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The Question of Emergence

If there is one question that transcends the field of so-called modern practices, it is the question of life and artifice. Whether technical artifice can produce life or only prepare the conditions for it, while awaiting the breath that will animate material that has been worked upon, whether the made being is faithful to its maker or escapes its grasp, whether it escapes accidentally or by vocation, or because the maker has "pierced" it, has partially broken it to escape the monotony of manufactured products—these are the timeless stories, each of which reprises another, older story, that populate our memories. And within this fundamentally anonymous perspective, it is possible to situate the impact of each new technique of delegation. From the medieval clock to contemporary informatics and genetic engineering, prosthetic devices, the synthesis of organic compounds from inorganic molecules, or metabolic activities reproduced in the test tube, every technical innovation capable of nibbling away at the difference between our ability to have something do something for us and what living things do by themselves arouses the same interest, the same confused passion, fear and pride. Every time a delegated agent acquires a new skill, a new figure of the living is made available for our stories, and a new figure of the risk assumed by those who dare to challenge the order of nature or creation.

However, if there is one problem that is far from anonymous, that immediately brings up the question of the "science wars" with which the ecology of modern practices can today be identified, it is indeed the problem of emergence. For in this case, it is no longer a question of human power confronting the order of nature or creation, but the possibility, for a scientific discipline, of assuming power in a field previously occupied by some other discipline.

Of course, we could claim that the question of emergence has endured throughout the ages. Aristotle's disciples were already arguing about composite bodies endowed with new qualities that arose from the elements that composed them. How could these new qualitative properties be explained? Was the form of composing elements weakened or destroyed by composition, or did it remain untouched so that the properties of the composite would be novel in appearance only? We might be tempted to claim that this same question was being asked in the eighteenth century, when antimechanistic chemists claimed there was a difference between composition, which was their problem, and the simple aggregation of physicists.[1] Except that, at this time, composite bodies and aggregates had distinct spokespersons: the difference between them was now inseparable from the question of the relationship between chemists and the supporters of mechanics. Similarly, when Leibniz pointed out the foolishness of those who dreamed of explaining sensation, perception, and consciousness in terms of the mechanics of inert matter, he seems to have been taking part in a quarrel that continues today with the unfortunately celebrated mind-body problem. Except that now the quarrel is no longer a conceptual one; contemporary "materialist" philosophers no longer claim any status other than that of being spokespersons for those who engage in what would finally be a scientific approach to the brain. And it is on their behalf that they signal a future in which, from psychology to the social sciences and therapeutic practices, all forms of knowledge concerning human behavior will be understood in terms of neuronal interactions.

The question of emergence arises from this polemical context. It was initially forged as a weapon against what would be called the reductionist bias. But any weapon can be used against its inventor. The thesis of emergence sounded like a challenge: you cannot "explain" this emerging totality, as such, as the sum of the parts in terms of which it is being analyzed. Naturally, the challenge, once stated, was used to organize an explanatory counterstrategy. In other words, the theme of emergence transforms the question of the obligations associated with the "emergent" into a field of confrontation. Will or won't this emergent entail the obligation to "add" something to the operation of the parts and, if so, does the addition in question entail the obligation to recognize the powerlessness of analytic thought?

In this context, the question of "laws," in the sense that we speak of the laws of physics, is both very close and very far. It is very close, in principle, because the reductionist argument is most often inscribed in a unitary vision of the world, in which the "parts" presented must, in one way or another, "obey the same laws" as the matter studied by physicists and chemists. It is very far, in practice, because no one dreams of requiring those "parts" to actually bear witness to such obedience.[2] The hierarchy that has already been established among the disciplines here does its work. If chemical transformations and the ensemble of interactions among molecules are claimed to satisfy the fundamental laws of physics, any biological mechanism that can be analyzed in these terms should as well.

On the other hand, reference to technical artifacts is far more prevalent. As early as the seventeenth century, long before the "science wars," the clock and the automaton, which had once celebrated the splendor of divine creation, were used as part of a philosophical operation that already forged the terms later used by scientists. The clock is a weapon against Aristotelian thought, for which matter is unintelligible as such but requires a form, with which are associated both the existence of individual beings, each of which is endowed with its own end, and the possibility of knowing them. In the case of the clock, matter and finality can be understood separately: consisting of inert parts, and as such subject to the laws of mechanics, it owes its clocklike existence to the genius of the maker, who has subjected those parts to their own ends, who has incorporated them into a coherent mechanism defined by a finality—telling time. From Leibniz to Bergson, some philosophers were able to challenge the relevance of the metaphor of the living organism the clock proposes. But in the context of a "science war," it provides an inestimable advantage. The question of finality designates the stronghold that must be defended or conquered. For a certain time, the "teleology" inherent in the living has served as a standard for so-called vitalist biology. Although "mechanistic" biologists might dissect the living at their leisure, organization toward an end would always be something that was "added" to the dissected parts, which those parts cannot, as such, explain. Jacques Monod's well-known book *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology* celebrated the fall of the stronghold. The teleological nature of living beings is only apparent, for they cannot be explained in terms of "final causes." However, they are "teleonomic," meaning that it is still on the basis of their finality—self reproduction—that they allow themselves to be described. For it is natural selection—significantly referred to as the "blind watchmaker" by Richard Dawkins—that must account for the singularity of living beings, supply a reason for the characteristic ways a living being has of reproducing, existing, behaving.[3]

I will return later to the blind watchmaker, for he is currently being challenged by new protagonists, on behalf of a new type of

artifact whose making corresponds to another kind of practice. At this stage, the example of the "defeat" of vitalist biology in the face of the so-called neo-Darwinist offensive, illustrated by the arguments of Jacques Monod and Richard Dawkins, provides an opportunity to highlight the reasons why the ecology of practices I am trying to conceptualize must confront the question of emergence and, more specifically, the way in which this question has been defined in polemical terms.

To what extent is the question of finality relevant to an understanding of living things? Only biologists not engaged in the polemic with vitalism, such as Stephen J. Gould, were interested in asking the question, which then becomes very complicated and very interesting, requiring fine distinctions and risky hypotheses. Every characteristic can present a different problem, can tell a story that will distinctly interlink heritage and novelty, the coherence of previously stabilized meanings and unforeseen possibilities. We'll return to that. What I want to emphasize here is that understanding the challenge to which the living being exposes the biologist is barred to the vitalist biologist just as it is to the believer in neo-Darwinism. In both cases, the polemical position is expressed by the production of an identity that is substituted for practical requirements and obligations the way a solution is substituted for a problem. What the biologist deals with cannot pose the problem of the relevance of the requirements in terms of which it is addressed, for, in doing so, the possibility of a betrayal, of a passage for the enemy, is liable to be created. As for obligations, these are mobilized by the supreme obligation of having the legitimacy of one's own approach prevail.

This mobilization, like any mobilization for war, introduces slogans, watchwords. Thus, the case favored in reductionist literature, the one that serves as proof and slogan, is the emergence of the molecule of water, with qualitatively new properties, from hydrogen and oxygen atoms. Similarly, the power of the laboratory should gradually dissipate the pseudo-problems posed by the "qualitative" emergences claimed by the adversary. And this "holistic" adversary, partisan of the emergence of a living "whole" irreducible to the sum of its parts, will, on the contrary, link his claims concerning the limits of experimental practice to the fact that real "wholes" are proof that they exist precisely to the extent that their properties can be objects for description but not for experimentation. Thus, even if the scientist can intervene in the development of an embryo, she has to recognize the relative "autonomy" of that development. Intervention can create monsters or kill, but the embryo cannot be redefined in such a way that its development is proven to obey a function whose variables would be manipulated by the experimenter.

Therefore, what the laboratory can do becomes the subject of a polemic. For instance, it is the existence of a new type of laboratory, that of the molecular biologist, that Jacques Monod celebrated when he announced that the "secret" of the teleonomy of living beings had finally been pierced. The laboratory of the molecular biologist has succeeded in turning living beings into reliable witnesses, in subjecting them to the variables the experimenter manipulates. Not living beings in general, however, bacteria and viruses. It is their performances that were articulated in terms of the catalytic, regulatory, or epigenetic functions of proteins, such functions relating to the associative, stereospecific properties of those molecules, which is to say, in the last analysis, to the DNA molecule containing the "genetic information" that determines their synthesis. The partisan of the irreducible emergence of the living organism (the "holist") was betrayed by some of the living organisms he intended to represent. Now, he is asked to specify where, exactly, he claims to break the chain of consequences that runs from the bacterium to the elephant, not to mention humans.

That the invention of new kinds of laboratories and new laboratory beings can in this way be mobilized for the polemic, that experimental questioning can be referred to as "reductive," is one of the most damaging consequences of the science wars. Where was the reductiveness when Pasteur had his microorganism "act" in a context such that its autonomy had to be recognized? Or when Körner, a student of Kekulé, subjected the three isomers of dibromobenzene to a substitution reaction, replacing hydrogen with an NO_2 radical, the distinct isomers he obtained demonstrating, by their relative proportions, the hexagonal structure of benzene? Or when the artificial DNA molecule synthesized by Nirenberg (UUUUUUU . . .) succeeded, on May 27, 1961, in "causing"—using all the necessary enzymes but "out of the body," in a test tube—the synthesis of a protein, an obviously "stupid" protein, composed of a single type of amino acid?[4] Events of this kind mark the creation of new laboratory beings and the new laboratories that correspond to them.[5] But they do not pose the problem of emergence and do not allow any reduction to occur. They mark the success of an operation of delegation. The delegated being, which bears witness to its existence (Pasteur), to what it acts on (Körner), or its specific responsibility (Nirenberg), brings about new practical possibilities. Similarly, bacteria and the other laboratory beings that molecular biology has managed to turn into "reliable witnesses" were in no way "reduced" to an arbitrary assemblage of molecules. Those beings were targeted by operations of delegation or were themselves delegated, and each of the "properties" that supposedly "explain" them celebrates the singularity of the successful operation, not the generality of the power of explanation.

From this viewpoint, there is no need to try to determine which characteristic would rightfully protect an elephant or a man from a reduction that would have succeeded with bacteria. It is much more interesting to point out how the operations of experimental delegation that have treated bacteria as targets or actors have been made possible. The experimental invention of the bacterium takes full advantage of the fact that the bacterium, unlike the elephant or the man, undergoes no embryonic development because it is "born" adult, whether in a test tube or anywhere else, whereas the elephant or the man need their mother's womb. That is why the question of embryological development is not the "same" question, only more complicated, as the multiplication of bacteria. While bacteria have made it possible the impressive construction of the experimental factish of DNA, with its properties of replication, transcription, translation, and regulation, this factish does indeed possess the truth of the relative. It owes its autonomy to the experimental tests it successfully underwent, and this autonomy is therefore relative to the tests the bacterium is able to experience from its environment without losing the stability of its definition—that is, without dying. That the human embryo or the elephant embryo cannot resist similar tests, that they require a "protected" environment, does not protect them "by right" from future experimental inventions. This difference signifies nothing more than that the question of how they are to be addressed will have to be invented. And if the precedent of the bacterium here had to serve as an argument, it would be to announce the possibility of surprises we are yet unaware of. For, prior to its experimental invention, no one could have foreseen the extraordinary sophistication of the models it would impose, and continues to impose, on the biologist. For biologists, the question of determining "what a bacterium is capable of" is only just beginning.

When DNA becomes a "program," claiming to be the ultimate explanation of all living beings and, at the same time, claiming to give natural selection the role of a (blind) "programmer," the sole (teleonomic) "reason" to which living organisms can respond, it is not the power of the laboratory that is being expressed but the power of the polemic that shaped the question of emergence on the field of confrontation. And along with it the various powers that are not interested in the question of

emergence at all but are greatly interested in capturing successful operations of delegation and the claims of reduction that may accompany them. This provides a twofold benefit: the power to create new ways of "doing" and the power to silence, in the name of "reduction" to an approach that is "finally scientific," those who would contest the way the problem (for which these new ways of doing supply a solution) is expressed.

The same situation occurred when the Pasteurian microorganism, vector of transmission of epidemic disease, became the "cause" of that disease, the royal road to a "finally scientific" medicine that would reduce illness and healing to "purely biological" processes. This was a typical case of the reciprocal capture of distinct interests. For doctors, reference to this royal road means adopting a position that gives them the power to disqualify charlatans.[6] For the majority of industries related to medical practice, the difference between doctor and charlatan has little interest. But its consequence, the fact that the doctor is made dependent on the network of laboratories providing her with a guarantee of an "anticharlatan" practice, interests them much more. Medicine, like all modern practices, each mobilized by conflict with other practices and all of them against opinion, is vulnerable to, and even demands, all the forms of capture that ratify the validity of its position.

In this joyous context, the fact that the "emergence" of mind in its relation to the "state of the central nervous system" may appear to set the stage for a "summit" between science and philosophy is a far cry from expressing a privileged purity. Rather, it is the glaring absence of any operation of delegation susceptible to reciprocal capture that ensures the disinterested character of this "great question." The notion of state haunts the rhetoric of the sciences because it constitutes the master reference for reductionist versions of emergence; but this reference indicates that emergence, in this case, is purely and simply defined in terms of confrontation. Confrontational reductionism has no need of the laboratory, and its relation with operational consequences and possibilities is simply a matter of rhetoric. The only thing that really matters is that the adversary be disqualified, that he be lined up against the wall.

The "state" is in effect responsible for uniting "anything" that might be a relevant element of understanding the situation and for expressing the possibility of organizing that multitude in such a way that "all" the relevant relations become relations of reciprocal determination from which one should be able to deduce a full description of what has become a "system."[7] Reference to the state is typically followed by a challenge, with the adversary lined up against the wall. If he accepts that "everything" has been accounted for in the definition of the state, will he appeal in order to avoid the "reduction" to "something else," some ingredient whose sole meaning will be to express irreducibility? And what is most curious is that this strategy "works." It succeeds in trapping some of those it targets. In *The Self and Its Brain*, John Eccles, wishing to "defend" mind, invents for it the ability to act through "infinitely weak" energy interactions with large numbers of neurons "in critical equilibrium."[8] What splendid freedom it is to "choose" between two evolutions from some critical point.[9] What an astonishing capability those large numbers of neurons have that they are able to maintain themselves in "equilibrium" at some critical point in order to allow the "mind" the responsibility of choice.

Eccles's speculation is representative of the astonishing intellectual regression provoked by the "science wars," a regression that explains why the mind-body problem is one for philosophers—and scientists who wish to "raise themselves up" by addressing the "great questions." Eccles's presentation of the problem is none other than that already found in the old thought experiment of "Buridan's ass," which is faced with the necessity of choosing between one of two equally attractive alternatives. If Buridan's ass doesn't have the ability to create a difference

where there is no preexisting difference, won't it die of hunger in the midst of the two alternatives? asked those who wished to see it assigned the freedom, or will, associated with the ability to decide "without reason." Leibniz had consigned the challenge to the ridicule it deserves. To satisfy the argument, the ass must be represented as a pencil standing on its point. It is not at rest, but "uneasy," any small difference will send it toward one alternative or the other. The "paradox" of Buridan's ass, which, absent free will, will never choose one side rather than the other, implies not the fiction of two equally attractive pastures but that of a plane that would cut the ass, as well as the entire universe, in two with no difference between the two halves. If the "mind" is to make "free" decisions, the "critical equilibrium" of neurons must also imply the entire universe. The universe, at this critical juncture, "waits" for John Eccles to choose between two possible futures—in one universe he will pull out his handkerchief to wipe his nose and in the other he will sniffle.

Today we can anticipate a new quarrel involving systems characterized in terms of determinist chaos. Doesn't the "state" of a chaotic system lend itself to an even more convincing reductive argument? It fulfills all the conditions for reductivism because it is "determinist," that is, supports the claim that all relevant relationships are made available when determining the system's behavior. And because of the erratic character of this behavior, all of the manifestations an adversary might use as indicative of the freedom to choose can be incorporated. This adversary will then have to show his true face (dualist, spiritualist, irrational, believer . . .) because he will have to argue the difference between "true" freedom and behavior that is erratic, unpredictable. The very terms of his argument will allow the reductionist to triumphally conclude that "we have left the domain of scientific rationality." Which means: we are entering the world of opinion, where anything is permitted but nothing counts.

Hollow confrontations, power relationships, claims of constituting a royal road, complaints and accusations against the conquering imperialism of a blind and calculating rationality, visions of the world, and reason—all the confrontations that serve as ecology in the modern sciences converge around the question of emergence. Therefore, it is from this field of battle that we must escape. More specifically, this field must be transformed into a problematic and practical terrain. But in order to do this, the meaning of the term "claim" must first be transformed. Emergence cannot be disentangled from claims about reducibility or irreducibility; therefore, a practical, constructivist sense must be given to the issues covered by that term.

