The Spirit, Grace, and Soul of Science
or
The Virgin Who Was a Wife

by

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The thesis by

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ABSTRACT

This thesis first explores how descriptions of non-equilibrium systems such as chemical clocks, taken from thermodynamics, might provide suitable models by which to represent how scientific understanding changes and evolves. Non-equilibrium models allow for a precise formulation of the complex interplay between individual and collective aspects of change. This thesis then explores the extent to which concepts formulated through the description of the behaviour of chemical clocks are equivalent to concepts formulated through Heinrich von Kleist's literary commentary on the dance of puppets, Meister Eckhart's mystical sermons on the fruitfulness of "virgins," and Deleuze and Guattari's philosophical mapping of the behaviour of the masochist. The demonstration of partial-isomorphisms between works of different disciplines and time periods is used to discuss how change in science is often brought about by processes that pierce the borders of disciplines, and recycle through time.

Keywords: History of Science, Thermodynamics, Mysticism, Spirit, Grace, Prigogine and Stengers, Eckhart, Kleist, Deleuze and Guattari.

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INTRODUCTION

Adventures of the Spirit

Let me tell you a true story. Have you ever heard how some brothers, in their seventies, were grouped around their father for a funeral vigil, weeping for a dead man aged thirty or less? He had been a mountain guide and, following an accident, had disappeared into a crevasse in the high mountains. He reappeared more than a half-century later, deposited in the valley by the glacier, perfectly conserved, youthful, from the depths of the cold. His children, having grown old, prepare to bury a body that is still young. That's the source of this alpine scene, which is precisely an anachronism, and is admittedly rare here, but often observed - between a writer and his critics. Art, beauty, and profound thought preserve youth even better than a glacier!
Admire how, on the problem of time, an unpretentious true story agrees with recent science, to produce good philosophy.
-Michel Serres (Conversations)

> Space travel challenges mankind not only technologically but also spiritually, in that it invites man to take an active part in his own biological evolution. Scientific advances of the future may thus be utilized to permit man's existence in environments which differ radically from those provided by nature as we know it. (Clynes and Kline 29)

In an article entitled "'Cyborgs and Space," an article originally presented at the Psychophysiological Aspects of Space Flight Symposium sponsored by the AF School of Aviation Medicine in San Antonio, Texas, in May 1960, Manfred E. Clynes and Nathan S. Kline propose altering "man's" biology by fusing it with certain technology in order to free "man" from the bodily limitations that tie "him" to an earthly environment. They suggest, for example, that replacing the lung "with an inverse fuel cell, capable of reducing

CO_2 to its components with removal of the carbon and recirculation of the oxygen, would eliminate the necessity for lung breathing" (32). Similarly, they note the development of an osmotic pressure pump capsule that is capable of continual slow injection into the body of "biochemically active substances at a biological rate" (31), and they speculate on how this might replace or augment bodily systems such as the digestive or the cardiovascular. For Clynes and Kline, cyborg technologies such as these promise to solve what they call the "spiritual" challenge posed by space travel. Inverse fuel cells and osmotic pressure pumps allow "man," or more specifically man's "spirit," to free itself from what Clynes and Kline characterize as "slavery" to the body and to nature.

> If man in space, in addition to flying his vehicle, must continually be checking on things and making adjustments merely in order to keep himself alive, he becomes a slave to the machine. The purpose of the Cyborg, as well as his own homeostatic systems, is to provide an organizational system in which such robot-like problems are taken care of automatically and unconsciously, leaving man free to explore, to create, to think, and to feel. (31)

Clynes and Kline's ideal, we might say, is a "free spirit," a spirit which is independent of "natural" limitations. Cyborg technologies are, for Clynes and Kline, an invitation for "man to take an active part in his own biological evolution" (29). Notably the word "man" in this sentence is not referring to a particular, individual body - particular, individual bodies do not "evolve" - but rather it refers to something essentially "man," to the essential "spirit" of man which remains unchanged through generations of changing bodies. For Clynes and Kline the spirit of man is distinct from the body. Remove a lung and add a fuel cell; the spirit however will not be affected, except to become freer, more independent of the body and its environment. One small step for man, one giant leap for mankind.

It is scientific progress which, according to Clynes and Kline, enables the spirit's freedom. "Scientific progress," they write, "may well provide a new and larger dimension for man's spirit." This is not surprising because science, as I will argue, has long been considered the work of independent spirits. Certainly science, as it has traditionally been understood, progresses only insofar as it is "objective," that is, it progresses only insofar as it is free of the influences of personal, and historical circumstances. Free from personal and historical circumstances science works by "spirit" alone. Is it ironic that progress in science, progress in the "spirit's" work, results in space travel, in cyborg technologies, in more independence for man's spirit, both from the body and the "natural" world.

Traditional Approaches to Science: How the Spirit Broke Loose

Dudley Shapere characterizes most "traditional approaches" to explaining scientific developments as "presuppositionist:"

> The major traditional approaches to the investigation of the knowledge-seeking enterprise, as represented by such diverse thinkers as Plato, Kant, the early Wittgenstein, and the logical empiricists, have held one assumption in common: namely, *that there is something which is presupposed by the knowledge-acquiring enterprise, but which is itself immune to revision or rejection in the light of any new knowledge or beliefs acquired.* (61)

This approach distinguishes "scientific" from "non-scientific" knowledge-seeking enterprises by suggesting that science has its own set of presuppositions upon which its knowledge is built. The success of science as a knowledge seeking enterprise may be witnessed in the purposeful and effective interventions that scientific knowledge continues to make possible in ever more areas of the natural world. The "traditional approach" explains this success by suggesting that the presuppositions of science are highly conducive to the development of maximally reliable knowledge.

The question as to what the presuppositions of science actually are has been answered in various ways throughout the history of science. Shapere mentions at least three general answers to this question: (1) science presupposes certain "claims about the way the world is which must be accepted before any empirical inquiry is possible, or before any further beliefs (well-grounded beliefs) can be acquired"(61); (2) science presupposes methodological strictures or "purely formal" rules "by application of which knowledge or well grounded beliefs about the world is obtained"(62); and (3) science presupposes "concepts" that "are not open to abandonment, modification, or replacement in the light of new knowledge"(62). There are many versions of this third answer:

> One such version maintains that the alleged immutable concepts are unavoidable ingredients in any fundamental scientific theory, as space and time were claimed to be for different reasons, by Kant and Heisenberg. In other variations, the unchangeable concepts are held to be "observational" ones upon which all scientific theorizing is supposed to rest. Still another variation maintains that certain "metascientific" concepts (or "terms"), like "evidence", "theory", "explanation", which are used in talking about scientific concepts, claims, and arguments, must have meanings which are wholly independent of the specific content of ongoing science. (Shapere 62).

In any case, however the presuppositions of science are defined, fundamental to the quest of accurately defining them is the belief that scientific understanding is indeed based on presuppositions. Larry Laudan identifies the *main* function of presuppositions, as conceived in traditional approaches to the knowledge acquiring process, as "providing an epistemic warrant for accepting scientific theories" (182). In other words, presuppositions act as arbiters of scientific disputes. They allow scientists to justify why a given theory or model should be accepted as more scientific than another. Theories and models which are more in keeping with established presuppositions are deemed more "scientific," more representative of reality, than others.

According to Laudan, the problem of justification has always been the central problem for philosophers of science. He distinguishes the problem of "justification" from the problem of "discovery." Laudan describes discovery as "'the *eureka* moment', i.e., the time when a new idea or conception first dawns" (174). Although prior to the 19th century many philosophers attempted to articulate a logic of discovery - "Bacon, Descartes, Boyle, Locke, Leibnitz, and Newton [...] all believed it was possible to formulate rules which would lead to the discovery of 'useful' facts and theories about nature" (Laudan 175) - the primary concern, even in the search for a logic of discovery, was to establish grounds for justification:

> Unlike now, there was then no distinction drawn between the contexts of discovery and justification. It is not that our forebears could not recognize the difference between discovery and justification; they could, and often did. But they were convinced that an appropriate (i.e., infallible) logic of discovery would automatically authenticate its products and that a separate logic of justification was therefore redundant and unnecessary. They were preoccupied with developing logics of discovery, not because they were indifferent to the epistemological problem of justifying knowledge claims, but precisely because they took the justification problem to be central. (Laudan 176)

By the middle of the last century, however, certain developments lead to an "abandonment" of logics of discovery. One such development, according to

Laudan, was the increasing acceptance of a fallibilistic conception of theories - i.e., the acceptance of the view that theories can never be *proven* true, no matter how they had been generated. This development shifted the efforts of scientists and philosophers away from evaluating theories on the basis of how they had been generated, and toward evaluating them on the basis of their consistency and testable consequences. What became most important, in other words, was not how a theory was generated, but how rigorously it was tested. On this view, the distinguishing trait of science, that which enables science to achieve such "powerful" representations of the world, is not in how it "generates" theories, but how it "evaluates" them.

Thomas Nickles suggests that events in 20th century science only entrenched this view of science:

> First phenomenological thermodynamics gave way to kinetic theory and statistical mechanics, followed by the far more dramatic fall of the long-established Newtonian world picture to Einsteinean relativity. With the falsification of Newtonian physics, the infallibilist view that science could establish the truth about the universe once and for all suffered a fatal blow, if the logic of theory justification had left any doubt. Then came the new quantum theory. Inductions from the facts hardly seemed the stuff of which such abstract principles and reasoning could be made. But the conception of theories as abstract, mathematical systems from which empirical consequences could be derived appeared to fit the new physics quite well. (4)

In short, according to the "traditional view of science," scientific representations are built off of well established presuppositions. It is the distinguishing mark of science that it is able to successfully decide which facts are most relevant, and which theories are most valid. It makes such decisions successfully because it always does so on the grounds of established presuppositions.

Again, in Shapere's words, a scientific presupposition is something "immune to revision or rejection in the light of any new knowledge or beliefs acquired" (61). Scientific presuppositions are unaffected by the passing of time; they are time-independent. Because a scientist's choices are *solely* based on only the most established, "unchanging" presuppositions, those choices are devoid of the influence of temporal or changing things. *This, the building of understanding based on reasoned choices, choices which are in keeping with an established ground, is the "spirit" of science.* The "traditional" view of science attributes the "success" of science to its "spirit" alone. A scientist, taken by the "spirit" of science, is freed from the influence of changing things, freed from the influences of his or her historical circumstances, of his or her bodily needs and desires.

Notice that by defining science according to its presuppositions - whether these be defined as presupposed claims about the world, presupposed methods, or presupposed concepts - the traditional approach to science renders science easily distinguishable from other disciplines. Anything that does not share the presuppositions of science is "unscientific." Because progress in science is presumed to be the result of continued application and adherence to particular presuppositions, anything that is "unscientific" can be ignored by scientists without jeopardizing progress. In other words, communication between the "sciences" and the "humanities" is not considered necessary for progress. Furthermore, because science is autonomous in this regard, i.e., because it is uninfluenced by anything "unscientific," and works by continued application and adherence to particular presuppositions,

> ...the *history of science* has long considered the succession of theories as a continuous phenomenon, composed of progress, correction and growth. Thus the principle of correspondence, so named by Neils Bohr, affirms that an earlier theory must at least

be "contained" in the theory that replaces it. (Hallyn 8)

In summary, I have outlined four general characteristics of the "traditional" view of how science works: (1) It is presuppositionist, and as such attributes the success of science to the "spirit" of science alone. (2) The "traditional" approach, particularly since the middle of the last century, marginalizes the moment of "discovery," focussing instead on "justification" as the place where science truly distinguishes itself. (3) The "traditional" approach regards science as autonomous; communication between the "sciences" and the "humanities" is not considered necessary for progress; and (4) The "traditional" approach conceives the history of science as a continuous rather than discontinuous process.

Challenges to the Traditional Approach: How the Spirit Got Caught

Recently, as we know, this "traditional" view of science has encountered difficulties. Various critiques of this view have been offered quite forcefully, particularly by historians and sociologists of science, since the 1950's. A major impetus for this wave of criticisms came in 1962 with T. S. Kuhn's *The Structure of Scientific Revolutions.* One of Kuhn's contributions was the recognition that the history of science may not be the "continuous" progression of ideas it was previously thought to be. Referring to specific examples in history, Kuhn suggests that periods of continuous progress in science, periods of what he calls "normal science," are punctuated by "revolutions." A period of normal science is a period dominated by a particular "paradigm," a particular research model established and accepted by the scientific community. From time to time a new paradigm replaces a previous one. These are times of revolution. Between paradigms, according to Kuhn, there is no continuity, but a logical break. Kuhn's suggestion that successive paradigms are "incommensurable," implies that the history of science is a discontinuous rather than a continuous process.

Since Kuhn's initial contributions, various other scholars have also suggested that science may not be organized by immutable presuppositions. Paul Feyerabend goes so far as to suggest that "science is an essentially anarchic enterprise" (5):

> *the events, procedures and results that constitute the sciences have no common structure;* there are no elements that occur in every scientific investigation but are missing elsewhere. Concrete developments (such as the overthrow of steady state cosmologies and the discovery of the structure of DNA) have distinct features and we can often explain why and how these features led to success. But not every discovery can be accounted for in the same manner, and procedures which paid off in the past may create havoc when imposed on the future. Successful research does not obey general standards; it relies now on one trick, now on another; the moves that advance it and the standards that define what counts as an advance are not always known to the movers. (Feyerabend 1)

Science, according to Feyerabend, is not distinguished by its adherence to immutable presuppositions. Whether they are defined as methods, rules of reasoning, claims about the world, or as concepts used in or in talking about science, the presuppositions of science are continually changing. Indeed, adherence to any presuppositions may have epistemological consequences: it may prevent scientists from "seeing" phenomena in new and perhaps more advantageous ways.

The observation that there is no unchanging, no "atemporal," final arbiter to scientific disputes, has in turn invited varying charges of relativism, charges that the choice of "epistemic warrants" within science may be politically motivated. Feminist scholars in particular, such as Evelyn Fox Keller and Donna Haraway, have been instrumental in tracing the influence of the social, the political, and the personal in science. Such forces perhaps play their most obvious role in the decision making processes that determine what directions scientific inquiry will take, i.e., in determining what scientists choose to know. For example, citing the massive military investments in research and development in the middle part of this century, Keller suggests that it is no accident that science has given us nuclear power rather than solar energy (Secrets 92). Science, on this view, can no longer be thought of as an enterprise progressing without influence from personal and historical circumstances.

Indeed, the very notion that science is independent of historical circumstances, must be regarded, on this view, as dangerous ideology. It is dangerous, first of all, because it prevents not only scientists but other members of the community from critically assessing and discussing what scientists should or should not be studying. It is dangerous, secondly, because of the type of relationship between the scientist and his or her world that this notion configures. As noted above, the scientist, and anyone else for that matter who may be taken by the "spirit" of science, is "distanced" from the world. Representing the world to him or herself on the basis of timeless presuppositions, the scientist may begin to experience, if not treat, the changing forms of this world with the same cold indifference as do the timeless "laws" of nature which the scientist discovers. In other words, the representation of science as independent of historical circumstances and grounded solely on immutable presuppositions, carries with it not only political, but personal consequences. It not only insures that science is directed by "special" rather than "global" interests, but it also conditions the very way we experience the world and our place in it.

The notion that science is independent from other disciplines such as the humanities has been put into question, furthermore, by the longstanding recognition that "different disciplines, sufficiently different from one another so that direct influence seems unlikely, should nevertheless focus on similar kinds of problems about the same time and base their formulations on isomorphic assumptions"(Hayles Chaos xi). Scholars such as Katherine Hayles, and Fernand Hallyn have mapped out various "isomorphisms" between the different disciplines of specific epoches: Hayles looking at similarities in the respective developments of physics, mathematics, biology, literature and literary theory in the twentieth century, and Hallyn looking at developments within astronomy, music, religion, philosophy, and art in the times of Copernicus and Kepler. For example, Hayles suggests - through a detailed analysis which can only be put in general terms here, but which I will take up again in more detail later - that contemporary research in non-linear dynamics, and in fluid mechanics in physics, fractal geometry in mathematics, systems theory in biology, and the coincident shift from structuralism to post-structuralism in literary and social theory, all reflect an overarching interest in the possibilities of disorder. In view of such "isomorphisms" both Hayles and Hallyn link scientific ideas to ideas and factors that are "trans-scientific."

In summary, I have suggested that recent historical and sociological studies of science have presented challenges to the "traditional" view of how science works. Perhaps the presuppositions of the traditional approach itself, the presupposition that science is indeed based on immutable presuppositions, and the corollary that science is an ahistorical, autonomous enterprise, worked to lessen, until recently, the merit of historical and sociological studies of science. Much of the current work in the study of science is devoted to developing representations of how science "works" which incorporate not only philosophical, but also historical and sociological insights on the matter. Current approaches must account for the observation that "new" theories and models may conflict with or be incommensurable with previous ones. They must account for the shifting grounds of science, i.e. for the observation that the presuppositions of science are continually changing. They must account, furthermore, for the observation that science does not change or progress autonomously, but rather in correspondence with other, seemingly unrelated disciplines. They must do this while at the same time accounting for the "success" of science, i.e., current approaches must still account for the fact that scientific representations of the world allow for purposeful and often effective intervention in the world. It is hoped that these "new" representations will also reconfigure the relationship between scientists and their world in a manner which brings scientists "back" to the world, heightening their concern for the changing "forms" of the world. In light of the research which suggests that science may be more value-laden and power driven than was once thought, it is also hoped that these representations will present possibilities for directing science toward global rather than special interests.

