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Dynamics in Action: Intentional Behavior as a Complex System

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The Problem

When dealing with hierarchical systems that are self-referential and display inter-level effects, the notion of causality must be reconceptualized in terms other than that of the billiard ball, collision conception that is the legacy of mechanism. Understanding all cause as collision like, and the explanatory ideal as deduction from deterministic laws, are part of a trend that has characterized the history of philosophy for over 2,000 years: the progressive elimination of time and context from metaphysics and epistemology. Aristotle had insisted that formal deduction from universal premises is the logic of reasoning proper to science. Noting that human behavior is temporally and contextually embedded, Aristotle made it the central concern of practical wisdom. Unlike deduction, wisdom varies "as the occasion requires." Modern philosophy, by contrast, insists that (ideally) all explanation is fundamentally deductive in form.

In Plato's dialogue *Phaedo*, which takes place while Socrates is awaiting execution, Socrates worries that earlier philosophers made air, ether, and water the only causes. What about Socrates' reasons for not escaping from prison? Are they not the true cause of his behavior? Later, and more systematically, Aristotle examined the difference between intentional and involuntary behavior. An adequate explanation of anything, he claimed, must identify those causes responsible for the phenomenon being explained. Aristotle's four causes are final cause (the goal or purpose toward which something aims), formal cause (that which makes anything that sort of thing and no other), material cause (the stuff out of which it is made), and efficient cause (the force that brings the thing into being). Explaining anything, including behavior, requires identifying the role that each cause plays in bringing about the phenomenon. Implicit in Aristotle's account of cause and crucially influential, however, is another of his claims: that nothing, strictly speaking, can move, cause, or act on itself in the same respect.

Contemporary causal theories of action have consistently adhered to Aristotle's principle that nothing moves or changes itself; intentions, volitions, and other alleged causes of action are supposed to be other than the behavior they cause. In addition, by also subscribing to a Newtonian understanding of efficient cause, these theories have also uncritically assumed that intentions, volitions, or agents cause action in the collision-like way that pool cues cause cue balls to move. Following Hume and in opposition to Aristotle, philosophers concluded that deduction from timeless and context-less laws is the ideal, not only of science but of any legitimate form of reasoning. A law of nature—at worst statistical, but ideally strictly deterministic—combined with statements specifying initial conditions must allow that which is being explained (the explanandum) to be inferred. Even human actions must be explained in that manner. By the middle of the twentieth century, the principle that the logic of any serious explanation must adhere to such a "covering-law model" was the received view.

Modern philosophy's understanding of cause and explanation has failed as a general theory. Today, there is no reason to continue to subscribe to this atemporal and acontextual approach. The conceptual framework of the theory of complex adaptive systems can serve as a "theory-constitutive metaphor" that permits a reconceptualization of cause, and in consequence a rethinking of action. A different logic of explanation—one more suitable to all historical, contextually embedded processes, including action—arises from of this radical revision.

COMPLEXITY AS A NEW ANSWER

Several key concepts of the new scientific framework are especially suited to this task. First, complex adaptive systems are typically characterized by positive feedback processes in which the product of the process is necessary for the process itself. Contrary to Aristotle, this circular type of causality is a form of self-cause. Second, when parts interact to produce wholes, and the resulting distributed wholes in turn affect the behavior of their parts, inter-level causality is at work. Interactions among certain dynamical processes can create a systems-level organization with new properties that are not the simple sum of the components that constitute the higher level. In turn, the overall dynamics of the emergent distributed system not only determine which parts will be allowed into the system: the global dynamics also regulate and constrain the behavior of the lower-level components.

The theory of complex adaptive systems can therefore be used as a metaphor for this form of causal relations, which had puzzled Kant as a form of causality "unknown to us." In other words, far from being the inert epiphenomenon that modern science claims all wholes are, complex dynamical wholes clearly—and in a distributed manner—exert active power on their parts such that the overall system is maintained and enhanced. Understanding dynamical systems can therefore revive Aristotle's concepts of formal and final cause by offering a scientifically respectable model of how such causes operate. Since the active power that wholes exert on their components is clearly not the gocart-like collisions of a mechanical universe, the causal mechanism at work between levels of hierarchical organization can better be understood as the operations of constraint.

We can distinguish between two types of constraints: context-free constraints, which take a system's components far from equiprobability, and context-sensitive constraints, which synchronize and correlate previously independent parts into a systemic whole. When organized into a complex, integral whole, parts become correlated as a function of context-dependent constraints imposed on them by the newly organized system in which they are now embedded. Catalysts, feedback loops, and biological resonance and entrainment embody context-sensitive constraints.

From the bottom up, the establishment of context-sensitive constraints is the phase change that self-organizes the global level. Or, to put it differently, the self-organization of the global level is the appearance of context-sensitive constraints on the system's components. Parts heretofore separate and independent are suddenly correlated, thereby becoming interdependent components or nodes of a system. But even as they regulate alternatives, context-dependent constraints simultaneously open up new possibilities. The more complex a system, the more states and properties it can manifest: novel characteristics and laws emerge with the organization of the higher level. Constraints work, then, by modifying either a system's phase space or the probability distribution of events and movements within that space, Since actions are lower, motor-level implementations of higher-level intentional causes, reconceptualizing mental causation in terms of top-down, context-sensitive dynamical constraints can radically recast our thinking about action.

Since the global level of all complex adaptive systems contextually constrains the behavior of the components that make it up, I postulate that behavior constitutes action when self-organized dynamics, as characterized by consciousness and meaning, originate, regulate, and constrain processes such that the resulting behavior "satisfies the meaningful content" embodied in the complex dynamics from which it issued. By serving as the order parameter, those contextual constraints that embody an intention (acting top down) would provide the behavior with continuous, on-going control and direction by modifying in real time the probability distribution of lower-level processes and, as a consequence, the behavioral alternatives available to and implemented by the agent.

