties, includes many more steps and details. But it remains a process through which signs become, with a certain likelihood, attached to events (production of particles), just as in the case of psychoanalysis we saw a process through which symptoms were attached to basic motivating drives.

Thus in particle physics experiments the natural order is reconfigured as an order of signs. Signs appear incorporated in particle physics experiments in a far more extensive sense than they are in other fields. This is not to deny that all sciences involve sign processes and can potentially be analyzed from a semiotic perspective. It is rather to say that in particle physics the construction of objects as signs[22] shapes the whole technology of experimentation. To give some simple examples, molecular genetics includes incipient forms of sign processing at the stage where protodata are transformed into publishable evidence, and there are signs involved in intermediary controls, as when a test tube is checked against the light to see whether the substance it includes has reached a certain stage, e.g., has formed a "pellet" (Amann and Knorr Cetina 1988). Signs in this

22. More precisely: the construction of objects as signatures and footprints of events.

case are used as indicators of the state of a process; they are not the objects which are processed. For the most part experiments describable in terms of a technology of intervention process material substances rather than their signatures. Experiments in particle physics, on the other hand, seem to start where processes not focusing upon signs leave off. Signs occur in many varieties and extend far back in the process of experimentation; they cannot be limited to the written output or "inscriptions" (Latour and Woolgar 1979), which in other sciences are the, (intermediary) *end products* of experimental processes. But the exclusive focus upon signs is but one aspect of the particle physics technology of signification. Other aspects have to do with features of the "closedness" of a universe in which knowledge derives from the (laboratory-) internal reconstruction of "external" events, with particle physics's use of language as a plastic resource and with its play upon shifts between language games as a technical instrument in reconstruction. If particle physics experiments reconstruct an external world from signs, they also constantly transcend—through their play upon language—sign-related limitations.

A proper exploration of particle physics's rather complicated technology of signification would be too technical for this paper.[23] Instead I want to turn now to the meaning of experiment in particle physics as compared to in the previously discussed sciences. Particle physics seems to upgrade features which arc also present in other sciences, and to sustain them as special characteristics of its pursuits. For example, in excluding whatever material processes lead to the production of signs, particle physics experiments rely on a division of labor between laboratory and experiment which we encountered in a rudimentary version in the distinction between "work on the laboratory" and experimental work in bench laboratories. In particle physics, however, this loose division between kinds of work which nonetheless remain continuous with each other appears transformed into a new separation between laboratory and experiment, a separation through which the laboratory becomes technically, organizationally, and socially divorced from the conduct of

23. I also want to turn the reader's attention to the fact that my argument is not that this technology of signification somehow "causes" all features of laboratories or experiments which use such a technology. Laboratories and experiments embody construals of objects, and in that sense, different construals imply different laboratories. On the other hand, there is more to be considered in the makeup of a laboratory than the construal of objects, and the construal of objects needs to be considered in more detail than is feasible in this paper. A full exploration of this can be found in KnorrCetina 1992.

experiments. Technically, laboratories build, maintain, and run accelerators and colliders, while experiments build, maintain, and run detectors. Experiments process signs. Laboratories become segregated providers of signs—they provide for the particle clashes whose debris leaves traces in detectors. Organizationally, science is conducted in experiments, while laboratories provide the (infra) structure for the conduct of science—they supply office space, computer time, living quarters, means of transportation, a local management that recruits financial resources, and above all, particle collisions. One laboratory sustains many smaller-scale fixed-target experiments but only a few big collider experiments. Most of the researchers and technicians that are part of the structure never have anything to do directly with experiments. And researchers on one experiment often know little of others, even if the two are sister experiments dedicated to the same goal. Experiments become relatively closed, total units, and laboratories become total institutions.

This is particularly interesting in view of the reconfiguration of the common, focused, interlinked life world we found to be the context of bench work laboratories. Experiments in particle physics involve huge collaborations (the LEP experiments at CERN have up to five hundred participants) between physics institutes all over the world. Sometimes all physics institutes in a country join in one experiment. There are only a handful of large particle physics laboratories in the world at this time, and hardly more collider experiments. These experiments and laboratories deplete scientific environments; there are virtually no active particle physics institutes or working particle physicists who are not drawn into one of the experiments and who are not thereby associated with one of the major labs. The external life world which in molecular biology is shared inside each laboratory in particle physics has become an internal life world encapsulated within experiments. The scientific community has become an internal community, a sort of collaborating organism instead of the territorial structure of independent professional locales which characterizes bench work sciences. Since collaborations tend to seed new collaborations when, after eight to sixteen years, an experiment ends, it is clear that experiments which have depleted whole scientific fields (and perhaps most of the field's manpower in single countries) also represent a tremendous political force. This leads to the curious situation in which experiments (collaborations) become counterparts of laboratories. Given their political force, experiments can, for example, play out their political strength. A collaboration may conduct an experiment at CERN and simultaneously submit a proposal for an experiment to be conducted in ten years at the SSC (superconducting supercollider) to be built in Texas, while keeping its options open for a bid at the LHC (large hadron collider) should it be built at CERN. Collaborations do not have to be loyal to laboratories (some are, if core members of a collaboration are employed by a laboratory), though of course they need laboratories, just as much as laboratories need good (technically and financially powerful) collaborations. It seems that strings of collaborations (experiments) may pass between laboratories, or fasten upon one of them, much as they please.

