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2

What Is a Laboratory?

Much of the literature on the history and methodology of science relies on the notion of the experiment as the basic unit of analysis. I want to suggest in this chapter how the notion of the laboratory—beyond its identification as just the physical space in which experiments are conducted—has emerged historically as a set of differentiated social and technical forms, carrying systematic weight in our understanding of science. The importance of this concept is linked to the reconfiguration of both the natural and social orders that, I will argue, constitutes laboratories in crucial ways. Further, I will argue that these reconfigurations work quite differently in different fields of science, generating different cultural, social, and technical stances.[1]

2.1 Laboratories as Reconfigurations of Natural and Social Orders

I want to begin by proposing that laboratories provide an "enhanced" environment that "improves upon" natural orders in relation to social orders. How does this improvement come about? The studies we have of laboratory work (e.g., Latour and Woolgar 1979; Knorr 1977; Knorr Cetina 1981; Zenzen and Restivo 1982; Lynch 1985; Giere 1988; Gooding et al. 1989; Pickering 1995) imply that it rests upon the *malleability* of natural objects. Laboratories are based upon the premise that objects are not fixed entities that have to be taken "as they are" or left by themselves. In fact, one rarely works in laboratories with objects as they occur in nature. Rather, one works with object images or with their visual, auditory, or electrical traces, and with their components, their extractions, and their "purified" versions. There are at least three features of natural objects a laboratory science does not have to accommodate: first, it does not need to put up with an object *as it is,* it can substitute transformed and partial versions. 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 need not accommodate an event *when it happens;* it can dispense with natural cycles of occurrence and make events happen frequently enough for continuous study. Of course, the history of science is also a history of lost opportunities and varying successes in accomplishing these transitions. But it should be clear that not having to confront objects within their natural orders is epistemically advantageous for the pursuit of science; laboratory practice entails the detachment of objects from their 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 imaging technology—the photographic plate with the help of which photons of light emitted by stellar bodies can be captured and analyzed. Astronomy thereby appears to have been transformed from a science that surveys natural phenomena into a science which processes images of these phenomena (see also Edge and Mulkay 1976). Further developments of imaging technology since 1976 have resulted in a replacement of the photographic plate by CCD chips (Smith and Tatarewicz 1985). For example, the light of Halley's comet in 1982 was collected by the gigantic 200-inch mirror of the Hale telescope on Mount Palomar and was focused on charge-coupled devices (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 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. And photographic plate astronomy, just like observation through small hand-held telescopes, may become a "backyard" astronomy.

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

1. Through imaging, the objects of investigation become detached from their natural environment and are made continually present and available for inquiry in the laboratory; through digitalization and computer networks, the availability of the same data is extended potentially to the whole scientific community.
2. With the transition to a symbol-based technology, the processes of interest to astronomers become miniaturized.
3. Planetary and stellar time scales become the time scale of the social order. Astronomers all over the world who are connected to the electronic networks simultaneously and continually process and analyze stellar and planetary responses.

The point is that with 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 resources that scientists can bring to bear on the work; for an initial ethnography of this work, see Gauthier 1991, 1992). In other words, laboratories allow natural processes to be "brought home" and to be made subject only to the conditions of the local social order. The power of laboratories (but, of course, also their restrictions) resides precisely in this "enculturation" of natural objects. Laboratory sciences subject natural conditions to a "social overhaul" and derive epistemic effects from the new situation.

Laboratories not only improve upon natural orders, but they also upgrade social orders, in a sense. This phenomenon has not been considered in the literature. Earlier studies analyzed the social system of science (e.g., Barber 1962; Cole and Cole 1973; Cole 1970; Zuckerman, Cole, and Bruer 1991; Griffith and Mullins 1972; Merton 1965, 1973; Storer 1972; Zuckerman 1967, 1977), or, alternatively, the interweaving of scientific interests with social and political factors (e.g., Barnes 1977; MacKenzie 1981; Pickering 1984; Shapin and Schaffer 1985; Latour 1987; Mukerji 1989; Haraway 1989). But they were not interested in how features of the social world, and more generally of everyday life, are played upon and turned into epistemic devices in the production of knowledge. Yet the social is not merely "also there" in science. Rather, it is capitalized upon and upgraded to become an instrument of scientific work. Laboratory processes align natural orders with social orders by creating reconfigured, workable objects in relation to agents of a given time and place. But laboratories also 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, the counterparts are agents enhanced in various ways to fit a particular emerging order of what one might call, following Merleau-Ponty (1945: 69, 1962: 57), "self-other-things" and 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 inquiry; they are part of a field's research strategy and a technical device in the production of knowledge.