Far from representing messy, noisy complications that can be safely ignored, time and context are as central to the identity and behavior of these dynamic processes as they are to human beings. Unlike the processes described by classical thermodynamics, which in their relentless march toward equilibrium forget their past, complex adaptive systems are essentially historical. They embody in their very structure the conditions under which they were created (including the chance events around which each self-organized stage reorganizes). The unrepeatable, random fluctuation or perturbation around which each phase of a sequence of adaptations nucleates leaves its mark on the specific configuration that emerges. The structure of a snowflake, for example, carries information about the conditions under which it was created. Each level is uniquely and progressively individuated, as is the developmental and behavioral trajectory of each organism (Salthe, 1993a).

The Role of Narrative

Far enough from equilibrium, dynamical systems can abruptly and irreversibly undergo a radical transformation. On the other side of this "bifurcation," a system either reorganizes into a higher level of complexity characterized by renewed potential and possibilities, or falls apart. Across phase changes, that is, there are no established dynamics that can serve as the context from which the parts derive their meaning; the change itself in the dynamics governing the system's stable states needs to be explained. How, then, must human action be explained?

I propose an interpretive, narrative model of explanation. In hermeneutical interpretation, the meaning of a complete text is constructed from the relationships among the individual passages. In turn, the meaning of the story's individual passages is derived from the meaning of the entire text in which those passages are embedded. This continual, interpretive "tacking" from parts to whole and back to parts reproduces the way dynamical systems self-organize out of the interrelationships among the parts, and then loop back to constrain those parts. The similarity in the dynamics of self-organization and hermeneutics makes the latter uniquely suited as the logic of explanation for stable states of the former. Since these phase changes are unpredictable, the only way to explain them is with a retrospective narrative that retraces the actual leap. Explaining these individual dramatic transformations, as well as the detailed trajectory that even everyday behavior takes, requires a genealogical narrative that makes ample references to temporal and contextual events. This historical interpretation must provide detailed descriptions of the singular incidents that the agent experienced and that both precipitated the transformation and served as the nucleus around which the bifurcation reorganized.

Narrative, interpretive, and historical explanations of action thus require an expanded appreciation of what counts as "reason" and "explanation," for they explain, not by subsuming an explanation under a generalization and thereby predicting it, as modern philosophy would require, but rather by providing insight into and understanding of what actually happened. They do so by supplying a rich description of the precise, detailed path that the agent took, including the temporal and spatial dynamics (both physical and cultural) in which the agent was embedded and in which the action occurred. Who could have predicted that Ibsen's Nora (*A Doll's House*) would leave her husband and child? And yet, at the end of the play, we understand why Nora slams the door, even if no one could have predicted it. We understand her behavior by coming to appreciate all the complicated and messy factors that became entangled in her life; the drama shows how they interacted to produce a break. Moreover, if we learn anything from watching the play, we also learn something about the quirks and idiosyncrasies of human psychology, of the circumstances in which humans function, and of how these contribute to the unpredictability of our actions. Historical, interpretive stories might not allow us to predict future behavior, but they do allow us to understand why it is unpredictable.

SELF-CAUSE

In a universe where only point masses and forces are considered real, qualities that are a function of the relation between atoms, or between organisms and the world, were also dismissed as subjective. By the end of the seventeenth century, all relational properties, such as temperature and color, that did not to fit into this scheme were relegated to the inferior status of "secondary" qualities. Galileo's ability to set aside the interference of friction from the equations governing the motion of bodies also suggested that context contributes nothing to reality. Once atomism became the ruling conceptual framework, context and environment were thus left without a role to play in either science or philosophy. Indexicals, such as here and there, this and that, now and then, lost their claim on reality as situatedness and point of view became unimportant. An object's only real properties were its so-called primary properties, characteristics such as mass that, because they are internal to the object, it would exhibit anywhere, anytime. Since only primary properties were essential properties, it was therefore no longer acceptable to explain action as Aristotle had, by embedding the organism in its environment. If real things (atomic particles), were unaffected by time and context, an object's interactions with its environment and the unique trajectory it traced through time and space also became secondary, "accidental" properties of no account to what really makes a thing the kind of thing it is and no other ("anthropological considerations," Kant would have called them).

True self-cause would involve localized parts interacting so as to produce wholes that in turn, as distributed wholes, could influence their components: inter-level causality between parts and wholes. But by following Aristotle in rejecting this possibility, philosophy closed off any avenue for explaining action in that fashion. Having discarded the notions of formal and final cause, moreover, philosophy was left without a way of understanding nonevent causation. As a result, philosophers who champion agent causation as the distinguishing mark of action have never satisfactorily explained either the identity of agents or their manner of causation.

Danto (1979b: 16) proposes that in the same way that "knowledge ... is a matter of bringing our representations into line with the world ... action is a matter of bringing the world into line with our representations." Guiding a plan of action to completion, however, as implied in the gerundive "bringing the world into line," requires the operation of a cause that, far from disengaging at the onset of the action, persists throughout the performance of the act and monitors and directs the behavior. Inasmuch as that type of cause would identify the action's origin, the label "cause" would still apply (Sosa, 1980). But it would not be a Newtonian forceful push. The intentional content according to which the agent shapes the world is not related to its behavioral effect in the way a Newtonian cause is related to its effect. A proximate intention is an action's origin or source, but it is not a discrete event that precedes the action and yet is not itself part of the action. What is significant for purposes of action is that even someone wanting to defend a causal theory finds something not altogether satisfactory about the traditional view of cause, in which the relation between cause and effect is one of "external coincidence." Searle was right: the intention must be in the action. So we need an account of the metaphysics of that type of cause. Still, the reluctance to countenance any kind of self-cause persists.

Following information theory, it is useful to think of action as informationally dependent and constrained behavior. Those intentions and other cognitive phenomena responsible for action must be robust enough to withstand the mischief of noise and equivocation and to flow into behavior. We can now appreciate, however, that behavior constitutes action if and only if it flows unequivocally from a cognitive structure in virtue of its meaningful content (Audi, 1995; Kim, 1995). And "it must be this content that defines the structure's causal influence on output" (Dretske, 1981, 199).