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The Practices of Emergence

It is not often that I have the opportunity to speak well of the work of philosophers of science. That is why I don't want to miss the chance to point out the parallel between the way I approach the concept of emergence and its proposed definition by J. K. Feibleman. He begins with a conventional definition of emergence, which associates the relation between a whole and its parts to the relation between ends and means. According to the "holist" version of this definition, the genuine "whole" expresses its autonomy over the parts in that it can be seen as its own end and its parts will be used as means to that end, or purpose. Therefore, the "whole" is defined as being *organized* as a function of that purpose. But to this conventional definition, Feibleman adds an element that could change many things: "For an organization at any given level, its mechanism lies at the level below, and its purpose at the level above. This law states that for the analysis of any organization three levels are required: its own, the one below and the one above."[1] In other words, the purpose of an organization is not found in itself but is always seen from the point of view of something else.

As a test, let us apply this three-level definition to a favored case of reductionism, the emergence of the molecule of water. The interest in such a swing toward chemistry resides in the questions it brings to light, in this case, those that associate the respective "identities" of whole and part to the practices that allowed those identities to be defined. For, using the three-level definition, the identity of water is immediately doubled, even within the practices of the chemists who defined it. Water plays two distinct roles: one of its identities corresponds to the chemist's purpose in understanding it as a molecule that will interact with other molecules; the other corresponds to the purpose of understanding it as a solvent, that is, a liquid. Consequently, "water" had to emerge twice: as a molecule composed of "parts" and as a liquid with specific properties, composed of molecules.[2] And, in fact, each of these emergences has three levels.

Let's look at the molecule, while remembering to distinguish the atom from the chemical element. Ever since Mendeleev, the element has been a part of the *chemical* definition of molecules and reactions, but it presents no problem for emergence. The chemical element, like matter in the Aristotelian sense, has no properties that could be used to define it "in itself." Its definition entails the definitions of simple and compound bodies and their reactions. The element does not explain the molecule, it is explained along with it. On the other hand, the atom claims to explain the molecule the way the part explains the whole. It owes its scientific existence to practices of a very different kind, which do not address it as a chemical actor; therefore it can, unlike the element, claim a separable identity. "Emergence" can be reduced to two levels if and only if we adhere to Épinal's image of a chemistry that has been "reduced" to physics. In fact, element and atom came to designate the same being only after a series of complicated negotiations in which data from various practices had been articulated and coadapted.[3] And in this process of negotiation, the "purpose" is found "above," on the level of the practice of negotiation itself. The identity of the molecule has been "organized" as a function of a known purpose—the

realization of coadaptation, the use of old properties that have been reinterpreted or new properties that have been ardently sought to show that the molecule can be fully explained by the atoms of which it is composed.

Another demonstration, very similar but this time involving statistical mechanics, would demonstrate the emergence of the "whole" formed by a liquid consisting of a population of molecules. But the problem can be made more complicated. For the physical chemist is not the only one "for whom" water is both molecule and liquid. The same is true for the living body. Molecule and liquid "exist" for cellular metabolism in distinct ways, each of which is defined by distinct purposes. In fact, the "purposes" of liquid water, as cellular metabolism as a whole constructs them, are far more subtle than those that made it a "solvent" long ago. Moreover, it is cellular metabolism that obligated the physical chemist to understand the subtlety of what liquid water can do.[4] We can thus state the problem as follows: from the point of view of cell metabolism, doesn't the "identity" of liquid water also "emerge" as being relative to the purposes metabolism invents?

The same type of problem can arise in the case of "detection." It is not only from uncontrolled anthropomorphism that biologists talk about "detectors" when they describe a metabolic function. In one way or another, living metabolism, as well as the laboratory, implies the construction of devices whose "purpose" seems to correspond to detecting (assigning an identity to) a molecule.[5] The irresistible character of the metaphor must be taken seriously, but not literally. Perhaps, borrowing an idea from Bruno Latour, who borrowed it from Michel Serres, we can make use of the prefix "quasi" to mark both the relatedness and the distinction between biological "practices" and practices of human understanding. A molecular quasi identity emerges from biological quasi detectors—a three-level quasi identity given that it relates to the quasi purposes of detection and to the quasi means constituted by the interactions among atoms used by quasi detectors.[6]

Let's return to the general question of emergence. If, as I have done, we include in Feibleman's definition the "purposes" associated with the practices of understanding, the question assumes a practical and political sense. It signals a way of relating two practices characterized by the fact that one includes in the definition of what it studies a reference to the object of the other in the form of a "purpose," which is to say, it includes the possibility of transforming what it studies into a means of explaining that object. In other words, the question of emergence is never "passively" asked, it is always actively asked. The whole and its parts always refer to a third term, a practice whose purpose is to articulate their relation. Practice or quasi practice: the articulation of relations between neurons and the ways of experience do not interest neurophysiologists alone but had to have been an issue throughout the history of living organisms with brains.

Once the question of emergence arises, whole and parts must be mutually defined, negotiate among themselves what an explanation of one by the others implies. The holist version of emergence denies the possibility of this negotiation because it identifies as a purpose for the "whole" the manifestation of properties that confirm that it cannot be reduced to parts. The reductionist version of emergence transforms the negotiation into unilateral determination because it is interested in the "whole" only to the extent that it promises to explain itself on the basis of its parts. It remains to be seen to what extent, when queried from the point of view of this negotiation, the question of emergence can cease being a battlefield where definitions of "whole" and "part" confront one another, each claiming both autonomy and the power to assign meaning to the other. This possibility, if it is to escape good intentions, can only be

confirmed by the appeal of its effects. The explicit recourse to an ecology of practices that my definition of emergence expresses will have to shift the appeal that competing visions of the world always promote.

To assimilate, as I have just done, purposes associated with practices of understanding with those that can be attributed to the living organism is somewhat forced, because the analogy is only partial. One way of making this partial character explicit is to point out the relative indifference of the experimenter (more specifically, the experimenters as a community) to the way in which "new water," redefined as a compound "emerging" from those parts known as hydrogen and oxygen, will redistribute the properties that could be attributed to old water. What is important is the construction of a new story. The experimenters' *appetite* is now directed toward the creation of new devices, new kinds of proofs and tests, far more than on the means to "recover" all of water's former properties. The question as well of finding out how composite water and solid-liquid-gaseous water are to be related is relegated to other research projects.

The experimenters' appetite for the world from which they take what will become the substance of their questions often assumes an aesthetic form. Thus, when Jean Perrin celebrates the "vast host of new worlds" that atomic reality allows physicists (us) to peer into, he also celebrates the defeat of values associated with "reality" by phenomenological physics, a reality defined as regular, predictable, and measured by instruments that assume its homogeneity.[7] The thermodynamic phenomena and their variables, which corresponded to laboratory practices that were quite distinct from those that, at the end of the nineteenth century, brought into existence the discrete world of microscopic events "beyond phenomena," are, of course, said to emerge from that host. But it is this host itself that caused Perrin to speak, which made him a visionary and a poet. In fact, we can go so far as to say that the question of emergence here is asked "backwards," for it is the parts that emerge from the "whole," from the observable phenomenon. Contrary to what has often been claimed, there is nothing reductionist about Perrin, for whom discrete reality is not a "means" of explanation. On the contrary, observable phenomena interest him only to the extent that they are reinvented as a "means" for that discrete reality to be characterized in observable terms.

The appetite of molecular biologists is quite different, but in this case as well the problem of emergence is presented asymmetrically, privileging the means. When they subject bacteria to tests that challenge their survival and their ability to proliferate, these biologists have effectively succeeded in occupying a position from which bacteria appear as being organized for survival and reproduction, and the mechanisms they study then appear as so many means at the service of that purpose. But this position is unique. The role biologists have invented for themselves with regard to bacteria does not constitute a right for the scientist with respect to the living organism. This role reproduces the one that bacteria are liable to confer upon the environment, the challenges they are capable of undergoing without necessarily dying from them.

The "vision" that confers upon DNA the status of a program, because it implies the omnipotence of selection in the role of the blind programmer, assumes and affirms that the uniqueness of bacteria is the truth for *all living organisms.* Every living being "says" the same thing as bacteria, except in a more complicated way, and *must* therefore be able to confer upon its environment the same kind of role. Regardless of the feature studied, its only explanation is found in its selection: in one way or another, it *must* have had a selective value, increasing its bearer's chances of survival and reproduction. In other words, the power of selection, which constitutes the "level above" from which the living organism can be endowed with a purpose, can survive and reproduce, would be limitless, so that no problem of articulation can arise between molecular "means" and the "whole" that constitutes the living organism. That is why, from the point of view of selection, the purpose can be attributed indifferently to genes or to the living organism. As Richard Dawkins has stated, and his witticism is quite to the point here, we could also say that the organism is a means that the gene gave itself so as to ensure its own transmission from generation to generation.

One of the most unexpected aspects of the "revolution" known as molecular biology is to have created the concept of "absolute" emergence, as Jacques Monod called it, satisfying no reason other than that of selection. Like the clock, which owes to the laws of mechanics properties of secondary consequence only, and everything to the intelligence of the watchmaker who made and assembled each piece, the living organism of molecular biology is "compatible" with physical chemistry but owes nothing specific to it. Jacques Monod has never celebrated the prodigious activity of proteins and their interactions, but rather the *cybernetic logic they obey.* In fact, molecular biology, while it celebrates the reduction of life to a gigantic network of catalytic reactions, associations, and intermolecular regulatory activities, also celebrates the triumph of technical artifice over Perrin's teeming matter. It was not without reason that the specific performance to which proteins are susceptible has been compared to microscopic "Maxwell's demons." Just as the demon embodied the rights of the probabilistic interpretation that enabled it to intervene at the level of molecular activity and to impose a form of collective behavior that broke with the rule of irreversibility, the performance of proteins *subjugates* chemical activity, turning it into a biochemical "means" for achieving an "end" that is foreign to it, that relates to a history of selection alone. Selection operates on a field that is always already defined by a logic of subjugation since it operates on the result of unpredictable mutations that primarily express the imperfection of subjugating chemical reactions governing the replication of DNA, the imperfection, therefore, of making those reactions subservient to the logic of conservation for which they are the means.[8]

Neither Jean Perrin, Jacques Monod, Richard Dawkins, or any other spokespersons of the all-powerful genes address emergence as a *problem*, thereby allowing the three "levels" corresponding to the problem to resonate. On the other hand, not far from them we can discern the figure of a true practitioner of the problem of emergence, whose appetite is stimulated by the possibility of emergence as such. This figure is the creator of technical artifacts, of beings who, if they manage to exist, will have overcome challenges that are associated not with the requirements of competent colleagues but with the possibility of reliable performance, endowed with meaning for an essentially heterogeneous collective and related to essentially disparate constraints.

The technical-industrial innovator has nothing to prove, in the sense that proof seeks to differentiate between fiction and fact. Her milieu is fiction. She is not, however, released from all obligations, quite the opposite. Her practice obligates her to start with, if not create, a twofold indeterminacy. An indeterminacy regarding the way in which the being she creates satisfies the constraints of the "level above," the level she addresses, that is, the level whose constraints that being will satisfy in giving them a determinate meaning. And an indeterminacy regarding the way in which that being will distribute the respective values of what it mobilizes from the "level below": what it will define as a "means" and what it will define as a possible source of breakdowns or problems to avoid.

The verb *envisage* is appropriate to this practice and its obligations. To "envisage" a problem does not imply its resolution, at least not initially, but relating the terms in which it has been expressed to the solutions it may authorize. The approach of someone who envisages is oriented, but not unilaterally. It involves answering a question, a possible, but the problem

as first formulated is only a hypothesis. Indeed, a "world" is implied, and it will become an integral part of any "solution," which may require that the problem be formulated differently. Of course, we can state that the experimenter also "envisages," but the space her practice delineates has a stable topology. She knows, a priori, what "the world" (that is, her colleagues) asks of her, and she also knows what will identify a well-formulated problem. The obligations of proof, the creation of a reliable witness, satisfying the requirements that put it to the test, supply stable criteria for success. The technical innovator does not know, a priori, how she is obligated nor what she may require. She inhabits a space for which a relevant topology must be drawn, one that subsequently will be deciphered in terms of "means" that are implemented and "needs" that are satisfied.

The question that orients the approach of the innovator (a neutral term that refers to a group) does not fall within the perspective of discovery, and what is constructed has no ambition to see any kind of preexistence recognized, the way a microorganism or DNA might claim it. The delegated agents do not have to explain themselves, their actions do not have to bear witness to the properties of corresponding actors.[9] They can do so, but that is not what is asked of them. Questions and agents respond to one another within the perspective of a new emergence that must define both its *prerequisites*, what it requires of materials, of the processes and agents it is going to mobilize, and the way in which it will be inscribed in the world, the purposes that will identify it.

Here the contrast between the possible and the virtual, the real and the actual, found in Deleuze may again be relevant. As Deleuze noted, the virtual, has the "reality of a task to be fulfilled." It is not just something that is susceptible to actualization, it confronts us with the problem of actualization. My earlier reference to the virtual concerned the question of quantum indeterminacy (see *Cosmopolitics*, Book IV). In that case, the "task to be fulfilled" was reduced to a mutually exclusive choice between a determinate number of measurement possibilities. With the question of the innovator, the virtual and its actualization rupture any relationship of nostalgia or mourning concerning the reality that would resist its "potentialization," the reduction of choice to a selection between already determinate possibilities. The innovator does not address a reality that would be "potentially" defined by categories of knowledge yet to be constructed, to preexisting "potential" actors, lacking nothing but the transition to scientific reality. Actualization is covered by the "and . . . or" of distinct possibilities of emergence, rather than the "either . . . or" of mutually exclusive possibilities of determination through measurement. Correlatively, the irony of Copenhagen is no longer relevant. The "and . . . or" does not impose abandoning a possibility. It brings about a new kind of appetite—appetite for the "field" as speculatively implied by the possibility of emergence, a field where both the emergent's requisites and the finalities that will be attributed to it must be actualized.

Yet, while innovators are practitioners of emergence, their practice does not allow the question of what might be a practice of emergence within the coordinates of science to be resolved. The technical-industrial-social factish to be constructed does not depend on the interest of colleagues, it has no ambition to raise new questions, to gather around itself practitioners who will connect it with other fields and other purposes. The appetite for the field its construction brings about usually has a limited horizon as the success of the factish imposes the (relative) stabilization of the purposes and means it distributes.[10]

However, the appetite for the field characterizes sciences such as geology, evolutionary biology, climatology, meteorology, and ecoethology, as sciences that address situations that cannot, as such, be "purified," reduced to laboratory conditions, that cannot, therefore, be reinvented in such a way that they become (in some cases) capable of supporting a position of judgment.

The scientist "in the field" is always on a specific terrain, never one that can claim to represent all the others.[11] The appetite of scientists in the field in no way resembles that of the experimentalist, and those who study such scientists have to learn to develop an analogous appetite. For the stabilized operations that ensure judgment in the laboratory are also those that create the distance between the competent inhabitant of the laboratory and those who venture forth in this place where they know that their questions will likely be judged idiotic, naive, and incompetent. The relative absence of such stability in the field can expose the one who studies fieldwork to temptations of ironic relativism. Each scientist would define his or her "own" field, all of them being equivalent before the ironic eye of the one who sees nothing other than the one thing that interests him, the power of fiction.[12]

The practice of the innovator spoke of emergence, not science. The practice of scientists in the field does not speak (directly) of emergence, for what is in play is first of all the question of how to "describe" rather than how to "interrelate." As we shall see, however, the practical problems presented by description have a direct connection with the question of a scientific practice that addresses the problem of emergence.

A geologist, a paleontologist, an ethologist does not "stroll" around, contemplating a scenic landscape; they do not explore a place the way a photographer does, in expectation of an event, of the photograph that will be risked. They set themselves up with their equipment and their skill, and these specify their questions and confer their meaning on the rather mundane photographs they come back with.[13] But what the field gives to them is not *the* answer to *the* question that such equipment and such skill refer to, but the description of a case, and nothing guarantees nor can guarantee that that case will serve as a reliable witness capable of creating a trustworthy, and generalizable, relation between question and answer. Also, the answer is not capable of being subsequently stabilized and narrated economically, as is the case after a successful operation of delegation, or any other experiment. The answer provided cannot economize reference to *this* exploration, carried out on *this* field. Nonetheless, we can speak of an answer provided by the field because of the learning such an answer entails, learning that does not result in conclusions but in narration.

Unlike the experimental factish, which, by definition, "explains itself" in the answer to the questions it authorizes, the field induces and nurtures questions, but it does not supply the ability to explain the answer that will be given to them. Of course, the practice that causes it to exist and is addressed to it assumes that the relationships that allow themselves to be deciphered are "conditions" for the answer, but they are insufficient conditions. However, the loss of the determining power of the condition, the fact that it is incapable of providing an explanation, are not negative categories here. For there to be a field, the indeterminacy must be interesting as such, the questions addressed to the field and the relationships it articulates must welcome the possibility of a mutation of their supposed meaning. The needed appetite for such a possibility and the role played by the field, which is liable to lend the narration the quality of an intrigue, constitute a practical difference between the experimental sciences and the field sciences. The latter, as I have characterized them in *The Invention of Modern Science*, construct stories in the sense that the causes they present can no longer claim to have the power to determine how they cause. The question "What can the cause cause?" here assumes an importance that is foreign not only to the cause associated with the Galilean object, which provides the = sign with its power, but also to the causes associated with all the practices of staging and delegation common to experimentation. Operations such as staging or delegating assume stable relationships and roles, which is precisely what the "field" challenges and for which it substitutes the interest of intrigue.