Presenting my Thesis:
A Recycling of Grace

This thesis attempts to describe how science works. It begins, in the first chapter, by recognizing that the difficulties recently encountered by traditional approaches to science bear striking resemblance to certain difficulties scientists have recently encountered in the field of thermodynamics. The behaviour of most thermodynamic systems would appear to be determined by time-independent laws - laws, that is, which are true always and everywhere, and which determine in a predictable way how systems will respond to changes in its parameters. Certain systems have been encountered, however, whose responses to change are not governed by any "transcendent" law. Under identical circumstances the same system may behave in two or more different ways in response to the same change in its parameters. This implies that at certain times there is an irreducible random element at work in the behaviour of certain systems. Similar to recent sociological and historical descriptions of science, which suggest that there is no method, concept, or claim that holds true through every instance of scientific success, there would also appear to be no time-independent law by which to predict the behaviour of certain thermodynamic systems. I will argue that models of change recently developed in thermodynamics to explain the behaviour of such systems provide compelling models for explaining how scientific understanding changes and evolves. As we shall see, these descriptions provide models of complexity: the behaviour of thermodynamic systems is produced by a complex interaction of forces which renders the system now predictable by laws, now unpredictable. Change is depicted here as neither entirely law-bound nor entirely arbitrary.

Science does not progress by "spirit" alone. There is no transcendent presupposition of science, nothing permanent to adhere to in order to guarantee that one's work is free of the influence of time. In the second chapter of this thesis I will argue that the spirit of science is more properly defined as a "mystic" rather than "ascetic" spirit. As I will discuss, an ascetic spirit is one which is ideally independent of the body, matter, and historical circumstances, while a "mystic" spirit is never ideally separate from historical things, i.e. things that are subject to change. I will argue that the mystic spirit never works alone but always in combination with grace. Grace, I should caution, is not conceived by the mystics as something received from a completely separate, transcendent God, a God cut off from the world. In my understanding, grace is a type of knowledge conferred from the most immanent, the most immediate, the most historical circumstances. It is my contention that a more adequate description of how science works can be achieved by mapping out the elements of both spirit and grace within science. After having considered, in the next chapter, how models of change recently developed in thermodynamics may be used to describe how science changes and evolves, it will be easier, in the following chapter, to locate where moments of both spirit and grace present themselves within science. Just as these thermodynamic models depict change as neither entirely law-bound, nor entirely arbitrary, it will become clear that scientific understanding is neither entirely "spirited," nor entirely "graceful." The advantage of mystic writings is that they tend to focus on the individual. They describe "methods" by which the individual may attain grace. While the use of thermodynamic models will allow us to describe how science works from a sociological and historical perspective, the use of "mystic" models will allow descriptions of how science is done at the level of the individual scientist.

Although I have been referring to mysticism in general, I will be basing my discussion of it on specific works of the mystic Meister Eckhart. I will not be attempting to do an historically authentic reading of Eckhart's work. Eckhart is a specific individual writing at a particular time within a particular set of cultural realities. He is a theologian. He writes in relation to the scriptures and other writings relating to the scriptures, and his work has most often been conferred the title "mystic" by virtue of the particular relation it establishes with these other writings. I am not interested, however, in how his work derives its formation from, and takes on meaning within his own cultural world, or within the theological tradition. I am interested, rather, in what, in relation to us, is most "contemporary" in Eckhart's work; contemporary, that is, in the second sense of Michel Serres' double definition of the term:

> The word *contemporary* automatically takes two contradictory meanings. It means that Lucretius, *in his own time,* really was already thinking in terms of flux, turbulence, and chaos, and, second, that *through this, he is part of our era,* which is rethinking similar problems.(Conversations 47)

The contemporaneity of Eckhart's work will be demonstrated, in the second chapter, by describing various connections that exist between Eckhart's work and the work of modern day philosophers like Deleuze and Guattari. As I shall demonstrate, Eckhart's descriptions of such notions as "spirit," "soul," and "God," and the relationships between them, are remarkably similar to Deleuze and Guattari's descriptions of "strata," "Bodies without Organs," and the "plane of consistency," and their relationships. I shall also show that the notions of spirit, soul, and God in Eckhart's work also resembles the notions of "steady states," "bifurcation points," and "field of fluxes" that are used to describe certain systems within contemporary thermodynamics. The connections, however, do not end there. Also in the second chapter, the relationship between spirit, grace, and soul as described by Meister Eckhart will be demonstrated to bear striking similarities to the relationship between spirit, grace, and soul as described in the short story On The Marionette Theatre by Heinrich von Kleist. As we shall see, Kleist' notion of "affectation" is equivalent to Eckhart's "creation," to Deleuze and Guattari's "stratification," and to the notion of "ordering" in contemporary thermodynamics. They are equivalent in terms of how each has the same relationship to a particular type of "principle." Kleist's "puppet" is equivalent to Eckhart's "virgin," to Deleuze and Guattari's "masochist horse," and to a thermodynamic system at a bifurcation point, also because each maintains the same relationship to a certain type of "principle." Demonstrating these connections will not only help in the effort of making sense of these varied writings, they will also help to show how the "mystical" has never really been left behind.

Again, despite the fact that Eckhart, Kleist, Deleuze and Guattari, and the contemporary discipline of thermodynamics, each find themselves working in different time periods, within different disciplines, and on different objects of study, connections can be established between them. Michel Foucault has exposed connections between the natural history, the economics, and the grammar of the Classical period and explained them this way: "unknown to themselves, the naturalists, economists, and grammarians employed the same rules to define the objects proper to their own study, to form their concepts, to build their theories" (xi). In this respect, when I say that the mystical has never really been left behind, by "mystical" I am referring to a set of rules or principles. Deleuze and Guattari employed the "mystical" principles to define the objects proper to a range of disciplines: geology, psychoanalysis, musicology, political theory, linguistics, ect. and in so doing developed a series of plateaus: "RHIZOMATICS=SCHIZOANALYSIS=STRATOANALYSIS =PRAGMATICS=MICROPOLITICS" (22). Eckhart employed the mystical principles to define the objects proper to theology and developed his "mysticism." We can add MYSTICISM, then, to Deleuze and Guattari's list of plateaus. However, it is important to note that the connections I will be dealing with are not confined to a single epoch but persists throughout history. I will argue that there are a number of principles, including the mystical, which, at any given time, may influence the organization of a discipline, now one principle determines how philosophers and scientists will define their objects, form their concepts, and build their theories, now another. Curiously, as I will discuss, both Deleuze and Guattari, and Eckhart claim that the "principle" of their respective works - the mystic principle - is *neither this nor that*. Although I will be explaining the principle of neither this nor that in detail, put simply, it is the principle of letting neither this set of rules nor that set of rules determine the organization of one's work or discipline. This principle corresponds neatly to the principle of the arbitrary within thermodynamics whereby the behaviour of a chemical system is determined by neither this law nor that law. The description of how the "mystical" persists through history, therefore, will help to demonstrate how the "arbitrary" and the "graceful" persist in the work of science. As I will argue, the moments when the "arbitrary," the "graceful," or the "mystical" appear as determining factors in the work of science, and the moments when some other principle becomes a determining factor, are equally the result of a complex interaction of forces.

Much has been written this century about science *and* mysticism. Most often, however, mysticism has been treated as science's other, usually in the sense that science and mysticism are described as dealing with mutually exclusive domains. Past treatments of science and mysticism, in other words, have reconfirmed the mutual exclusion of the spiritual and the material domains, between the transcendent and the historical, by suggesting that mysticism deals exclusively with the spiritual domain, while science deals with the material domain. Because the two deal with separate domains the one needs to be supplemented by the other in order to acquire "complete" understanding or experience. As each other's "other" mysticism and science are capable of supplementing each other without affecting each other; they can be mixed, as Schrödinger claims, without "clotting:"

> our science - Greek Science - is based on objectification, whereby it has cut itself off from an adequate understanding of the Subject of Cognizance, of the mind. But I do believe that this is precisely the point where our present way of thinking does need to be amended, perhaps by a bit of blood transfusion from Eastern thought. That will not be easy, we must beware of blunders - blood transfusions always need great precaution to prevent clotting. We do not wish to lose the logical precision that our scientific thought has reached, and that is unparalleled anywhere in any epoch. (54-5)

Similarly, Arthur Eddington writes in a chapter on science and mysticism: "'Here,' says science, 'I have left a domain in which I shall not interfere. I grant that you have some kind of avenue to it through the self-knowledge of consciousness'" (339).

Comparative studies of science and mysticism, such as those of Capra and Jones, have mostly considered the extent to which contemporary physics, particularly quantum physics and relativity physics, share a common "world view" with Eastern mysticism. While these studies recognize similarities between the respective views of contemporary science and mysticism, they continue to regard the two as two; i.e. science and mysticism are considered to have worked towards the "one" view of the world in two different ways.

Unlike the above mentioned works on science and mysticism, I am not dealing with science and mysticism as two in that respect; rather, I will be considering the mystical elements *within* science. Again, it is my contention that by locating the mystical elements within science - elements comparable to notions of grace for example - we will have a more adequate representation of how science works than the aforementioned traditional representation. Mysticism does not just provide a conceptual framework by which to understand the new "world view" of contemporary physics, it also provides conceptual tools for understanding the workings of science itself. Perhaps another distinguishing factor between my own approach to science and mysticism is that most of the previous approaches base their understanding of mysticism on Eastern texts, while I am working with the specific, Christian texts of Meister Eckhart. Eckhart wrote in a different era, but, in my view, by a complex interaction of forces not unlike the interaction of forces which moves glaciers, Eckhart's work arrives to us today as youthful as ever.

Of course, many of the scholars whom I have already mentioned, who have been providing critiques of traditional approaches to science, have also been suggesting alternative descriptions of science. My description of science, built by using models from thermodynamics and mysticism as conceptual tools, is not necessarily an alternative description to those of Serres, Feyerabend, Haraway, Keller, etc. Time and again I will borrow from the observations of these scholars in order to demonstrate the merits of using thermodynamic models to describe science, and in order to bring into focus the elements of grace and spirit within science, while in turn the description of science presented here may at times provide a footing from which to understand the current field of science studies.

CHAPTER I

From Scientific Descriptions to Descriptions of Science

It sometimes looks like a solitary activity, but it is as much the opposite of solitary as human behaviour can be. There is nothing so social, so communal, so interdependent. An active field of science is like an immense intellectual anthill; the individual almost vanishes into the mass of minds tumbling over each other, carrying information from place to place, passing it around at the speed of light.

There are special kinds of information that seem to be chemotactic. As soon as a trace is released, receptors at the back of the neck are caused to tremble, there is a massive convergence of motile minds flying upwind on a gradient of surprise, crowding around the source. It is an infiltration of intellects, an inflammation.

There is nothing to touch the spectacle. In the midst of what seems a collective derangement of minds in total disorder, with bits of information being scattered about, torn to shreds, disintegrated, reconstituted, engulfed, in a kind of activity that seems as random and agitated as that of bees in a disturbed part of the hive, there suddenly emerges, with the purity of a slow phrase of music, a single new piece of truth about nature.

- Lewis Thomas, 1974

In this chapter I shall discuss parallels between the views that philosophers take toward science at a given time, and the prevailing views that scientists take toward their world at that time, i.e., between descriptions of science, and scientific descriptions. I shall demonstrate, first of all, that early "traditional" descriptions of how scientific understanding changes, as I have characterized those descriptions in the introductory chapter, have analogous features to descriptions of dynamic systems made by classical physicists. In both cases change is considered to be *lawful*, *determined*, and *reversible*.

This notion of change has proven to have only a limited range of applicability. Perhaps the science of thermodynamics has demonstrated its limitations most forcefully. The formulation of the second law of thermodynamics early in the 19th century introduced a concept foreign to dynamics, that of *irreversible* change: the entropy of the universe is increasing, never decreasing. Notably, the introduction of this concept of change occurs at roughly the same time as the abandonment of logics of discovery in the philosophy of science. The acceptance of the concept of "irreversible" change by philosophers of science would explain the abandonment of logics of discovery. Indeed, as I shall attempt to demonstrate, developments within thermodynamics parallel developments within the philosophy of science quite remarkably. Early studies in thermodynamics concentrated predominantly on closed, "stable" systems. These systems provide models of lawful, determined, and irreversible change. More recently, however, certain systems - open, "unstable" ones - have been encountered which do not behave according to the same model. I suggest, in this chapter, that the difficulties facing traditional approaches to science arise from attempts to build descriptions of science based on similar models of change as those provided by closed, stable, thermodynamic systems, and that descriptions of open, unstable systems provide better models for explaining how scientific understanding changes.

Parallels between descriptions of science and scientific descriptions are not the result of mere coincidence. By this, however, I do not mean to say that there is a direct or causal relationship between the two. The ways that scientists view nature does not necessarily determine the ways that philosophers view science, nor vice versa. It will become clear that partial-isomorphisms between disciplines are the result of a complex interaction of forces.

1.1 Science as a Dynamic System: Lawful, Determined and Reversible Change

Descriptions of science are descriptions of change. Scientific understanding changes as a function of scientific activity continued over some period of time. Descriptions of science, therefore, are only useful in so far as they explain how scientific understanding changes.

Scientific descriptions of natural phenomena, as well, are often descriptions of change. For example, describing change, particularly changes from motion to rest, and from rest to motion, as well as, more generally, all changes of velocity, is the central preoccupation of classical physics. The laws of motion that Newton formulated apply to dynamic systems, systems in which change, being governed by time-independent laws, is highly predictable and reversible.

> In the world of dynamics, change is identified with acceleration or deceleration. The integration of the laws of motion leads to the trajectories that the particles follow. Therefore the laws of change, of time's impact on nature, are expressed in terms of the characteristics of trajectories.
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> The basic characteristics of trajectories are *lawfulness, determinism, and reversibility*. We have seen that in order to calculate a trajectory we need, in addition to our knowledge of the laws of motion, an empirical definition of a single instantaneous state of the system. The general law then deduces from this "initial state" the series of states the system passes through as time progresses, just as logic deduces a conclusion from basic premises. The remarkable feature is that once the forces are known, any single state is sufficient to define the system completely, not only its future but also its past. At each instant, therefore, everything is given. Dynamics defines all states as equivalent: each of them allows all the others to be calculated along with the trajectory which connects all states, be they in the past or the future. (Prigogine and Stengers 60)

Given the position and momentum (momentum is the product of an object's mass and its velocity), at any instant, of a ball thrown in the air, classical physics allows us to determine where and when it will hit the ground, and when and from where it was thrown, along with its acceleration, velocity, and position in space at any time in between. The ball's trajectory is *determined* by *laws* of nature, and may be *reversed* by reversing the direction of the forces acting on the ball.

While the notion that change is *lawful*, *determined*, and *reversible* is central to dynamics, it is also central to early, traditional approaches to science as I have characterized them. Just as the trajectories of thrown balls are determined by the time-independent laws of classical physics, the trajectory of scientific understanding - the movement from an unclear understanding to a clearer one - was thought to be determined by time-independent presuppositions. Early philosophers of science, like classical physicists, attempted to formulate the time-independent presuppositions which determined change in scientific knowledge. Although scientists, unlike thrown balls, were thought to have a choice as to whether or not to follow the rules of science, it was still thought that in order for science to progress they must follow the most scientific presuppositions.

Along with believing that scientific progress was determined by laws, early traditional approaches also considered scientific progress to be reversible. Knowledge of the forces acting on a thrown ball at any single position on its trajectory, allows one to describe the state of the ball at every other position of its trajectory, both past and future. Similarly, early philosophers of science, as I have mentioned, attempted to formulate logics of discovery on the belief that the "trajectory" of scientific understanding - progress - could be deduced from a single "initial state." In other words, they believed that demonstrating how initial observations lead to a scientific hypothesis or theory was sufficient for validating that hypothesis or theory.

1.2 Science as a Thermodynamic System: From Reversible to Irreversible Change

The formulation of the second law of thermodynamics early in the 19th century introduced a concept foreign to dynamics, that of *irreversible* change: the entropy of the universe is increasing, never decreasing.

All isolated systems move spontaneously toward a state of maximum entropy, *a state of equilibrium where there is no further net change in entropy with time.* No isolated system moves away from equilibrium. If one imagines an enclosed glass aquarium with two inert gasses, say a red gas and a blue gas, contained on either side of the aquarium, and separated by a glass barrier, and if one were to imagine that the barrier was suddenly removed, one could easily envision the two gasses diffusing to a state of maximum disorder, a state wherein both gasses would be interspersed with each other, each of them now occupying the full volume of the now violet coloured aquarium. One would not expect the system to move in the reverse direction: the two gasses, once dispersed, will not spontaneously return to their previous order. Unlike the trajectory of a thrown ball, where the ball's initial position and momentum determine its entire trajectory, including its final resting position, the "trajectory" of the two gasses in an aquarium is determined independently of the initial positions of the gasses. In other words, whether the two gasses initially occupy separate halves of the aquarium, or whether the two gasses are originally compartmentalized in checkerboard fashion throughout the aquarium, does not matter, the final state will be the same: the state of maximum entropy. Unlike dynamic systems, it is not possible to determine the previous history of a thermodynamic system regardless of any empirical knowledge one may have of the system at a given time.