When the environment that is part of the system's external structure is also taken into account, at least three levels are simultaneously involved: the focal level, the environmental level immediately above, and the component level immediately below (Salthe, 1985)—with feedback paths among them. In control hierarchies with this sort of leakage between levels, a clean dynamic theory referring to one level at a time cannot be formulated. Simon calls systems like these nearly decomposable. This apparent design flaw can have remarkable consequences: inter-level leakage makes the system robust to noise, context sensitive, and, in the case of artificial neural networks, able to generalize. Multilevel, dynamic coupling of components, both at the same level and between levels (such as one finds in the cells, tissues, organs, and so forth of biological organisms), “maintains a certain autonomy at all hierarchical levels” (Jantsch, 1980: 247). Components at different levels are not subsumed or fused into the highest level, but they do interact. Given sufficient environmentally imposed structure, they can be labeled as Prigogine calls them, “dissipative.”

Dissipative Structures

Once in place, the dynamics of a dissipative structure as a whole “provide the framework for the behavioral characteristics and activities of the parts” (Zeleny, 1980: 20). By delimiting the parts’ initial repertoire of behavior, the structured whole in which the elements are suddenly embedded also redefines them. They are now something they were not before, nodes in a network, components of a system. As such, they are unable to access states that might have been available to them as independent entities. Insect colonies are an example of this phenomenon, self-organizing systems whose complexity “permits the division of functions, particularly the division of labor, as well as hierarchical relationships and mechanisms of population control” (Janisch, 1980: 69). The evolutionary advantage of such systematic hierarchical differentiation is that the whole can access states that the independent parts cannot. The overall hive can do much more than the individual bee. The price is that workers in a hive lose the ability to reproduce.

In short, not only individual but interacting parts suddenly correlate to create systematic wholes; once organized, the resulting systems affect their components. In other words, self-organizing systems exhibit that previously unknown inter-level causality, both bottom up and top down. They display bottom-up causality in that, under far-from-equilibrium conditions, their internal dynamics amplify naturally occurring fluctuations around which a phase change nucleates. When this discontinuous and irreversible transition occurs, a qualitatively different regime self-organizes. A new “type” of entity appears, one that is functionally differentiated. In turn, the newly organized hierarchy constrains its components’ behavior top down by restructuring and relating them in ways in which they were not related before. Dissipative structures thus operate on two levels simultaneously: part and whole, which interact in the manner of Douglas Hofstadter's (1979) "strange loops," or Kant's "unknown causality." In Chuck Dyke's (1988) great phrase, they are "structured structuring structures."

Objections Considered

An objection commonly raised against systems theory is worth mentioning at this point. Because of claims such as Dewan's (1976) to the effect that entrainment is an example of an emergent, holistic property of control that has causal potency, Bunge (1979) charges holism with the false claim that wholes act on their parts. Wholes cannot act on their parts, he maintains, since a level of organization "is not a thing but a set and therefore a concept ... levels cannot act on one another. In particular the higher levels cannot command or even obey the lower ones. All talk of interlevel action is elliptical or metaphorical" (13–14). Since there is, on Bunge's account, no ontological (only an epistemological) relationship between levels of organization, there can be no actual control by one over another.

Complex adaptive systems have proven Bunge wrong; their interlevel relationships, however tangled, are real, not just epistemological. The emergence of relatively autonomous levels of organization carries with it the emergence of relatively autonomous qualities; quantitative changes produce qualitative changes (Bohm, 1971). Once a transition point is passed, new modes of being emerge, in particular new modes of causality. "The most essential and characteristic feature of a qualitative transformation is that new kinds of causal factors begin to be significant in a given context, or to 'take control' of a certain domain of phenomena, with the result that there appear new laws and even new kinds of laws, which apply in the domain in question" (53). Aversion to the possibility that wholes might act on their parts betrays both the continuing and uncritical acceptance of philosophy's refusal to countenance self-cause as well as the prevalent philosophical tendency toward reification: an ontological bias that favors concrete things over processes and relations, substances over properties. It is true, of course, that wholes do not act on their components forcefully; but neither are wholes other than or external to the components that make them up. And to claim that they do not causally affect their components at all begs the question by assuming that all cause must be billiard ball like to be causally efficacious at all.

Contradicting Bunge, Zeleny (1980: 20) suggests that the lesson to be learned from the theory of autopoiesis is precisely "the lesson of holism."

Far from being an inert epiphenomenon, the dynamics of the autopoetic whole serve as the orderly context that structures the behavioral characteristics and activities of the parts, a clear formulation of one of Bunge's (1979: 39) characteristics of a holistic point of view: the dynamics of the global level control the functioning of components at the lower level. The whole as whole most assuredly acts on its parts: self-cause—but not, as some would have it, *qua* other—one part forcefully impressing itself on another. Instead, complex adaptive systems exhibit true self-cause: parts interact to produce novel, emergent wholes; in turn, these distributed wholes as wholes regulate and constrain the parts that make them up.

Bunge (1979) also explicitly rejects the concept of hierarchy because, he notes, "hierarchy" implies a "dominance relation," always by the higher level on the lower one. It is true that the word "hierarchy" implies a unidirectional flow of order or authority, always and only from higher to lower (see Dyke, 1988). To counteract this connotation, students of complex dynamical systems have coined the neologism "heterarchy" to allow inter-level causal relations to flow in both directions, part to whole (bottom up) and whole to part (top down).

BACK TO CONSTRAINTS

The orderly context in which the components are unified and embedded constrains them. Constraints are therefore relational properties that parts acquire in virtue of being unified—not just aggregated—into a systematic whole. For example, the physical link between the tibia and both the peronei and the knee joint systematically constrains the movement of the lower leg. As a result of the connection, the tibia's physiology is not independent of the knee, the linkage creates an orthopedic system that controls the tibia in ways to which it would not otherwise have been limited. The anatomical tie restricts the lower leg's range of motion. The constraints that the tibia's relationship to the knee places on the tibia limit the number of ways in which the lower leg can move: it can bend backward but not forward, for example. In this example, a constraint represents a contraction of the lower leg's potential range of behavior: the lower leg has less freedom of movement, given its connection with the knee, than it would have otherwise.