The appearance of scientists endowed with the appetite I have just described is an important ecological fact within the population of contemporary scientific skills, but the meaning this fact may harbor depends on that ecology. For a long time, "Darwinian" science has been presented in a form that enabled it to claim the same power to judge as the laboratory sciences. Natural selection had to be all-powerful so that its representative could claim the power to judge, to explain, even rhetorically, the history of living creatures. That we would arrive at the "just so stories" of sociobiology when speaking of primate or human behavior was, in this sense, entirely predictable. What is much more interesting is that some Darwinian biologists today seem capable of presenting themselves differently. I am referring to *Wonderful Life: The Burgess Shale and the Nature of History*, in which Stephen J. Gould states that the field sciences are now capable of claiming the uniqueness of their practice, of inventing themselves as different without fearing the judgment that would call them inferior.[14]

Moreover, although the new EcoDevo (ecological developmental) biology explores the embryo's development with the full array of sophisticated tools provided by experimental science, it is nonetheless something like a "field science." The field in this case is the amazing "causal choreography" associated with processes of development that had been characterized by both finalists and neo-Darwinists as directed by a cause (the final cause or the program). The characterization of the continuously self-redefining developmental entanglement mobilizes all the words we have to describe encounters that affect the very fate of the encountering terms. From infection or mobilization to hijacking, seduction or reciprocal induction, the common feature of these narratives is that any simple relation between "cause" and effect" is lost without regret.

When the interest I associate with the field sciences is addressed to living organisms customarily judged in terms of purpose, as creatures of natural selection, directed toward an end, what is learned instead is the risk of such judgment, a risk that cannot be overcome, that will recur at each successive step. Such sciences not only speak about the hazard of circumstance, they create interest in the intrigue that binds heterogeneous elements whose meaning is produced in the encounter itself. In doing so, they serve as a decisive ingredient in the problem of emergence. For, the two confrontational positions that destroyed this problem are similarly challenged. Neither the finalist biologist, for whom the ends of organization define the irreducibility of emergence, nor the "reductionist," who accepts his adversaries' purposes as such only to relate them to the power of selection, have any desire to conceptualize the dual indeterminacy of "ends" and "means." The question that now arises concerns practices that would eagerly welcome this dual indeterminacy, practices that would require an alliance with the field sciences in order to construct the problem of articulation between the requisites of emergence and the purpose that will be associated with what emerges.

To approach this question, I want to examine the answers supplied by the experimental sciences and, more specifically, those sciences that, during the past years, have claimed to "renew" the question of emergence: the physical chemistry of nonequilibrium and the study of neoconnectionist networks. I will try to show that, in both cases, a mutation is produced with respect to the domain of origin. The physical-chemical being "far from equilibrium" may cause a divergence between "condition" and "determination" whose coincidence was formerly ensured by the state of thermodynamic equilibrium. The artificial "neoconnectionist" being brings about a divergence between "fabrication" and "mastery," which the watchmaker's artifice celebrated. Such divergences are what the term "self-organization," shared by both domains, reflects. For the scientists who suggested it, the loss of power, that of the ability to

determine or master, has given rise to new values, new interests, and, of course, new claims.

Thus, new, practical faces of emergence, resulting from the experimental sciences as well as from the sciences of artifice, arise, which will allow us to explore possibilities of articulation between laboratory creations and field creations. Some may criticize these new faces as masks that conceal a new strategy for conquering the terrain. Indeed, self-organization can be seen as a new "all-terrain" response. In fact, it was the clearly differentiated—enthusiastic or disparaging—but all too often caricatured responses engendered by nonequilibrium physics that forced me to take the first steps toward what I have here referred to as the "ecology of practices."

These reactions also indicate the limits of the "interdisciplinary project" of which *Order out of Chaos: Man's New Dialogue with Nature,* which I coauthored with Ilya Prigogine, was a part. Whenever the question of scientific practices is involved, interdisciplinarity, whether it finds the source of its references in physics or cybernetics, information theory or some "theory of complexity," suffers from the same weakness as the concept of an "idea" (or an ecology of ideas). The idea seeks to "be applied" and is eager to exaggerate any resemblances. It entails no requirements or obligations, and therefore travels freely as some kind of shared currency that would permit an "exchange" or "dialogue" among the sciences but that dissimulates the glaring difference among the use-values it is able to claim in various scientific domains. So, it is not in terms of "interdisciplinary promise" that I conceive of the possible faces of self-organization, but in terms of the test I associated with emergence as a problem: a practice of articulation that brings about and stabilizes abandonment of the position of a judge who has no need of a terrain because he knows ahead of time what that terrain has to say. Whenever there is a question of emergence, indeterminacy must become a part of the meaning of what is constructed in the laboratory.

15

Dissipative Coherence

In the next few pages, I want to return to physics, but not the physics of laws. The physical chemistry of nonequilibrium refers, through "equilibrium," to thermodynamics, a "phenomenological" physics that was said to have been reduced to the terms of the probabilistic interpretation that led to the triumph of the laws of the Queen of Heaven (see *Cosmopolitics,* Book III).

I want first to briefly recall the rather curious structure of so-called equilibrium thermodynamics characterized in Book III. This science stands out in that its object is not energy, or thermodynamic, processes as such but their "rational mimicry": the displacement of equilibrium, where process time is replaced by the progressive manipulation that forces the transition from one equilibrium state to another infinitesimally close. In this way, we arrive at the three-part definition of entropy as a state function. In the ideal case, when the change of state it measures is a reversible displacement between equilibrium states, entropy is defined in terms of the system variables. When this displacement does not fully satisfy the ideal of a transformation that never brings the system at a finite distance from equilibrium, entropy remains a state function, but its definition becomes indeterminate: it includes some "uncompensated

heat" that expresses the fact that any deviation from the ideal results in "dissipation." And when the problem is not displacement, ideal or not, from one equilibrium state to another, but an evolution toward equilibrium, only the maximum value of the entropy is defined, corresponding to the equilibrium state. The evolution of an isolated system toward equilibrium "causes" undefined entropy to increase until it reaches its well-defined maximum.

The definition of entropy, and other thermodynamic potentials, thus gives a central role to the concept of an equilibrium state. More specifically, the two concepts define each other: the equilibrium state is defined by the maximum or minimum value of the potential (according to the definition of this potential) and the potential guarantees the stability of this state. Once at equilibrium, the system remains there and any evolution that would spontaneously move the system away would contravene the second law of thermodynamics. For example, in an isolated system, it would correspond to a decrease in entropy. The existence of a thermodynamic potential function thus characterizes a dissipative evolution by its final state, when all dissipation will have vanished. In short, the thermodynamics of equilibrium is by and large characterized by the opposite of the obligations of a field-based approach: its questions revolve around a state that is unique precisely because it has the power to silence all questions, that is, to provide a final reckoning for a process for which it has neither the means nor the need to give an account.

In *Cosmopolitics,* Book V, I introduced Ilya Prigogine as the successor, then as the heir, to Boltzmann. However, when the work that resulted in his 1977 Nobel Prize is being discussed, he should be referred to as a student of Théophile de Donder. Successor and heir are a matter of choice, being a student is primarily a "fact," even if this fact also implies a choice (not every teacher becomes a "master" for her students). De Donder was a mathematical physicist and a correspondent of Einstein. For him, science was something that "embodies the purest image that the sight of Nature can bring to life in the human mind." And when he was required, out of professional duty, to teach thermodynamics, he did not find that purity. So he decided to create it. For that to happen, Clausius's mute, uncompensated heat would have to learn to speak, would have to participate in the harmony of functions and reveal the musical truth of the indistinct noise known as dissipative evolution. And de Donder turned to that field of thermodynamics where dissipation is entirely intrinsic, where the ideal of a reversible transition from state to state is the most obviously artificial—chemistry. For, measurement by means of reversible displacement was able to normalize chemical reactions only by stripping them of their most important characteristics: the spontaneous heat given off or absorbed by every reaction and the reaction rates that qualify them and that kinetics studies.

Dissipation and chemistry. It required the freedom of a mathematical physicist inhabited by the beauty of his science to challenge the hierarchical structure that sanctified the power of that science. De Donder did this in two ways: by asking about irreversibility, which had been deprived of any meaning on the fundamental level, and by attributing to it, as its "topos," as the site where the corresponding problem could be constructed, a chemical activity that had been reduced to the interaction between the atoms of physics. In discussing the growth of entropy, I spoke of an "enigmatic factish" that raises questions it is, as such, incapable of answering (see *Cosmopolitics*, Book III). But the enigma in question cannot be separated from the final decades of the nineteenth-century crisis concerning the values and obligations of physics. For de Donder, who was in the service of harmonious beauty rather than the power to impose requirements, the crisis never existed. The enigma was free to become a question, and that question created an interest in what it designated as the terrain on which it could become a problem:

the dissipative activity of matter.

With de Donder, thermodynamics, a science that is deliberately blind to what it cannot subject to a rational equivalence through which it can articulate its variables, would reorient itself around a new physical-mathematical being that, in itself, said no more than other thermodynamic properties but raised a question where those other beings gave only answers: it is the *production of entropy* that describes the growth of "uncompensated heat" over time. Concerning the production of entropy, thermodynamics as such doesn't say much, except that it is the most general of thermodynamic potentials. Regardless of the conditions that define a system (isolated, constant temperature and pressure, etc.), the production of entropy at equilibrium is, by definition, identically zero. Correlatively, all irreversible evolutions toward equilibrium are, by definition, "entropy producing." The enigma has become a problem: with what kind of variable can this production of entropy be associated?

Chemistry is privileged in that, aside from thermodynamic variables, chemical transformations are characterized by other variables that immediately introduce time: the kinetic variables that refer to equilibrium as the state in which processes continue to occur but with velocities such that their effects are canceled. De Donder would make the production of entropy the setting in which an explicit link could be forged between irreversibility, process, and time. Forging refers to the art of making alloys, which force disparate materials to become one. In this case, kinetics, which evaluates chemical velocities, and thermodynamics, which qualifies chemical reactions on the basis of the equilibrium state in which the production of entropy is canceled, although previously rivals, will now be forced to participate in the definition of the production of entropy.

The production of entropy is the crucible where the link is forged, in the sense that it defines the question asked by de Donder of every chemical reaction: What do you contribute to the production of entropy? Here, the term "contribution" is critical. It seems to refer to the possibility of "judging" a chemical reaction on the basis of a "value," the value of its contribution. Earlier, Clausius had judged the respective values of the conversion of heat into work and the passage of heat from one temperature to another using as a fixed point their equivalence defined by the ideal Carnot cycle. When the system has returned to its initial state, conversion and passage are exactly balanced. But the "value" defined by de Donder (in this case, the contribution of each reaction to the production of entropy is defined by the product, Av, of its thermodynamic potential, the affinity A, and its velocity v) is part of the question, not part of the solution. The overall production of entropy must be positive, yes, but this thermodynamic definition leaves the specific contribution of each chemical reaction to this production *indeterminate*. This allows de Donder's thermodynamic Av, which defines the overall production of entropy for the ensemble of reactions that participate in a chemical transformation as being positive everywhere, except at equilibrium, where it is zero, to take into account kinetic description, which describes this ensemble as a "system" of reactions that are *coupled* to one another. From the point of view of kinetics, each reaction has a velocity that depends on the concentration of its reagents, that is, on the other reactions that contribute to the production or destruction of the reagents in question. And this coupling of reactions can result in the fact that some of them provide a *negative* contribution to the production of entropy.

The production of entropy, therefore, can be used to present a problem—the difference between each separate reaction and the ensemble of coupled reactions. And this problem is open-ended. The thermodynamic condition expressing the second law, the positive production of entropy, is inadequate for determining its solution. Except in one case. At equilibrium, it is thermodynamics's glorious simplicity that triumphs:

the rate of each reaction is separately compensated by the rate of the inverse reaction. However, the production of entropy as de Donder redefined it only makes the significance of this simplicity explicit. At thermodynamic equilibrium, the coupling of dissipative processes—kinetic description—is without consequence. But the clarification, as is the case whenever it is creative, transforms the meaning of what it makes explicit. Equilibrium is no longer the thermodynamic "state," but a particular situation within a landscape that asks to be explored. And if the system is maintained *out of equilibrium*? If, instead of letting it evolve toward the state that has the power to make coupling insignificant, the experimenter forces exchanges between the system and the exterior—for example, through the permanent flow of chemical reagents that prevents it from reaching equilibrium? What might then be the effect of the negative contributions to the production of entropy that makes coupling between processes possible?

This was the problem Prigogine set for himself, and he provided it with a clear purpose from the outset. For Prigogine, a student of de Donder, was preoccupied with the question of emergence as exhibited by biology. And the uniqueness of his position among physicists arises from the fact that he wanted physics to have the ability to address this question. Living organisms do not have to be answerable to physics, it is physics that has to be answerable to the fact that the living organism is actually possible. In other words, Prigogine required that physical-chemical processes become a relevant "terrain" for the question of life. He insisted that "irreversibility"—the production of entropy—be able to tie its fate not with the evolution toward equilibrium but with the processes that, in one way or another, constitute a living organism.

In his doctoral dissertation, Prigogine generalized to all physical-chemical processes the relationship that de Donder had forged between chemical kinetics and the production of entropy. In 1945, he showed that if exchanges with the environment *constrain* the system to remain outside equilibrium but maintain it *close* to equilibrium, the evolution will reach a stationary state (non-zero velocities) determined by the minimum (non-zero) value of the production of entropy compatible with those exchanges. In this way, the power of thermodynamics can be extended to the neighborhood of equilibrium. And in collaboration with the biologist Jean Wiame, Prigogine immediately published an article in which he examined the possible relevant relationships between his theorem and the question of the living organism.[1] In it, he showed how the stability of the stationary state when entropy production is at a minimum may be associated with various properties of the organism.

The limited scope of his theorem was not an obstacle to Prigogine, for he had established a critical finding: the equilibrium state has become a special case (where the production of entropy is zero because the constraints are zero) and stationary states close to equilibrium can be characterized by a certain "order." For instance, spatial differentiation of the concentration of chemicals can appear in a system subject to a continuous temperature differential: thermodiffusion "couples" the thermal diffusion that produces entropy to the chemical "antidiffusion" resulting in negative entropy production, which would be impossible in isolation. Isn't the order associated with the living organism also impossible when that organism is cut off from its exchanges with the environment?

During this time, Erwin Schrödinger published his highly celebrated *What Is Life?*. The contrast between the two "physicalist" approaches to the order that characterizes the living organism is revealing. For Schrödinger, the order of the living organism is "negentropic," characterized by "negative entropy," which implies that this order questions, in one way or another, the principle of entropy increase. The living organism imposes the concept of an order capable of *resisting* dissipation and

disorder. And Schrodinger, celebrated as a precursor by molecular biologists, assumed that it was the chromosome (DNA had not yet been discovered) that contained and transmitted the secret of this order, an order that was defined, given that it was a question of struggling against physical irreversibility, by the language of artifice: chromosomes contain both the law and the key to the means for implementing that law, they must explain both the "program" the living organism obeys and the mechanisms that give that program the power to direct the development and operation of the organism. But for Prigogine, the living organism was dissipative. It did not have to maintain itself against entropic disorder, it challenged the simple identification of the increase of entropy with disorder. For, quite obviously, the living organism causes entropy to increase. In order to live, it must feed itself. To extend Schrödinger's concept of negentropy, we could say that for Prigogine it is the processes that produce entropy that we must turn to in seeking the key to those "negative contributions" required by the order characterizing the living organism.

Yet, it was only in 1969 that the now famous term "dissipative structure," expressing the association of order and dissipation, came into use. It celebrates Prigogine's new assurance that he had resolved the contradiction between entropic dissipation and the emergence of order required by living organisms. A crucial element of his work, which extended over more than twenty years and for which he was awarded the Nobel Prize, is the divergence between "condition" and "determination" required by certain couplings of dissipative processes far from equilibrium.

The production of entropy, which is minimal near equilibrium, has the power of thermodynamic potentials. Based on the conditions it determines—the intensity of the flux that imposes a fixed distance from equilibrium—its minimum value can be used to determine the stationary state and ensure its stability.

And it is this thermodynamic power that Prigogine initially attempted to extend far from equilibrium, until his work, conducted in collaboration with Paul Glansdorff, underwent a *practical* mutation. For the interest in far-from-equilibrium states came to be associated with the fact that they escape the power expressed by the possibility of defining a potential, or a state function: identifying the end point of dissipative evolution and ensuring the stability of that final state. The central question instead became that of stability or instability, and it is the coupling of processes that the answer to this question depends on. In other words, process coupling no longer serves only to define the production of entropy but replaces the production of entropy as the focus of the definition of the *activity regime* toward which the system will evolve. In short, far from equilibrium, the states that prolong the stationary state near equilibrium ("thermodynamic branch") may become unstable. "Dissipative structure" is the name given by Prigogine to the new activity regimes, which owe their stability to interprocess coupling.

The remainder of this history is outside the scope of this book. But I want to discuss two aspects that help clarify the practical novelty of Prigogine's approach. One is the association—the source of several fads and misunderstandings—between dissipative structures and "order through fluctuation."[2] The other is the term I introduced above, "activity regime."