> In dynamics, a system changes according to a trajectory that is given once and for all, whose starting point is never forgotten (since initial conditions determine the trajectory for all time). However, in an isolated system all non-equilibrium situations produce evolution toward the same kind of equilibrium state. By the time equilibrium has been reached, the system has forgotten its initial conditions - that is, the way it had been prepared. (Prigogine and Stengers 121)

Equilibrium is the state toward which a thermodynamic system spontaneously moves. As mentioned, for isolated systems, equilibrium is defined by the state of maximum entropy. Once equilibrium is achieved, there is no further change in entropy. Most systems are not isolated however, but can exchange heat or matter with their environments. Such systems seldom exist at equilibrium for very long. Obviously, the moment a green gas is injected into our gas filled aquarium, our previously established equilibrium will be disturbed. The new gas will spontaneously disperse throughout the aquarium, however, until equilibrium is regained.

Systems which are not isolated but which are "closed," i.e., systems which are contained within boundaries across which heat can be exchanged with the environment, move toward a state of equilibrium - zero entropy change - which is determined by its boundary conditions: temperature, pressure, and volume, for instance. For this reason the type of internal change described above, the change from a state of non-equilibrium within a system at constant boundary conditions to a state of equilibrium, may be distinguished from the changes of state that a system may undergo in response to transformations in its boundary conditions. If one were to continually decrease the temperature surrounding our gas filled aquarium, for example, the aquarium would loose heat. We would eventually reach some critical temperature where one of the gasses, say the blue one, would begin to condense into liquid. If this temperature were to be maintained the system would arrive at a quite different state than that of its initial equilibrium: there would now be a blue liquid at the bottom of the aquarium, and a blue and red gas dispersed throughout the rest of its volume. This type of change, unlike the "internal" change described above, is reversible; one need only return the temperature to its previous level. In either case, the final state of equilibrium for a closed system may be described for each set of possible boundary conditions. It corresponds to the state where there is no further change in entropy. What is important here is that "in order to produce equilibrium, a system must be 'protected' from the fluxes that compose nature. It must be 'canned,' so to speak, or put in a bottle" (Prigogine and Stengers 128). Once an equilibrium system is attained, its state, and its "exchanges" with the environment, can be "controlled" with a high degree of accuracy by manipulation of its boundary conditions.

Because of the success of statistical descriptions by Maxwell and Boltzmann, equilibrium production is now widely explained in terms of interactions at the molecular level. Maxwell showed that the movement from non-equilibrium to equilibrium in systems such as our glass aquarium may be described as a movement from an arbitrary distribution of molecule velocities to a normal distribution. Boltzmann, following Maxwell, showed that a system's movement toward equilibrium (maximum entropy) is a system's movement to a state corresponding to maximum probability. In other words, the equilibrium condition in our aquarium wherein both red and blue gasses are equally distributed over the entire volume corresponds to the state wherein the number of possible combinations of the gasses' molecules is at a maximum. Any given molecule has an equal chance of being found at any location in the aquarium. There are, for example, far fewer possibilities of combining the molecules in the aquarium if we are confined to placing all of the red molecules on one side and all of the blue molecules on the other. In such a case any given molecule does not have an equal chance of being found anywhere in the aquarium, but must be found on one side or the other.

Maxwell and Boltzmann's statistical approach to entropy demonstrates that the movement from non-equilibrium to equilibrium within thermodynamic systems is describable in terms of changes in the movement of molecules. Whether or not the laws which govern these changes at the molecular level are deducible from the laws of classical physics has been a debated question, the history of which is beyond the scope of this paper. Prigogine and Stengers insist that thermodynamic laws are *not* deducible from classical laws. In thermodynamics

> there appears a dissymmetry in time: entropy increases in the direction of the future, not of the past. This seems impossible when we consider dynamic equations that are invariant in respect to time inversion. As we shall see, the second law is a selection principle compatible with dynamics but not deducible from it. It limits the possible initial conditions available to a dynamic system. The second law therefore marks a radical departure from the mechanistic world of classical or quantum mechanics. (Prigogine and Stengers 125)

Despite the likelihood that the laws which govern the molecular motions which produce equilibrium are not deducible from the laws of dynamics, the movement of molecules does appear to be law bound: their movements always move the entire system toward equilibrium. Unaffected by external conditions, the movements and interactions of the molecules of a "canned" system, being determined by the time-independent laws of thermodynamics, ultimately bring the system to the state of maximum entropy corresponding to its boundary conditions.

What is important here is the analogy which may be drawn between the descriptions of thermodynamic systems as summarized above, and traditional descriptions of science. Since the early nineteenth century, the science of thermodynamics has concentrated predominantly on equilibrium systems, and those system's responses to changes in their boundary conditions. By "equilibrium system" I mean a "canned" system which moves spontaneously towards a state of equilibrium characterized by a normal distribution of molecule velocities and maximum probability. This concentration on equilibrium systems reflects the traditional approach to science which, I suggest, sees science itself as an equilibrium system.

Just as thermodynamic systems must be "canned" in order to produce equilibrium, the traditional approach to science, as I have characterized it, believes that science must be "canned" in order to produce objective knowledge. Grounding scientific investigations on immutable presuppositions in effect "cans" science; it "protects" science from the vicissitudes of time and history.

While the production of equilibrium is the result of an "internal" process, equilibrium systems may be "controlled" by manipulation of external conditions. Similarly, while the attainment of scientific understanding itself is considered, by the traditional view, to be solely an "internal" process, how scientific understanding gets "used" or "harnessed" is considered a matter of external conditions.

Scientists, according to the traditional view, behave like molecules in our glass aquarium. Unaffected by external conditions, and acting according to time-independent laws or presuppositions, scientists and molecules alike produce equilibrium/objective knowledge within a "canned" system.

The laws of thermodynamics began to be formulated in the early 19th century. Fourier's law - stating that heat flows from the hot source to the cold and not vice-versa - was formulated in 1811, and Sadi Carnot first formulated the second law of thermodynamics in 1824. As already noted, the time of formulation of these laws roughly coincides with the abandonment of logics of discovery within the philosophy of science. The final state of equilibrium, for isolated, thermodynamic systems, is determined independently of the initial conditions of the system. One cannot trace the trajectories of thermodynamic systems back to their initial conditions. In like manner, demonstrating how initial observations lead to a hypothesis or theory was no longer considered sufficient for validating that hypothesis or theory.

1.3 Science Far from Equilibrium: Change that is Not Determined by Time-Independent Laws.

Just as traditional approaches to science have recently met with appalling difficulties, so too have traditional approaches to thermodynamic systems. It would seem that certain thermodynamic systems have been discovered which do not behave as the established laws of thermodynamics would predict. When moved away from equilibrium these systems do not return spontaneously to a state of equilibrium. Systems, for example, that would be expected to return to states corresponding to the definitions of Maxwell and Boltzmann - normal molecule velocity distributions and maximum probability - instead arrive at, and maintain themselves in, qualitatively different states. These systems arrive at and are maintained in states "far-from-equilibrium," which are not determined by any time-independent law.

> Far from equilibrium, the system may still evolve to some steady state, but in general this state can no longer be characterized in terms of some suitably chosen potential (such as entropy production for near-equilibrium states).
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> The absence of any potential function raises a new question: What can we say about the stability of states toward which the system evolves? Indeed, so long as the attractor state is defined by the minimum of a potential such as the entropy production, its stability is guaranteed. It is true that a fluctuation may shift the system away from this minimum. The second law of thermodynamics, however, imposes the return toward the attractor. The system is thus "immune" with respect to fluctuations. Thus, whenever we define a potential, we are describing a "stable world" in which systems follow an evolution that leads them to a static situation that is established once and for all.
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> When the thermodynamic forces acting on a system

> become such that the linear region is exceeded, however, the stability of the stationary state, or its independence from fluctuations can no longer be taken for granted. Stability is no longer the consequence of the general laws of physics. We must examine the way a stationary state reacts to the different types of fluctuations produced by the system or its environment. In some cases, the analysis leads to the conclusion that a state is "unstable" - in such a state, certain fluctuations, instead of regressing, may be amplified and invade the entire system, compelling it to evolve toward a new regime that may be qualitatively quite different from the stationary states corresponding to minimum entropy production.
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> Thermodynamics leads to an initial general conclusion concerning systems that are liable to escape the type of order governing equilibrium. These systems have to be "far-from-equilibrium." In cases where instability is impossible, we have to ascertain the threshold, the distance from equilibrium, at which fluctuations may lead to new behaviour, different from the "normal" stable behaviour characteristic of equilibrium or near-equilibrium systems. (Prigogine and Stengers 140)

Steady state structures that are defined by the minimum of a potential such as the entropy production may therefore be distinguished from steady state structures that result from far-from-equilibrium conditions. Prigogine and Stengers call the later "dissipative structures." Continuing to rely on the work of Prigogine and Stengers, I will describe systems that produce dissipative structures in more detail because they provide models of change that will be useful for explaining how scientific understanding changes. These types of systems are called "non-equilibrium systems," in contradistinction to "equilibrium systems" which do not produce dissipative structures.

In the above quotation Prigogine and Stengers state that most systems are "immune with respect to fluctuations." I mentioned two sources of fluctuations when discussing our gas filled aquarium: the addition of a new gas, and a change in temperature. Both the addition of a new gas and a change in temperature caused the system to "fluctuate" away from equilibrium, but in both cases the system spontaneously moved back to equilibrium. We can readily envision random fluctuations in the aquarium: at any given instant there may be slightly more molecules on one side of the aquarium than the other. These fluctuations may be attributable to "untraceable" forces: perhaps slight fluctuations in the temperature or pressure surrounding the aquarium, or perhaps a random element inherent to the molecular interactions of gaseous molecules. Nevertheless, the "second law of thermodynamics" remains the most "powerful" force in such a system and any fluctuations are quickly "brought back" to equilibrium. This describes a "stable" system. Certain systems, those that produce dissipative structures, are "unstable" however. Similar "untraceable" forces may cause fluctuations within these systems which are "amplified and invade the entire system, compelling it to evolve toward a new regime." Such systems, in other words, can change or reorganize, often in response to even slight changes in their environment.

> These far-from-equilibrium phenomena illustrate an essential and unexpected property of matter: physics may henceforth describe structures as adapted to outside conditions. We meet in rather simple chemical systems a kind of prebiological adaptation mechanism. To use somewhat anthropomorphic language: in equilibrium matter is "blind," but in far-from-equilibrium conditions it begins to be able to perceive, to "take into account," in its way of functioning, differences in the external world (such as weak gravitational or electric fields). (Prigogine and Stengers 14)

Systems that produce dissipative structures do not change their organising principle spontaneously in response to any and all changes in the environment. Rather, as Prigogine and Stengers suggest, there is a "taking into account" involved. We will see that this taking into account involves "communication," even at the molecular level, between individual molecules and between collectives of molecules within the system.

Let us consider a more concrete example of a dissipative structure. I want to consider "chemical clocks" which are a type of "organization" that chemical systems are known to produce under certain conditions when chemical reactions are pushed far-from-equilibrium. First of all, what does it mean to say that a chemical reaction is at or far from equilibrium? Let us recall our gas filled aquarium, and let us pretend that the two gasses are no longer inert. Let us pretend, rather, that the molecules of the red gas react with the molecules of the blue gas to form a green gas and a yellow gas. The reaction might be written as follows: R + B --> G + Y. This reaction equation means that whenever a red molecule collides with a blue molecule there is a certain probability of the two molecules exchanging atoms and changing into a green molecule and a yellow molecule. By "probability" it is meant that only certain collisions occur with enough energy to push the reaction forward. If the probability is high, i.e., if only a small amount of energy is required to drive the reaction, then most collisions will result in the production of a green and yellow molecule, and the rate of the reaction will be quicker. If the probability is negligibly small then the reaction will not occur at any perceptible rate. This probability is related to the velocity of the molecules combining in the collision; only molecules travelling at or above a certain combined velocity can drive the reaction. For reasons to be stated in a moment, this probability can be assumed to be constant for systems with constant boundary conditions. It is referred to as the rate constant, k, for a reaction. Because the reaction is driven by collisions between molecules, the reaction rate is also proportional to the product of the concentrations of the two types of reacting molecules. Obviously, as more green molecules are being produced the concentrations of the reacting molecules will decrease and the red and blue molecules will collide together much less frequently. Given that the rate of a chemical reaction is proportional to k, and to the product of the concentrations of reactants (signified as [R][B] for the reaction equation above), the reaction rate equation for the above reaction is written: rate = k[R][B].

However, if a red and blue molecule can react to form a green and yellow molecule, then a green and yellow molecule can also exchange atoms to return to a red and a blue molecule. This reaction would be the reverse of the above reaction: G + Y --> R + B. As above, this equation means that this reaction will occur at a rate proportional both to the rate constant of this reaction, say k_2, and to the product of the concentrations of the green and yellow molecules. The rate of this reaction may be written: $rate_2 = k_2[G][Y]$. In any case, both this reaction, reaction two, and the above reaction, reaction one, will be occurring in our aquarium at the same time. Our original molecules will collide together to form yellow and green molecules, which will in turn begin to collide together to reform the original molecules. Chemical equilibrium is achieved when the rate of reaction one is balanced with or equal to the rate of its reverse reaction, reaction two. Once equilibrium is reached there is no further net change in the reactant or product concentrations. In other words, chemical equilibrium is achieved when $k[R][B] = k_2[G][Y]$, or $k/k_2 = [G][Y]/[R][B]$. Given that, for systems at constant boundary conditions, k/k_2 is constant, it is possible to determine the concentrations of all the reactants and products at equilibrium given what the initial concentrations are. For instance, if we know the numbers of blue and red molecules initially in our aquarium, and we know the respective rate constants of reactions one and two, then we can determine the number of red, blue, green, and yellow molecules that will be in our aquarium when the system reaches equilibrium.

If we know, for example, that it is slightly more likely that a red and blue molecule collision will result in a yellow and green molecule than vice versa, and if we begin with an equal amount of red and blue molecules and nothing else, then when the system reaches equilibrium there will be only slightly more green and yellow molecules in our aquarium than red and blue ones.

What is important here is that no matter what the final concentrations of the reactants and products are, because the system's boundary conditions are uniform and unchanging, at equilibrium all the molecules of all the gasses will be equally dispersed throughout the aquarium. The second law of thermodynamics, after all, demands that the system move toward a normal distribution of molecule velocities and maximum probability. Indeed, the assumption that the gasses move toward a normal distribution of molecule velocities is necessary for the assumption that the rate constants of the chemical reactions will remain constant at equilibrium. This is true since, as noted above, the rate constants are a measure of the probability that colliding molecules will have a given velocity.

Chemical equilibrium defined by the equation $k/k_2 = [Y][G]/[R][B]$, is a stable, stationary state. If, after the system reaches equilibrium, we add more red molecules, the system will be moved away from equilibrium. We can call this a fluctuation. However, the system will spontaneously move back to equilibrium. Given the numbers of red molecules added we can once again determine the new concentrations of all the gasses at the new equilibrium. In this case, given that at equilibrium $k/k_2 = [Y][G]/[B][R]$, we know that increasing the number of red molecules will lead to an increase in [R], [Y], and [G], and a decrease in [B] at the new equilibrium. If we increase the temperature surrounding the aquarium, heat (energy) will be transferred into the aquarium which will translate into higher molecule velocities (kinetic energy), and into a higher probability that a given collision will drive a chemical reaction. This is another fluctuation. The ratio k/k_2 will change, but the system will spontaneously move to equilibrium concentrations corresponding to the new ratio. Again we can determine the new concentrations of all the gasses at the new equilibrium because we know that the "second law" always pushes the system to a state defined by k/k_2 = [Y][G]/[R][B], the state of "thermodynamic equilibrium."

Now, what about chemical clocks? Various types of chemical reactions have been identified wherein fluctuations such as those described above can be large enough to push the system so "far-from-equilibrium" that the system does not move spontaneously back to equilibrium. Rather, the system will move spontaneously into a steady state that cannot be defined by reaction rate equations such as those that define thermodynamic equilibrium. I mentioned, for example, that the addition of more red molecules to our aquarium causes a fluctuation from equilibrium. Prigogine and Stengers note that there are certain chemical reactions wherein such an addition of a reacting species to a system can be large enough that the system does not move back to a state characterized by constant reactant and product concentrations. Rather, it moves to a state wherein there are oscillations in the concentrations of certain reacting species, at regular time intervals.