Limiting or closing off alternatives is the most common understanding of the term "constraint." But if all constraints restricted a thing's degrees of freedom in this way, organisms (whether phylogenetically or developmentally) would progressively do less and less. However, precisely the opposite is empirically observed. Some constraints must therefore not only reduce the number of alternatives: they must simultaneously create new possibilities. We need to understand how constraints can simultaneously open up as well as close off options (Campbell, 1982). To do so, it is helpful to examine another usage of the concept of constraint. Let us turn, therefore, to information theory, in which constraints are identified not as in physical mechanics, with physical connections, but with rules for reducing randomness in order to minimize noise and equivocation.

INFORMATION-THEORETICAL CONSTRAINTS

Lila Gatlin quotes Weaver (of Shannon & Weaver fame) as saying that "this word 'information' in communications theory relates not so much to what you do say, as to what you could say" (quoted in Gatlin, 1972: 48). In a situation of complete randomness where alternatives are equiprobable, you could say anything but in fact say nothing. Random, equiprobable signals are static, thus unable to transmit actual messages. It is true that in situations in which all alternatives are equally likely, potential information or message variety is at its maximum: before the process of selection in the Herman example, any one of the employees could be chosen. Likewise, the equiprobability of static crackle equates with unpredictability and maximum freedom; in short, with the possibility of constant novelty. But a series of totally random or equiprobable signals is meaningless: no pattern or message is extractable from the disorder. There is none.

At equilibrium, message variety is therefore a great but idle potential; actual information is zero. "Capacity is of no value if it cannot be utilized" (Gatlin, 1972: 99). Without contrasts there can be no message; television snow is as meaningless as white noise. Transmitting or receiving a message requires a clear demarcation between message and background noise. The transmitter as well as the receiver must reduce the randomness in the sequence of signals to a "manageable" level. Encoding (and deciphering) the message according to certain rules is one way of doing so. Whether in communications or genetics, therefore, actual information content—a difference that makes a difference—requires an ordering process that harnesses the randomness. Constraining "the number of ways in which the various parts of a system can be arranged" (Campbell 1982: 44) reduces randomness by altering the equiprobable distribution of signals, thereby enabling potential information to become actual information. Constraints thus turn the amorphous potential into the definite actual; following Aristotle, constraints effect change—and inform. Constraints embodied in encryption rules also take the signals away from equiprobability and randomness.

The "most random state is ... characterized by events which are both independent and equiprobable" (Gatlin, 1972: 87). When anything is as possible as anything else, and nothing is connected to anything else, however, nothing can signify or communicate anything. Flashes from a lighthouse pulsing regularly three long, three short, three long, on the other hand, can carry information precisely because regular flashes are more improbable than random ones, and can therefore be differentiated from background noise. Even to an extraterrestrial, the improbability of regularly pulsing flashes of light says "signal," "signal," "signal," even if ET cannot tell what it means.

The same is true of language: if all sounds were equiprobable and every letter of the alphabet were as likely to show up as any other, no message could be communicated. Hence in any language, some letters appear more often than others. A number on a fair die has the same likelihood of being thrown as any other. The probability that a particular letter of the alphabet will appear in a word or sentence, however, is not like that. Some letters are more likely than others: in the long run they repeat more often (with increased redundancy) than they would in a random distribution. Each become possible; additional contextual constraints (on top of the contextual constraints that create words) make sentences possible. Systems, systems of systems, and so on can be assembled. By making the appearance of letters in an alphabet interdependent, contextual constraints thus allow complex linguistic structures to emerge.

As is the case in all complex systems, newly synchronized components pay a price for creating a global system: the number of ways in which they can be individually arranged is correspondingly reduced. In English, once "*-t-i-o*" appear toward the end of a noun, the probability of *a*'s appearing next decreases dramatically. But the payoff trumps the cost: the interdependence that context-sensitive constraints impose offers the advantage of permitting unlimited message variety despite limited channel capacity. A contextually coded alphabet yields more i-tuplets than its 26 letters; there are more words than i-tuplets, more sentences than words. To achieve the requisite variety, and because Mandarin Chinese limits words to one or two syllables, for example, the context-sensitive constraints of inflection are sometimes needed. Phonetic, syntactic, and stylistic layers of context-sensitive constraints, added on top of the context-free constraints on the prior probability of individual letters, thus provide a significant advantage over ideograms, pictograms, or hieroglyphs.

Without contextual constraints on sounds and scribbles, communication would be limited to a few grunts, shouts, waits, and so forth that would be severely restricted in what and how much they could express. Language's increased capacity to express ideas rests not on newly invented grunts and shouts, but on the relationships and interconnections established by making interdependent the sounds in a sequence of grunts or shouts; that is, by making the probability of their occurrence context dependent. Context-sensitive constraints are thus as efficient but not as expensive as context-free ones, for they "can be increased by a reasonable amount without cramping the message source too severely" (Campbell, 1982: 9). By correlating and coordinating previously aggregated parts into a more complex, differentiated, systematic whole, contextual constraints enlarge the variety of states that the system as a whole can access.

EXAMPLES FROM NATURE

All of this would, of course, be of minimal interest to action theorists or philosophers of mind if it were a mechanism found only in language. That this is emphatically not so is one of the lessons to be learned from complex dynamical systems. I have used examples from language merely as a heuristic illustration of the process. The emergence of Bernard Cells and B–Z chemical waves signals the abrupt appearance of context-sensitive constraints in mutualist-driven, open processes far from equilibrium. This discontinuous change occurs when previously unrelated molecules suddenly become correlated in a distributed whole. A complex dynamical system emerges when the behavior of each molecule suddenly depends both on what the neighboring molecules are doing and on what went before. When components, in other words, suddenly become context dependent.