How are aspects of social orders reconfigured? Let me take an example from the history of the medical sciences (Lachmund 1997). As Ackerknecht (1968) and Jewson (1976) have argued, the medical sciences in the late eighteenth and very early nineteenth century were primarily "bedside" sciences. They were practiced by doctors who came to their patients' houses to conduct their inquiry and provide treatments and advice. This situation changed with the advance of a new epistemic culture that emerged in the late eighteenth century at clinics in Paris described by Foucault and others (e.g., Ackerknecht 1968; Jewson 1976). These clinics were at the core of a newly developing clinical medicine. They formed the framework within which different preconceptions of illness and medical procedure were developed and tried out—the arenas in which they were negotiated and implemented. The transition to clinical medicine brought with it a redefinition of illness. Illness was no longer equated with a specific constellation of symptoms—rather, it was seen to reside in bodily "lesions"; the symptoms became the outward signs of these lesions.

What were some of the reconfigurations that accompanied these transitions? Lesions, for example, could only be observed through an autopsy. Detecting them required a dissection room, the kind that had become available at the new clinics. The transition from a bedside medical science to clinical medicine approximates that of a field science to a laboratory science (the term *laboratory medicine* was used for the physiological and bacteriological medicine established in the middle of the nineteenth century). Patients were taken out of their natural setting and subjected to the spatial and temporal discipline of a clinical environment. The dissection room emulated the setting of a laboratory workbench on which objects are taken apart, studied from the inside out, and experimented on. As Lachmund has shown (1997), the new technology of the stethoscope was tested and developed further in the new setting, where it thrived as a means of bridging the gap between anatomical knowledge gained from dead patients and the need for medical treatments applicable to the living (the noises the stethoscope picked up were linked to anatomically defined causes of illnesses, which were directly observable only in the anatomy theater). But the point of interest is how the social order became reconfigured in connection with this process of laboratorization.

Take the case of the medical doctor. With bedside medicine, the social authority of the doctor was extraordinarily precarious. The doctor went to the household of the patient, where he conducted his inquiry amidst a skeptical audience of relatives, neighbors, and, possibly, competing "wise" women and men also called upon to help the patient. None of those present were shy to offer their opinion on behalf of the patient. The whole medical profession was weak, at the time, since doctors failed to adhere to the same medical principles and to consolidate their opinion. Instead, they competed with each other and felt pressured to demonstrate their superior medical skills by offering advice that differed from that of other doctors. This weakness was enhanced by the way the "examination" was conducted, at the bedside of the ill. Doctors had to obtain from the patient a comprehensive account of his/her illness or injury. With the question-answer method they used, the patient's discourse had absolute priority. Doctors had to avoid medical jargon, were not to interrupt the patient, were not to irritate the patient through nonverbal responses (such as frowning, shrugging the shoulders, pacing up and down the room), and had to have the patience to conduct the examination over several days. They had to consider not only the illness, but any circumstantial evidence that could be connected to it. They had to remain aware of the fact that an illness followed its own individual course, which was influenced by the peculiarities of single patients.

Medical historians have called this system of inquiry—which privileged the patient and the lay public—"patronizing"; it was the patient or the patient's household that patronized the doctor and not, as one might expect given the nature of medical examinations today, the other way round. The patient's dominance changed with the onset of clinical medicine. Doctors' power was enhanced by a combination of factors. First, patients had to leave their homes and enter a new setting, where they would be available for continual medical observation and comparison with other patients. Second, patients were primarily recruited from the poor quarters of society; they were in no position to change clinical practice or impose their will on those who ran the clinic. Third, instead of the private, dyadic relationship between patient and doctor, there now existed at the hospital a small public of cooperating doctors and students with which the patient was confronted, and to whose collective judgment he or she had to submit. Collective judgments were often arrived at in Latin; use of the language of learning effectively excluded the patient—as an epistemically relevant agent—from the group that established medical diagnoses.