> We therefore have a periodic chemical process - a chemical clock. Let us pause a moment to emphasize how unexpected such a phenomenon is. Suppose we have two kinds of molecules, "red" and "blue." Because of the chaotic motion of the molecules, we would expect that at a given moment we would have more red molecules, say, in the left part of the vessel. Then a bit later more blue molecules would appear, and so on. The vessel would appear to us as "violet," with occasional irregular flashes of red or blue. However, this is NOT what happens with a chemical clock; here the system is all blue, then it abruptly changes its colour to red,

> then again to blue. Because all these changes occur at REGULAR time intervals, we have a coherent process.
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> Such a degree of order stemming from the activity of billions of molecules seems incredible, and indeed, if chemical clocks had not been observed, no one would believe that such a process is possible. To change colour all at once, molecules must have a way to "communicate." The system has to act as a whole. (Prigogine and Stengers 148)

In order for the oscillations observed in chemical clocks to occur, all of the reaction driving collisions of the billions of molecules of the system must be synchronized to occur at the same time. Obviously, such a degree of synchronicity requires a type of organization far different from the type defined by Maxwell and Boltzmann.

Chemical clocks are dissipative structures resulting from fluctuations in molecule concentrations. We might think of an increase in the concentration of a molecule within a system as a "force" imposing the occurrence of certain processes in the system. Normally such a force would cause reaction processes to occur in such a ratio as to drive the system back to thermodynamic equilibrium. In the above example the force was "strong" enough to impose a chemical clock. This same "force," however, also imposes the occurrence of other processes in the system, such as diffusion processes. Normally, as was the case with our aquarium, when a collection of molecules is introduced into a system, it will diffuse until the system is spatially homogeneous. When the "force" is strong enough however, it can cause diffusion processes to occur in such a way as to lead to structures other than spatially homogeneous ones.

> Indeed, whereas at equilibrium and near-equilibrium the system remains spatially homogeneous, the diffusion of the chemical throughout the system induces, in the far-from-equilibrium region, the possibility of new types of instability, including the amplification of fluctuations breaking the initial spatial symmetry. Oscillations in time, chemical clocks, thus cease to be

> the only kind of dissipative structure available to the system. Far from it; for example, oscillations may appear that are both time- and space-dependent. They correspond to chemical waves of X and Y concentrations that periodically pass through the system. (Prigogine and Stengers 148).

Fluctuations in concentrations are not the only "forces" that impose processes on systems. Temperature fluctuations, for example, impose processes of conduction and convection which have been known to induce, in the far-from-equilibrium region, very elaborate dissipative structures. The rates of the various processes imposed by such forces are called "fluxes." There are "lines of flux" permeating all non-isolated systems as a result of internal fluctuations, and fluctuations in their environments. Most thermodynamic systems exist in a state characterized by a type of "thermal chaos," where individual molecules, "unconcerned" by macroscopic conditions, bounce randomly off each other. These are the states where rules of equilibrium apply. The molecules of certain systems, however, when forces due to fluctuations become too great, will spontaneously "organize" along lines of flux. For such systems there may be a variety of steady structures available to them corresponding to the number of "forces" and "fluxes" to which they can "organize" themselves.

The point where a fluctuation is so great that a system moves from one steady state to another - such as the point where a system moves from thermal chaos to a chemical clock - is called a "bifurcation point." At bifurcation points the system has a "choice" between two or more states, i.e., there is more than one way that the system can self-organize in response to a given fluctuation.

> At the bifurcation point two new stable solutions merge. Thus a new question: where will the system go when we reach the bifurcation point? We have here a choice between two possibilities [...]. How will the system choose between left and

> right? There is an irreducible random element; the macroscopic equation cannot predict the path the system will take. Turning to a microscopic description will not help. There is also no distinction between left and right. We are faced with chance events very similar to the fall of dice. (Prigogine and Stengers 161-2)

The "choice" spoken about here between two possible organizations of a system, between, for example, a steady state organization definable by a standard reaction rate equation, and a chemical clock organization which is not definable by the same equation, points to the "time-dependence" of the equations that describe the various possible organizations of a non-equilibrium system. The equation depends not only on the particular configuration of the various parameters of the system *at a given time*, but on an "irreducible random element" - at times, under identical conditions, the same system must organize according to one equation or another in response to a given fluctuation; because the conditions remain identical, the choice is random.

The "choice" that a system makes is often determined by the "previous history of the system," (Prigogine and Stengers 161) or on untraceable occurences - "a microscopic fluctuation occurring at the 'right moment'" (Prigogine and Stengers 176). The fact, for example, that the concentration of red molecules may have been at one level rather than another when the concentration of blue molecules "fluctuated" could determine whether the system organizes into a chemical clock or some other structure, or a slight fluctuation in temperature coinciding with the fluctuation of blue molecule concentration could determine a different choice.

At any bifurcation point there may occur fluctuations in one area of the system that are different than in another area, resulting in different choices, and hence different structures being organized in the same system. The phenomena of various steady states coexisting in the same system, arranged both spatially and temporally, causes the system to appear "chaotic." This "turbulent chaos," however, is distinguishable from the "thermal chaos" mentioned above.

> In thermal chaos as realized in equilibrium, all characteristic space and time scales are of molecular range, while in turbulent chaos we have such an abundance of macroscopic time and space scales that the system appears chaotic. (Prigogine and Stengers 168)

> For a long time turbulence was identified with disorder or noise. Today we know that this is not the case. Indeed, while turbulent motion appears as irregular or chaotic on the macroscopic scale, it is, on the contrary, highly organized on the microscopic scale. (Prigogine and Stengers 141)

We can think of "turbulent chaos," the "unsteady" state of a system at a bifurcation point, as an organization or "ordering" of dissipative structures within dissipative structures. The term "chaos," in any case, must be cautiously employed.

> It is difficult to disentangle the meaning of words such as "order" and "chaos." Is a tropical forest an ordered or a chaotic system? The history of any particular animal species will appear very contingent, dependent on other species and on environmental accidents. Nevertheless, the feeling persists that, as such, the overall pattern of a tropical forest, as represented, for instance, by the diversity of species, corresponds to the very archetype of order. Whatever the precise meaning we will eventually give to this terminology, it is clear that in some cases the succession of bifurcations forms an irreversible evolution where the determinism of characteristic frequencies produces an increasing randomness stemming from the multiplicity of those frequencies. (Prigogine and Stengers 169)

This distinction, incidentally, between thermal and turbulent chaos, will help to put Feyerabend's notion of science as anarchy into perspective. Although science may appear chaotic by the way in which its methods and models are distributed in their application across time and space, it is not "disordered." It will become clear that the "anarchy" of science is more properly regarded as turbulent rather than thermal chaos.

Previously, I compared scientists to molecules in an equilibrium system. Unaffected by surrounding conditions, the movement of molecules in an equilibrium system is determined solely by the time-independent laws of thermodynamics. As such, molecules collide randomly with each other, ultimately producing the type of steady state described by Maxwell and Boltzmann. Similarly, unaffected by surrounding conditions, and acting according to time-independent presuppositions, scientists produce objective knowledge within a "canned" system.

If we continue in our comparison of scientists with molecules, but look at science as a system "far-from-equilibrium" rather than an "equilibrium" system, we will begin to see science in a different way. From a "far-from-equilibrium" point of view, science would no longer be seen as a collection of independent scientists acting and making decisions according to time-independent methods and presuppositions. Scientists, rather, would be seen to act in synchronicity with other scientists, and their decisions would not be based on time-independent presuppositions, but rather their presuppositions would change in accordance with a "changing field of fluxes." This changing field would be produced both by "internal" and "external" forces.

Steady states are produced and maintained by all chemical systems when the rates and directions of the various processes occurring within the system - convection, conduction, chemical reactions, diffusion, etc. - become determined by some "principle." Both thermodynamic equilibrium and chemical clocks are steady states. For simplicity, we might say that "zero entropy change" is the principle which determines the processes that produces the former, while "periodicity" is the principle that determines the processes that produces the latter. The principle of the system determines how fluctuations in the various forces of the system - fluctuations in temperature, pressure, volume, or the number of molecules present, for example - will affect the various processes of the system. Most fluctuations affect the processes of the system in such a way as to keep the system in a steady state. Some fluctuations, however, can bring the system to a bifurcation point, and may possibly lead to a fundamental rearrangement in how the various processes of the system work together and respond to change - i.e. the system's processes may become determined by a new "principle." Between the state of thermodynamic equilibrium and the chemical clock state, there is a bifurcation point where neither this principle nor that principle determines the behaviour of the molecules. The "choice" that the system makes as to which principle to follow depends both on the history of the system and on an irreducible random element.

> We expect that near a bifurcation, fluctuations or random elements would play an important role, while between bifurcations the deterministic aspects would become dominant. (Prigogine and Stengers 176)

In the following section I will identify the processes within science which produce scientific knowledge, the forces which affect those processes, and the principles which determine how these processes work together. To foreshadow, the processes of science are the practices which make up the everyday life of science, including, most notably, the communication practices by which facts, theories, and problems get "chosen" within science. The "forces" which affect these processes include not only the array of facts, ideas, models, problems, and techniques available to scientists, but also include various "forces" relating to the social and political contexts of scientists at a given time and place. The "organizing principle" of science will be identified as a "discourse regime" which "determines" how the "practices" of science, and hence how the knowledge produced by science, are affected by changes in the various "forces" of science. Considering scientific knowledge to be the "steady state" which the system called "science" produces, it would appear, from a far-from-equilibrium point of view, that scientific knowledge is produced when the practice of science follows principles, but these principles are not immutable.

Reconsidering our gas filled aquarium, we can visualize various "areas" within the aquarium arbitrarily defined by imaginary "boundaries" across which molecules freely pass. Fluctuations may occur within any given "area" differently than in others. Indeed, as I mentioned above, different dissipative structures may develop in different areas of a system. Any given "area," furthermore, may be further divided into yet smaller areas. Similarly, science may be conceived in terms of "areas" or communities within communities. We may be able to conceive, for example, of boundaries distinguishing "harder" from "softer" sciences. Within the harder sciences chemistry may be distinguished from physics, thermodynamics from quantum mechanics, and so on. Perhaps individual laboratories may be considered as dissipative structures organized within and in conjunction with other dissipative structures. Similar to the various areas of our aquarium, any given scientific "area" is not unaffected by fluctuations in surrounding areas. In our aquarium fluctuations in one area send lines of flux in all directions. Molecules diffuse from one area of the system into another. A flux of heat or energy drives processes within the system at faster rates, now here, now there. Do ideas, observations, or models "discovered" or "chosen" in one area of science not move like heat into other areas causing "reaction processes" to occur in different directions and/or at different rates?

What are the forces which might cause fluxes within science and how do they move through science? Where are the bifurcation points located within science? How do scientists, both at the individual level, and as communities, "choose" their "principles?" What types of random elements, and historical elements might influence such choices? I believe that further elaboration of "order through fluctuation" models, as named by Prigogine and Stengers, will bring us closer to answers to these questions. They provide models for complex interactions between individual and collective behaviour.

1.4 How Termites Build a Nest: Organizing in a Changing Field of Fluxes

> A system far from equilibrium may be described as organized not because it realizes a plan alien to elementary activities, or transcending them, but, on the contrary, because the application of a microscopic fluctuation occurring at the "right moment" resulted in favouring one reaction path over a number of other equally possible paths. Under certain circumstances, therefore, the role played by individual behaviour can be decisive. More generally, the "overall" behaviour cannot in general be taken as dominating in any way the elementary processes constituting it. Self-organization processes in far-from-equilibrium conditions correspond to a delicate interplay between chance and necessity, between fluctuations and deterministic laws. (Prigogine and Stengers 176)

> Let us consider an example where the growth of a fluctuation leading to a new structure can be followed in detail.

> The construction of a termites' nest is one of those coherent activities that have lead some scientists to speculate about a "collective mind" in insect communities. But curiously, it appears that in fact the termites need very little information to participate in the construction of such a huge and complex edifice as the nest. The first stage in this activity, the construction of the base, has been shown by Grassé to be the result of what appears to be disordered behaviour among termites. At this stage, they transport and drop lumps of earth in random fashion, but in doing so they impregnate the lumps with a hormone which attracts other termites. The situation could thus be represented as follows: the initial "fluctuation" would be slightly larger concentrations of lumps of earth, which inevitably occurs at one time or another at some point in the area. The amplification of this event is produced by the increased density of termites in the region, attracted by slightly higher hormone concentration. As termites become more numerous in the region, the probability of their dropping lumps of earth there increases, leading in turn to a still higher concentration of the hormone. In this way "pillars"

> are formed, separated by a distance related to the range over which the hormone spreads. (Prigogine and Stengers 187)

Originally, the termites, acting independently of each other, are evenly dispersed throughout an area, much like the molecules of a gas might be dispersed throughout an enclosed aquarium. Their random movements, however, will eventually cause slightly more termites to collect in a given location. This fluctuation is amplified when more termites are attracted to the higher concentration of hormone in that area.

We can see how environmental forces can establish fluxes in the system which can change the rate of the nest building process, and influence the "choice" of the area where the termite nest will be built. A food supply, for example, which is unevenly dispersed, may cause the termites to diffuse toward different locations. The existence of predators in a given area may further influence the rate and direction in which termites move. The more forces or "bifurcation parameters" acting on a system, "the more complex a system is, [and] the more numerous the types of fluctuations that threaten its stability"(Prigogine and Stengers 188).

We can see, also, that not every fluctuation will lead to a termite nest. Slightly more termites might randomly appear in a given location relative to other locations, but along with increasing the concentration of hormone in the area, this fluctuation may decrease the amount of food in the area, or increase the amount of predators. These later forces might act as a "diffusion mechanism" leading to the regression of the original fluctuation.

According to Prigogine and Stengers, "there is a *nucleation* mechanism. Depending on whether the size of the initial fluctuating region lies below or above some critical value [...], the fluctuation either regresses or else spreads to the whole system" (187). With increasing efficacy of the system's "diffusion mechanisms," the critical nucleus size increases. "The critical size is thus determined by the competition between the system's "integrative power" and the chemical mechanisms amplifying the fluctuation" (Prigogine and Stengers 187).

I will compare the various "choices" made by termites that lead to the construction of a termite nest, to the various choices made by scientists that lead to the construction and acceptance of scientific theories. I will argue that various forces, or "bifurcation parameters," may be identified which influence both the rate and the direction of scientific change. These fluctuating bifurcation parameters establish a complex "field of fluxes" which often acts now as a "diffusion mechanism" inhibiting discoveries and the acceptance of certain types of new theories, and later as an "amplifying power" encouraging those same discoveries and theories. I will attempt to provide examples of diffusion mechanisms and amplifying mechanisms within science.

Scientists make choices as to what constitutes a worthy problem for investigation. They also make choices as to which theories or models are worth testing, as to which tests are worth applying, and as to which theories or models are worth accepting. Just as the choices made by individual termites are made within a field of fluxes which influence those choices, so too are each of the choices within science made within a field of fluxes.

Bruno Latour and Steve Woolgar (1986) have found, simply by asking working scientists about their motivations, that various "non-scientific" factors influence how individual scientists choose what and where they will study.

> [The scientist's] calculation thus involved consideration of available funds, the extent of positive feedback, the general funding policy of a given state, and the publication and reception of his papers. Since all these factors are reckoned to vary with time, [the scientist's] major concern was to determine when best

> to capitalize on the opportunities available. (Latour and Woolgar 191)

Scientists do not choose their "areas" based on scientific curiosity alone; rather, factors such as the availability of credible colleagues in that area also influence the choice. Such a factor is in turn influenced by a second primary factor, the availability of funding in a given area, which is in turn influenced by political factors. A given state may, for political reasons, feed more funding into military research for example, while at the same time, the political or moral disposition of scientists may lead certain scientists away from military research.

The history of science, as well, is a factor involved in such decisions. Obviously, a scientist could not choose to study non-equilibrium systems until such systems had been discovered. But what does it mean to "discover" non-equilibrium systems? Keller points out that "only in the late [nineteen-]twenties and early thirties did explicit distinctions between equilibrium and non-equilibrium (or between closed and open) systems - and the contemporaneous characterization of living organisms as open, nonequilibrium systems - begin to appear in the literature" (Refiguring 65). Prior to this, "non-equilibrium systems" had most certainly been observed; they simply were not understood *as* non-equilibrium systems. Prigogine and Stengers point out that chemical clocks were probably observed in the nineteenth century but for "cultural" or "ideological" reasons were not studied (307). One might say that non-equilibrium systems were there to be studied since the nineteenth century, but various factors acted collectively as a diffusion mechanism preventing most scientists from studying them until much later. What were these factors? And what were the factors which eventually amplified the interest in and the study of non-equilibrium systems as non-equilibrium systems?

The "discovery" of non-equilibrium systems *as* non-equilibrium systems is an example of what I have been calling a "change" in science. Evelyn Fox Keller (Refiguring) describes a parallel change that occurred in the field of molecular biology: a change from what Keller calls a "discourse on gene action" which prevailed during most of this century, to what she calls a "discourse on gene activation" which began to develop with the growth of developmental biology in the 1960's, and has now become more prevalent. According to the "discourse on gene action," genes not only carry the information required for protein synthesis and development, they also "direct" the processes of synthesis and development.