The same is true of auto catalysis. As physical embodiments of context-dependent constraints, catalysts are therefore one way in which natural processes become subject to conditional probabilities. Because of their geometry, catalysts can take molecules away from independence, not just equiprobability, the way context-free constraints do, by enhancing the likelihood that certain other events will occur. Once the probability that something will happen depends on and is altered by the presence of something else, the two have become systematically and therefore internally related. As a result of the operations of context-sensitive constraints and the conditional probabilities they impose, *A* is now part of *B*'s external structure. Because *A* is no longer "out there" independent of *B*, to which it is only externally related, the interdependence has created a larger whole, the *AB* system. Insofar as it is part of *B*'s new context or external structure, *A* has been imported into *B*. By making a system's current states and behavior systematically dependent on its history, the feedback loops of auto catalysis also incorporate the effects of time into those very states and behavior patterns. Indeed, precisely what makes these complex systems dynamical is that a current state is in part dependent on a prior one. Feedback, that is, incorporates the past into the system's present "external" structure. Feedback thus threads a system through both time and space, thereby allowing part of the system's external structure to run through its history.

Feedback processes thus embody the context-sensitive constraints of history. By embodying context-sensitive constraints, mutualist feedback renders a system sensitive to (constrained by) its own past experiences. This makes nonlinear dynamical systems historical, not just temporal the way near-equilibrium thermodynamical systems are. Once the system's subsequent behavior depends on both the spatial and temporal conditions under which it was created and the contingent experiences it has undergone, the system is historically and contextually embedded in a way that near-equilibrium systems of traditional thermodynamics are not. Because dissipative structures are not just dropped into either time or space the way Newtonian atoms with only primary qualities are, their evolutionary trajectory is therefore not predictable. Mutualism thus makes a dynamical system's current and future properties, states, and behaviors dependent on the context in which the system is currently embedded as well as on its prior experiences. As a result, unlike the near-equilibrium processes of traditional thermodynamics, complex systems do not forget their initial conditions: they "carry their history on their backs" (Prigogine, Spring 1995, US Naval Academy). Their origin constrains their trajectory.

Operating as enabling constraints (Salthe, 1993b), context-sensitive constraints make complexity possible. The emergence of auto catalytic cycles and slime molds—of self-organized systems in general—is the phenomenological manifestation of the sudden closure of context-sensitive constraints. As mentioned earlier, the new relationship among the components is the establishment of a new context—a new external structure or boundary conditions—for those components. Once particles and processes are interrelated into a dissipative structure, they become components or nodes of a more highly differentiated whole. By correlating previously independent particles and processes, context-sensitive constraints are therefore one mechanism whereby chemical and biological hierarchies are created.

By taking the organism far from equilibrium and precipitating a bifurcation, the persistent interaction of conditioning establishes context-sensitive interdependencies between the organism and its environment. Parts interact to produce a greater organism–environment whole, which in turn affects (top down) those very parts. Conditioning and learning import the environment into the agent's dynamics by reorganizing and recalibrating those dynamics. In this sense, components are embedded in and not just dropped into an environment, as in an experiment. Once self-organized, the global dynamics of the overall organism–environment system become the control knob of its components—top-down causality, in effect.

The difference in the way individual slime mold amoebas behave while they are independent entities and after they self-organize into the complex slug is not explicable solely as the result of bumping into another amoeba (as mechanics and modern philosophy would have it). The difference is largely a measure of second-order context-sensitive constraints embodied by (in) the whole self-organized slug. So, too, the difference in the way molecules of water behave while they are isolated and independent and after they self-organize into the Bernard cell is a measure of the second-order, context-sensitive constraints embodied by (in) the hexagonal cell. That difference is also a measure of each system's complexity or degree of organization (Brooks & Wiley, 1988). Top-down constraints that begin to weaken cause a system to become unstable. When this happens, the conditional probability that a component will behave in a certain way given the systematic context in which it is embedded begins to alter, and the behavior of the components fluctuates much more widely. The overall system's integrity (identity) and survival are in danger.

CONTEXTUAL CONSTRAINTS

Contextual constraints thus perform double duty. From the combined effects of context-free and first-order contextual constraints, dynamical structures and patterns at a higher level of complexity self-organize. Parts interact to produce wholes, When context-free and first-order contextual constraints correlate flows of matter (reactants) and energy and thereby take them far from equilibrium and independence, a dynamic dissipative structure of process suddenly emerges. This discontinuous transition to entrainment and hierarchical organization is the sudden establishment of second-order context-sensitive constraints: abruptly, the behavior of an individual cardiac cell, generator, water molecule, or letter of the alphabet is no longer independent of those around it. The renewed repertoire of behavioral alternatives and properties that suddenly becomes available to the emergent system as a whole is the phenomenological counterpart of the sudden appearance of second-order contextual constraints. By coordinating previously independent parts, context-dependent constraints allow a more complex organization to emerge, with novel properties that the isolated parts lacked. Self-organization enlarges a system's phase space by adding degrees of freedom. Enabling constraints thus create potential information by opening—bottom-up—a renewed pool of alternatives that the emergent macrostructure can access.

The explosion of potential message variety available to each new global level is its expanded potential. The coherent laser beam can cauterize flesh; the waves of the individual laser atoms, separately, however, cannot. The emergent level is thus qualitatively different from the earlier one. As an integrated organism, the slime mold has properties the independent amoebas that make it up did not. Tissues (which are organized webs of cells) can do different things than independent cells, organs different things than tissues, proteins different things than amino acids, Bernard cells different things than independent water molecules—all because of homologous dynamics at work. Gatlin (1972) argues that the explosion of phenotypes that took place with the appearance of the vertebrates occurred because vertebrates managed to maintain context-free redundancy constant while allowing context-sensitive constraints to expand.

As a distributed whole, a self-organized structure imposes second-order contextual constraints on its components, thereby restricting their degrees of freedom. As we saw, once top-down, second-order contextual constraints are in place, energy and matter exchanged across an auto catalytic structure's boundaries cannot flow any which way. The auto catalytic web's dynamical organization does not allow any molecule to be imported into the system: in a very important feature of self-organizing dynamical systems, their organization itself determines the stimuli to which they will respond. By making its components interdependent, thereby constraining their behavioral variability, the system preserves and enhances its cohesion and integrity, its organization and identity. As a whole, it also prunes inefficient components. Second-order contextual constraints are thus in the service of the whole. They are, also therefore, the ongoing, structuring mechanism whereby Aristotle's formal and final causes are implemented (Ulanowicz, 1997).