Order through fluctuation expresses, in an immediate way, the emotive charge of the event for a specialist in thermodynamics: the loss of power for the second law, which, through a potential function, ensured the stability of the state, that is, the regression of the inevitable and unceasing "fluctuations" (the state being described in terms of macroscopic values, or means). The fads and misunderstandings arose because the concept of fluctuation was associated with a "cause" or "responsibility": chance fluctuations would be responsible for a "choice" or else would be creative. Rather, the expression "order through

fluctuation" indicates that the *practice* of physicists has changed. If they are no longer able to require that a potential function be defined, they are obligated to address the problem of possible instability. They are obligated to "test" an activity regime deduced from its equations in order to determine if that regime will be restored when subjected to a perturbation or, on the contrary, if the perturbation will increase. The perturbation introduced by the test expresses the question imposed by an activity regime that must be conceived as intrinsically fluctuating, once the insignificance of those fluctuations can no longer be guaranteed. That is why, in the case of instability, the physicist can describe a fluctuation as what will be amplified and the new, stable activity regime as a "giant fluctuation" stabilized by irreversible processes. But "chance," here, has no value independent of the (nonlinear) coupling that creates the landscape of possibles and the question: which will be realized?[3]

To speak of an "activity regime" as I have done expresses the fact that it is no longer possible to speak of a "state," for the definition of a state always follows from a power relationship, the satisfaction of the requirement that the definition of a system's identity means the ability to define its state(s). But this power relationship also disappeared along with the disappearance of thermodynamic potential. Whatever controls the external variables (pressure, temperature, reagent flow) no longer controls the system. Not only does the second law of thermodynamics no longer guarantee that uncontrolled local fluctuations will regress without consequence, the *very identity of the system* can be transformed. A factor that is insignificant at equilibrium, such as the existence of the gravitational field, can play a crucial role, that is, it can make distinct activity regimes possible. This "sensitivity" of the activity regime when far from equilibrium to factors that are insignificant at equilibrium transforms the nature of the questions asked. For now it is the activity regime of the system that determines its relevant definition, what this definition must take into account, what the system can become "sensitive" to. Therefore, to study an activity regime is also to study the stability or instability of a definition this regime might justify under certain circumstances but might cause to be modified in others. Correlatively, the notion of "constraint" assumes a meaning very different from "limit." Relationships with the "exterior" constrain the system to remain far from equilibrium, but the "limit conditions" do not provide the ability to determine (as was the case near equilibrium) what, from among the various possibles, will eventually be realized. Although limits are usually associated with meaningful imposition, far-from-equilibrium constraints are given their meaning by the activity regime they make possible. And this meaning will be determined by the *production* of the solution to the problem posed by the constraint. In any event, the constraint will be a condition, but it will lose the ability to determine what it might be a condition for.

Although physical chemists have not abandoned the concept of a system as such, that concept no longer corresponds to the power relationship resulting from the ability to deduce possible behaviors from the definition of the system. They preserve the concept because they can. What they address has been prepared in the laboratory, and they know what the definition of a system at equilibrium allows them to treat as negligible. That is why they can trace the landscape in which stable and unstable activity regimes can be distinguished, and the bifurcations that indicate a transformation of distribution between stable and unstable. But this ability to define the landscape of possibles as preexisting the realization of a given possible is now strictly correlated to the power given to the physicist by preparation in the lab. The concept of an activity regime as such entails a distinction between the "abstract" problem, expressed in terms of constraints, and the concrete solution produced by the effective coupling of processes in space and time. It is this distinction that has been, biographically, my pathway to the Deleuzian distinction between actualization and realization, or the virtual and the possible.

Under far-from-equilibrium conditions, the scientist can no longer "require" but the activity regime can "obligate." It is this new configuration of requirements and obligations that is referred to by the term "self-organization." The term was, significantly, borrowed by Prigogine from the tradition of prewar "antireductionist" embryologists (notably Paul Weiss), who noted the ability of the embryo to determine for itself what would be a "cause" and what would be insignificant. It tells us that physicists who adopt it now consider themselves to be directly confronting the problem of emergence: far-from-equilibrium physics is able to "comprehend" the arguments of embryologists against the reductions that had, in one way or another, joined forces with the defining power of a state. However, the term "comprehend" has two distinct meanings—to include and to understand—and only the distinction between the two can create the difference between a physics that claims to "explain" emergence and a physics that becomes a partner in a practice of negotiation through which emergence can be constructed as a problem.

Chemical clocks that exhibit periodic behavior, Bénard cells that imply coherent collective movement at the macroscopic level in a crowd of innumerable molecules—far-from-equilibrium physics results in the creation of new experimental factishes that signal the emergence of activity regimes that break with the general ideas associated with microscopic disorder. Here, laboratory and theory work in tandem, constructing new descriptions about emerging "order" and natural processes that can be included within the new framework. However, this inclusion concerns beings who "depend" on a "constraining" environment, but, unlike living organisms, *have not created a milieu for themselves*. It is true that far from equilibrium, coupling, or the interrelation of processes that produce it "create" a being whose behavior cannot be identified as the effect of the constraints imposed by its environment. But the being in question appears or disappears, depending on circumstances, without a fuss. Additionally, the coupling between processes is silent about differences that may matter if a "purpose" comes to be involved; for instance, the difference between two possible activity regimes, one chaotic and the other periodic. Physical-chemical self-organization is "factual" in nature, and the term "organization" here does not correspond to any kind of "purpose" that might articulate, for anyone but the scientist, risks, values, and challenges.

Yet, those same beings are also factishes of a very different kind, one that does not bear witness. For a long time I have searched for an adjective that would reflect this difference and, finally, it is the word *promising* that seems most appropriate, because it binds ordinarily disparate semantic uses. What is "promising" often refers to a self-interested approach, whereas a promise is often associated with a commitment. The "technical" innovator I have presented as a practitioner of invention most often assumes, as her point of departure, a "promising" possible, only to discover that there is a great distance between what she thought was promised and the actualization of that promise. In fact, what is "promising" promises nothing in particular to anyone in particular. Unlike the promise, it has no recipient but stimulates, on the part of whoever allows himself or herself to be captured, the appetite (quite unlike that of the experimenter) I have associated with the verb *envisage*. Those who envisage on the basis of a "promising" problem or possibility know they are obligated by a world, even if they don't know how that world obligates them. They know that actualization of what they envisage as promising implies a creation of meaning about which they cannot freely decide. Unlike the experimenter, they negotiate with a world they must encounter as partly indeterminate, susceptible to new relationships of meaning, but

which they can encounter as such only if they first recognize it as material for obligation.

The promising factish, therefore, creates interest in the "terrain" where a promise and its recipient will be actualized. But should we take seriously the intense association between the promise and a face-to-face situation, when looking into the face of the one who promises? Yes, possibly, providing that "faciality" is understood in the asignifying, asubjective sense given by Deleuze and Guattari. The face is not that of the "other who promises," the foundation of intersubjective relationships, it is an "abstract" machine, inductive of deterritorialization, and it is as such that it can, in certain circumstances, become a condition of the signifier and the subject. Face as "voice carriers" are not, for Deleuze and Guattari, an anthropological universal: "These are very specific assemblages of power that impose signifiance and subjectification."[4] Similarly, here, there is a very specific appetite that the "promising factish" stimulates when it induces a new kind of relationship between the laboratory and the world. The question of what a being "far-from-equilibrium" is capable of suddenly refers to the price paid for the power of the laboratory. For, it is "outside" where the answers become more interesting, where the power of the laboratory is replaced by the possibility of "reading" histories, of "following" the part played by an activity regime whose intelligibility has been produced by laboratory practices within those histories.

If physical-chemical self-organization is a fact, it also raises questions that the "fact" is unable to answer but for which it is available as something "promising." A self-organized activity regime could indeed be what the emergence of living organisms requires. What is requisite and not what explains—this distinction reflects the difference between *understand* and *include*, both of which the verb *comprehend* refers to. The requisite refers to what a problem needs, without which it could not be presented. It implies that the scientist situates herself with respect to the living organism as she would when confronting a problem, rather than a "fact," for example, the fact constituted by the ensemble of far-from-equilibrium activity regimes in a physical-chemical system. If the possibility of such regimes designates what is requisite, this means that they invite us to wonder about the meaning *they might have assumed* within a story they do not explain. They "promise" in the sense that they can be used to identify an issue: what must be "narrated" is the way an activity regime far-from-equilibrium eventually came to play a *role*, that is to say, assume a meaning for something other than the scientist. In this case, and from the point of view of this role, not all far-from-equilibrium regimes are equivalent. A story could be told in which the stabilization of one regime rather than another—but also, possibly, mutated assemblages, transformations of coupling—could assume a meaning the laboratory cannot provide, the meaning of events affecting a "body," that is, events capable of an evaluation that implies and initiates a distribution between "interior" and "exterior," between "function" and "milieu." The requisite creates an appetite for situations in which the "fact" would become an issue *for something other than the scientist*. It creates an appetite for the problem of emergence, for stories in which the question of the "value" of the possibles it allows would be invented.[5]

It is this new appetite, drawing the physicist "outside the laboratory," that the original title of *Order out of Chaos, The New Alliance*, expressed. The physicist evoked by the "new alliance" would no longer be interested solely in the "world" she has learned to judge in the laboratory, it is the diversity of "cases" she desires. She must then form working alliances with the diversity of knowledge practices liable to identify couplings, arrangements, and coherent collective behaviors whose meaning would "emerge" from asignifying local activities. But here too the question of an ecology of practices is relevant. Physicists may indeed limit themselves to proposing *models*, whose value

is relative to the pertinence of the knowledge they will capture and rearrange. But with them the authority of physics moves forward, for it alone, situated at the summit of the hierarchy of the sciences, is authorized to determine what has a right to truly exist, and what must be categorized as an illusion.

Order out of Chaos was inhabited by the hope of a new coherence in our knowledge, one that would heal the deep rifts created by physics's denial of becoming. It called for a dialogue among the sciences, united by the open question of becoming, a question none of them could appropriate.[6] What this well-intentioned offer neglected is that those sciences were also modern, and haunted by the power of disqualification and conquest, more eager for an alliance with the generalizing power of the "new model" revealed by physics than for the risks, questions, and challenges the physicist's "desire" might arouse. At best, in practices such as biochemistry or the study of "social insects," which already dealt with the contrast between multiply coupled activities and coherent overall behavior, connections were made without too much fanfare. I'll return to this later. But at worst, and with considerable commotion, new paradigms (with short life spans) were announced, turning dissipative structures or order through fluctuation into one of those all-purpose concepts that seems to proliferate wherever the will to science takes the place of practice. The "promising factishes" invented by physics can become ingredients of a practice of emergence only if the world they encourage us to investigate is populated with knowledge that is not awaiting the surplus legitimacy and power that physics-inspired "model making" would confer upon it. Such knowledge would need to be capable of obligating the physicist to take an interest in what the model must capture in order to actualize the promise and its recipient.

16

Artifice and Life

The problem of emergence in the context of the sciences of the artificial presents itself quite differently. Here, the question is not at all that of the possible "emergence" of meaning "for" a world. The artifact always has meaning. It can always be understood in terms of a logic that relates means to ends. If we consider the two distinct fields, "artificial intelligence" and "artificial life," that, in the past thirty years, have claimed to "explain" intelligence or life, the common trait that characterizes them (and expresses their shared connection to John von Neumann's work on computers) is the radical distinction between "information processing," which must be understood in logical terms (computation), and the material "implementation" of such processing. Here, the concept of an artifact should no longer evoke the image of a clock, nor that of a robot laboriously assembled. What human art intends to reproduce is the "form" that controls matter, that is, which can be conceived independently of the matter it will control. Computer beings are not actualized; they are indifferently realized for a given physical medium. This physical medium can be a source of breakdowns or crashes, but not differentiation. Here, the artifact is staged in a way that is foreign to the natural sciences: "mind" controls matter. The ideal is submission not to laws but to a project.

I want here to turn my attention to the field of "artificial life." The promoters of this field associate its ambitions with what they define as the failure of "artificial intelligence." It is not possible to construct a "brain" capable not only of reasoning but, especially, of learning to explore a milieu and extract from it the ingredients of "adapted" behavior, unless we have first endowed that brain with a computing "body" capable of encountering that milieu, of moving, falling, touching, and taking into account the consequences of its own actions. Which is to say, unless we have raised the question of the "evolution" either of a population of such bodies or the behaviors characterizing that body. We must first construct a body one can call living, one that is capable of learning, before we can construct a being we could call thinking.

It is quite remarkable that the physical-chemical self-organization I have presented and the "artificial" self-organization I am about to present converge from opposite horizons toward the question of the "body," a being endowed with a topology that creates a substantive difference between "interior" and "exterior," to which corresponds a differentiation between two types of "variables."[1] The body forces a distinction among variables that refer, to return to Feibleman, to the "level below"—variables that, if they belong to a body, no longer characterize physical-chemical interactions but relationships that have a meaning "for" the body—and those that refer to the "level above," which correspond to the milieu that exists for the body and for which it exists, a milieu of welcome or catastrophic encounters, a milieu in which not everything has the same value from the point of view of the risky wager that has produced a given body.

The two horizons are indeed opposed. The "promising factishes" of physical chemistry pose the problem of the emergence of an "exterior" that serves as a milieu. In contrast, if there are to be "promising factishes" created by artificial life, the definition of a "milieu" would not pose a problem. On the contrary, it is the value "for the exterior" that generally fully defines the artifact.

Here, the problem will be one of the emergence of variables that can be called "internal," and which must not be defined from the viewpoint of an "external" finality. In other words, the term "self-organization," shared by both fields, does not have the same meaning. In physical chemistry, the "autonomous" character alluded to by the prefix "self-" is something acquired, but the possibility of speaking of "organization" has yet to occur. In the case of "artificial life," organization is something acquired, but the possibility of characterizing it as autonomous is in question.

The field currently known as "artificial life" may have claimed that the ambitions of its predecessor—the emergence of intelligence—were very premature, but its own ambitions are not much more modest. Chris Langton, a leader in the field, wrote the first manifesto for the inaugural conference in Los Alamos in September 1987. Every word was carefully weighed and every visionary accent carefully deliberated: "Artificial life is the study of artificial systems that exhibit behavior characteristic of natural living systems. It is the quest to explain life in any of its possible manifestations, without restriction to the particular examples that have evolved on earth. This includes biological and chemical experiments, computer simulations, and purely theoretical endeavors. Processes occurring on molecular, social and evolutionary scales are subject to investigation. The ultimate goal is to extract the logical form of living systems. Microelectronic technology and genetic engineering will soon give us the capability to create new life forms *in silico* as well as *in vitro*. This capacity will present humanity with the most far-reaching technical, theoretical, and ethical challenges it has ever confronted. The time seems appropriate for a gathering of those involved in attempts to simulate or synthesize aspects of living systems."[2]

Some twenty years later, it cannot be said that "artificial life" has kept the prophetic promises of its promoter. Artificial life was a gamble because its federative ambition depended on its ability to mobilize the various fields enumerated by Langton.

In order for the bet to pay off, computer scientists or robot manufacturers, for example, would have to agree to identify their products as part of this field, to refer to it, to situate themselves within the perspective it promotes. And to do that, they would have to see some benefit in it. Their products, when situated within the framework of emergence, of the manufacture of life, of a contribution to its logical identification, would have to become more interesting than if they were situated within the more traditional framework of technological innovation. However, this was not quite the case. It is quite probable that these products will confront "humanity," as Langton writes, with a number of far-reaching challenges. Yet, how can we fail to recognize, in the way in which he presents those challenges, a mobilization, in the furtherance of scientific ambition, of the ancient figure of "man" defying the order of creation—man's confrontation with the product of a knowledge that would finally fulfill his ultimate goal, the definition and reproduction of "life" as such, independent of the contingency of his earthly origins? Knowledge products do create, and will, of course, continue to create, challenges, although more dispersed, arising from the labyrinth of technological innovations that capture and reinvent for their own use what Langton wishes to mobilize.

However, "artificial life" does not simply satisfy a mobilizing rhetoric. Something has happened, a "factish" has been invented and recognized that has created the possibility for a relative mutation of what we understand by an artifact. While the scope of this event will not be what Langton hoped for, nonetheless, it may enable emergence to partly escape the traditional frame of the "human artifact/living organism" analogy. But to address this issue, it is best to abandon Langton, who, from his computer's keyboard, wished to be the creator of "worlds" populated by quasi-living creatures.[3] It is not a matter of judging the scientific value of a work but of turning away from the slightly premature questions it has inspired: "What of man's view of himself? He now takes pride in his uniqueness. How will he adjust to being just an example of the generic class 'intelligent creature'? On the other hand, the concept of 'God' may take as much a beating as the notion of 'man.' After all, He is special now because He created us. If we create another race of beings, then are we not ourselves, in some similar sense, gods?"[4] We need to abandon the apparent grandiosity of such claims for they conform to a mythic mold that has been reduced to cliché. I now want to turn to the man without whom I would never have investigated the question of artificial life, Stuart Kauffman.