It is interesting to note that in addition to, or despite, their political nature, experiments (collaborations) in particle physics acquire a cultural face in the sense that they identify with and become known for a particular style of work and organization. UA2, for example, the collider experiment I study at CERN, is known and sought out for its "liberal," "informal" style of organization and its "painstaking," "trustworthy" style of work that is contemptuous of strategics of self-promotion at the cost of science. If this style cost UA2 one or another prize or first publication,[24] it does make for the image of an agreeable atmosphere to which newcomers are attracted. The style is cultivated by participants not only in terms of the selection of new participants but also in terms of characteristic behaviors displayed by leading figures in the collaboration on a day-to-day basis.

Everyday Life: Foundation or Active Agent in Science?

I have argued that the notion of a laboratory in recent sociology of science is more than a new field of exploration, a site which houses experiments, or a locale in which methodologies are put into practice. I have associated laboratories with the notion of reconfiguration, with setting up an order in laboratories that is built upon upgrading the ordinary and mundane components of social life. The configuration model claims that science derives epistemic effects from a particular reconfiguration of the natural order in relation to the social order, from, for example, reconfiguring agents and objects in ways which draw upon, yet at the same time transcend, natural courses of activities and events. From the examples it is clear how

24. This is implied by descriptions of the very different, more "ruthless" style of UA2's sister experiment UA1, which, as gossip has it, may have helped UA1 win the Nobel prize in 1984. The **nobel** prize went to Carlo **Rubbia,** leader of UA1, and Simon van der Meer, for the discovery of the W and Z intermediate bosons with the help of the UA1 detector. For a journalist's description of the style of UA1, see Taubes 1986.

this "transcendent mundanity" of science draws in features which are as diverse as those found in **twelfth-and-thirteenth-century** cathedral building, in the psychoanalyst's office, or in the war game played on a sand table. Reconfigurations are neither uniform nor consistent across different areas of science, and this has consequences in terms of the meaning of laboratory and experiment in different fields. It appears that in accordance with the construction of objects, some sciences endorse a correspondence model of the relationship between experimental activities and the world, others base their discovery strategy on the processibility and "trafficability" of material objects, and a third category construes its universe as a universe of signs and deploys a language-transcending[25] technology of signification. In terms of laboratory-experiment relations which respond to these constructions, some sciences display themselves as experimental sciences which manage almost without laboratories, others appear to be laboratory sciences in which experiments dissolve into streams of research tasks continuous with laboratory work, and some are sciences in which laboratories and experiments are institutionally separate units which enter into "uneasy partnerships"[26] with each other. It is clear that from a cultural perspective, the notion of "experiment" too must be reconsidered in relation to its environment and the changing meanings and alliances it embodies.

The point about juxtaposing these cases is not only that it directs attention to the enormous disparity between different empirical sciences but also that it emphasizes the necessity to understand the manifold transformations, through the order instituted in the laboratory, of the natural and social order of the wider context from which and into which laboratories are built. Edmund Husserl was among the first to criticize the sciences for their forgetfulness about the taken-for-granted modalities of experience which are the conditions of the possibility of scientific inquiry and which in his opinion are part of the makeup of our everyday life world. Through them he thought science was deeply and inextricably anchored in everyday life, despite its technical and mathematical orientation.[27] Quine made a similar argument when he pointed out that all scientific theories were ultimately rooted in "our overall home theory," by

25. I am alluding to **the** phenomenon that particle physics deploys different technical languages for the solution of its problems and appears to extract epistemic advantages from the transition from one language to another.

26. This expression has been used by Lazarsfeld to describe **the** relationship between politics and science.

27. See in particular Husserl 1976.

which he meant our everyday language (1969). Both authors accord to everyday life a role in science, but it is a *foundational* role which reduces everyday life to the common ground science shares with everything else and which construes science as a new kind of enterprise connected to everyday life through no more than a relationship of ultimate dependence. The transformations I think we need to understand between the natural and social order and the order instituted in the laboratory arc not of an ultimate nature that is open only to philosophical reflection. They do not link the eidetically perceivable universe of the everyday world to some abstract concepts which are thought to lie at the core of science. These transformations are concrete and omnipresent in the conduct of science underneath the cover of technical jargon, they are entrenched in cognitive pursuits, and inscribed in methodical practices. Taken together, and through the reconfigurations they imply, they set up a contrast to the surrounding social order. Yet it is precisely through the active recruitment, the clever selection, the deployment, enhancement, and recombination of features of this order *in relation to* the natural order—and through the clever selection and enhancement of features of the natural order in relation to social practice—that this contrast is effected and that epistemic effects can be reaped for science. Everyday orders appear to be a malleable resource and an active agent in scientific development. The laboratory embodies these resources, but as we have seen, it embodies them in different ways as it reshapes itself according to different reconfigurations.

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