Organization limits the degrees of freedom of a system's components. Once auto catalytic closure takes place, molecules become components in a system. As such, their behavioral repertoire is selectively constrained (their degrees of freedom curtailed) by the systematic context of which they are now a part. Unlike electrical generators and other allopoielic devices that require externally imposed governors, however, both auto catalytic closure and biological entrainment signal the spontaneous emergence of a field or dynamic network that is the endogenous establishment of second-order, context-sensitive constraints on the components at the first level. As distributed wholes, complex adaptive systems are virtual governors that give orders to themselves—*qua* thing, not *qua* other. The coherent laser beam "slaves" its component atomic waves even though "there is nobody to give orders" (Haken, 1987: 420). That is, one particle does not push another around. The orderly relationships that characterize the structure of the overall laser beam as a whole are the context that "gives orders" to its components, The same can be said of individual cardiac cells: the systematic context of the overall heart confers an otherwise absent stability on individual cardiac cells.

Top-down constraints that wholes exert on their components are inhibiting, selectionist constraints. Components that satisfy the requirements of the higher level will be classified as well-fitting. The constraints that wholes impose on their parts are restrictive insofar as they reduce the number of ways in which the parts can be arranged, and conservative in the sense that they are in the service of the whole. But they are also creative in a different, functional sense: those previously independent parts are now components of a larger system and as such have acquired new functional roles. The newly created overall system, too, has greater potential than the independent, uncorrelated components.

Paradoxically and simultaneously, self-organization also constitutes the appearance of the remarkable and unpredictable properties of the global level: the cauterizing ability of the laser beam, the enzymatic capabilities of a protein—or, I speculate, consciousness and self-consciousness—and their attendant states. These emergent properties of the higher level are the phenomenological manifestation of those dynamic relationships. But I emphasize that they are emphatically not epiphenomenal. Although not in a push–pull, forceful manner, the higher level of organization is causally effective: as a second-order, top-down constraint.

On the other hand, bottom-up, enabling contextual constraints simultaneously renew message variety by enlarging the overall system's state space. The renewed possibilities of the expanded phase space available to the emergent level of organization more than offset (see Alvarez de Lorenzana, 1993) the local order that top-down contextual constraints effect by limiting alternatives at the component level. It is important to emphasize that the potential behavioral repertoire that the context-sensitive ordering process creates is at a dynamical level of organization different from that on which the selective constraints operate. The higher level of organization—whether thermodynamic, chemical, biological, psychological, or social—possesses a qualitatively different repertoire of states and behavior than the earlier level, as well as greater degrees of freedom. The global level, which in one sense is nothing more than the combined enabling constraints correlating components at the lower level, is at the same time the locus of emergent properties. You can write a book; the blastula from which you developed could not. Increased variety is one way in which greater complexity is identified. Not only can you or I write a book, we can do so carefully, sloppily, easily, and so forth. As the number of options open to the overall system increases, the potential for disorder is simultaneously renewed.

Identity and Attractors

A system's identity is captured in the signature probability distribution of its dynamics. A useful way of visualizing this is as ontogenetic landscapes depicting a "series of changes of relative stability and instability" over time (Thelen & Smith, 1994: 122). If a system accessed every point or region in its phase space with the same frequency as every other (that is, randomly), its ontogenetic landscape would be smooth and flat. A completely flat, smooth initial landscape would portray an object with no propensities or dispositions; that is, with no attractors. It would describe a "system" with no identity, a logical impossibility. (On a graph, such a "system" would look like TV snow.) In contrast, the increased probability that a real system will occupy a particular state can be represented as wells (dips or valleys in the landscape) that embody attractor states and behaviors that the system is more likely to occupy. The deeper the valley, the greater the propensity of its being visited and the stronger the entrainment that its attractor represents.

Topologically, ridges separating basins of attraction are called separafrices or repellers. Sharp peaks are some points representing states and behaviors from which the system shies away and in all likelihood will not access; the probability of their occurrence is lowered or eliminated altogether. These landscape features capture the impact of context-sensitive constraints over time. Separatrix height represents the unlikelihood that the system will switch to another attractor given its history, current dynamics, and the environment. The steeper the separatrix's walls, the greater the improbability of the system's making the transition. On the other hand, the deeper the valley, the stronger the attractor's pull, and so the more entrenched the behavior described by that attractor and the stronger the perturbation needed to dislodge the system from that propensity. The broader the floor of a basin of attraction, the greater the variability in states and behaviors that the attractor allows under its control. The narrower the valley, the more specific the attractor; that is, the fewer the states and behaviors within its basin.

Since a system's external structure can recalibrate its internal dynamics, probability landscapes also incorporate the role of the environment in which a system is embedded. Since a system's prior experience constrains its behavior, that history, too, is embodied in its ontogenetic landscape. Ontogenetic landscapes, therefore, are constantly modified, dynamical portraits of the interactions between a system and its environment over time: they capture, in short, a time-lapse portrait of individual systems. Although complex dynamical systems theory is science, *pace* Aristotle, it can account for the particularity and concreteness of individual cases.

Furthermore, attractors and separatrices of complex systems are neither static givens in the manner of an Aristotelian telos, nor external control mechanisms (as was the temperature cranked up from the outside in the Bernard cell example). Nor are they determinants operating as Newtonian forces. Representing constrained pathways within self-organized space, attractors embody the system's current control parameters (its self-organized knobs), which have been constructed and continue to be modified as a result of the persistent interactions between the dynamical system and its environment. The probability that a system will do *x* next depends on its present location in the current overall landscape, which in turn is a function both of its own past and of the environment in which it is embedded. Attractors thus embody the second-order context-sensitive constraints of the system's virtual governor.

More precisely, attractor basin landscapes describe the effects of those second-order context-sensitive constraints that give a system its particular structure and identity. They identify regions of equilibrium in a system's dynamical organization. As such, a system's dynamical portrait maps the contextual constraints that its attractors and organization embody. The difference between random behavior on the one hand, and the actually observed behavior on the other, provides evidence that an attractor is constraining the latter. Once again, this difference also measures the system's organization (Brooks & Wiley, 1988), and confers on it its identity.