> The Mendelian theory postulates discrete, self-perpetuating, stable bodies - the genes - resident in the chromosomes, as the hereditary materials. This means, of course, that the genes are the primary internal agents controlling development. (Brink cited in Keller Refiguring 7)

The "discourse on gene activation," on the other hand, describes synthesis and development by pointing "neither to cytoplasmic nor to nuclear determination but rather to a complex but highly coordinated system of regulatory dynamics that operate simultaneously at all levels: at the level of transcription activation, of translation, of protein activation, and of intercellular communication - in the nucleus, in the cytoplasm, indeed in the organism as a whole" (Keller Refiguring 30). On this view, developmental processes are not reducible to the "agency" or "governance" of genes; rather, these processes are the result of a complex interaction of factors wherein no one factor overdetermines or governs the others. In order to benefit from the work already done by Keller, I will focus on this change within biology, rather than the aforementioned, parallel change within thermodynamics, in order to get an idea of the types of factors which may be involved in the diffusion and amplification of now one and now another discourse within science.

> When a number of American geneticists did turn their attention to development in the mid-1930's, such a [discourse on gene action] helped define the approach they took: it framed the questions they could or could not meaningfully ask, the organisms they would choose to study, experiments that did or did not make sense to do, the explanations that were or were not acceptable. In this sense the discourse on gene action served cognitive as well as political functions. (Keller Refiguring 11)

Keller argues, first of all, that there was never any solid evidence supporting the discourse on gene action to begin with, and that this discourse developed despite evidence which should have worked against it.

> Geneticists could say nothing about what genes are, or how they were subsequently connected to adult characters or traits, and little about how they interacted with the cytoplasm of the fertilized egg (the specifically maternal contribution), [...] nonetheless [Morgan] wrote in 1924, "It is clear that whatever the cytoplasm contributes to development is almost entirely under the influence of the genes carried by the chromosome, and therefore may in a sense be said to be indifferent." (Keller Refiguring 7)

On the other hand, it might seem more "obvious" - given that the genetic content of all the cells of a complex organism is the same despite manifest differences that occur among the cells - that the genes are not determining agents. Indeed, various embryologists, early in this century, warned against placing too much attention solely on the genome. "To the embryologist it seemed self-evident that this problem of differentiation, so deeply at the heart of their own concerns, was simply incompatible with the notion that the gene was the exclusive locus of action" (Keller Refiguring 13). In short, the earliest observations within molecular biology might have supported a "discourse on gene activation" more so than a "discourse on gene action."

Although evidence did seem to be available to support the early whispers of some embryologists whose arguments resembled a discourse on gene activation, those whispers were "repressed" in favour of a discourse on gene action, and were not "amplified" until much later. What were the diffusion and amplification mechanisms involved? Since "observations" within biology alone did not seem to support the discourse on gene action, Keller looks to factors external to the discipline to explain why the discourse prevailed. She suggests that the discourse on gene action developed initially, and most forcefully, in America. This was in part a consequence of political and economic rivalry between America and Germany.

> The nucleus was the domain in which American genetics staked its unique strengths, associated with American interests (and prowess), whereas the cytoplasm was associated with European, especially German, interests and prowess. (Keller Refiguring 36)

Keller also suggests that the prevailing gender ideology of the time encouraged the development of the discourse on gene action over and above other possible discourses. Given that in humans the male gamete is mostly genetic material, while the female gamete is mostly cytoplasm, Keller claims that the discourse on gene action flourished in part because "the overwhelming historical tendency has been to attribute activity and motive force to the male contribution while relegating the female contribution to the role of passive, facilitating environment" (Keller Refiguring 39).

Just as traditional thermodynamics considers change within equilibrium systems to be determined by time-independent laws which may be formulated once and for all and used to predict the behaviour of systems, so too does the discourse on gene action consider development to be determined by time- and context-independent laws of which the genes are the embodiment. One can see, therefore, how prevalent models of change within science, may have conditioned the way in which development was initially conceived. This also suggests the possibility that discourses within both thermodynamics and biology may have at once supported and been supported by similar discourses within other fields.

In short, external forces - including, as mentioned above, political and economic rivalries between nations, gender ideologies, and discourses within other fields - have influenced the development of the discourse on gene action. Although some embryologists, early in the century, did argue against paying too much attention to the genome, the above mentioned "forces" acted as a "diffusion mechanism" causing such arguments to regress, while at the same time amplifying the discourse on gene action. These external forces act within science in much the same way external forces act within a system of termites. Within a system of termites such forces influence the "choices" made by individual termites as to their direction of motion, which eventually leads to a termite nest being built in one area rather than another. Within a system of molecular biologists such forces influence the choice as to which discourse - gene action or activation - is used, which in turn influences the types of organisms microbiologists study, the types of experiments they do, and the explanations they accept. The discourse on gene action has lead to phenomenal advances in the understanding of genes - their structure, and their role in protein synthesis for example - but has lead to few advances in the understanding of cell differentiation, and development. This point should be made very clear, a given discourse does not just condition the way scientists think about and discuss their work, it also conditions the way the science is organized. The change from a discourse on gene action to activation marks a fundamental change in the organization of scientists: "In 1972 the first graduate programs explicitly designating developmental biology appear in *Peterson's Annual Guide to Graduate Programs in the Biological Sciences*. By 1981 the number of such programs had grown to fifty, by 1992 to eighty, and in

1985 the Stanford University Board of Trustees voted to establish an entire department in developmental biology" (Keller Refiguring 26).

So why did this amplification of the discourse on gene activation eventually come about? What fluctuation(s) occurred to bring the "system" of molecular biology from a "state" organized according to a gene action discourse to a "state" organized according to a gene activation discourse? Keller points out that it was not new techniques that allowed for the new progress in the study of development. "The first experimental studies to spark the interests of molecular biologists in the early development of higher organisms relied solely on classical techniques" (Refiguring 32). If observations and technical advances alone are required to amplify a given discourse, then the discourse on gene activation should probably have been amplified sooner than it was.

Perhaps the types of observations which lead to the early whispers of a gene activation discourse among embryologists had to increase before the discourse could flourish. Perhaps, for example, the falsification of explanation after explanation of how genes actually "direct" development may have eventually pushed the discourse on gene action beyond return, driving it, as it were, to a bifurcation point. Perhaps, to borrow terms from Thomas Kuhn, the processes of normal science carried out under a given paradigm or discourse produced "anomalies" which eventually became so numerous that they caused a crisis or "revolution." I do not believe, however, that such arguments which look to fluctuations within microbiology alone can explain the change from a discourse on gene action to activation however. First, the development of metaphors of DNA as information in the 1950s and 60s, and the subsequent and continued success in decoding the human genome, far from producing a "crisis" in the science, may have, as Keller argues, reinforced scientists' concentration on genes as the key loci of control, and of the cytoplasm as ""indifferent" (Refiguring 24). Secondly, and more importantly, such an argument does not account for very similar developments or changes taking place outside of genetics and molecular biology, not the least of which is the development of non-equilibrium thermodynamics, and, as Keller (1995) suggests, the development of systems analysis and computer science.

I have pointed out that forces external to molecular biology - political and economic forces, gender ideologies, and discourses within other fields - supported the discourse on gene action despite "internal" forces which worked against that discourse. This would suggest that factors internal to the discipline are not the only bifurcation parameters, that external forces might also influence the timing of any change in discourse.

The world around which cells multiply and differentiate has been changing. Outside microbiology labs, "life - the life of political, economic, and military exchange - was daily growing more chaotic and vastly more complex" (Keller Refiguring 82). New disciplines have been developing - such as information theory, cybernetics, systems analysis, operations research and computer science - as a consequence of new complexities associated with continued population and technological growth.

Keller points out that there has been extensive traffic from these disciplines to molecular biology in the post-war period - "in philosophy, in techniques, in legitimacy, and in actual bodies" (Refiguring 88). She suggests that notions of networks and of organizational complexity borrowed from systems analysis and computer science and then applied to systems of development studied in microbiology could have lead to new ways of describing the role of genes within development. She suggests, in other words, that fluctuations external to microbiology most certainly influenced the change from a discourse on gene action to activation. It would seem certain as well that all of the developments mentioned above also supported and were supported by the development of non-equilibrium thermodynamics.

Changes within a science can begin with internal fluctuations - such as new observations falsifying previous theories - or with external fluctuations - such as new models borrowed from other disciplines - but in either case the fluctuation will not be amplified unless it "resonates" with the various lines of flux permeating the science. Change within science is not determined by any one factor or principle. Feyerabend explains the 'Copernican Revolution' in similar terms:

> We see here very clearly how misguided it is to try reducing the process 'Copernican Revolution' to a single principle, such as the principle of falsification. Falsification played a role just as new observations played a role. But both were imbedded in a complex pattern of events which contained tendencies, attitudes, and considerations of an entirely different nature. (150)

Perhaps in one case internal fluctuations alone could lead to a given scientific change, while in another external fluctuations would be more influential. Most changes in science are likely the expression of a complex interaction of various internal and external fluctuations. The addition to a chemical system of a sufficient amount of only one molecule could lead to a chemical clock, but this is not the only parameter affecting the system. The same addition of molecules may or may not lead to a chemical clock depending on the temperature of the system. Theories or models "borrowed" from external disciplines may be amplified or repressed within a different discipline depending on such factors as (1) the strength of the original fluctuation, i.e., the "success" or popularity of a given model outside of a given discipline, (2) the rates of diffusion, i.e., the extent of traffic or communication between disciplines, and (3) the stability of the system, i.e., the "success" of the previous theory or model in explaining data, and in persuading scientists and funding agencies.

> The problem of the stability of a system vis-à-vis this kind of change may be formulated as follows: the new constituents, introduced in small quantities, lead to a new set of reactions among the system's components. This new set of reactions then enters into competition with the system's previous mode of functioning. If the system is "structurally stable" as far as this intrusion is concerned, the new mode of functioning will be unable to establish itself and the "innovators" will not survive. If, however, the structural fluctuation successfully imposes itself - if, for example, the kinetics whereby the "innovators" multiply is fast enough for the latter to invade the system instead of being destroyed - the whole system will adopt a new mode of functioning: its activity will be governed by a new "syntax." (Prigogine and Stengers 189-90)

In the previous section I mentioned that steady states are produced and maintained by all chemical systems when the behaviour of the molecules of the system becomes determined by some principle, such as the principle of "periodicity" which organizes molecules into a chemical clock. Similarly, scientific disciplines and knowledge are produced and maintained when the behaviour of a collection of scientists becomes organized according to some discourse. The change from one discourse to another, as with the change from an equilibrium state to a chemical clock, occurs as the expression of a complex interaction of forces. Previous organizations are not lost when new ones develop. The discipline of developmental biology does not replace genetics. Previous models for understanding development remain available for the consideration of scientists, and changing factors - both internal and external to the discipline - may restore an old discourse in new circumstances. In like manner, "*the same* nonlinearities may produce an order out of the chaos of elementary processes and still, under different circumstances, be responsible for the destruction of this same order, eventually producing a new coherence beyond another bifurcation" (Prigogine and Stengers 206).

Notice that the non-equilibrium model describes at least two types of change. First, there are changes in the "organizing principle" of a system, and secondly there are "fluctuations" that take place within a system that may or may not lead to a change in the organizing principle. Recall that fluctuations in any number of a system's parameters - such as, for example, the temperature, pressure, volume, and number of molecules of a chemical system - may cause changes in the rates and directions of various processes - for example, diffusion and reaction processes. The organizing principle organizes the various processes of a system in such a way as to bring the system back to, or maintain the system within, a definable steady state.

Non-equilibrium systems, therefore, provide a model for the relationship between at least two types of change within science. First, there are the changes in the organizing principles of sciences - these are changes in discourse regimes corresponding to the appearance of new fields of study such as developmental biology, systems analysis, cybernetics, non-equilibrium thermodynamics, relativity physics, etc. Secondly, there are the "fluctuations" in the bifurcation parameters of science - such as changes in the techniques and instruments available to a science, changes in the number of scientists in a particular field, changes in the quantity of information, in the pool of "models," "observations," and "anomalies," and changes in various social and political parameters. Fluctuations in these "bifurcation parameters" affect the rates and directions of scientific processes. By "processes" I mean the practices which make up the everyday life of science, including the communication practices by which facts and problems are chosen and concepts built up. However, as with chemical systems, the "organizing principle" of a science organizes these processes - it constrains the communication processes of science, setting limitations both on what constitutes worthy questions and meaningful answers, and on the possibilities for communication between different types of scientists. The "organizing principle" assembles these processes such that only those fluctuations in its bifurcation parameters that reach a certain magnitude might alter the organization. The "discourse regime" renders certain facts, ideas, models, problems, techniques, etc. more salient or valuable than others. In this manner, a "discourse regime" maintains the "stability" or "integrity" of a science; it secures a field's "autonomy."

Importantly, organizing principles are not transcendent. They are not independent of the processes they determine, or the fluctuations they stabilize. Any given fluctuation in a given parameter, depending on how it finds itself in relation to the other fluctuating parameters of the system, could change the organizing principle of a system and fundamentally alter the rates and directions of its processes. Indeed, the "organizing principle" of a system is constituted by the very "forces" it governs.

1.5 The Limitations of Modelling: Some Difficulties Posed by Complexity

The use of termite colonies or of chemical clocks as models for science has its limits. Scientists are not termites; nor are they molecules. They are not as interchangeable as molecules or termites. One scientist may be more influenced by a particular line of flux than another. This is because scientists' peculiar individual histories influence the respective choices they make. I have already suggested, for example, that scientists trained in embryology tended to explain development differently than those trained in genetics. The fact that individual histories and idiosyncrasies may lead scientists in different directions when facing the same problem decreases the "stability" of scientific disciplines or organizations. How then do such disciplines composed of individuals with diverging histories and presuppositions, avoid chaos?

> The stabilizing affect of communication, of diffusion processes, could be a partial answer to these questions. In complex systems, where species and individuals interact in many different ways, diffusion and communication among various parts of the system are likely to be efficient. There is competition between stabilization through communication and instability through fluctuations. The outcome of that competition determines the threshold of stability. (Prigogine and Stengers 189)

Despite the efficiency of human communication processes, individual scientists invariably acquire unique combinations of experiences which do provide a degree of complexity to science that exceeds the complexity of chemical systems, or systems of termites. Change within science often begins with persistent individuals for whom a particular "line of flux" is more salient or influential than it is for others.

We can say today that Galileo was on the right track, for his

> persistent pursuit of what once seemed to be a silly cosmology has by now created the material needed to defend it against all those who will accept a view only if it is told in a certain way and who will trust it only if it contains certain magical phrases called "observational reports". And this is not an exception - it is the normal case: theories become clear and "reasonable" only *after* incoherent parts of them have been used for a long time. Such unreasonable, nonsensical, unmethodical foreplay thus turns out to be an unavoidable precondition of clarity and of empirical success. (Feyerabend 18)

Fluctuations in the distribution of termites are either amplified or repressed depending upon the configuration of the various lines of flux permeating the system. Here we find another difference which suggests that changes within science may be more complex than changes in the organization of termites. Within science a given fluctuation could create the conditions necessary for its own amplification. In other words, whether fluctuations within science are amplified or repressed is not necessarily determined by a pre-existing niche. A new theory, for example, does not necessarily die if it does not gain support from the available collection of "observations" in a given discipline. *Theories, perhaps borrowed from another discipline, very often produce the observations needed for their acceptance in a new discipline, often due to the obstinacy or "genius" of individuals.*

> The development of the Copernican point of view from Galileo to the 20th century is a perfect example of the situation I want to describe. We start with a strong belief that runs counter to contemporary reason and contemporary experience. The belief spreads and finds support in other beliefs which are equally unreasonable, if not more so (law of inertia; the telescope). Research now gets deflected in more directions, new kinds of instruments are built, "evidence" is related to theories in new ways until there arises an ideology that is rich enough to provide independent arguments for any particular part of it and mobile enough to find such arguments whenever they seem to be

> required. (Feyerabend 17-8)

Some changes - new discourses or theories - spread quickly throughout a system, while others may spread more gradually, or not at all, depending on how well the new fluctuation exploits the lines of flux that guaranteed the stability of the previous regime, and on how well it "produces" new conditions that encourage its acceptance. The use of chemical clocks and systems of termites as models for science is limited also because such models do not adequately reflect the "evolution" of science. Chemical clocks can easily be shifted back to near-equilibrium conditions, merely by shifting one of its bifurcation parameters - temperature, pressure, volume, molecule concentrations, etc. Similarly, a liquid can shift from laminar flow to turbulence and back. "The situation for models involving the size of the system as a bifurcation parameter is quite different. Here, growth occurring irreversibly in time produces an irreversible evolution" (Prigogine and Stengers 189). Science is an ever increasing collection of data, technologies, and theories which become recorded in journals and textbooks. Past theories and observations always remain in the "collective memory" of science to influence current decision processes. Unlike chemical clocks, "we cannot take as given either a definite set of interacting units, or a definite set of transformations of these units. The definition of the system is thus liable to be modified by its evolution" (Prigogine and Stengers 189).