For Kauffman as well, God is not far away. This is how he recounts the passion that has driven him ever since he began trying to understand life: "I've always wanted the order one finds in the world not to be particular, peculiar, odd or contrived—I want it to be, in the mathematician's sense, generic. Typical. Natural. Fundamental. Inevitable. Godlike. That's it. It's God's heart, not his twiddling fingers, that I've always in some sense wanted to see."[5]

So, Kauffman wants to "see" order as godlike and not "become god" as Langton did. Also, he doesn't want to see "God's twiddling fingers," which are the required intermediary in the clock metaphor of creation. According to the metaphor, we cannot identify with God in terms of his ends, which for a believer are impenetrable; but we can recognize the work of his "fingers," the arrangement he has imposed upon matter. Particular, odd, contrived—these are the adjectives that describe the genius of the designer, his freedom of creation. They bear witness to the power of the mind that conceives the project, a power that is all the more evident because it imposes upon matter a way of being that is foreign to it. In contrast, the words *typical, natural,* express a mathematical requirement: order should be "generic." Consequently, the relation of ends and means becomes misleading. Not all performances are of equal value. Anyone who wishes to understand the obligations

associated with the order of living organisms must reject the triumph of someone who succeeds in getting his artifact to do what he wanted it to do. By way of affirming a value that refers to the type of order that would be needed to characterize "artificial life," Kauffman relates a requirement and an obligation that question the possibility of referring to the creator's project as bearing exclusive responsibility for the artifact's creation. As for the value he affirms, we still need to examine the two terms used enigmatically by Kauffman to characterize it: "generic" and "heart."

In mathematics, the term "generic" designates a behavior that is not only "robust" in the sense of being relatively stable compared to perturbations or the imprecision of initial conditions.[6] The property of genericness implies that behavior is also qualitatively stable, in terms of the details of the *relations, connections,* and *interactions* that bring it into existence. We can say, trivially, that evolution toward equilibrium is a form of generic behavior for physical-chemical systems because it may be characterized by the diminishing significance of interprocess coupling. But the term can only be used for equilibrium retroactively, following the discovery of much more unexpected kinds of generic behavior.

Kauffman himself participated in the early history of the field. In 1965, as a young student already excited by the themes of complexity and self-organization (in the tradition of "second-order cybernetics" associated with the names of W. Ross Ashby and Heinz von Foerster), he assembled a rather unusual network of Boolean automata.[7] Kauffman's automata are logical artifacts; the term "Boolean" refers to the functions the different automata obey. Each of them "calculates," using one of sixteen Boolean relations, an output value (0 or 1) based on its input values. The fact that they are networked means that each of them, in synchronization, will (if it outputs 1), or will not (if it outputs 0), send a signal to those automata with whom its "output" is connected, based on the signals it has received from other automata in the previous step. Until then, the performance of networks of Boolean automata had been predetermined. But the young Kauffman connected a hundred automata "randomly" and found that the collective behavior of the resulting network was one of unexpected simplicity, given the ensemble of possible a priori "states." Moreover, this behavior was robust: up to a certain point, it resisted changes in its connections until it "shifted" into another, different behavior (the landscape of states is characterized by "attractor basins").

Kauffman's model was the origin for the field of "neoconnectionism," an explosion of new technological tools and mathematical theories that allowed researchers to "understand" what had initially been discovered. Along with the "cellular automata" for which Conway's Game of Life was the prototype, it served to bolster the belief that "artificial life" was not mere rhetoric. It ushered in a new model of the artifact that satisfied, as is frequently remarked, a bottom-up rather than a top-down approach.[8] The artifact's creator no longer needs to be represented as a designer endowed with twiddling fingers that enable him to carry out his project, to impose downward what he has conceived topward. The creator "profits" from a new form of causality we can call "coupling causality," which is neither linear nor circular as in cybernetics. It is the fact of coupling that is important, not the type of interaction (physical, chemical, logical, electronic) or the purpose for which they are arranged. The creator is interested in behavior that is already qualified, *already endowed* with a relatively robust landscape of possibles "emerging" from that coupling.

If the generic properties exhibited by the Boolean network make it a "promising factish," "God's heart" should singularize the new interest these properties arouse on the part of someone who addresses a "randomly connected" network, the new, practical relationship between the artifact and its maker. For,

the "neoconnectionist maker" is not only looking to map the stable behaviors of the network. He wants to modify, to model those behaviors in such a way that on the map of possibles, "bottom" assumes the meaning for "top." The most typical example of such a relationship is the one in which the network acts as an "agent" for the recognition of shapes.

The example of shape recognition is interesting in that it refers to an apparently simple performance—something we do without even thinking—but which had always been difficult for artificial intelligence to get right. For example, what is a "B"? Yes, it is possible to formulate criteria for identifying the shape "B." But those criteria must satisfy a rather formidable requirement, they must allow for the recognition of an indefinite multiplicity of Bs, one more "poorly written" than the other, some of which resemble "D," others resembling "8," and others even resembling "A." This is why it is crucial that neoconnectionist behavior be robust. The fact that the relationship between an initial distribution of the values, 0 or 1, of automata and the resulting stable behavior is resistant to modification of the initial configuration "promises" that if that relationship could be constructed as a "recognition" of the configuration in question, that recognition would be *indulgent* by definition, robust with respect to variations. No longer is it a question of the production of criteria that make explicit how the recognized shape is to be specified but of the "learning process" that will make the difference between a welcome indulgence and one that is unwanted. It is a question of establishing an optimal coincidence between the attractor basin for all initial configurations leading to the same behavior and the ensemble of all initial configurations that, *for us*, are "Bs." In this case, learning involves a modification (based on a process that is fundamentally random but automatically controlled) of the connections or weighting of connections among automata until the network adopts the same behavior for everything that *we* recognize as "B," and adopts other behaviors for everything that is not "B" for us.

A "random" network can learn, but it's important to understand that it doesn't learn all alone and, of course, it has no knowledge of what it learns. The learning process involves two elements and cannot be reduced either to a design, no matter how tentative or negotiated, or to spontaneous evolution, no matter how controlled. The maker proposes but the network disposes, in the sense that, given the maker's proposition—the initial configuration that was imposed—the network evolves toward a form of stable behavior that belongs only to itself, which the maker may acknowledge but about which he harbors no ambition of predicting. For the maker, such behavior, regardless of what it is, will be the answer, the translation, emerging from the networked ensemble, of what was initially proposed, and it is based on that response that learning will begin. For all the initial configurations that the maker judges or wants to be similar, the translation must remain the same, and for other propositions, which he judges or wants to be different, the translation must be different. No matter how approximately we write them, we recognize that twenty-six distinct letters compose our words. The network must be able to distinguish them. Leaving aside the technical aspects of the algorithms used to modify the network so "learning" can take place, the important point to remember is that we are dealing with an *inter*action in the strong sense.

"The network is capable of learning!" "It is an artificial *neuronal* network, the first appearance of the absent body of artificial intelligence, that has just been invented." Such statements are not the laborious conclusions of specialists, but they clarify the premises of their interest, the conviction these networks brought about almost immediately. Namely, that the network's operation is a vector of meaning and, yet, incapable of justifying the meaning that "emerges" from that operation, creates the topology of a "body." The "internal coupling" whose robustness can be used to make the transition from the ensemble of

interactions to the meaning of that ensemble "for" its operation is distinct from any relationship to a milieu, for there is no "milieu"; a completely artificial environment determines the initial configuration of the network. The invention of learning practices creates a "body" by exposing what I have called the causality of coupling—the causality that singularizes the network—to another, heterogeneous "causality" that couples the network to operators that will set about teaching it to actualize their own objectives.

With the appearance of the neoconnectionist artifact, every speculative argument concerning our mysterious ability to "recognize" things without being able to specify the criteria of resemblance, which has engaged philosophers from Plato to Wittgenstein, has been captured. There is no need to have an "idea" of a table to be able to state "It's a table." The recognized object "emerges" as a collective response, in the here and now, without a model or a localizable memory. More specifically, here "self-organization" causes a "quasi object" to emerge for a "quasi subject," which should not be confused with the network as such. The network itself is inseparable from the "quasi purpose" it fulfills, but the meaning of that "quasi purpose" relates to the one for whom emergence occurs.

It is this "emergence" of a body through coupling between the network and the maker that can, I believe, give to the term used by Kauffman, "God's heart," an interesting interpretation, even if it's not the one he intended. Whatever he intended, he used a charged analogy that contrasts the heart not so much to the fingers but to the rational mind of the designer who causes his fingers to move on the basis of his project. Such analogies always reveal much more than what their user may have intended. Judith Schlanger, in her marvelous *Penser la bouche pleine*, used the example of an Egyptologist who "demarcates" his object, the Egypt of Egyptologists, by disqualifying all the other "fictive" Egypts.[9] Nevertheless, all of them, she claims, are included—the Egypt of myths, the Egypt of films and novels, the Egypt of dreams. They all coexist alongside the demarcated Egypt that disqualifies them within a dense milieu that makes interesting the demarcation that apparently excludes them. And it is this density, this muffled and stubborn "cultural memory," that allows us to understand the interesting innovation. The demarcation, if it were to create a vacuum, would be stable, attached to its evidence. It isn't, because whenever it produces new consequences, these are liable to create resonance in the dense milieu that feeds it, a milieu that, for the speaker as well as for the hearer, becomes the vibrating matter of a new actualization.

In our case, the "heart," in contrast to a "reason" capable of accounting for its operations, does indeed mobilize a dense cultural memory, in which the capacity that identifies reason continues to hesitate between recognition of unique legitimacy and indictment for arrogant pretense that bars access to a different order of truth. But it is not as one of philosophy's "great themes," first with Pascal and then in psychotherapy, that the problem of the heart finds the means to insist.[10] On the contrary, what is innovative is the way in which the problem is liable to be reorganized around one of its components. What Kauffman's "God's heart" expresses is that the consequences "promised" by the factish concern the way in which the "psychosocial" identity of the makers of artifacts will be demarcated.

Andrew Pickering has compared the development of a new, classical detector, one that uses a physical or chemical process to identify an entity or process that is also chemical or physical, to a kind of two-step dance.[11] The scientist adjusts the machine, then withdraws and allows it to operate. He observes what it "does," in this case, what it detects, and interprets the reasons for what he judges to be its defects. He then goes back to work and readjusts the machine, and continues to do so until the machine detects what it is supposed to detect. There is certainly an interaction, but once the machine is stabilized, the scientist

has learned a great deal and can tell the story quite differently. Now, the machine assumes a passive role, the action is entirely redefined in terms of what the scientist "did not know" at the start, problems he hadn't noticed, distinctions he hadn't thought to make. The maker, when involved in the "dance," may indeed have experienced extraordinary things, becoming a detector, confronting a world a distinctive feature of which he seeks to capture. But his psychosocial identity incorporates the way in which the story will achieve its conclusion, with the final separation between himself, on one side, the world and the machine, also physicochemical, on the other. The world bears witness through the machine, the machine's operation is explained by the world. The same is not true in the case of neoconnectionist networks, however. Here, the site of the "dance" is a coupled causality that will never be disentangled. The maker will never know how his device operates. And the device doesn't detect in the ordinary sense. Its purpose is not to become the witness of distinctions that could be said to belong to the world and need only be recognized. It must produce conventional distinctions, those to which the maker attributes value, among the resolutely confusing shapes proposed by "the world." The culmination of the process is not the separation of the maker, on one side, the machine/world, on the other, but the maker/machine, on one side, whose values are mutually adjusted, and the world, on the other, always as confusing and bound to remain so. In fact, success for the maker occurs when "his" machine has succeeded in recognizing the "B" that he had so carefully mangled when writing! And when the network finally, spontaneously "recognizes" what has been put before it, its operation can never be compared to a fragment of "nature" that may well have been selected, staged, and purified, but should still obey the same "reasons" as nature. The maker's judgments have passed into the machine, the only "reason" for its operation being the conventions it has "learned" to obey.[12]

The learning network is not a hybrid comparable to the clock, for example. It does not necessitate a historical and constructivist reading that struggles against the triumphal syntax wherein we distinguish the laws of mechanics, on the one hand, from the design associated with the human project, on the other. It is as a hybrid, exhibiting the processes of stabilization and negotiation from which it originated, that the device is presented. And the maker is someone who has caused it to emerge as a hybrid, to the extent that a part of himself has "passed" into the machine and has bound with the properties of genericness inherent in the machine to form a composite that no one is supposed to ever be able to separate. What God has united . . .

When scientists talk about God, they are often talking about themselves. The God of Einstein, a mathematician, occupies the site Einstein hoped to construct. The demon-god of Laplace knows the world as Laplace, the astronomer, thought he was capable of knowing the planetary system (which he believed to be stable). Maxwell's demon sorts particles that the physical chemist cannot at the macroscopic level. Langton's God plays on the world's keyboard. Kauffman's God has a heart, which refers, I believe, to the *inter*action and hybrid world of reciprocal capture that is productive of meaning. A world in which the "factish" made promising by its generic properties explains nothing as such, but implies and assumes a maker who interacts and evaluates, and whose values are "passed on" to the world, becoming, in the strong sense, an integral part of that world, inseparable from it, an ingredient of an order that nonetheless remains "typical," "generic," and, as such, impenetrable, "even to God."

Learning the alphabet is a poor example, however, because the maker's values cannot be affected by the process. It is not impossible that the new psychosocial maker of these new artifacts will one day refer to open-ended learning, where the maker's "values" would be partly generated by the answers of his

device ("this just gave me an idea . . ."). In this case, construction should be told in the form of a story: a story in which the demarcation between the maker and the machine continuously transforms itself; a story in which the maker's identity—what he seeks, the possibles he intends to actualize—would "emerge" along with the behaviors of his device; a story in which the roles would remain radically asymmetrical but would no longer put before us the owner of a project and the device that is supposed to realize it. A constructivist story.

Identifying the possible creation of a new psychosocial type of maker is a form of speculation. But the possibility of such a speculative stance is part of the resonance effects resulting, within the dense cultural milieu that entangles the themes of fabrication, autonomy, emergence, and the link between creator and creature, from the redistribution of agencies that may be associated with a new type of artifact. In our story, the creation of the clock that ideally satisfies, autonomously and solely on the basis of the laws of mechanics, the intentions of the clockmaker, has had effects of which we are the heirs. Theology has been able to emancipate itself only by turning God into an absent God. Biology is still an heir, and has given natural selection the figure of the clockmaker, or, more accurately, according to Richard Dawkins's expression, the blind watchmaker, adjusting, permutating, modifying the mechanisms of a population of "clocks" that, in the most highly diverse ways, tell the only time that "counts" for the clockmaker, the rate of transmission of genes over succeeding generations. And it is to biology that Stuart Kauffman turned in attempting to read in it the consequences of a possible "marriage between self-organization and selection."[13] For Kauffman, the blind watchmaker must "marry" the generic properties of coupled causalities. Through its metaphors, language acknowledges the dense milieu in which such references are distinguished: let no man put asunder.

Yet it is also, whenever living organisms are involved, at the point where the clockmaker goes blind, where the figure of God and the maker must both disappear, that the question arises of determining how the "factish" of a coupling causality can become an ingredient for the problem of emergence and evolution.

For Stuart Kauffman, the issue is that of "theoretical biology," but the notion of theory is profoundly ambiguous in this case. If it were to function as it does in the theoretical-experimental sciences, it would imply the construction of a power to judge that should minimize the reliance on history and turn the terrain into a theater of proof, much like a laboratory. But redefined in terms of the practices of negotiation I associate with the problem of emergence, it can signify an approach to what biological evolution requires as we are able to puzzle it out. In this case, the mutation imposed on the notion of "theory" by the theoretical biology with which Kauffman nourishes his dream would imply a mutation of the "theorist." Whether this mutation is clandestine or mutilated, whether mutant theoretical practice is persuaded to claim it resembles what it disagrees with, the way Darwinian practice was persuaded to claim it retains the power to judge, or whether it has the freedom to assert itself, is an issue for the ecology of practices.

The research that, for Kauffman, ushers in the new field he calls "theoretical" is collected in his massive *The Origins of Order*, which can be considered the leading work of contemporary "theoretical biology.[14] But the book will be unreadable for anyone who expects theory to provide the miracle of an approach that comprehends diversity within the luminous affirmation of a principle to which it is subject. The book contains a series of studies of formal situations, which introduce relationships judged to be typical of biology, but in a highly simplified manner, through the use of *toy models* (here toy signifies both that the model is something to play with, rather than one that claims to provide a faithful representation, and that we *can play*, that it can be manipulated). The behavior "emerging" from the model

is compared to observable biological data that, when compared to the behavior of the toy, become interesting, capable of providing, in certain situations, information in the language of the model.