Medical collectives instead of single doctors, the use of technical devices instead of a shared discourse for conducting a medical examination, communication through a specialized language not understood by the patient, and the possibility of autopsy awaiting the patient—these were the ingredients that went into the remaking of medical doctors. The doctor became a whole new being, aligned with the reconfigured objects (patients) that the clinic created. No longer did the doctor manage complicated interactions with patients and families in familiar social settings; other behavioral possibilities were now in demand. For example, these behavioral possibilities included the capacity to *hear* and classify noises, to dissect organs and see lesions, to operate and develop further technical devices, and to function in medical collectives. Hearing and seeing became privileged senses called upon in medical inquiry, and discursive skills for dealing with patients became devalued.

My point is that scientists have been similarly shaped and transformed with regard to the kind of agents and processing devices they use in inquiry. Just as objects are transformed into images, extractions, and a multitude of other things in laboratories, so are scientists reconfigured to become specific epistemic subjects. As we shall see later, the scientist who acts as a bodily measurement device (by hearing and seeing signals) is also present in molecular biology (Chapter 4). By the time the reconfigurations of self-other-things that constitute laboratories have taken place, we are confronted with a newly emerging order that is neither social nor natural—an order whose components have mixed genealogies and continue to change shape as laboratory work continues.

2.2 From Laboratory to Experiment

What I have said so far refers to laboratory processes in general. I have neglected the fact that concrete laboratory reconfigurations are shaped in relation to the kind of work that goes on within the laboratory. This is where experiments come into the picture; through the technology they employ, experiments embody and respond to reconfigurations of natural and social orders.

Let me draw attention to three different types of laboratories and experiments 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 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. First, laboratories and experiments can encompass more or less distinctive and independent activities; they can be assembled into separate types, which confront and play upon each other, or disassembled to the extent that they appear to be mere aspects of one another.

Second, the relationship between local scientific practices and "environments" also changes as laboratories and experiments are differently assembled. In other words, reconfigurations of natural and social orders 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 that emerges between these units, and beyond.

In the following, I shall do no more than outline some of these issues in a most cursory manner. I shall thereby introduce a first *set of differences* between the sciences of molecular biology and high energy physics, which will be the focus of much detail in later chapters. In this section I want to draw attention to the diverse *meanings* of "experiment" and "laboratory" that are indicated in different reconfigurations (see also Hacking 1992b). I want to indicate the varying significance of laboratories and experiments in relation to each other in three situations, which I distinguish in terms of whether they use a technology of correspondence, a technology of treatments and interventions, or a technology of representation (see also Shapin and Schaffer 1985). The construction placed upon the objects of research varies accordingly; in the first case, objects in the laboratory *stage* 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; rather, they are an 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, I shall first draw upon examples of "laboratories" and "experimentation" from outside natural science—the psychoanalyst's couch, the medieval cathedral, and the war game.

2.2.1 EXPERIMENTS (ALMOST) WITHOUT LABORATORIES: OBJECTS THAT STAGE REAL-TIME EVENTS

I begin with the war game. The hallmark of a *Kriegsspiel* 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 and whole battles were fought by toy armies. The landscape was modeled after the scene of a real engagement in all relevant respects, and the movements made by the toy soldiers corresponded as closely as possible to the expected moves of real armies. The sandbox war game was an eighteenth-century invention and was developed further by Prussian generals. Its modern equivalent is the computer simulation, which has become widely used not only in the military but in many areas of science, where real tests are impracticable for one reason or another. Computer simulations are also increasingly used in laboratory sciences to perform experiments. Indeed, the computer has been called a laboratory (e.g., Hut and Sussman 1987); it provides its own "test-bench" environment.