> [Science] so conceived is not a series of self-consistent theories that converge toward an ideal view; it is not a gradual approach to the truth. It is rather an ever increasing ocean of mutually incompatible (and perhaps even incommensurable) alternatives, each single theory, each fairy-tale, each myth that is part of the collection forcing the others into greater articulation and all of them contributing, via this process of competition, to the development of our consciousness [...]. The history of science

becomes an inseparable part of the science itself. (Feyerabend 21)

We begin to see here a complex interaction between the history of science which produces a multiplicity of competing theories and observations, and social and political factors which influence the individual and collective "choices" as to which theories and observations are acceptable.

As discussed above, the "choice" of discourse within molecular biology has been influenced by such factors as political and economic rivalries between nations, and expanding populations - factors which are in turn affected by "advances" in science. Such interrelated processes create very complex situations. Each change within science has a collective aspect that can lead to quite unanticipated global changes, which in turn can lead to new changes in science.

CHAPTER 2

Lines and Knots

Paul Klee. *Bifurcations and Snail (Gabelungen und Schnecke)*, 1937/82.

2.1 The Puppet and the Horse

In Kleist's short story, On the Marionette Theatre, the concepts of "spirit" and "grace" can be easily distinguished. On the one hand, "spirit" is associated with human intentions and consciousness:

> I replied that this [puppeteer's] work had been represented to me as being rather spiritless - something like turning the crank that plays a hurdy gurdy.
>
> Not at all," he answered. "In fact, the movement of his fingers are related to the movements of the puppets attached to them somewhat like numbers to their logarithms or the asymptote to the hyperbola."
>
> But at the same time, he believed that even the last fragment of spirit of which he had spoken could be removed from the marionette, and that its dance could take place totally in the realm of mechanical forces - by means of a crank as I imagined. (416)

On the other hand, "grace" is associated with a lack of human intentions, and with mechanical forces and matter:

> I said that no matter how deftly he presented the case for his paradoxes, he would never make me believe there could be more grace in a mechanical puppet than in the structure of the human body.
>
> He responded that it was absolutely impossible for man even to equal the puppet in this. Only a god could compete with matter in this field; and here is the point where the two ends of the cyclical world connect. (418)
>
> In the organic world, to the extent that reflection grows dimmer and weaker, the grace therein becomes more brilliant and powerful. (420)

In short, spirit is associated with mind, while grace is associated with matter. However, as Kleist's use of the word "soul" will help to make clear, this binary is not an opposition; there is no dualism between spirit and grace, mind and matter.

"Soul," in Kleist's short story, is both a *line,* and a *site,* depending on whether Kleist is writing about a puppet, which has grace (in which case the soul remains a line), or whether he is writing about a human, which has spirit (in which case the soul is found in a particular site or position). Kleist writes about a type of puppet which is controlled by a single string attached to the puppet's "center of gravity." Kleist describes this string or *line* as "the path of the dancer's soul:"

> The line that the center of gravity had to describe was certainly simple and, he believed, in most cases straight. In cases where it was curved, its curvature seemed only of the first or at most the second degree; and in the latter case, it was only elliptical, a form of movement altogether natural to the human body (because of the joints), which therefore took the operator no great skill to indicate.
>
> But from another point of view, this line was something very mysterious. For it was nothing other than the *path of the dancer's soul*; and he doubted if it could be found unless the operator imagines himself at the puppet's center of gravity - that is, in other words, dance. (416)

This line, Kleist writes, is the path *of* the dancer's soul, not *to* the dancer's soul. The actions of the puppet, the movement of its limbs, its dance, cannot be *traced* up the path of the dancer's soul *to* their origin in the intentions of the puppeteer. In fact, they cannot be traced *to* an origin in any one site or position:

> He answered that I mustn't imagine that every limb was pulled or positioned separately by the operator during the different movements of the dance.
>
> Each movement, he said, had its center of gravity; it suffices to control this point within the interior of the figure; the limbs, which were nothing but pendula, followed by themselves in a mechanical way without any further assistance.
>
> He added that this movement was quite simple; that

> whenever the center of gravity was moved in a *straight line*, the limbs would still describe *curves*; and that the whole figure, shaken at random, often assumed a kind of rhythmical movement that was similar to dance. (Kleist 415)

The puppet is "shaken at random." The puppeteer does not *intend* the puppet's dance. The puppeteer does not place him or herself at the *origin* of the puppet's dance, trying to control the various limbs of the puppet into a unified form based on an image in his or her head. Puppeteering is not mimetic. Rather, the puppeteer imagines him or herself at the puppet's "center of gravity." With the puppeteer's intentions, and the forces of gravity *at the same center*, neither intentions nor gravity forms a root or origin of the dance.

Kleist's "center of gravity" is, in Deleuze and Guattari's terms, a "plateau:"

> The "plateau" designates something very special: a continuous, self-vibrating region of intensities whose development avoids any orientation to a culmination point or end. (Deleuze and Guattari 22)

We can see similarities as well between Kleist's "center of gravity," Deleuze and Guattari's "plateau," and Prigogine and Stengers' "bifurcation point." Recall that a bifurcation point is the point where a fluctuation exceeds a certain size such that a system is between two or more possible steady states. Just as neither intentions nor gravity forms the root or origin of the puppet's dance, neither the organizing principle of one state nor the other determines the behaviour of a chemical system at a bifurcation point.

> At the bifurcation point two new stable solutions merge. Thus a new question: where will the system go when we reach the bifurcation point? We have here a choice between two possibilities[...]. How will the system choose between left and right? There is an irreducible random element; the macroscopic equation cannot predict the path the system will take. Turning to a microscopic description will not help. There is also no

> distinction between left and right. We are faced with chance events very similar to the fall of dice. (Prigogine and Stengers 161-2)
>
> We expect that near a bifurcation, fluctuations or random elements would play an important role, while between bifurcations the deterministic aspects would become dominant. (Prigogine and Stengers 176)

In short, the puppet's soul, the soul that in Kleist's short story is associated with grace, is a line that cannot be traced *to* any point; it has neither beginning nor end but always a center from which it grows or dances. Like a chemical system at a bifurcation point, the puppet's actions are not determined by any principle; the puppet is shaken at random.

The imagining of oneself at the puppet's center of gravity, this imagining which somehow brings the forces behind the puppet's actions onto the same plane, is, in Deleuzean terms, "a way of constituting a body without organs and bringing forth a plane of consistency of desire" (155). The puppeteer's imagining of him or herself at the puppet's center of gravity is similar, in Deleuzean terms, to a masochist's "becoming horse:"

> PROGRAM... At night, put on the bridle and attach my hands more tightly, either to the bit with the chain, or to the big belt right after returning from the bath. Put on the entire harness right away also, the reins and thumbscrews, and attach the thumbscrews to the harness. My penis should be in a metal sheath. Ride the reins for two hours during the day, and in the evening as the master wishes. Confinement for three or four days, hands still tied, the reins alternately tightened and loosened. The master will never approach her horse without the crop, and without using it. If the animal should display impatience or rebelliousness, the reins will be drawn tighter, the master will grab them and give the beast a good thrashing. (Dupouy cited in Deleuze and Guattari 155)

For Deleuze and Guattari, this masochist's "becoming horse," like the puppeteer who imagines him or herself at the puppet's center of gravity, is not engaged in imitation or mimesis. The masochist is not imitating a horse, just as the puppeteer is not trying to imitate, with the puppet, the image of a dance in his or her head.

> These are not phantasies or subjective reveries: it is not a question of imitating a horse, "playing" horse, identifying with one, or even experiencing feelings of pity or sympathy. Neither does it have to do with an objective analogy between assemblages. The question is whether Little Hans can endow his own elements with the relations of movement and rest, the affects, that would make it become horse, forms and subjects aside. Is there an as yet unknown assemblage that would be neither Hans's nor the horse's, but that of the becoming horse of Hans? (Deleuze and Guattari 258).

Neither Hans nor horse, neither intentions nor gravity, neither this steady state nor that one: becoming horse, imagining oneself at the puppet's centre of gravity, entering a bifurcation point - in each case it is a question of forces, a question of letting neither this force nor that force overdetermine or govern the others:

> The masochist presents it this way: *Training axiom - destroy the instinctive forces in order to replace them with transmitted forces.* In fact, it is less a destruction than an exchange and circulation ("what happens to a horse can also happen to me"). Horses are trained: humans impose upon the horse's instinctive forces transmitted forces that regulate the former, select, dominate, overcode them. The masochist effects an inversion of signs: the horse transmits its transmitted forces to him, so that the masochist's innate forces will in turn be tamed. There are two series, the horse's (innate force, force transmitted by the human being), and the masochist's (force transmitted by the horse, innate force of the human being). One series explodes into the other, forms a circuit with it: an increase in power or a circuit of intensities. The "master," or rather the mistress-rider, the equestrian, ensures the conversion of forces and the inversion of signs. The masochist constructs an entire assemblage that simultaneously draws and fills the field of

> immanence of desire; he constitutes a body without organs or plane of consistency using himself, the horse, and the mistress. (155-6)

The "center of gravity," or the "circuit of intensities," is a center, or circuit, where no force overdetermines or controls another: neither intentions nor gravity, neither innate nor transmitted forces. Should one force overdetermine another, should there be a "power takeover in the multiplicity," then, in Deleuzean terms, the BwO becomes *organized*, or *stratified;* in Kleist's terms, the soul becomes *affected*, or *spirited*; and in Prigogine and Stengers's terms a system becomes ordered out of the turbulence of a bifurcation point. Affectation is the reason, according to Kleist, that a human dancer cannot attain the level of grace of a puppet.

> "And the advantage this puppet would have over living dancers?"
>
> "The advantage? First of all a negative one, my excellent friend; namely, that it would never be affected. For affectation appears, as you know, when the soul (*vis motrix*) is found at any point other than the movement's center of gravity. As the operator now has absolutely no other point in his control through the wire or string except this one, all of the other limbs are what they should be - dead, mere pendula, following the basic law of gravity - an admirable quality looked for in vain among the greater part of our dancers.
>
> "Just look at P--," he continued, "when she plays Daphne and, pursued by Apollo, turns to look back at him; her soul is in the vertebrae of her lower back; she bends as if she were about to break, like a maid from the school of Bernini. Or look at young F-- when, as Paris, he stands among the three goddesses and presents the apple to Venus; his soul is actually (it is frightful to see) in his elbow.
>
> "Such mistakes," he added, stopping short, "are inevitable since we have eaten from the tree of knowledge. But paradise is barred and the cherub behind us; we must make the journey around the world to see if maybe there is some opening from behind."

> I laughed. "Of course," I thought, "the spirit cannot err where there is none." (Kleist 417)

Young F--'s elbow is the *determining joint.* All the other joints and limbs must be positioned just so in order for the elbow to lift the apple in such and such a manner. The body becomes "organized," "unified" around a predetermined intention or role: in F--'s case, the role of Paris which demands - prior to the dance - that the apple be handed to Venus. All of the dancer's moves can be *traced* back to this "unifying role" - we may call it the dancer's "ground." Unlike the puppet whose feet only skim the ground, the human dancer's feet *always come back to the ground.*

> We use the ground to rest upon and recover from the effort of dance - a moment that is obviously not dance itself, and allows for nothing better than to make it disappear as much as possible. (Kleist 418)

For equilibrium systems the minimal entropy production is the determining function, the system's ground. All of the molecular collisions and processes of the system are directed in such a way as to bring the system to a state of minimal entropy production. Minor fluctuations are always brought back to equilibrium. For chemical clocks "periodicity" is the determining function. All of the molecular collisions and processes of the system are directed in such a way as to keep the system in a clock-like organization. In this regard stable structures are "spirited" in Kleist's sense of the term. Like human dancers they always come back to an established ground in accordance with a determining function. Major fluctuations, however, can bring a system to a bifurcation point. A bifurcation point lies between equilibrium and a chemical clock. At this point neither minimal entropy production nor periodicity is the determining function. The system is, as it were, ungrounded, and responsive now to even slight fluctuations in its environment. In Kleist's terms the system becomes "open to grace."

> The important point is that, depending on the chemical process responsible for the bifurcation, this mechanism expresses an extraordinary sensitivity. Matter, as we mentioned earlier in this chapter, perceives differences that would be insignificant at equilibrium. Such possibilities lead us to think of the simplest organisms, such as bacteria, which we know are able to react to electric or magnetic fields. More generally they show that far-from-equilibrium chemistry leads to possible "adaptation" of chemical processes to outside conditions. This contrasts strongly with equilibrium situations, in which large perturbations or modifications of the boundary conditions are necessary to determine a shift from one structure to another. (Prigogine and Stengers 165)

Young F--, like an equilibrium system, is so much involved in following a predetermined role that he cannot be as responsive to his immediate environment as is the puppet, or as is a system at a bifurcation point. His performance is *spirited*, but not *graceful*.

To get a clearer idea of the nature of "soul" in Kleist, we can compare it to Deleuze and Guattari's BwO. I suggest that, for Kleist, spirit is to the soul what, for Deleuze and Guattari, the organism is to the BwO.

> The organism [or spirit] is a stratum on the BwO [or soul], in other words the organism [spirit] is a phenomenon of accumulation, coagulation, and sedimentation, that, in order to extract useful labour from the BwO [soul] imposes upon it forms, functions, bonds, dominant and hierarchized organizations, organized transcendences. (159)

In Prigogine and Stengers' terms, the BwO is a field of fluxes. All systems are permeated by changing lines of flux. Concentration, temperature, and pressure gradients send lines of flux, processes of diffusion, of convection, of chemical reactions, etc. through every chemical system. Chemical systems organize according to lines of flux. The BwO is a field of always fluctuating fluxes.

Equilibrium structures and chemical clocks are strata on the BwO. Once stratified, the various processes of the system follow deterministic laws which keep the system in a particular steady state and all but the strongest fluctuations do not alter the general direction of those processes. Once stratified, however, such structures can destratify, reach a bifurcation point, and become sensitive to even the slightest, random fluctuations in the environment, at which time they may restratify, perhaps into an altogether new order.

To distinguish between the puppet and the human dancer is not to suggest that affectation does not occur, or cannot occur, while puppeteering, nor is it to suggest that a human dancer cannot be graceful. Certainly one can imagine a puppeteer "yanking too hard" or "trying too hard" in such a way as to lead to a tangled puppet rather than to graceful dance. Likewise, the human dancer, just as his or her feet come to momentary rest on the ground, swings between moments of affectation (spirit), and moments of grace.

> There is no dualism between here and there, no axiological dualism between good and bad [...] there are knots of arborescence in rhizomes, and rhizomatic offshoots in roots [...]. The important point is that the root tree and canal-rhizome are not two opposed models. (Deleuze and Guattari 20)

There is no dualism, no separation between spirit (mind, the human dancer) and the soul which is associated with grace (matter, the puppet); rather, the difference between them is a question of lines - lines of flux - and of positions within their field of interaction: there are "knots" of grace in spirit. It is by acting according to transcendent or time-independent principles that spirit has traditionally been separated from matter. In the opening chapter I described the "spirit" of science as the building of understanding based on reasoned choices, choices which are in keeping with an established ground. Because traditional approaches to science have by and large attempted to define the proper grounds of science in terms of time-independent presuppositions, the "spirit" of science has traditionally been regarded as separated or at least separable from the time-dependent, changing world of "nature." Indeed, separation on this view has been regarded as an ideal: the more in keeping with transcendent principles one's methods and representations are, the more separated from the determining forces of history, and the more objective or scientific they are presumed to be. Hence, Nietzsche describes science as the latest expression of ascetic ideal:

> The truthful man, in the audacious and ultimate sense presupposed by the faith in science, *thereby affirms another world* than that of life, nature, and history; and insofar as he affirms this "other world," does this not mean that he has to deny its antithesis, this world, *our* world?... It is still a *metaphysical faith* that underlies our faith in science - and we men of knowledge of today, we godless men and anti-metaphysicians, we, too, still derive *our* flame from the fire ignited by a faith millennia old, the Christian faith, which was also Plato's, that God is truth, that truth is *divine*. (Nietzsche 152)

The spirit of science, as I have described it in the first chapter, is what I called an "ascetic spirit." An "ascetic spirit" is a spirit [ideally] separated from the vicissitudes of time and the natural world. There is dualism between an ascetic spirit and the historical world. Kleist's spirit is not ascetic. Again, there is no dualism between spirit and the immediate world in Kleist's view, rather, any separation between spirit and the immediate world is a question of lines and positions.

The relationship between spirit and matter, as Kleist envisions it, is similar to the relationship between stable structures and the fluxes that permeate them. The processes of stable structures appear to follow transcendent or time-independent principles, principles which hold true regardless of the changes in the fluxes which permeate the system. The processes of equilibrium systems, for example, always bring the system back to a state of minimum entropy production, and this would seem to be true regardless of the fluctuations that take place in the system. Minimum entropy production would appear, in this regard, to be a transcendent principle. However, this is true only to a point. When a fluctuation becomes large enough the organizing "principle" of the system may change. The system may become, for example, a chemical clock, in which case its principle would now be that of periodicity. At the bifurcation point the organizing principle of the system is neither this nor that, neither minimum entropy production nor periodicity.