INFORMATION THEORY

Approaching the problem of action through the lens of information theory allows us a new way of conceptualizing how intentional meaning flows into action. I previously suggested that behavior constitutes an act-token if and only if it is a trajectory that is dependent on a reduction of possibilities at an intentional source. For behavior to qualify as action, the information generated must then be transmitted uninterruptedly into behavior. The technical concepts of noise and equivocation gave us a way of measuring that dependence of outcome on origin; as such, they also gave us a way of understanding how information can flow without interruption from source to terminus, which Newtonian causality could not. The problems and objections of wayward chains and act individuation, which earlier theories of action had repeatedly encountered, could thereby be circumvented or resolved. Information theory, however, was unable (a) to account for the set of alternatives from which the selection is made, (b) to provide a plausible account of the method people use to settle on a determinate course of action, or (c) to handle meaning.

Complex dynamical systems theory is able to assist in all these tasks. The key to self-organization is the appearance of second-order context-sensitive constraints as a result of the closure of positive feedback. Second-order contextual constraints are sudden changes in the conditional probability distribution of component behavior. By partitioning a system's state space into an ordered subvolume, dynamical self-organization is therefore also analogous to information theory's "reduction of possibilities" at the source. In the case of dynamical systems, the range of alternatives available to a complex structure at any given moment is given by its organization's coordinates and dynamics—its order parameter. Evidence from artificial neural networks also suggests that the very organization of those dynamics can embody a robust sense of semantics. Finally, acting as a system's control parameter, attractors of self-organized dynamics can serve as a causal—but not efficiently causal—mechanism.

INTENTIONS

Prior intentions and plans of action, Bratman (1987) argues, channel future deliberation by narrowing the scope of alternatives to be subsequently considered. Reparsing cognitive space in this way helps us act. In the language of dynamical systems prior intentions restructure a multidimensional space into a new organization characterized by a new set of coordinates and new dynamics. Since contextual constraints that partition a prior intention's contrast space embody the emergent property of meaning and the laws of logic, it is plausible to assume that the cognitive level of organization will show semantic and logical consistency. Dynamically, that means that once I form the prior intention to greet you, not every logical or physically possible alternative remains open downstream, and those that do are contoured differently: the probability of waving or saying "Hi!" goes up; the probability of turning away goes down.

It is reasonable to stipulate that agents who are aware, however faintly, of their behavior's nonbasic ramifications include them among the alternatives of their contrast space and its dynamical pathways, if only by default. Knowingly not preventing something adverse of which one is (however dimly) aware is tantamount to choosing it, in a derivative sense of "choice." We often assume that the degree of awareness is correlated with the significance of those ramifications and accuse those who fail to take appropriate action to prevent their occurrence of being "in denial." As the medievals consistently remind us, acts of omission are acts nonetheless, but only if the agent is aware of the omission! By definition, if the agent logically, cognitively (or emotionally?) could not even have considered an alternative as such, it is not something he or she could have "omitted." The question "Of what was the agent minimally aware, and when?" thus remains central to the question "What did the agent intend?"

Thinking of prior intentions as parsing a self-organized dynamics in this way also explains why settling on one prior intention (say, the intention to rob) precludes settling on a logically conflicting one (not to rob). Once I decide to perform act-token *A*, non-*A* is no longer a viable alternative (Bratman, 1987): it drops out downstream as one of the coordinates. There is, *a fortiori*, no attractor that will get me there from here. Once I decide to greet you, the probability of my insulting you decreases dramatically.

Each level is partly decoupled from the specific components that make it up. The higher level is meta-stable despite multiple realizability at the lower level. So, too, with respect to the mental. Once the cognitive, intentional level self-organizes, the fact that any one of several neurological processes can implement the same mental event becomes irrelevant. Under normal circumstances, my intention and subsequent action are indifferent to whether the former is realized in any particular neurological process. The alternatives that matter with respect to whether the behavior "raise my arm" constitutes an act-token are whether I intended to raise it, whether someone else lifted it, and whether it occurred as a result of a muscle spasm, for example. What matters, that is, is whether or not the neural process transmits information as mental. The presence and interference of those possibilities matter because trajectories originating in a spasm, for example, would take place entirely outside semantic space. Since the same neurons can be implicated in trajectories inside or outside semantic space, the neurological processes, as neurological, don't matter. The role that the intended meaning plays in bringing about the behavior is what counts.

Imposing order is what all top-down constraints of dynamical systems do (Pols, 1975, 1982). Whether in auto catalytic cycles or human beings, significance is a result of the interplay between the system's own top-down inhibiting constraints and the alternatives available to its components. In linguistics, constraints supplied by a sentence's context narrow the potential meaning of individual words. In genetics, the overall context in which a particular DNA codon is located affects its phenotypic manifestation. There is no understanding meaning independently of those inter-level relationships.

Robert Ulanowicz (1997) labeled an organized entity "ascendant" insofar as it develops as a focus of influence that grows in cohesion and integrity and thereby withstands the environment's destabilizing influence. The in-house pruning and streamlining of auto catalytic webs are carried out in the service of the higher level's focus of influence. While the system is ascendant, its overarching dynamics function as its formal cause, constraining the lower levels that make it up. In that way, they ensure the continuity and enhancement of the global level. In self-organizing, that is, a complex system partly decouples from the environment, from which it wrests a measure of autonomy. The difference between the behavior of objects while they are independent entities and their behavior once correlated and interdependent provides a measure of the contextual constraints in effect at the global level (see Brooks & Wiley, 1988). The greater the difference between random and systematic behavior, the more stringent the constraints reducing potential variation must be. That difference measures the system's degree of organization and its autonomy *vis-à-vis* the environment. Dynamical systems are also partly independent of their parts, which, in self-organizing, have become replaceable components. Once organized, a system's attractors serve as its formal and final cause, both preserving its identity and drawing behavior into its overall organization.