The point here is that many real-time laboratory experiments bear the same kind of relationship to reality as the war game bears to real war or the computer simulation bears to the system being modeled: they *stage* the action. As an example, consider most experiments in the social sciences, particularly in social psychology, or in economics, in research on problem solving and the like. To illustrate, in experimental research on decision making by juries, research participants (often college students) are set up in the way real juries would be in court. They are given information on a case and asked to reach a verdict in ways that approximate real jury decision processes. They may even be exposed to pleas by the mock accused and other elements of real-time situations (e.g., MacCoun 1989). Research on the heuristics of problem solving uses a similar design. Experts, lay persons, or novices to an area are recruited and asked to search for a solution to a simulated problem (Kahneman, Slovic, and Tversky 1982). One difference from the war game in the sandbox is that the experimental subjects in the social sciences are not toys but members of the targeted population. For example, they may be real experts who play experts in the laboratory, or students who are thought to be representative of the jury pool. Nonetheless, social science experiments receive the same kind of criticism as computer simulations do. While the subjects recruited for the experiment may not differ much from the persons about whom results are to be generated, the setting is artificial, and the difference this makes, with respect to the behavior generated in experimental situations, is poorly understood. What the critics question is whether generalizable results can be reached by studying behavior in mock settings when the factors distinguishing the simulation from real-time events are not known or have not been assessed.

Researchers in these areas are, of course, aware of this potential source of error. As a consequence, they take great care to design experimental reality so that in all relevant respects they come close to the perceived real-time processes. In other words, they develop and deploy a *technology of correspondence.* For example, they set up a system of assurance through which correct correspondence with the world is monitored. One outstanding characteristic of this system of assurance is that it is based on a theory of nonintervention. In "blind" and "double-blind" designs, researchers attempt to eradicate the very possibility that they will influence experimental outcomes. In fact, experimental designs consist of implementing a world simulation, on the one hand, and implementing a thorough separation between the experimental subjects and the action, interests, and interpretations of the researchers, on the other.

Now consider the laboratory in social science areas. 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 is reduced to a room with a one-way mirror that includes perhaps a table and some chairs. 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 be used only when an experiment is conducted, which, given the short duration of such experiments, happens only rarely. The laboratory is a virtual space and, in most respects, co-extensive 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" featured on the stage are *players of the social form.* The hallmark of their reconfiguration seems to be that they are called upon to perform everyday life in a competent manner, and to behave under laboratory conditions true to the practice of real-time members of daily life.

2.2.2 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 after earlier, smaller churches. They demonstrate a rapid transmission of innovative designs, manifest, for example, in the spread of the flying buttress (see Mark and Clark 1984 for a detailed analysis of this transmission). From structural analyses of these churches, Mark and Clark have argued that "cathedral builders learned from experience, using the actual buildings in the way today's engineer relies on instrumental prototypes" (1984: 144). It appears the builders observed in already built churches wind-pressure damage, cracking in the mortar of older churches, flaws in the original buttressing scheme, light influx, and, generally, how a particular design held up over time.

Given that architectural changes were made to correct problems in earlier designs, a system of surveillance must have existed which permitted the designers to build upon (rather than to deplore, find the culprit of, ignore, or otherwise deal with) past mistakes. Since at the time no design drawings were circulated, the system of surveillance must have rested upon travel between cathedrals and upon a traffic of orally transmitted observations. The observation circuit, together with the actual buildings, acted as a kind of laboratory (Mark and Clark 1984) through which builders experimented. But another point to note is that experimentation in this laboratory consisted of changing architectural designs and building cathedrals. In other words, it involved *manipulation* of the objects under study, a sequence of "cures" classified today as architectural innovations.

Consider now a typical experimental setup in a molecular biology laboratory, such as the ones in Heidelberg and Göttingen where the present research was conducted. These laboratories are bench laboratories; all experimental work is conducted at workbenches, on and around which specimens are stored and manipulated. As in twelfth-century cathedral building, the work in this laboratory is not concerned with staging a reality from somewhere else. The most notable feature of experiments in this laboratory is that it subjects specimens to procedural manipulations. In other words, experiments deploy and implement a technology of intervention (compare Hacking 1983). In this way natural objects are treated as *processing materials* and as *transitory object-states* corresponding 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. There is no assumption that the transitory object-states obtained in the laboratory and the manipulations generating these objects correspond or are supposed to correspond to natural events. Consequently, the conclusions derived from such experiments are not justified in terms of their *equivalence* with real-world processes (though there are some experiments in which equivalence plays a role—for example, those which address the origin of life). In addition, the assurances installed with such experiments do not create a separation between experimenter and experiment in the sense discussed before. They are not based on a doctrine of noninterference by the experimenter or on a doctrine of object integrity, which sees experimental objects as not-to-be-tampered-with performances rooted in the natural course of events. 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 researchers?