It becomes obvious that the organizing principle of the system is not transcendent but relative to historical circumstances. It changes with fluctuations in the configuration of forces and fluxes permeating the system. But the extent to which a system changes with respect to fluctuations is a question of degree: steady state structures would appear to be less responsive to slight changes in their environments than systems near a bifurcation point. The system, one might say, is more or less affected, more or less spirited, more or less determined by transcendent principles depending on how close it is to a bifurcation point.

Kleist envisions the line from grace to spirit, from matter to infinite consciousness, from puppets to gods, to be joined in a circle, such that any movement away from the soul that is associated with grace is also a movement towards it. Indeed, one does not *get away* from the soul that is associated with grace: this line joined in a circle is in fact the soul; it is merely more or less affected on this or that part of the circle. Yet, just as one can never *get away* from it, one can never "reach" the soul:

> You never reach the Body without Organs, you can't reach it, you are forever attaining it, it is a limit. People ask, So what is this BwO? - But you're already on it, scurrying like a vermin, groping like a blind person... On it we sleep, live our waking lives, fight - fight and are fought - seek our place. (Deleuze and Guattari 150)

You cannot get away from it, and you cannot "reach" it: the BwO, the soul, is at once immanent and transcendent. A steady state system may appear to follow transcendent principles, it may appear to be independent of the changes in the field of fluxes on which it is built, but in fact the system does not "get away from" the field of fluxes. And while it does not escape that field, it does not reach it either. Particularly at a bifurcation point the direction in which the system will be pushed by the field of fluxes can often not be determined: "There is an irreducible random element; the macroscopic equation cannot predict the path the system will take. Turning to a microscopic description will not help" (Prigogine and Stengers 161).

Deleuze and Guattari "distinguish between: (1) BwO's, which are different types, genuses, or substantial attributes [...] (*remisso*). (2) What happens on each type of BwO, in other words, the modes, the intensities that are produced, the waves that pass (*latitudo*). (3) The potential totality of all BwO's, the plane of consistency (*Omnitudo*, sometimes called the BwO)" (157). The types of BwO are the BwO's one makes oneself. The puppeteer becoming puppet, and the masochist becoming horse, are two types of BwO's. One imagines oneself at the puppet's center of gravity, one constructs a field of intensities where no force overdetermines another, and something is produced - a dance - something which cannot be traced to any "ground" or pre-established principle. We call this production, "grace." And how is it possible for this "becoming" to occur? Because there are knots of grace in spirit. Spirit is a stratum or territorialization on a field of fluxes. This field of fluxes is always prior to spirit. We might use Kleist's term, and call this field, "soul." We might also use another of Deleuze and Guattari's terms and call this field of fluxes "absolute deterritorialization." The knots of grace in spirit are the constant fluctuations, however imperceptible, however random, that occur in an ordered system; they are, in Deleuze and Guattari's terms, "relative moments of deterritorialization:"

> Absolute deterritorialization becomes relative only after stratification occurs on that plane or body: it is the strata that are always residue, not the opposite. The question is not how something manages to leave the strata but how things get into them in the first place. There is perpetual immanence of absolute deterritorialization within relative deterritorialization, and the machinic assemblages between strata that regulate the differential relations and relative moments also have cutting edges of deterritorialization oriented toward the absolute. The plane of consistency is always immanent to the strata. (Deleuze and Guattari 56-7)

One makes oneself a BwO, one becomes puppet or becomes horse, one's soul, as spirit, is deterritorialized into a line. And when all these souls, these lines, these BwO's, are connected together into a continuum, a great circle, then we have the plane of consistency - absolute deterritorialization.

2.2 The Virgin Who Was a Wife

> "Our lord Jesus Christ went up into a little town, and was received by a virgin who was a wife" (Lk. 10:38).
>
> Now notice carefully what this says. It must necessarily be that the person by whom Jesus was received was a virgin. "Virgin" is as much as to say a person is free of all alien images, as free as he was when he was not. Observe how people may ask how a man who has been born and who has advanced to the age of reason could be as free of all images as when he was nothing; he who knows so many things that are all images: How then can he be free? Keep in mind this distinction, which I want to make clear for you. If I were so rational that there were present in my reason all the images that all men had ever received, and those that are present in God himself, and if I could be without possessiveness in their regard, so that I had not seized possessively upon any one of them, not in what I did or what I left undone, not looking to past or to future, but I stood in this present moment free and empty according to God's dearest will, performing it without ceasing, then truly I should be a virgin, as truely unimpeded by any images as I was when I was not. (Eckhart Sermons 177)

Meister Eckhart distinguishes here between possessing images and not possessing them. Eckhart suggests that for one to have images present in one's reason and possess them is to be impeded; while on the contrary, to have images present in one's reason and not possess them is to be free. He compares the lack of the possession of images to a state when one was not, i.e. to a state prior-to-creation. To be as unimpeded by the possession of images as one was when one was not is to be a virgin.

I will argue that Eckhart uses the notion of possession or attachment to images in very much the same sense that Kleist uses the term affected or grounded. Recall that the human dancer, Young F--, was affected. All of his actions could be traced back to an image he possessed, an image of Paris, which he had to imitate if he wanted to dance his role well. For this reason, according to Kleist, Young F-- was impeded from achieving the same level of grace as a puppet. Concentrating on a pre-determined role, human dancers like Young F-- become less responsive to their immediate environment. Human dancers are too deliberate, too spirited, and as such they cannot "get into the music." To dance with grace is to be, like Eckhart's virgin, "in the present moment," "not looking to past or to future" but responsive to all that is immediately before one. Eckhart's "present moment," in this regard, I will argue, is equivalent to Kleist's center of gravity, to Deleuze and Guattari's plateau, and to Prigogine and Stenger's bifurcation point. At the center of gravity neither gravity nor the puppeteer's intentions determine the actions of the puppet. Similarly, in the "present moment" neither this image nor that image determines the virgin's actions.

Eckhart writes that "an image insofar as it is an image receives nothing of its own from the subject in which it exists, but receives its whole existence from the object it images" (Sermons 129). The notion of the image, then, implies a subject/object distinction. Images exist in subjects but always refer to things external to the subject. An image is a medium through which a subject receives an external object.

Eckhart's virgin is divorced from images, but is also a wife:

> For if a man were to be a virgin forever, no fruit would come from him. If he is to become fruitful, he must of necessity be a wife. "Wife" is the noblest word one can apply to the soul, much nobler than "virgin." That a man conceives God in himself is good, and in his conceiving he is a maiden. But that God should become fruitful in him is better; for the only gratitude for a gift is to be fruitful with the gift, and then the spirit is a wife, in its gratitude giving birth in return. (Sermons 178)

Eckhart's virgin is *wife* to God. To marry God and at the same time remain free of images the virgin must, by necessity, receive God in some way other than through an image. This is to say that the virgin cannot receive God as a subject does an object, rather, the virgin's attachment to God must dissolve the subject/object distinction.

> You should perceive him without images, without a medium, and without comparisons. But if I am to perceive God so, without a medium, then I must just become him, and he must become me. I say more: God must just become me, and I must just become God, so completely one that this "he" and this "I" become and are one "is," and, in this is-ness, eternally perform one work, for this "he," who is God, and this "I" which is the soul, are greatly fruitful. (Sermons 208)

As noted above, images for Eckhart are associated with creation. This is so because creation for Eckhart is the rendering distinct of all things. Created things gain their existence according to Eckhart, as God's Word. "All created things are God's speech" (Sermons 205). "All things were spoken in the Everlasting Word." God's Word, therefore, contains difference. "The prophet says: 'Lord, you say one thing and I hear two things' (Ps.61:12)" (Sermons 205). In other words, through creation the subject, as a created thing, is rendered distinct, or separated, from all other things. Through creation as well the subject is seperated from God. "As God speaks into the soul, the soul and he are one; but, as soon as this goes, there is separation" (Sermons 205). The subject, or soul, therefore, insofar as it is "created," knows only external things, and therefore knows only through images.

The multiplicity of different created things do not exist in relation to God as particulars relate to a general, or species to a genus, however, such that one can understand qualities of God, the general, through his Word, the particulars. "The intellect, which begins in the senses, is clouded by the images through which and in which it knows" (Sermons 153). We know God's Word, created things, as images, but it seems that it was part of the divine idea that his words be "cloudy," i.e., marked by difference, such that we cannot get to the source of the word through the word: "What all creatures have received is quite unlike him, except only that they would gladly express him as closely as they can" (Sermons 205).

Although the soul, insofar as it is created, knows only through images, Eckhart also suggests that there is a part of the soul which is "uncreated:"

> Sometimes I have spoken of a light that is uncreated and not capable of creation and that is in the soul. I always mention this light in my sermons; and this same light comprehends God without a medium, uncovered, naked, as he is in himself. (Sermons 198)

This light of the soul goes by many names in Eckhart: "little town," "guard of the spirit," "spark," but in each case it "never touches either time or place" and "rejects all created things, and wants nothing but its naked God, as he is in himself" (Sermons 198).

But how can the soul be at once created and uncreated? Eckhart envisions the soul in much the same way as does Kleist. For Kleist the soul is a line joined in a circle, a line which is more or less affected, more or less spirited, on this or that part of the circle. Similarly, Eckhart's soul, as it is being created through the Everlasting Word, flows out from God like a line, which remains, at the beginning part of the line, always one with God, always uncreated, such that it may, through its beginning, return to God.

> The father speaks the Son always, in unity, and pours out in him all created things. They are all called to return into whence they have flowed out. All their life and their being is a calling and a hastening back to him from whom they have issued. (Sermons 205)

> The first grace consists in a type of flowing out, a departure from God; the second consists in a type of flowing back, a return to God himself. (Teacher 218)

The soul for Eckhart, just as for Kleist, is both uncreated and created, both open to grace and spirited. In Deleuzean terms, spirit is a stratum on the BwO, a stratum which remains connected to the BwO such that it may destratify in order to return to the BwO. In Eckhart's terms, spirit is a creation out of the uncreated which retains a spark of the uncreated within it, and with which it may detach itself from created things in order to become one with the uncreated, God.

> You should love God unspiritually, that is, your soul should be unspiritual and stripped of all spirituality, for so long as your soul has a spirit's form, it has images, and so long as it has images, it has a medium, and so long as it has a medium it has not unity or simplicity. Therefore your soul should be unspiritual, free of all spirit, and must remain spiritless; for if you love God as he is God, as he is spirit, as he is person, and as he is image - all this must go! "Then how should I love him?" You should love him as he is a nonGod, a nonspirit, a nonperson, a nonimage, but as he is a pure, unmixed, bright "One," separated from all duality; and in that One we should eternally sink down, out of "something" into "nothing." (Sermons 208)

It is stated here that God is both God and nonGod, person and non-person, we might say "being and nonbeing." Where God is being, he is, like all created things, received through an image. God, as being, is distinct, separate. Because God, *as being*, cannot be received through the senses as other beings can, but can only be received through images, God, *as being*, is transcendent. Where God is nonbeing, he is not received through images, but is received as One('s) being. Because God, as nonbeing, is received as One('s) being, God, *as nonbeing*, is immanent or indistinct: being is God.

By the fact that something is created, it is distinct, and is

> unequal, and many. By its descent from the One and the Indistinct the created thing falls from the One and into distinction and hence into inequality. The Uncreated, on the contrary, has no fall or descent and therefore remains and stands in the fountainhead of unity, equality, and indistinction. (Teacher 154)

Because God is the source and existence of all created things, all created things are indistinct at their source: in God all things are One. "This is most clear if in place of the word 'God' we use the word 'existence.' God is existence. It is clear that existence is indistinct from everything which exists and that nothing exists or can exist that is distinct and separated from existence" (Teacher 166). That created things, the multiplicity, are indistinct in God, the One, does not imply that in God - in existence - the multiplicity is lost. God and the multiplicity are indistinct in the sense that God *is* the multiplicity, and the multiplicity *is* One. Eckhart writes, "Every multiplicity is one and one thing in the One and through the one" (Teacher 224).

The relationship between the multiplicity and the One with which the multiplicity is indistinct, in Eckhart, similar to the relationship between the One and the rhizomatic multiplicity in Deleuze and Guattari's work:

> Principle of multiplicity: it is only when the multiple is effectively treated as a substantive, "multiplicity," that it ceases to have any relation to the One as subject or object, natural or spiritual reality, image and world. Multiplicities are rhizomatic, and expose arborescent pseudomultiplicities for what they are. There is no unity to serve as a pivot in the object or to divide in the subject. There is not even the unity to abort in the object or "return" in the subject. A multiplicity has neither subject nor object, only determinations, magnitudes, and dimensions that cannot increase in number without the multiplicity changing in nature. (8)

As an example, let us consider once again a chemical system. A chemical system may be considered as a multiplicity of molecules. When a chemical system is in a steady state, such as thermodynamic equilibrium, the system appears to follow a transcendent principle. Regardless of changes that might occur in the system, an addition of molecules for example, the system will always move toward a predetermined order. Any given molecule's actions and reactions are determined by a transcendent principle and are thereby independent - "distinct" we could say - from any changes in the multiplicity. This is an example of an arborescent multiplicity. The final steady state exists as an "other" that has to be returned to and that unites the multiplicity into its predetermined organization.

When a chemical system is at a bifurcation point, however, the direction of the system may change with even slight changes in the multiplicity. The actions and reactions of a given molecule are not determined by a transcendent principle, they are not independent of changes in the multiplicity, but are determined rather by the immediate conditions of the multiplicity. Changes cannot be made, molecules cannot be added or taken away without affecting the direction the multiplicity takes. The way that molecules react and interact with each other is not independent of the size and conditions of the multiplicity, rather the size and conditions of the multiplicity determine the actions of individual molecules. Deleuze and Guattari write: "A multiplicity has neither subject nor object, only determinations, magnitudes, and dimensions that cannot increase in number without the multiplicity changing in nature" (8). Eckhart puts it this way: "Six is not twice three, but six times one" (<u>Teacher</u> 224).

When Eckhart's virgin becomes One with God, (s)he becomes One with a multiplicity. At this point (s)he does not act as a distinct individual but rather (s)he acts in synchronicity with the multiplicity of created things. On the other hand, to act in accordance with some principle, or in relation to an image that does not change with changes in the multiplicity, is to act independently - as a distinct being.

Eckhart's virgin, when detached from images, becomes indistinct, and the multiplicity itself, which is all created things, becomes the will of the virgin. If "I stood in this present moment free and empty according to God's [the multiplicity's] dearest will, performing it without ceasing, then truly I should be a virgin, as truly unimpeded by any images as I was when I was not" (Sermons 177).

Likewise, Young F--, insofar as he bases his dance on an image or idea of what the dance should be, is spirited and not graceful, independent of his immediate environment and not One with it. To become graceful Young F-- must become puppet:

> Puppet strings as a rhizome or multiplicity, are tied not to the supposed will of an artist or puppeteer but to a multiplicity of nerve fibres, which form another puppet in other dimensions not connected to the first: "Call the strings or rods that move the puppet the weave. It might be objected that ITS MULTIPLICITY resides in the person of the actor, who projects it into the text. Granted; but the actor's nerve fibres in turn form a weave. And they fall through the gray matter, the grid, into the undifferentiated..." (Deleuze and Guattari 8)

The dynamic system of flowing out and flowing back into God, as described by Eckhart, is similar to Deleuze and Guattari's stratification and destratification on the Body without Organs. Deleuze and Guattari call stratification, "the entire system of the judgment of God" (40):

> For the judgment of God weighs upon and is exercised against the BwO [...] the judgment of God uproots it from its immanence and makes it an organism, a signification, a subject. (Deleuze and Guattari 159)

Deleuze and Guattari's "judgment" is Eckhart's "Divine Idea." In order to be judged one requires a criteria - some *principle* - to be judged against. "The entire system of the judgment of God" is a system of criteria: Young F-- *must* lift the apple, otherwise he is not playing Paris well; an eye *must* see, otherwise it is not a good eye. Just as God's Word has its principle in the Divine Idea - "In the principle was the Word" (Sermons 123) - so too are the actions of the judged always traced back to a principle.

We can say that the principle behind Deleuze and Guattari's stratification, and Meister Eckhart's creation, is the "why?" The "why?" is the *reason* that beings are the *way* that beings are. On the other hand, if there is a principle behind Deleuze and Guattari's destratification and Eckhart's return to God, it is decidedly apophatic. We might call it the "why not?"

> Instead of a mouth and an anus to get out of order why not have one all-purpose whole to eat and eliminate? We could seal up nose and mouth, fill in the stomach, make an air hole direct into the lungs [...] Is it really so sad and dangerous to be fed up with seeing with your eyes, breathing with your lungs, swallowing with your mouth, talking with your tongue, thinking with your brain, having an anus and larynx, head and legs? Why not walk on your head, sing with your sinuses, see through your skin, breath through your belly? (Deleuze and Guattari 150-1)

Why not? It is as if they were saying "neither this nor that:" neither digestion nor breathing is the principle of the belly, so why not breathe through your belly? Digestion, breathing, thinking, singing, are all possibilities for the belly; for the belly to be limited to digestion is for a power takeover, in the multiplicity of possibilities, to take place: stratification. The masochist puts on a bridle and attaches the bit to his hands with a chain - why not? Neither horse nor human is the "principle" of the masochist's *becoming*. And what is the "principle" of Eckhart's virgin? Neither this nor that. Eckhart writes:

> You should perform all your works without asking, "Why?" [...] If anyone went on for a thousand years asking of life: "Why are you

> living?" life, if it could answer, would only say: "I live so that I may live." That is because life lives out of its own ground and springs from its own source, and so it lives without asking why it is itself living. If anyone asked a truthful man who works out of his own ground: "Why are you performing your works?" and if he were to give a straight answer, he would only say, "I work so that I may work." (Sermons 183-4)

To act with neither this nor that *as* one's principle is not to restrict oneself to particular *ways* of being, but to let the *being* that *is*, God, *be* as it *is*.