The common feature of all of Kaufmann's toy models is that they accept the hypotheses of Darwinian evolution but, contrary to neo-Darwinism, do not assume that selection is all-powerful. They present the effects of a hypothetical selective pressure on the exploration of a landscape of possibles, where the very point is that everything is precisely not possible because exploration, from mutation to mutation, has as its subject the transformations to which beings characterized by internal coupling (for example, "interconnected genomic networks") are susceptible.[15] It is the network itself rather than any given trait that is characterized by a coefficient of "aptitude," and the characteristic connection rate of the network measures the number of genes on which the meaning (in terms of aptitude) of a mutation affecting a gene depends. In other words, Kauffman's models are not based on any new biological hypothesis. They are limited to *taking seriously* what every biologist knows: the correspondence between a trait (more or less adapted) and a gene is in no way representative of the living organism. Whereas the neo-Darwinian evolutionary biologist generally tends to minimize the complications resulting from this minor problem, Kauffman's models propose making it "the problem," primarily by studying the effects of selective pressure as relative to the type of being to which it applies.

A single general hypothesis finally falls out of Kauffman's exploration and it is upon this hypothesis that his desire for a theory is concentrated. If selection favors the ability to differentiate, if it "encourages" the network to explore a spectrum of diversified "activities," selective pressure should cause emerging behaviors—and, therefore, the connection rate characterizing the coupling from which they emerge as well—to evolve toward the *edge of chaos*. Here, perfect order is behavior that is completely predictable and robust. Kauffman refers to it as "frozen." The system is locked into one and only one mode of operation. In contrast, perfect chaos is compared to a fluctuating, erratic liquid, in which any alteration of an element can trigger a cascade of consequences throughout the network. When order dominates, the freeze percolates throughout the network, but it leaves behind isolated, unfrozen, pools. In the predominantly chaotic regime, however, it is the liquid regions, fluctuating chaotically, that percolate, leaving frozen islands here and there. The edge of chaos thus corresponds to a generic behavior that preserves the "best" of both worlds: the possibility of cascading innovation and relatively stable modes of operation resistant to chance.[16]

"If it proves true that selection tunes genomic systems to the edge of chaos, then evolution is persistently exploring networks constrained to this fascinating ensemble of dynamical systems."[17] In other words, selective pressure does not confer differentiated "adaptive" values only on those beings that emerge from coupling, but also on the coupling itself, as requisites for an evolution capable of providing its fecundity to the "marriage between self-organization and selection."

Kauffman's "toy models" obviously do not constitute a theory in the sense that the multiplicity of forms of marriage might find their respective contracts referred to a single institution that would define the truth of marriage as such aside from any anecdotal differences. Quite the contrary, it is the apparent generality of "selective pressure" as a vector of evolution, the possibility of assigning to it the responsibility of evolution independently of what it bears upon in *each* case, that is annulled, whereas a generality of a different kind is offered in its stead: a hypothesis like that concerning systems "balanced" at the edge of chaos can orient questions, not answer them. It can bring into existence, as a problem, the emergence of "adaptive values" that cause life and

artifice to converge. Broad statements such as "natural selection must have . . ." are replaced by the indeterminacy of "we do not know a priori." We do not know how to formulate the question of "value" in general terms, in that it may refer to a particular trait or to generic properties of interconnected ensembles, such as those that characterize the "edge of chaos." And, in this last case, we do not know which coupling situation is the subject: the genomic network, specific ontogenesis, the dynamic of interspecific coevolution? This is what needs to be *conceptualized*.

But the "promising factishes" of Kauffman's toy models are vulnerable, as is self-organization far from equilibrium, to the theoretical ambition that refers to itself, now and always, as the power to economize the terrain. This vulnerability is primarily expressed by the possibility of grand considerations that appear to communicate scientific practice and wisdom. And in this case, it is a "stoic" wisdom that celebrates a universe that "awaits" us, in the sense that we are the expression of chance, yes, but also an expression of the generic order promoted by theory, a fraternal universe because coupling is everywhere, but a dangerous one because of cascading consequences. "Our smallest moves may trigger small or vast changes in the world we make and remake together. Trilobites have come and gone; Tyrannosaurus has come and gone. Each tried; each strode uphill; each did its evolutionary best. Consider that 99.9 percent of all species have come and gone. Be careful. Your own best footstep may unleash the very cascade that carries you away, and neither you nor anyone else can predict which grain will unleash the tiny or the cataclysmic alteration. Be careful, but keep on walking; you have no choice. Be as wise as you can, yet have the wisdom to admit your global ignorance. We all do the best we can, only to bring forth the conditions of our ultimate extinction, making way for new forms of life and ways to be."[18]

We could say that, in this case, Kauffman, as he did when he spoke of "God's heart," thinks with his mouth full. But there is a difference, and it is crucial for the ecology of practices. In the latter case, what is being expressed is what, for Kauffman, understanding life demands. In the present case, stoic wisdom *includes* an ensemble in which everything—from paleontological data to the historical, technological, and political dynamics that "identify" us—bears witness in one way alone, that of an allegory of exploration exposed to selective pressure (we all do the best we can) and the price of that exploration (the unforeseeable catastrophe). Here too, questioning the obligations of a practice of emergence entails questioning the kind of appetite this practice induces for the "terrain." Is the factish's "promise" the submission of the terrain to a theoretical-ethical-speculative generalization or does it create an appetite for the terrain, where the indeterminate promise to which it gives meaning might be actualized.

17

The Art of Models

It would be a misunderstanding to confuse an appetite for the terrain with the creation of "good" science, respectful of beings and participating in the secret harmonies of Being. If the practices that bring about the terrain-as-problem evoke a precedent, it is not one of utopian reconciliation, where knowledge would break any connection to power. Rather, it is the problem of another form of power, analogous to the kind of power that, according to François Jullien, Imperial Chinese civilization favors, as evidenced by the omnipresence of the word *chi*.[1]

Chi is a word with as many meanings as our term "energy." It refers to a dynamic configuration associated with nature as well as with art and calligraphy, the composition of poetry, government, and warfare. The use of the word in Chinese thought contradicts any possibility of contrasting *phusis* and *technē*, spontaneity and manipulation, submission and action, conformity and efficiency, whether these refer to human government or the grand cosmic design. *Chi* implies the disposition of things, of characters, of intrigue, of political or military power relationships. And it refers equally to the arrangement that produces their respective propensities and to the intervention that will, without force, noise, or, apparently, effort, take advantage of this arrangement and lead the situation, as if by its own dynamics, to the desired issue. A part of *chi*, therefore, is the art of relying on *chi* for some advantage, the art of manipulation and enticement. The art of the great warrior is letting his enemies kill one another or betray their agreement while he remains invisible, so that the enemy army grows demoralized to the extent that the final battle is no more than a formality. Here, reason does not triumph over force, it weds force, it becomes force, and does not respond to any criteria other than those of efficient manipulation.

The art of *chi* despises violence, not because it would contradict a moral ideal but because it is not effective, because it indicates failure by opposing the propensity of things rather than confirming that propensity by taking advantage of it. Nor is it eager to discover a truth beyond dispositions and mechanisms, or seek confrontation or harrowing dilemmas. But it would be especially stupid, because this art escapes our excesses and closes the perspectives in whose name we have committed great crimes, to see in it the position of wisdom we are said to have betrayed. On the other hand, it is worthwhile pointing out that the practical mutation that could transform the dual identity of the artifact and its maker, as well as the question of the "marriage" between biological selection and self-organization, find their most apt metaphors in the art of conforming to the propensity of things.

No doubt the Chinese would have understood Kauffman's statement that "Evolution is not just 'chance caught on the wing.' It is not just a tinkering of the ad hoc, of bricolage, of contraption. It is emergent order honored and honed by selection."[2] But they would have certainly understood it without the slightest sentimentality. "Honoring" and "honing" have nothing to do here with moral respect; it is a question of using another's force to bend him to our own purposes. This may be characterized as (and all such characterizations are pejorative for

us) "manipulation," "suggestion," "seduction," "appropriation," "instrumentalization." The interesting point is that we are accustomed to using these pejorative terms whenever they refer to relations between human beings. However, they are now presented as metaphors for a new type of relationship between *phusis* and *technē*. The psychosocial image of the technician has, until now, emphasized a practice conceived as submitting an ideally inert material to a purely human project. And it established the figure of free choice and will as the problematic point of contrast between the "emergence" of assemblages that were respectively natural and human. The "technician of *chi*" has not renounced his will in order to make room for the democratic or revolutionary utopia of a "self-organized" nature that produces order, beauty, and truth through the free spontaneity of its self-creation. He is "without principles," no longer respects the master word used to organize the hierarchy between knowledge and application: "Understand the principles nature obeys in order to bend her to our purposes." It is enough that he can make nature *bend*, follow her folds, marry them so he will be able to create others.

It is interesting to approach from this point of view the mutation the term "universal" underwent within the problematic of "self-organization." The law of gravity is said to be universal in the sense that any mass, no matter where it is in the universe, is supposed to obey it. However, the "promising factishes" of the physical chemistry of systems far from equilibrium and network dynamics also allow one to speak of universality.[3] The very beautiful word *attractor* accurately expresses what this notion of the universal entails, the type of necessity with which it communicates. This necessity is always relative to a mathematical or logical model, a hypothetical schema of relations expressed by the model. Furthermore, when we deal with situations that make evolutionary sense, the model aims less at representing the situation than at relating it to a problem. The universal defined by the model cannot claim to be that to which the situation is subject. It only claims to be relevant for an understanding of that situation. Although the model introduces a robust attractor, characterized by generic properties that apply regardless of the circumstances, it designates a situation one of whose ingredients may have been the *question* of the universal that has, literally, captured it, infected it with these generic properties. Various situations may be "judged" according to the terms of the universal into whose grasp they have fallen. However, they are not necessarily defined by the categories of this judgment because they are capable, in return, of defining it in their own terms.

The problem of emergence may be approached through the art of models. The identification of a universal is no more the answer to this problem than a propensity is an answer for the "technician of *chi.*" Such a universal is characterized by the insistence of a question for which an answer may eventually emerge. The necessity with which it communicates implies that, *if the model is relevant,* the modeled situation, in one way or another, *must have* taken it into account and assigned a meaning to it. Does this situation express it immediately? Do the generic properties serve as an opportunity? Has an activity regime acquired its meaning and purpose because of them? Has it succeeded in becoming a requisite for other activity regimes for which the model would then provide an ingredient? Or does an aspect of the situation that the model failed to take into account become interesting and intelligible precisely because it allows the situation to *avoid* being captured by the universal? The universal is a question, a proposition. As for the intelligibility being constructed, it is related to the way in which the situation has disposed of that proposition. The necessity—if the model is relevant—arises from the fact that, in one way or another, determining "how," the way in which the proposition has been disposed of, must have taken place.

At this point, the model severs its connections with the theoretical-experimental practices that have made it a weaker substitute for theory, a representation that is not supposed to resist the challenges that a theory must overcome. A model, as it functions in the theoretical-experimental sciences, has a domain of validity that is carefully delimited, for, through its definitions, it employs simplifying expedients whose scope is explicitly relative to this domain. On the other hand, anyone who speaks of "theory" assumes the risk of claiming that the theory must remain a reliable guide, even when used outside the practical domain for which it was constructed. Once it is a question of the "field sciences," however, the model is no longer defined in contrast with a theory. The model is no longer defined by its simplifications or by ad hoc hypotheses. It no longer belongs to a practice designed to "prove," because the validity of a given proof would, in any event, be valid only for a given situation. Rather, it is a question of producing a problematic tension between what the model requires and what the field discloses. By identifying its requisites, a model makes a wager and assumes a risk: what it requires of reality should be necessary and sufficient for making intelligible what has been learned in the field.

We can compare this use of the model with what Gould defines as "Darwinian discovery." "We define evolution, using Darwin's phrase, as 'descent with modification' from prior living things. . . . We have made this discovery by recognizing what can be answered and what must be left alone."[4] Darwinian evolution requires the prior existence of living things. All of the reasoning it employs presupposes this. It gambles, therefore, that biological evolution, in putting forth its own problem, has no need of a solution to the question of the origin of life. In other words, it positively denies a hypothesis like that of "vital force," which would be *simultaneously* responsible for life's origin and its history.[5] What has been "discovered," in the sense that the model actively implies the reality it proposes, is the possibility of using a "disconnect," the possibility of separating the question of life's origins from what happens once living things exist. The model of evolution cannot investigate the origins of life, for it requires selection, which assumes the presence of living beings; it requires the specific relationship that every living thing invents with its milieu, its congeners, most often its predators and, in some cases, its prey.[6]

Whenever it's a question of evolutionary models associated with the field sciences, realist ambition—what the model requires of reality and the obligations entailed by the model's claims to relevance—relies on *requisites*, on what the model takes the risk of treating as securely given in order to proceed. This ambition is not trivial. Most models in the social sciences and economy fail to satisfy this requirement. Equations are written expressing the consequences of rules, norms, laws, or conventions which, the model claims, "explain" the evolution of social or economic situations. But these rules, norms, laws, and conventions vary over time, and the model would only make sense if this variation were noticeably slower than the evolution the model is supposed to explain. Which, in general, is not the case. If the time scales are comparable, the model is worthless. This was Norbert Wiener's objection to the hope of Margaret Mead and Gregory Bateson, who urged him to focus on the social and economic sciences and make them fully scientific disciplines that would finally contribute to solving the urgent problems facing society.[7]

To overcome Wiener's objection, a model must assert the risks associated with it, the power relationship that characterizes the situation if the model is to be relevant. Only the situation can authorize the modeler to separate what the model will define as variables and constants, or forget certain aspects of the situation in order to highlight others. The dimension of the situation that is responsible for the satisfaction of the model's requisites can be forgotten to the extent that (as is the case for

the history that has given life its "origin") it does not, or no longer, intervenes in the terms of the problem. However, the question of determining *how* the problem will be formulated is part of what the model must explore.

I want to turn now to models that specifically concern the problem of emergence. Unlike a model that might be called "scenographic," because it tests the consistency between the history it can be used to predict and the history of the "field," whose terms, witnesses, and indices are identifiable within the modeled situation, the model of emergence attempts to articulate a hypothetical emergence with requisites that are associated with other practices, that is, requisites whose meaning is initially relatively indeterminate with respect to the question of emergence for which they are, hypothetically, a possibly necessary but always insufficient condition.

It is here that we again encounter the question of "universals" associated, primarily, with self-organization. These universals are part of a strategy that relates emergence with requisites. They are relative to the construction of the model from the perspective of mathematical practice: the model in question belongs to a class characterized by a generic property, a "promising" property in that it is impossible to "escape" it other than by radically transforming the model. Once recognized, a universal of this type creates a terrain for the question of emergence, for it defines one of the issues that "must have" polarized the situation. If the model is relevant, if its requisites are legitimate, what emerges had to have "confronted the problem" and been determined by determining the meaning that would be attributed to it. The universal gives the situation the significance of a critique.

But the role of mathematics in the question of emergence doesn't end there. It can also "shift" the issues associated with a scenographic model toward a problematic of emergence. I will give three distinct examples of such shifts, three typical cases of what singularizes the questions of emergence when compared to theoretical-experimental questions: in each case, as the modeler learns to formulate a problem, she discovers that this problem has been (partly) formulated before.

Take the problem of eco-ethological models that make use of a predator and its prey. The initial scenographic model, designed to account for situations where statistical series are found to exist because humans, as predators, have been interested in the frequency of capture over long periods of time, is the so-called Lotka-Volterra model, which makes use of predator–prey interactions. The model typically results in a form of periodic behavior. Predators eat abundantly and reproduce easily, but at the expense of their prey, whose numbers decline. Consequently, hunger and famine occur and the number of predators decreases, which benefits their prey, whose numbers increase. This allows the predator population to increase again, and so on. This first example, however, is simply a starting point toward the general case that introduces competition among predators. We can then ask about the evolution of populations coupled by their shared dependence on a set of resources. However, the empirical relevance of the model of interspecies competition encounters limits that have nothing to do with the complicated details of such coupling. In fact, field studies lead to a change in the nature of the model. Rather than being a scenographic model of coupling to which competing populations are subject, it becomes a description of the coupling that some species *manage to escape.* Seasonal changes in reproduction, the choice of resources, the amount of food needed at different times of the year—all these "details," which the model "smoothed," can become interesting to the extent that they *counteract* the effects of interspecies competition. The relevance of the model changes. It is no longer tied to coordinating its predictions with empirical data but to identifying specific behaviors that falsify those predictions.[8] Moving from the question of solving equations to the problem introduced by those equations, modeling has allowed scenographic practice to "rise" to the "how" of emergence. This rise is expressed by the correlative appearance, for the modeler, of a quasi subject, the populations of competing predators, responding to a quasi object that is none other than the very object of her modeling: the "universal" problem of interspecies competition for predator populations.

Therefore, the modeler *should not trust* her model, not because the model might be wrong or irrelevant but because she does not know, a priori, *how* it is relevant. The Lotka-Volterra model apparently designates an "object," but it must be used with *tact* in order to expose the possibility that a "quasi subject" might have appropriated the problem corresponding to the model. The question of knowing "how to describe" is no longer one that concerns the scientist alone. Correlatively, the nature and scope of "objective" definition are transformed. Objectivity is beside the point. Interspecies competition is a problem for specific groups, but it does not allow a solution to be deduced: it raises the question of finding out *how,* with what ingredients, using what expedients, a solution has "emerged."