If we now turn to the laboratories where the manipulation takes place, it should come 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, the configuration of objects as materials to be interfered with, 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 biology (see also Lynch 1985; Jordan and Lynch 1992; Fujimura 1987; Amann 1990, 1994). 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 specific goals and activities. In the laboratory, different plant and animal materials are maintained, bred, nourished, warmed, observed, and prepared for experimental manipulation. Surrounded by equipment and apparatus, they are used as technical devices in producing experimental effects.

The laboratory is a repository of processing materials and devices that 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, and the preparatory and maintenance tasks of the lab. Scientists are not only researchers but also caretakers of the laboratory. As will become clearer in later chapters, certain types of tasks become of special concern to heads of laboratories, who tend to spend much of their time representing and promoting "their" lab (see Chapter 9). In fact, laboratories are also social and political structures that "belong" to their heads in the sense that they are attributed to them and identified with them. Thus, the proliferation of laboratories as objects of work is associated with the emergence of a two-tier system of social organization of agents and activities—the lab level and the experimental level. Experiments, however, tend to have little unity. 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" they display in social scientific fields. When the laboratory becomes a permanent facility, experiments can be continuous and parallel, and they even begin to blend into one another. Thus, experiments dissolve into experimental work, which, in turn, is continuous with laboratory-level work.

But there is a further aspect to the permanent installation of laboratories as *internal processing environments*. This has to do with the phenomenon that laboratories now are collective units that encapsulate within them a traffic of substances, materials, equipment, and observations. Phrased differently, the laboratory houses within it the circuits of observation and the traffic of experience that medieval cathedral builders brought about through travel. At the same time, neither the traffic of specimens and materials nor the system of surveillance is solely contained in the laboratory. If the laboratory has come of age as a continuous and bounded unit that encapsulates internal environments, it has also become a participant in a larger field of communication and mutual observation.

The traffic of objects, researchers, and information produces a *lifeworld* within which laboratories are locales, but which extends much further than the boundaries of single laboratories.

2.2.3 LABORATORIES VS. EXPERIMENTS: WHEN OBJECTS ARE SIGNS

The laboratory as an internally elaborated locale of a more extended lifeworld contrasts sharply with the third case to be considered, where much of the lifeworld appears to be drawn into *experiments* that are no longer merely streams of work conducted under the umbrella of a laboratory but that "confront" the laboratory. In this case objects are not reconfigured as not-to-be-interfered-with performances of "natural" events or as decomposable material ingredients of processing programs, but as *signs*. The case in point, from outside the natural sciences, is psychoanalysis. Freud repeatedly referred to psychoanalysis as analogous to chemistry and physics; he likened the method of stimulating patient recollection through hypnosis to laboratory experimentation (see for example Freud 1947: vol. 10, 131, 320; vol. 12, 5, 184, 186). He also compared psychoanalysts to surgeons. He envied a surgeon's ability to operate on patients in a setting removed from everyday social and physical environments under clinical conditions—a situation Freud emulated by what he called the special, "ceremonial" treatment situation (1947: vol. 11, 477f.; vol. 8, 467). In a nutshell, this ceremony consisted of the patient being put "to rest" on a couch while the analyst took his seat behind the couch so that the patient could not see the analyst. The patient was not to be influenced by the analyst's nonverbal behavior, and the analyst was to remain motionless during the encounter.

Some of Freud's instructions are reminiscent of the rules doctors were asked to follow in bedside medicine (see Section 2.1), but the psychoanalytic encounter always took place at the psychoanalyst's office; the patient's surroundings, kin group, and advisors were excluded from the encounter. The setting at the psychoanalyst's office shared some features with the characteristics of a clinical (laboratory) science. Moreover, the protocol Freud introduced strengthened these features. It immobilized the patient and subjected him or her to a strict regime of stimulus and response in which the doctor dominated. Thus, the ceremony proposed by Freud served a purpose entirely different from that of the rituals followed by the practitioners of bedside medicine. Together with certain rules of behavior the patient was asked to observe in everyday life during the analysis, the special setting Freud created helped to disengage patients from everyday situations by sustaining a new system of "self-other" relationships, which he, as the analyst, developed in his office. One could say that Freud went to some lengths 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 series of pathological "symptoms." S/he tries to associate these with basic drives, which, via complicated detours having to do with events in the patient's biography, are thought to motivate the symptoms. "Analysis" is the progression from outward signs (the patient's symptoms) to the motivating forces that are the elements of psychic activity. Unlike the previous type of science, psychoanalysis does not process material objects but rather processes *signs*. The office ritual of the couch and the way inquiry is conducted produces these signs. When they elicit and interpret these signs, psychoanalysts are *reconstructing the meaning and origin of representations*.