> Whoever is seeking God by ways is finding ways and losing God, who in ways is hidden. (Sermons 183)

CHAPTER 3

Conclusion: The Whys and Why Nots of Science

"For science would go completely mad if left to its own devices."
- Deleuze and Guattari 24

3.1 Spirited and Unspirited Science

> In complex systems, where species and individuals interact in many different ways, diffusion and communication processes among various parts of the system are likely to be efficient. There is competition between stabilization through communication and instability through fluctuations. The outcome of that competition determines the threshold of stability. (Prigogine and Stengers 189)

We may identify two aspects of science: one that maintains the organization of a science, a stabilizing or stratifying aspect, and another that amplifies fluctuations, a destabilizing or destratifying aspect. In its first aspect science is principled. It is "spirited" science. In Eckhart's terms, we might call it "created" science. Deleuze and Guattari call this aspect of science by many names: "state science," "royal science," and "legal science." There are "stabilizing mechanisms" which lead scientists to adopt common principles which, depending on the strength of the mechanisms stabilizing them, become immune to fluctuations. Communication among scientists is certainly the location where the main stabilizing mechanisms of science take effect.

Scientists educate, persuade, convince each other of their views. In order to gain funding and continue as a scientist a scientist needs credibility, the respect of fellow scientists. The constant need to align one's views with others has a stabilizing effect on a prevailing discourse. To the extent that a prevailing discourse continues to determine the choices of scientists, science is "spirited."

The discourse on gene action organized the field of molecular biology in much the same way that the image of Paris organized the dance of Young F--. The image of Paris provides the criteria by which to judge Young F--'s dance: Young F-- must lift the apple just so, otherwise he is not playing Paris well. Similarly, the discourse on gene action was a system of criteria that helped define the approach that scientists took within a particular field: "it framed the questions they could or could not meaningfully ask, the organisms they would choose to study, experiments that did or did not make sense to do, the explanations that were or were not acceptable" (Keller Refiguring 11). In other words, it organized the thought and communication processes by which facts are chosen and concepts built up, and by which scientists choose their fields, instruments, techniques, etc. Young F--'s dance was "spirited." When scientists' choices are in keeping with an organizing principle - a prevailing discourse - his or her science is "spirited" as well.

Constant fluctuations in the various bifurcation parameters of science continually threaten the stability of its organization. These parameters include the instruments and techniques available to scientists, the pool of facts, models, and problems available, the number of scientists in the field, and other factors having to do with the social and political contexts of a scientist's life and work. Spirited science, science wherein thought and communication processes are organized by a determining discourse, always brings fluctuations back to the order of the same. If one adds a certain amount of a reacting species to a reaction mechanism at equilibrium, for example, the respective concentrations of reactants and products will change, but their final ratios will continue to be defined by the same reaction equation as before the fluctuation. Similarly, though new instruments, facts, and ideas may present themselves to scientists, when science is "spirited" these facts and ideas will be accepted, rejected, and arranged according to an organizing principle such that the final knowledge produced will remain within the same "order" as previous knowledge. "The ideal of reproduction, deduction, and induction is part of royal science, at all times and in all places[...]. Reproduction implies the permanence of a fixed point of view that is external to what is reproduced: watching the flow from the bank[...]. One is constantly reterritorializing around a point of view, on a domain, according to a set of constant relations" (Deleuze and Guattari 372). Microbiology reterritorialized around the gene. The discourse on gene action lead to an increase in the knowledge of the human genome, and in the role of the genes in protein synthesis, but to few increases in the knowledge of cell differentiation and development.

The destabilizing aspect of science is "unspirited" or "uncreated" science. Deleuze and Guattari call it "nomad science," or "ambulant science." Unspirited science occurs "when one escapes the force of gravity to enter a field of celerity; when one ceases to contemplate the course of a laminar flow in a determinate direction, to be carried away by a vortical flow" (Deleuze and Guattari 372). Scientific fields are organizations or stratifications on a BwO, on a constantly fluctuating field of fluxes. In "unspirited" science one places oneself on the BwO. One does not bring a given fluctuation back to the order of the same, but considers it on an open field, considers how it might resonate with the various other parameters and fluctuations influencing the system; how a new idea, for example, might find support from repressed observations and ideas, or how it might exploit to its advantage the very relations between forces and fluxes guaranteeing the stability of the current regime or organizing principle. Like Eckhart's virgin, the scientist places him or herself "in the present moment," "not looking to past or to future" but responsive to all that is immediately before one. They are open to grace.

> This is how it should be done: Lodge yourself on a stratum, experiment with the opportunities it offers, find an advantageous place on it, find potential movements of deterritorialization, possible lines of flight, causing conjugated flows to pass and escape and bringing forth continuous intensities for a BwO. Connect, conjugate, continue: a whole "diagram," as opposed to still signifying and subjective programs. We are in a social formation; first see how it is stratified for us and in us and at the place where we are; then descend from the strata to the deeper assemblage within which we are held; gently tip the assemblage, making it pass over to the side of the plane of consistency. It is only there that the BwO reveals itself for what it is: connection of desires, conjunction of flows, continuum of intensities. (Deleuze and Guattari 161)

Deleuze and Guattari say that ambulant sciences consist in following. One follows a line of flux. One picks up a model or idea in one field and follows its ramifications in other fields. *"There are itinerant, ambulant sciences that consist in following a flow in a vectorial field across which singularities are scattered like so many 'accidents'"* (Deleuze and Guattari 372). In the previous chapter I discussed how techniques, models, and actual persons moving across disciplines may rearrange the existing observations, problems, and ideas of these different disciplines and lead to various new fields: across non-equilibrium thermodynamics, developmental biology, and cybernetics, for example, partial-isomorphisms are scattered like so many accidents.

Spirited science and unspirited science are not two independent sciences. They are two aspects of the same thing. The relationship between the two is comparable to the relationship between spirit and soul in Kleist and Eckhart, or between steady states and the field of fluxes in Prigogine and Stengers. "What we have, rather, are two formally different conceptions of science, and, ontologically, a single field of interaction in which royal science continually appropriates the contents of vague or nomad science while nomad science continually cuts the contents of royal science loose. At the limit all that counts is the constantly shifting borderline" (Deleuze and Guattari 367). Stabilizing forces and destabilizing fluctuations work concurrently within any science, but the relative strength of one over the other is variable. Individuals and communities are more or less affected by fluctuations, more or less determined by established principles, depending both on individual idiosyncrasies, and on the current state of the complex interaction of social, political, and empirical forces which permeate their field. A given individual may have acquired a combination of experiences that gives him or her more facts, ideas, models, and techniques to work with, or gives him or her unique possibilities for reorganizing those parameters within a field of science. On the other hand, the state of relations of the various bifurcation parameters at a given time will influence the extent to which individuals may be inclined or able to "destratify," and the extent to which arguments from individuals may affect the organization of a scientific field and its accepted knowledge.

> The many positions which already make up the field influence the likelihood that a given argument will have an effect. An operation may or may not be successful depending on the number of people in the field, the unexpectedness of the point, the personality and institutional attachment of the authors, the stakes, and the style of the paper. (Latour and Woolgar 237)

In certain circumstances individual choices and arguments will be doomed to insignificance, while at other times the same arguments can upset the global state of science.

Nomad science and state science are not two independent models; there are knots of nomad science in state science. Nor is the one better than the other.

> You have to keep enough of the organism for it to reform each dawn; and you have to keep small supplies of significance and subjectification, if only to turn them against their own systems when the circumstances demand it, when things, persons, even situations, force you to; and you have to keep small rations of subjectivity in sufficient quantity to enable you to respond to the dominant reality. Mimic the strata. You don't reach the BwO, and its plane of consistency by wildly destratifying [...]. Staying stratified - organized, signified, subjected - is not the worst that can happen; the worst that can happen is if you throw the strata into demented or suicidal collapse, which brings them back down on us heavier than ever. (Deleuze and Guattari 160-1)

Again, there are times when an individual's arguments will be doomed to insignificance. If one fails to understand the strength of the forces stabilizing a given discourse, one might endanger one's credibility by working too much against them. Scientists must always be able to communicate. Arguments which might, under a given set of circumstances, gain credence, are dismissed, under another set, as mystic babble.

> It is not that the ambulant sciences are more saturated with mystery or magic. They only get that way when they fall into abeyance. And the royal sciences, for their part, also surround themselves with much priestliness and magic. Rather, what becomes apparent in the rivalry between the two models is that the ambulant or nomad sciences do not destine science to take on an autonomous power, or even to have an autonomous development. They do not have the means for that because they subordinate all their operations to the sensible conditions of intuition and construction - following the flow of matter, drawing and linking up smooth space. Everything is situated in an objective zone of fluctuation that is coextensive with reality itself.

> However refined or rigorous, "approximate knowledge" is still dependent upon sensitive and sensible evaluations that pose more problems than they solve: problematics is still its only mode. In contrast, what is proper to royal science, to its theorematic or axiomatic power, is to isolate all operations from the conditions of intuition, making them true intrinsic concepts, or "categories." This is precisely why deterritorialization, in this kind of science, implies a reterritorialization in the conceptual apparatus. (Deleuze and Guattari 373)

3.2 Taking Stock and Measuring Distances

In this thesis frontiers have been redrawn and things normally far apart have been brought closer, and vice versa: instead of relating Eckhart's sermons to other theological texts, I have compared them to Kleist's short story on puppets, Prigogine and Stengers' descriptions of non-equilibrium systems, and to Deleuze and Guattari's plateaus. Prigogine and Stengers descriptions of non-equilibrium systems are in certain respects closer to Kleist's description of dance, than to Newton's descriptions of dynamic systems. From these varied comparisons emerged a network of analogies, a network of connections that appear to ignore the diversity of the works under study. These comparisons constitute a "map" in Deleuze and Guattari's sense of the term:

> [The map] fosters connections between fields, the removal of blockages on bodies without organs, the maximum opening of bodies without organs onto a plane of consistency. It is itself part of the rhizome. The map is open and connectable in all of its dimensions, it is detachable, reversible, susceptible to constant modification. It can be torn, reversed, adapted to any kind of mounting [...]. A map has multiple entryways, as opposed to the tracing, which always comes back "to the same." (12)

The various works studied organize the elements of their respective fields in similar ways, leading to similar relations between elements. Each work is a map for the others. Connected through comparative studies, we arrive at an "abstract" map with multiple entryways and interchangeable elements: stratum = spirit = steady state.

This thesis attempted to extend this map, fostered by connecting the elements of these various works, to the field of science studies. I compared scientists to molecules, to puppets, and to a virgin. I compared doing science to dancing. I attempted to identify elements of science that might be interchangeable with those of our map, and then to organize them in accordance with our map. I did this with the hope of arriving at a more permeable assemblage of these "elements," a dissipative structure. I will conclude this thesis by summarizing how the assemblage that I arrived at might frame some problems inherent to science studies.

The problem of change.

This assemblage allows us to isolate and describe the relationship between at least two types of change in science. Changes in the organization of a science - changes corresponding to the development of new fields of study, or, at times, the disappearance of old ones - are distinguished from those changes that result from the daily work of science, the work by which new facts are isolated and new concepts built up. These types of change are distinguished from each other just as fluctuations in bifurcation parameters are distinguished from the more global "steady state" changes of non-equilibrium systems. Both types of change are inter-related. While the principles which organize a scientific field governs the processes by which facts and ideas are "chosen," fluctuations in the pool of facts and ideas can lead to fundamental changes in organizing principles.

It is seldom easy to determine what has caused a specific change in science. A given fluctuation, a new observation or argument, will cause fundamental changes in the organization of a science only if it happens "at the right moment." Its affect depends upon how it interacts with a complex system of changing parameters. Such fundamental changes in science, therefore, cannot be reduced to "single causes" such as an increase in the number of anomalies in a field, or a change in available technology. These fundamental changes, rather, are the result of a complex interaction of forces in which now a fluctuation in one force will result in a change, now a fluctuation in another.

The cause of those changes which result from the everyday work of science is also not easily traced. What leads a scientist to isolate this as an important fact rather than that? Why interpret an observation this way rather than that way? While organizing principles or discourse regimes tend to determine the choices and interpretations of scientists, we have also seen that unique circumstances and personal idiosyncrasies can direct individuals in different directions. Again, change in science, at all levels, is the result of a complex interaction of forces.

Because new facts and ideas may be organized, and old ones reorganized, in support of a different principle, perhaps a principle taken from another discipline or another time; and because a new principle may resuscitate discarded arguments and observations, all of these - facts, ideas, arguments, observations and organizing principles - may be recycled through time. The history of science folds back on itself making facts, ideas, and principles which originate from different time periods, contemporary.

> Consider a late model car. It is a disparate aggregate of scientific and technical solutions dating from different periods. One can date it component by component: this part was invented at the turn of the century, another, ten tears ago, and Carnot's cycle is almost two hundred years old. Not to mention that the wheel dates back to neolithic times. The ensemble is only contemporary by its design, its finish, sometimes only by the slickness of the advertising surrounding it. (Serres 45)

The problem of the subject.

The subjects responsible for scientific discourse would at once appear to be "determined in their situation, their function, their perceptive capacity, and their practical possibilities by conditions that dominate and even overwhelm them" (Foucault xiv), and at the same time appear to be able to profoundly alter those determining conditions. The success that an individual may have in bringing about profound changes in science, however, cannot be attributed to their "spirit" having gained independence from the conditions that dominate them. Science does not work by spirit alone. We can speak of individual idiosyncrasies, unique social and historical contexts and distinct abilities to perceive and negotiate the various lines of flux which compose a scientific field, but the possibility of causing profound changes in science must ever depend on moments of grace, moments when the complex interaction of forces permeating a science is such that one can see things differently. Tracing a genealogy of geniuses does not constitute a complete history of science; mapping the complex interaction of forces which now constrain and now enable possibilities for change remains a matter of enquiry.

The problem of power.

I mentioned in the introduction of this thesis that representations of how science works that describe science as "autonomous" are dangerous because they prevent people from critically assessing and discussing what scientists should or should not be studying. The assemblage constructed in this thesis confirms that science is more "power" driven than "spirit" driven. While it gives hope that raising awareness of certain social and political realities may influence the directions of science and the uses of its products, it also takes away much of the hope that the effects of any change in science can be predicted or measured. "In spite of its simplicity, our model succeeds in showing some properties of the evolution of complex systems, and in particular, the difficulty of 'governing' a development determined by multiple interacting elements. Each individual action or each local intervention has a collective aspect that can result in quite unanticipated global changes" (Prigogine and Stengers 203).

It is difficult to predict how developments in thermodynamics might lead to developments in biology or even in theology. It is difficult to predict how techniques developed in medical science to solve one problem might lead to other, unanticipated problems. Michel Serres recounts something Jacques Monod once said to him:

> I used to laugh at physicists' problems of conscience, while the physicists made contributions to arms, to violence and war. Now I see clearly that the population explosion of the third world could not have happened without our intervention. So, I ask myself as many questions as physicists ask themselves about the atomic bomb. The population bomb will perhaps prove more dangerous. (16)

Even if every special interest group could arrive at a consensus as to the directions of science and the uses of its products, it is likely that the work of science would still lead at times to unpredictable, perhaps horrifying ends.

The problem of methodology.

To understand how science works why turn to Meister Eckhart and not to Karl Popper? To understand the mysticism of Meister Eckhart, for that matter, why turn to Prigogine and Stengers, Deleuze and Guattari, and Kleist rather than to one of the many Meister Eckhart exegetes? How one answers these questions is dependent on conditions and rules of which one is largely unaware. So how then does one justify a reading of Eckhart through Deleuze and Guattari, Kleist, and Prigogine and Stengers over and against a reading of Eckhart in terms of his relation to other mystics and theologians?

I would argue, simply, that such a reading brings to bear upon the problems in one field a much wider and deeper pool of models and ideas with which to approach them. As to whether or not the assemblage constructed here provides a better account of science than other assemblages is not the question. There is still plenty of work to be done. This assemblage may be compared more rigorously to other assemblages that describe science - like those of Popper, Kuhn, Haraway, Serres, etc. - in order to isolate just what the differences are and where connections may be made. The principle, however, is not to establish one assemblage over and against others, but to bring as many as possible together, onto the same plane of consistency.

Perhaps the only honest answer to the question of methodology is a simple "why not?"

If anyone asks a truthful man who works out of his own ground:

"Why are you performing your works?" and if he were to give a straight answer, he would only say, "I work so that I may work." (Eckhart Sermons 184)

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