Tact is a quality most often exercised among humans, but it points to a much more general problem—that of a relationship created with a being for whom a problem is assumed to exist, a problem that can be identified, or so it is believed, although *how* the problem presents itself to this being is unknown. Tact, therefore, expresses an obligation that limits the power of whoever is situated by her knowledge of the other's problem. She "knows," accepts, and desires a relationship that incorporates the *open* question of the "how" and "tactfully" respects the fact that time is needed for the answer to this question to "emerge" for the concerned being. Teachers who lack tact do not feel this obligation, and most often those who are tactful fail to capture the identity of the "how" that has been invented during the course of the relationship. The goal of the modeler—and it is in this sense that her tact is part of a scientific practice—is to define the way in which the situation she models answers the model's question. "Tact" then comes to imply a transformation of requirements and obligations compared to those that govern experimental procedure. We could even say that it is no longer the scientist alone who imposes requirements. Of course, the scientist must require that what she addresses has a stable existence in terms of the relationship that is established. Wherever the conditions of a field science are found, the features studied must be robust with respect to the type of intervention that allows them to be studied.[9] But the field also allows itself to be characterized in terms of its own requirements. The relevance of the scientist's problem depends on the fact that this problem has actually required, long before the model that makes it explicit, an answer that gives it meaning. Correlatively, the field "obligates" the scientist to recognize its "preexistence," to recognize that she, the scientist, will only encounter it by acknowledging that preexistence.

This same quality of tact is at the center of my second example: biochemical modeling. Take the behavior of the amoeba *Dictyostelium discoideum* in the presence of cyclical AMP. Cyclical AMP, a creature of biochemistry laboratories, intervenes in the intracellular behavior of amoebas and in their intraspecies relationships. The rhythmic production of cyclical AMP in the milieu serves as a "signal" for the population, that is, it modifies the intracellular behavior of "receptor" amoebas.[10] The data of biochemical analysis culminate finally in a "scenographic" model of nine interconnected equations with nine variables. Can the model be used to explain the behavior of the amoeba in terms of the molecular interactions it introduces? In one sense, fortunately, yes, as this behavior is not that of the amoeba itself but a partial description, one that has already been worked and reworked to allow the question to be asked. But the interesting point is that the work the successful explanation has obligated

the modeler to perform can become the starting point for a new question that uniquely designates the behavior being explained as the specific behavior of a living being.

The "system" of nine (nonlinear) equations taken as such defines a literally "unmanageable" system that may generate extremely diverse behaviors, even though it is supposed to explain "what the amoeba is capable of," "what it does," that is to say, behavior that is stable and reproducible. Consequently, the practice of the modeler cannot be reduced to one of simple confrontation between the model's predictions and described behavior. The modeler doesn't require that the amoebas verify her equations, she is obligated by the amoebas to recognize that not all the possibles defined by the equations are valid for them, that some are excluded and others privileged. The amoebas, therefore, obligate the modeler to pose the problem of her model, for it is now a question of understanding how they themselves, in one way or another, "manage" the diversity that the equations define as unmanageable. Can the modeler reduce the number of equations, distinguish, for example, which are "slow" and can be decoupled from the others? In this case, she will have to "trace back," through the values of the parameters that must be selected in order to support the appropriate behavior, to what the model now allows her to identify: an ensemble of biochemical "quasi choices," which have intervened in the very invention of *Dictyostelium discoideum*.

The modeler's practice, the detailed negotiation with the parameter values, the calculation of their consequences, in a sense closely follows the problem of selective evolution as it is made explicit by the model. Selective evolution then corresponds to a figure closely allied to tact. The model builder's initial equations form the matrix of a "luxuriance" of possible temporal behaviors and imply that a mutation that modifies a reaction rate, or introduces, eliminates, or alters a coupling, may have uncontrollable, and usually catastrophic, consequences for the amoeba. Selection no longer has much to do with the figure of the watchmaker, blind or not. The selective history of the biochemical mechanism of the amoeba's behavior has much greater need of the precautionary prudence of an apprentice pickpocket working on a mannequin covered with bells. Tact, the clever negotiation to obtain one thing rather than another, more often one thing rather than the unavoidable other, correlates the problems the modeler faces when confronting her equations and the problems selective history (from which the role conferred on cyclical AMP by the amoebas emerged) had to resolve.

The practice of modeling in biology is often the work of researchers who take inspiration from economic models, but the problem with economy is that it radically lacks tact. Its appetite for theorems, used primarily to determine optimal conditions, takes the place of relevance. Why not have the model hypothesize, for instance, that unemployed workers "disappear" from the market if that is a condition for a theorem?[11] The economist requires, with a unilateral brutality that is the opposite of tact, that the modeled situation give her the right to publish a theorem. When employed in biology, this lack of tact immediately conspires with the omnipotence that neo-Darwinian theorizers give to selection. What emerges must optimally satisfy a given adaptive value, and the existence of the optimum allows evolution to proceed from theorem to theorem. On the other hand, "modeling the field" can, as we shall see, enable us to counteract the theorem-based inspiration of the economist and "return" to the problem that singularizes a behavioral trait.

Take the typical behavior of ants in search of food.[12] The uniqueness of this behavior is its intelligibility on the group level. Although individual behavior may appear somewhat erratic, the behavior of a group of ants is a key example of efficiency, and it seems to deserve an explanation maximizing some adaptive value. If we assume an optimum, we can always construct it, but if we don't, other questions arise. Not to assume

an optimum means understanding the efficiency, not deducing it. The emergence of collective behavior has to be "followed" according to the way in which interactions among ants "modulate" (but do not determine) individual behavior. And the collective behavior that "emerges" from such interactions turns out to be remarkably efficient indeed, capable of preferring a large source of food over others, or systematically exploring a milieu, similar to a projector revolving around a nest. The erratic and nonrobotic (programmed) behavior of the individual ant becomes, in this type of model, an essential component of group efficiency. It requires that the individual be somewhat "entrepreneurial" in order for the group to "explore" the opportunities in its milieu. But a more general concept also arises, which changes the stakes when studying collective behavior. Not only does a given population of ants in a given environment select the food sources that "count," but the way in which it selects them suggests a hypothetical "tracing back" to the problem of that multitude of species we call "ants." The interactions among ants are such that a small quantitative change in a parameter (which may correspond to a random genetic variation) qualitatively transforms the way in which the method of seeking out and selecting resources operates. "Ants" in the generic, multispecies, sense could then coincide with the invention of a relation between individuals and the group, which is the "matrix for significant variants." The relationships that allow the transition from the individual to the group would not only belong to a species, they would (partially) identify that species with a "choice" made on the basis of a genetic matrix of "hypotheses," subject to selection in each different environment, a genuine "machine" that is no longer adapted but adaptive. Here too, the question of emergence appears with the acceptance of the problem, with the possibility not of "reducing" one level to another, but of introducing a quasi-practice of inter-"level" articulation.[13]

The three examples above—interspecies competition, amoebas, and ants—apply to different aspects of biology, but they have one thing in common: they describe how we read a way of functioning that is stable and capable, to a certain extent, of reproducing itself from generation to generation. The modeler wagers that since it is robust, it must be understood as having invented the means to be robust, and the relevance of her activity as a modeler depends on this wager. If we look at the way Deleuze and Guattari define the concept of a body, by relating it to "informational coordinates of separate, unconnected systems," we can say that the wager is that the situation is "embodied," and as such defines the emergence of a disjuncture between internal and external variables in relation to the milieu, which has nothing to do with the distinction between internal variables and the limit conditions of physical-chemical systems.[14] To define a system by its limit conditions does not imply tact, and the principle of exploration to which this definition corresponds is one of variation (to increase pressure, temperature, the intensity of the temperature gradient, or the imposed relationship of chemical concentrations). To define an "organism" does not imply tact either, if the organism refers to a body judged in terms of a relation between ends and means, where every organ fulfills a function through the harmonious division of responsibilities and tasks. Addressing a "body" imposes this specific art I have called "tact." The model must explore the disjunction as such, approach it from two sides at once. It must negotiate the relevant internal variables with respect to observable external behavior, but also approach that external behavior from the point of view of the milieu it defines for by itself and for itself, that is, identify the selection and values of the variables it requires from the milieu in which it emerged "as a body," identify how, from its point of view, all milieus are not equal.

The body, in the customary sense, is certainly composed of a multitude of bodies in the sense I have introduced above. But it is not at all certain that it functions as a body in the same sense.

In other words, it is not at all certain that a practice whose ideal is the convergence between the requisites of the model and the requisites of the body "itself" retains its relevance in the case where it addresses a living being whose experience includes the feeling that it "has a body." Whenever it is a question of the human body, in particular, and its marvelous or terrifying ability to allow itself to be "modeled" by cultural practices, the question of determining what a model wishing to address "the body" should address becomes critical. To speak of "modeling" cultural practices is itself significant. The "model," in the sense in which it refers to a scientific practice, can no longer be dissociated from other "modeling" practices. The human body is always that of a being belonging to a given family, a given group, a given culture, and this belonging also implies the way in which the body is "fabricated," the way in which it is "understood," and how the requisites of its "normality" are identified. And at this point the power relationship "within the modeled situation," which the scientific practice of modeling requires and benefits from, disappears.[15] Trap, temptation, and curse, the question that arises is less one of the disappearance of this power relationship than of the derisive ease with which it is obtained. The human "collaborates" with the project of elucidating what it requires and, in some cases, even what it is subject to. We are in the process of preparing to explore the transition to the limit, where the relationship between construction and definition will again change its nature.

18

Transition to the Limit

In physics, approaching a limit imposes a number of precautions whenever several variables simultaneously tend toward the infinite or toward zero at the limit. To avoid any confusion, these variables must be individually managed. Physicists must take the risk of emphasizing a single variable in order to construct reasons why the description of the problem that gave them their meaning (for example, what is a gas?) loses its relevance at the critical point, even though they know that they are changing their meaning collectively. Similarly, I must try to "slow down" the loss of relevance to which the transition to the limit corresponds. In this case, that means trying to remain for as long as possible within the framework of my initial question, that of scientific practices in which the scientist can risk requiring, so as to identify where and why this requirement changes meaning. But this is only a first step, for the question of the limit returns. What the initial question assumed was a pathway to the limit, but not *the* pathway, the one that would coincide with the general definition of that limit. On the contrary, for it is from that limit that one can attempt to turn the pathway itself into a problem.[1]

Unlike the situations studied in physics, the "limit" here

does not constitute a given problem, imposed by a change in the properties to be interpreted. More specifically, if properties do change, the way such change is characterized involves a critical question about the very issue of characterization. To make this question and the commitment it demands perceptible is to make perceptible the "critical point" at the limit. Here, therefore, the existence of the limit belongs to the "present" of whoever effects, but first experiences, the transition to the limit. It defines this present relative to the perplexity, the "perplication," of the questions and distinctions that the limit has stripped of their tranquil differentiations.[2] The critical questioning of knowledge does not have the generality of critical thought, which always silently assumes the ability to judge on behalf of what is not questioned. It is part of the risks the present obligates us to take.

In *Cosmopolitics*, Book I, "The Science Wars," I described the problem that, for me, requires a transition to the limit, namely, the "modernist" practices I took the responsibility of characterizing as constitutively polemical. For, in order to present themselves as scientific, they *need* to disqualify the opinions, the beliefs, of others, the nonmodern practices of which some claim to serve as rational substitutes. Identification of the problem and the question it raises situate me because they express the conviction I have tried to implement until now with respect to other scientific practices. The way in which those other scientific practices create their questions and their risks satisfies requirements and obligations whose singularity instantiates a difference with what precedes or surrounds them, a difference that has no need to be reinforced through polemics and disqualification. The same is not true of "modernist" practices, whose claims postulate that the one who asks questions, because she is a scientist, which is to say rational, which is to say modern, escapes the illusions, traditions, and cultural assumptions that, *on the contrary*, define those she is dealing with. Modernity here is an integral part of the definition of science in the sense that it gives the right to invoke a stable difference, a difference that allows one to judge and claim kinship with the power relationship whose invention the experimental laboratory celebrates.

The critical questioning I associate with the transition to the limit refers to this commitment to dissociate modern science and modernist science. The critical point signals the appearance of modernist practices, discussed in "The Curse of Tolerance" (Book VII), where I clarify the "cosmopolitical" question that gives its name to this series of books. The domains I'll address are those where the definition of a scientific practice can no longer benefit from a stable difference between the scientist's practice and what she interrogates. And it is the heteroclite ensemble of practices, modern or otherwise, and the beings, factishes and fetishes, to which they refer and which are ingredients of their existence, whose modes of coexistence will then be (begin to be) examined. But before risking this approach, in which perplexity would have to construct the practical obligations that satisfy the perplication of questions and distinctions, we must slow down, examine situations where the problems that will trigger the transition to the limit are already present, but where modeling is not yet a caricature and still has a chance to express what the being the model describes requires of the milieu with which it has been coinvented.

It would be worthwhile to take as an example those studies in experimental psychology that attempt to penetrate the mystery of an activity such as reading, which has some interesting characteristics: the laborious manner in which it is learned, the way it breaks down under the effect of neurophysiological disturbances (recognizing letters but not words, words but not sentences), and the fact that the reader, once she has "emerged," "reads the way she breathes," that is, cannot prevent herself from identifying a word but, on the contrary, must make an effort to identify individual letters. This is a very interesting example of

an external device that is liable to literally "pass into" the human and, therefore, seems to promise a stable definition in the face of life's contingencies. But the example is too complicated to slow us down reliably. The number of young humans who will never be "one" with the alphabet even though they are supposed to have "learned to read" is too high not to suspect that the question of "emergence," here apprenticeship, cannot eliminate everything that "knowing how to read" allows us to ignore. Possibly, among the ingredients of apprenticeship are the multiple components that, in another form, belong to the art and experience of reading (about which "knowing how to read" is equally silent), namely, those that enter into the effective encounter with a particular text. The "true" reader is one who may well be able to read "in general," but for whom the encounter with a text has nothing general about it. The slowdown turns out to be impossible, for even assuming that what "emerges" could really be modeled, what this descriptive, scenographic model would benefit from, that is, the irrepressible nature of "knowing how to read," turns out to be an obstacle to the possibility of tracing the description back to the question of emergence. The model would reproduce the final emergence but provide no clue for the many questions that cluster around what "learning to read" requires.

On the other hand, there is another episode, one that is truly generic in human life. It is the one that leads infants, in one way or another, to transition from the mode of existence of a young mammal, not fundamentally different based on appearances from a newborn primate, to that of a young human engaged in language learning and the relationships their specific identity presupposes but that must "be produced" for each of us individually. This episode is so fascinating that it has brought about the equally fascinating but relatively indecipherable series of experiments attempting to get primates to "talk." And it is the subject of an indefinite number of speculations and variants, where science, myth, and religion freely intersect. But most extraordinary is that, in the face of such divergent interests, one way or another small children continue to successfully manage this transformation, in any event, the vast majority of them.

It seems, then, that we are dealing with an extremely robust "history" whose success is tied to the very invention that defines what it is to be human, a history made to be repeated and that could, *in this sense and to this extent,* be defined as an extrauterine extension of human ontogenesis. It is as if the infant had its own requisites, as if it were capable of a power relationship with an environment that, barring any dramatic circumstances, enables it to learn and become. And yet, we also know that, at the same time, another kind of history is beginning, inseparable from the first. In fact, when the infant manages to stand and take its first steps, and even earlier, it is indeed possible that this history has already begun. But in the case of learning to speak, I feel I can take it for granted that the situation is clear: the infant does not learn to speak in general. Together with words, there is an indefinite ensemble, implicit and explicit, of ways of being, of entering into relationships, of interpreting and anticipating, that is created or stabilized. The two-year-old child is no longer a small, generic being; it is the child of a family, a culture, a tradition. It would seem, then, that the requisites of the newborn do not communicate solely with the notion of a necessary but insufficient condition but with that of a necessary and *necessarily* insufficient condition. Which is to say that they incorporate in their very definition ingredients that must be determined by what is no longer a "milieu."

In any event, this is the reading Daniel Stern proposes in *The Interpersonal World of the Infant.*[3] Psychoanalysts quickly recognized that Stern's book made use of a disquieting approach, one likely to classify as "professional legend" the version of the myth of paradise lost and original sin that were the basis of their own

categories. The psychoanalysts' infant would have to "fantasize," it would have to experience the original illusion of a fusion, and the adult, barring nearly irreparable damage, would have to renounce that initial experience of well-being.[4] It seems to me that what Stern is suggesting is a new kind of model, which introduces the requisites of the infant but also assigns a crucial role to the unique nature of its interaction with adults. For, according to Stern, the manner in which adults "respond" to the infant's "behavior" poses the same question as apprenticeship itself, which involves both "repetition" and "acculturation." It would incorporate both their cultural, familial, and personal interpretation of what those behaviors signify and what those same behaviors lead them to feel and do irrepressibly, that is to say, robustly. Correlatively, "emergence" would occur through asymmetrical capture over time. Through its behavior, the child suggests a response from adults, who in turn suggest to the child a new way of being, and the process repeats.