Now consider a field in contemporary particle physics, experimental high energy physics. This is a science that indubitably involves laboratories and experiments, in fact, the largest and perhaps the most complex ones in all the sciences. In the collider experiments studied at CERN and described in Section 1.6, detectors register particle traces and transmit their signs to offline operations, where these signs are suitably "reconstructed" and interpreted according to real-time particle occurrences and properties of events. In physics the signs are not words in the usual sense; and the process of producing the signs, as well as the process of reconstructing their identity and origin, is not literary or psychological in character. But these processes nonetheless attach signs to underlying causal events (particle occurrences), within the limits of certain probabilities—as is done in psychoanalysis, where a process exists by which symptoms are attached to basic motivating drives.

In high energy physics experiments, the natural order is reconfigured as an order of signs. In the next chapter, I will say more about the nature of these signs. Signs are 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 that can potentially be analyzed from a semiotic perspective. Most sciences include a mix of technologies in several respects. For example, HEP experiments may require imitating the energy levels and subatomic activities present in the early universe. The goal of such imitation resembles the goal of the simulation in the social and behavioral sciences. In molecular biology, too, there are experiments whose explicit goal is to recreate and explore naturally occurring phenomena and events—for example, the circumstances surrounding the creation of life. However, such goals are often limited to specific experiments, clearly distinguished from other, more "common" types of work. Sign-creating technologies, on the other hand, in so far as they turn out verbal renderings, visual images, or algorithmic representations of objects and events, seem to be present in all sciences. If for no other purpose, they are needed for the transmission and publication of scientific results. Not all of these technologies produce "inscriptions" (Latour and Woolgar 1979), however; many, like the stethoscope mentioned earlier, involve visual or auditory signs. In addition, the way they are utilized and the degree to which a science depends on them varies strongly across fields.

For the most part, experiments that can be described in terms of intervening technologies process material substances rather than their signatures and representations. They use sign-related technologies mainly to produce (intermediary) end products from experimental processing. Experiments in high energy physics, on the other hand, seem to start with processes focusing upon signs—the point where other sciences leave off. The construction of objects as "signatures" and "footprints" of events, rather than as the events themselves, shapes the whole technology of experimentation. Such signs occur in many varieties and extend far back into the process of experimentation; they cannot be limited to the written traces, which in other sciences signify experimental results.

A more detailed exploration of high energy physics' rather complicated maneuvering in a world of signs will be left to the next chapter. Instead, I want to turn now to the meaning of experiment in high energy physics, as opposed to its meaning in the other sciences discussed in this chapter. High energy physics upgrades some features that are also present in other sciences and sustains them as special characteristics of its pursuits. For example, in excluding whatever material processes lead to the production of signs, HEP experiments rely on a *division of labor* between laboratory and experiment. We encountered a rudimentary version of this division of labor in the distinction between "work on the laboratory" and experimental work in molecular biology laboratories. In high energy physics, however, this loose division between kinds of work, which remain continuous with each other, appears to have been transformed into a new separation between laboratory and experiment—a separation through which the lab becomes technically, organizationally, and socially divorced from the conduct of the experiment. *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" that are the signs of particles in detectors. *Organizationally,* experiments conduct "science," while laboratories provide the (infra-) "structure" for carrying it out—they supply office space, computers, living quarters, transportation, financial resources, and, above all, particle collisions. One laboratory sustains many small-scale "fixed target" experiments, but only a few big collider experiments. Organizationally, most of the researchers and technicians that are part of the "structure" do not have any direct contact with experimenters. Researchers with one experiment often know little about others, even if the others are part of "sister experiments" dedicated to the same goal. Experiments become relatively closed, total units, and laboratories become total institutions.