In this case, we can speak of emergence as a *productive and functional misunderstanding,* whose terms change continuously but irreducibly entangle human genericness and cultural-familial specificities, producing a child who has become capable of experiencing itself and others as endowed with continuity, historical materiality, and intentions, but who experiences them in a way that integrates fundamentally heterogeneous ingredients, rhythms and refrains in adult value judgments, whether implicit or explicit, concerning affects, legitimate or illegitimate, expressible or inexpressible. These ingredients can arise from a mode of action that may or may not be deliberate, and they may be consistent or contradictory among themselves. They coexist in distinct ways, each of them understood in what Félix Guattari recognized, in his own terminology, as "incorporeal universes" and "multiple, dislocated, and entangled existential territories."[5]

Several paths are possible with such a model. One that should obviously be avoided is using the model in the predictable operation of normalizing the description and confusing the "successful" relationship between parents and infants in our own culture with what the human infant requires in general.

Another path leads to a consideration of the relationship between apprenticeship and misunderstanding. *Misunderstanding* is a loaded word, but here it has no Freudian–Lacanian connotation implying the impossible fulfillment of desire, or the always failed relationship, or the painful lack at the core of any illusion of belonging. This type of dramatization is very interesting from the professional point of view of the psychoanalyst, who effects a decentering and creates a highly specific power relationship that stabilizes the therapeutic process in a unique and radically unilateral way.[6] I will attempt to follow how the concept of a model changes meaning without the operation suddenly having dramatic or disparaging consequences. Stern's description "models" the young human, but here there can be no question of condemning a given form of alienation but of approaching practices that "introduce" a human into a world it can inhabit only if it learns to comply with the requirements of what it will encounter there. After all, even, and especially, in a highly formalized science like mathematics, it is through misunderstanding that definitions and rules are held to be self-sufficient, operating in such a way that compliance, understanding, and application go strictly hand in hand.

Mathematics, which in Greek meant "that which is readily transmissible," in this sense constitutes a very interesting example of a "misunderstanding." Even when a mathematical definition is transmitted for the billionth time, what we call "comprehension" remains an event, the production of a "before" and an "after." It is only "after," once we have understood, that the normative words through which this knowledge is transmitted assume their *effective* meaning, which transforms them into references, instruments, and constraints for exploring, reasoning, and constructing. It is only "after" that the words retroactively appear sufficient to define the knowledge that is transmitted through them.[7] Between the "after," where the teacher cannot but dwell, regardless of her good intentions, and the "before," where those she addresses are positioned, transmission implies a genuine practice of misunderstanding.[8] We can even speak of a "categorical" misunderstanding to the extent that, contrary to other kinds of learning (walking, riding a bike, driving a car, juggling, mountain climbing), mathematics is unique in that it confronts the one who learns it with explicit formulations that comprise both conventional rules and normative injunctions. However, as in other kinds of learning, it is a matter of "embodiment," of rules and injunctions "passing into" the body. Whereas the set of definitions and rules appears to introduce a purely "spiritual" operation, the pure product of abstract formulation, reasoning, and proof, what must be produced when one "gets it" are ways of perceiving and being affected in a functional, nearly automatic, way. To be able to recognize "$(a-b)^2$" in an algebraic text and automatically adopt the mental gestures and practices appropriate to the problem expresses the success of the corresponding modeling operation.

In such a case, misunderstanding is not another way of expressing the question of human existence, the failure of language, which never lets us say what we "desire," or the tension between the never satisfied quest for truth and the risk of cynical abandonment. It does not designate the kind of staging that confers the power to recognize sameness throughout each step of a psychoanalysis or the "phenomenology of the spirit." This kind of misunderstanding could, however, communicate with the concept of *transduction* created by Gilbert Simondon in *L'Individu et sa genèse physico-biologique.*[9] Transduction does not refer to the human, to language, or the search for genuine rapport, but to the problem of individuation, through which an individual characterized by discreet relationships with its milieu is produced. In fact, Simondon used the physical-chemical phase transition and the concept of a critical point as an experimental field for creating his concept. But anyone who might claim to draw from transduction the power to recognize that the production of an infant with an individuated relation to language responds to the "same" problem as the genesis of a crystal would be misusing the concept. Comparing the crystal with the infant has meaning only because the first step in the process of transduction is *not* to define the process of individuation but to learn to *resist* the way in which the problem has generally been presented. Transduction applies both to the crystal and to the human to the extent that neither the terms that enable us to explain the individuated crystal (interatomic forces, a configuration that corresponds to the minimum potential energy resulting from those forces) nor the terms that can be used to explain the human (genetic programming or social, cultural, economic, or symbolic structures) allow us to describe the process of individuation.

In all cases, what must be resisted is the temptation to explain the genesis of the individual from *previously individuated* conditions, the way the mold would explain the statue or hypothetical statements a solved problem.[10] Atoms, genes, and structures make the individual the simple realization of the possible they define, which is to say they miss the process of individuation.

Simondon also tried to provide a generic description of the process of individuation through transduction. "This is," he wrote, "the physical, biological, mental, and social operation by which an activity is propagated gradually within a field, basing that propagation on a structuring of the field enacted from place to place."[11] The crucial point is that this operation always implies communication, but first as a problematic tension, between two *scales of reality*, one "greater" than the future individual, the other "smaller." And it is this "primordial heterogeneity" that will be retranslated, once individuation takes place, into two rival explanations, each of which confers upon one of the

scales of reality that are able to communicate with one another through transduction the power to obscure the process of communication, that is, the power to explain the individual.[12] In this sense, the first difference between the human and the crystal is that genetics and macrostructure are rival explanations, while the beauty of the perfect crystal relies on its ability to effect a harmonious convergence of two rivals: the forces of interaction between atoms and the energy equilibrium between the crystal and its environment.

Wherever it is relevant, transduction attempts to bring about a form of thought that is capable of resisting the temptation to choose between rival principles of explanation, a temptation Simondon qualifies as "hylomorphism": the Aristotelian duality between form and matter. For Simondon, this duality has served as the matrix of every position that has been adopted since then. Some of these base explanation on a "form" that imposes itself on matter thought to be available, others on "matter" conceived as being capable of causing form to emerge. Is it "symbolic order" or the norms of mathematics that are transmitted unaltered that "inform" an available mind, or is it the "matter" of the operation, a form of generic competence of the human psyche, that is responsible for the possibility of learning? It is as a vector of resistance that does not limit itself to celebrating the "failure" of these alternatives but creates a new appetite and riskier obligations[13] that transduction might assist in constructing the problem presented by the relationship between apprenticeship and "misunderstanding."[14] The asymmetrical capture correlated in time that, for Stern, "models" the infant would then be a primary example of the communication of two "scales of reality" whose heterogeneity is their primordial given.

This would be a good place to slow down, for it is not enough simply to have good intentions. Transduction, because it enables us to simultaneously contemplate crystallization and human modes of individuation and individualization, is *speculative*, and the intrusion of speculation is part of the transition to the limit that I am attempting to initiate.[15] There would be no more unfortunate confusion than to treat this intrusion as a victory, as the conquest of a point of view that considers the distinction between construction for a scientific purpose and speculation to be pointless. Nothing could be worse than to view Simondon's ideas as the basis for a scientific approach to "emergence." The inherent challenge of speculative thought is the creation of concepts that allow us to speak, simultaneously and at the same time, of what our habits oppose (for example, crystallization and thought), but this creation is an experiment in which our habits are both ingredient and target. It does not seek the discovery of a point of view that would guarantee the right to unify what we oppose and to establish a judgment concerning the "proper" way to answer questions that produce hesitation, perplexity, or expectation.[16] The practical effect that singularizes speculative thought is to contradict the temptation of a judgment that recognizes and anticipates. This thought straddles abysses, but the "same" that it constructs, the "anticipation" it feeds must accept the constraint of "accommodating" no one, of not confirming any particular practical requisite, not justifying any power relationship. That is why this thought is fundamentally descriptive, and the possibility of drawing normative consequences from it, regardless of the register of the norm, indicates either its failure or the (mis)appropriation of its use.[17]

Transductive thought produces the effects proper to speculative thought to the extent that we cannot, without possible contradiction, make use of it without also introducing at the same time the "transductive" nature of its use as soon as it becomes a part of practice. Practices of apprenticeship may take their inspiration from various forms of hylomorphic thought, with an emphasis either on the "form" to be transmitted or on "matter," as is the case with constructivism, or from Simondon's critique of hylomorphism; all are distinct examples of transduction, and the latter cannot claim any superiority over the others by virtue of its conceptual reference. It should be added to the others, along with its own requirements and obligations. And its own risk of failure. In other words, transductive thought provides no benefits with respect to the strictly *empirical* problem found in these examples. It provides no guarantee. Its role is to create words that might stabilize thought capable of resisting the slogans and legitimations through which the risks associated with a practice become rights (of reason, progress, objectivity) for which the practitioner is merely the representative.

Speculative reference to transduction thus puts at risk the power of models that claim to authorize an economy of perplexity. Experimental factishes can, through a constitutive vocation, claim to "explain" the world, and it is possible to assert that the world "explains itself" through them. Reference to transduction reminds us that, here, explanation, made possible by the coming into existence of each factish, primarily celebrates the primordial heterogeneity between the requirements of the scientist and the world that is supposed to satisfy them. But the reference to transduction can also help recognize and celebrate the occasions when the scientist, temporarily putting aside any professional plausibility, searches for the words to express the question that the experience of what she is involved in invincibly imposes.

So, when I tried to put into words the expression that appeared on Kauffman's lips, "God's heart," I created the figure of an interaction involving a "Maker" whose values pass into the world. I made use of a figure that expresses transduction, which can be used reciprocally to assert that the maker's "values" do not explain what is made, even though they "explain themselves" through the making process. But in doing so, I borrowed the words that Stephen Jay Gould dared employ at the end of an article in which he tore apart the "just so" stories of sociobiology. The biological theory we need, he wrote, should replace the questionable charm of such stories with the profound joy arising from an understanding of evolution as integration: "the world outside passing through a boundary . . . into organic vitality within."[18] Here, Gould doesn't claim to be a "vitalist," but he effects, with a joy that accepts perplexity rather than the pretense that must deny it, a transition to the limit. Gould also uses the word *integration* "with his mouth full." It is in terms of "integrative insight" that Gould, in the same book, evokes the way in which Barbara McClintock allowed herself to be invaded by the apparently disparate multiplicity of "data" produced by maize in an attempt to understand that data. And Gould compares this integration with the experience of Dorothy Sayers's detective hero, Lord Peter Wimsey: "He no longer needed to reason about it, or even to think about it. He knew it."[19] And when Gould talks about his own experience, he writes, "And so my work has been integrative; that's what I'm best at doing. I do figure out Dorothy Sayers's mysteries because Peter Wimsey is constructed as that kind of thinker. If you read *Whose Body?*, her first novel, I'm sure that Dorothy Sayers had a theory of thought and that she wrote those novels to counter the Sherlock Holmes tradition that thought was simply deductive and logical."[20]

Here, Gould describes in the same terms, with his mouth full, a theory of life that should help biologists do their work, a theory of thinking, and equally his own experience as biologist and writer when the outside, the scattered elements and bizarre connections of a situation, move inside and contract into a living unity—"he knows." It is here that speculative thought can assume its "ecological" scope, bring into existence the perplexing joy of this convergence, and give it the means to produce its own divergence, one that would prevent it from becoming a pretense, a skeleton key that would open all doors and would be confirmed in all cases: the birth of the kind of all-purpose response produced by a transition to the limit that is brought about unnoticed, accompanied by the exaltation that the feeling

of truth provides. Convergence mustn't be avoided, it should be celebrated, but in suspense, held in its problematic space, "countereffectuated" and not precipitated into triumphal solution.[21]

The divergence to be recognized, and which indicates an approach to the limit, affects all the terms required by scientific practice. Consider the term "confirm." Even Popper had to admit that scientists are right to seek experimental confirmation when their theories are bold and fragile. Confirmation, he proposed, is not a proof but the nourishment the fragile creature requires. But here confirmation will always be experienced as proof or as an argument that can be put forth to support a proposition. It will always express the power relationship between the one who asks the question and the one who answers it. Adults who encourage the young child to take its first steps also "confirm" its attempts, and this confirmation is itself likely to be as vital for the child as "fact" is for the bold proposition. However, it will never serve as a proof or an argument. What about the distinct and entangled modes of confirmation negotiated by teachers and family for children in school? What about the analysand whose dreams "confirm" the interpretation of her analyst? What about the experiences that, it is said, confirm "faith"? To follow and map such divergences, it is necessary to countereffectuate the proposed convergences and deliberately ascend the slope, resist being carried down by the power of resemblance.[22]

I have associated the art of modeling emergence with tact, but tact is no longer a secure thread. Even when it is associated with human relationships (doctor/patient, adult/adolescent), it always refers to a power relationship that is able to control itself and can create the space the other should come to fill in its own way. The modeler, the doctor, the adult all propose and know that it is up to the other to dispose.[23] Yet, it is the very meaning of propositions that is affected by the transition to the limit, that is, the meaning of the confirmation we expect from the other.

Suspending triumphal confirmation—through the device or disposition implementing the proposition—forces the history of our satisfactions to ebb, and it is the "our" that begins to blink, that causes what those satisfactions have identified to diverge. We have benefited, and will continue to benefit, from all power relationships, from every stratification that may allow for a stabilization of the difference between the question asked and the answer that confirms it. We can find out how a "body" defines its milieu. But what it means to "live" or "die" does not follow from the thread of our definitions. Experiencing this marks the critical moment when constructivism escapes, as event, from the stories in which the practices that allow us to claim to know what we know are constructed. The moment when the question of the impersonal nature of the infinitive insists through "us," when "knowing" begins to resonate with its opposites.

In "The Science Wars" (Book I), I limited the scope of an ecology of modern practices to the question of determining if new psychosocial types could be generated, new "we's" not defined by polemics and hierarchies. Resolving the question of the ecology of practices through the speculative becoming of practitioners would be a trivial solution. Rather, the question is one of asking which "type" of practitioner would not have a phobic relationship—"but if we introduce this type of problem, we can no longer work"—at the moment of reflux, when their categories are confused. That is why it's important to acknowledge that speculation is not part of a fascinating "beyond" but already inhabits those moments of confused joy when the scientist thinks with her mouth full. That is why the way physicists have learned to define gas and liquid in terms of a transition to the limit is also interesting. For this transition does not require criticizing the gaseous state and the liquid state, but integrates into their definition the question of the critical point at which the distinction between those two states is, in fact, at issue.

Practitioners familiar with those "critical points" at which

they think with their mouth full would probably be less interested in hollow generalizations, reflexive recursiveness, or other irresolvable paradoxes. But the question doesn't end there, doesn't affect only "us," our knowledge and its relationships. I'd like to return, one last time, to the starting point of the transition to the limit I have attempted, the description that Daniel Stern provided for the "emergence" of the infant.

What is unique about this emergence is that it concerns a becoming that is of interest to us all, and by all I mean all cultures, all traditions, *modern and nonmodern.* Stern's description may, initially, challenge hylomorphic models of all stripes that modern researchers have proposed for giving the infant the ability to establish their hypotheses. That is why, for example, the Sternian baby challenges the Freudian baby, which is made to establish that what will follow its emergence will confirm the power of "matter," the universality of the unconscious conflicts of psychoanalysis, as well as the behaviorist baby, which celebrates the power of an exterior "form" to inform matter and the availability of matter to form. It challenges the Lacanian baby as well, which it prevents from dramatizing the misunderstanding, the discordance between "interior" and "exterior." But, distinct from the risk of its normative becoming, to which I've alluded in passing, the Sternian baby presents another, more insidious danger. It is capable of allowing us to claim that we have now understood how "the others were not mistaken." Those others are the "nonmoderns," who, for example, believe that the newborn is a stranger from another world, who speaks another language, a stranger whose identity must be discovered so it can be named, and who must be welcomed and humanized.[24] Couldn't we see in this a marvelous illustration of Stern's description, a wonderful confirmation of the definition he proposes? Thanks to Stern, we "now know" that the way in which we "welcome" the newborn, the way in which we conceive of, anticipate, and interpret its behavior, is a vital ingredient of its becoming. Isn't it wonderful that others have, without having read Stern, created the words and references that inhabit and guide parents in this process?

But that is the danger, for this "wonder" is liable to be celebrated as follows: "*Thanks for confirming the progress of our knowledge, the validity of our new definitions. Thanks, and forgive us for understanding you better than you understand yourselves, for having constructed in your place the meaning of what you are doing. In order to protect you, we will avoid telling you that we understood what your beliefs 'really meant,' what they enacted without realizing it. Your ancestors and your fetishes no longer surprise us, neither do they disgust us. We have taken from them what we needed to learn, and they confirm that our descriptions are right. They will serve as an argument against our backward colleagues.*"

Suspending the confirmation, safeguarding the moment when the impersonal—"to speak to a child" or "to come into the world"—vibrates, are essential here. Not in order to avoid the unavoidable, the feeling that "we have understood," but in order to stand back and experience it in such a way that the suspension of its confirmation is incorporated in its occurrence. For the triumphant confirmation I have presented above qualifies us. If we yield to this triumph, we will trample, with the best intentions in the world and with the additional satisfaction of remembering our own arrogance, the inappropriable space "where angels fear to tread."

BOOK VII

The Curse of Tolerance