Consider the reconfiguration this implies of the common, focused, interlinked lifeworld that was the context of benchwork laboratories. As indicated before, experiments in HEP involve huge collaborations; up to 500 physicists from physics institutes all over the world participate in each of the 4 currently running LEP experiments at CERN. Sometimes all physics institutes in a country join one experiment. There are only a handful of large high energy physics laboratories in the world at this point, and hardly more collider experiments. These experiments and laboratories deplete scientific resources; there are few active HEP institutes or working high energy physicists who are not being drawn into one of the experiments and who are not thereby associated with one of the major labs. The external lifeworld that in molecular biology is shared from inside each laboratory is, in particle physics, substituted by internal lifeworlds encapsulated within experiments. This has implications for the notion of a scientific community and for the concept of a scientific field. For example, it is clear that experiments, which are at the same time "collaborations" of physics institutes, also represent a tremendous political force, particularly since core members of collaborations tend to stay together and form the seeds of new collaboration. The political and financial strength of collaborations leads to the curious situation in which experiments "match" laboratories. They become counterparts of laboratories, near-equals that, in some sense, stand almost independent of the terrain of a laboratory. How do experiments play out their political strength? A collaboration conducting an experiment at CERN may simultaneously submit a proposal for a continuation of the experiment at its home base and at another competing laboratory (for a while, this was the case with the SSC in Texas). Collaborations and experiments do not have to be "loyal" to laboratories, though most are. On the other hand, experiments need laboratories just as much as laboratories need good (technically and financially powerful) collaborations and experiments (see Chapters 7 and 8).

2.3 Some Features of the Laboratory Reconsidered

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 (Shapin 1988), or a locale in which methodologies are put into practice. I have associated laboratories with the notion of reconfiguration, with the setting-up of an order in laboratories that is built upon upgrading the ordinary and mundane components of social life. Laboratories *recast* objects of investigation by inserting them into new temporal and territorial regimes. They play upon these objects' natural rhythms and developmental possibilities, bring them together in new numbers, renegotiate their sizes, and redefine their internal makeup. They also invent and recreate these objects from scratch (think of the particle decays generated by particle colliders). In short, they create new configurations of objects that they match with an appropriately altered social order.

In pointing out these features I have defined laboratories as *relational* units that gain power by instituting *differences* with their environment: differences between the reconfigured orders created in the laboratory and the conventions and arrangements found in everyday life, but of course also differences between contemporary laboratory setups and those found at other times and places. Laboratories, to be sure, not only play upon the social and natural orders as they are experienced in everyday life. They also play upon themselves; upon their own previous makeup and at times upon those of competing laboratories. What I said in Sections 2.1 and 2.2 implies that one can link laboratories as *relational* units to at least three realities: to the environment they reconfigure, to the experimental work that goes on within them and is fashioned in terms of these reconfigurations, and to the "field" of other units in which laboratories and their features are situated.

Laboratories introduce and utilize *specific differences* between processes implemented in them and processes in a scientific field. Take the case of the space telescope mentioned earlier, or the recently developed underwater telescope. The underwater telescope does not operate in space or on mountaintops, but three miles beneath the ocean. Unlike previous telescopes, it does not observe electromagnetic radiation but streams of neutrino particles thought to be emitted by components of distant galaxies, such as black holes. Neutrinos are an elusive type of particle that travels easily through the earth and through space, undeterred by cosmic obstacles. The water under which the telescope is built serves as a screening system that filters out unwanted high energy particles that might mask the neutrino signals. Since even several miles of water do not offer enough shielding, however, the telescope, looking *down* rather than up, picks up signals from particles that fly all the way through the earth and emerge from the ocean floor.

The notion of reconfiguration needs to be extended to include issues continuously at stake in laboratories: the ongoing work of instituting specific differences from which epistemic dividends can be derived, and the work of boundary maintenance with regard to the natural and everyday order (see also Gieryn 1983). We need to conceive of laboratories as processes through which reconfigurations are negotiated, implemented, superseded, and replaced. Doing so would imply a notion of *stages* of laboratory processes, which can be historically investigated and which may also be important for questions of consensus formation (see Shapin 1988; Hessenbruch 1992; Lachmund 1997; Giere 1988). But it also implies that we have to expect different *types* of laboratory processes in different areas, resulting from cumulative processes of differentiation. It is the task of Chapters 3 and 4 to begin to describe these differences in the two sciences chosen for analysis here.