Divergence from randomness is a measure of any dynamical system's integrity or cohesion relative to the environment's disintegrating effects; that is, of the system's independence from its environment. That ontology underwrites a particular epistemological stance: behavior constrained top down is always amenable to purposive and intentional characterization (Dennett, 1987). This is why behaviorists described their pigeons teleologically as "seeking food," and why news agencies phrase their reports as: "In an attempt to stave off a takeover, GM today took measures to..." The more robust a system's higher levels of organization, the more they and not external mechanical forces control the output. The more robust a system's higher levels of organization, therefore, the freer the resulting behavior. The system is autonomous; it behaves "from its own point of view." That is one sense in which any behavior constrained top down can be considered free.

FREEDOM AND WILL

Insofar as all self-organizing structures, from hurricanes to ecosystems, act to preserve and enhance the overall global level, even at the expense of the particular components, complex systems are goal directed, if not fully goal intended (Dretske, 1988). By curtailing the potential variation in component behavior, however, context-dependent constraints paradoxically also create new freedoms for the overall system. As we saw, each emergent level of self-organization is nearly decomposable from the one below, and each new order possesses emergent properties absent at lower levels. That ontological feature allows scientists to identify and study chemical processes without having to refer to physical processes. Emergent, high-level psychological properties correspond to complex neurological dynamics constructed as a result of the co-evolution of human beings and the complex social organization that they both structure and are structured by (Artigiani, 1995). Once the neuronal processes self-organize into a conscious and meaningful space, behavior constrained by that organization can express and carry out an agent's intent. And just as the constraints of syntax allow meaning to be expressed, constraints on behavior thus make meaningful actions possible. At the same time as the intention's meaning and values limit behavioral alternatives, a renewed variety of possible behaviors also opens up.

In humans, there emerges both the remarkable capacity for self-awareness and the sophisticated ability to think of, describe, judge, and act in terms of the meaningfulness of our choices—even in terms of ethical and aesthetic values (Artigiani, 1996). The greater the phase space, the greater the number of alternatives available to the organism. To the extent that higher-level semantic considerations constrain behavior, it has more and different alternatives open to it than before. The enlarged phase space is the novel, emergent capacity to act. The astounding number of dimensions (which dynamical self-organization has made available to human beings) provides a second sense in which human beings are free.

A DIFFERENT APPROACH—HERMENEUTICS

Because deduction has failed as a generalized model that can explain complex systems' evolutionary sequence, a different logic of explanation appropriate to action is necessary. I propose that from now on the covering-law model of explanation (including its probabilistic incarnation) should be considered the limit of explanation, adequate for those phenomena that can be idealized as atemporal and acontextual. For isolated, linear systems, the covering-law model often works fine. For those phenomena, the lighter the inference, the better the explanation and the more accurate the prediction. For open, complex dynamical phenomena in which context-dependent constraints (both bottom up and top down) create inter-level interactions—that is, for phenomena which that "strange form of causality" progressively individuates and marks as essentially historical and contextual—the deductive model simply won't do, however. Understanding human action must begin from the assumption that people are dynamical entities whose behavior reflects their complexity.

The logic of explanation of hermeneutics is appropriate for explananda whose very nature is a product of that strange circle of whole and part. In contrast to covering laws and algorithms and deductions therefrom, that is, interpretation or hermeneutics reproduces the very logic of nature's open, adaptive dynamics. In textual interpretation, "the anticipation of meaning in which the whole is envisaged becomes explicit understanding in that the parts, that are determined by the whole, themselves also determine this whole" (Gadamer, 1985: 259). Interpreters must move back and forth: the whole text guides the understanding of individual passages; yet the whole can be understood only by understanding the individual passages. This inter-level recursiveness, characteristic of hermeneutics, is thus "a continuous dialectical tacking between the most local of local detail and the most global of global structure in such a way as to bring both into view simultaneously" (Geertz, 1979: 239). The inter-level tacking of the hermeneutic "circle" reproduces the self-organization of complex dynamical processes. By showing the dynamics of complex adaptive systems, hermeneutical narratives are uniquely suited as the logic of explanation of these strange-loop phenomena.

Like intentional actions, interpretations are characterized by strange-loop, inter-level relations and are, in consequence, essentially contextual and historical. Interpretations therefore explain by showing those nonlinear, inter-level processes at work. Behavior that occurs between phase changes must be explained by a hermeneutical, interpretive reconstruction. First, the agent's mental state that initiated the behavior must be identified. To do this, the explainer must describe both the contrast space of alternatives that embodies the agent's frame of mind and the attractor–separatrix dynamics that govern those coordinates. Unlike that of Newtonian particles, dynamical systems' behavior depends crucially on their history and experience and on the environment they are currently in. Whether the explanandum is a snowflake or a person, explaining any dynamical system's behavior requires that we fill in all that relevant background. Explanations of actions must therefore provide a narrative that interprets and recounts what those cognitive and affective dynamics were like at the time they initiated the action.

Next, because the agent opted for one of the alternatives in the contrast space, the historical and interpretive narrative must describe the specific path the behavior took, mentioning at each step along the way how much was specifically constrained by the intention and how much by the lay of the land or the external structure of the intention's control loop, as well as by the agent's other dynamics. The explainer must also determine how much equivocation, if any, compromised the flow of the intention's content into behavior, as well as how much information available at the behavioral end is extraneous noise unconstrained by intentional attractors.

Narrative hermeneutical explanations are not simple temporal listings of discrete events; that is, mere chronology, a linear sequence of independent frames on a film. In a true interpretive narrative, the telling of the tale explains by knitting together sequential but interconnected threads, such that it describes a temporal and contextual pattern, the meaningful organization that flows through the singular sequence of events and binds them into a whole. Just as first-order contextual constraints bind individual molecules into an integrated auto catalytic network, hermeneutic explanations of actions must construct a narrative that hangs together as a story. Unlike covering-law explanations of behavior, which abstract away time and space in favor of universalities, hermeneutics explains by highlighting and showing the concrete and temporal, context-dependent dynamical inter-relationships that give the action its unique character.

The Role of Phase Changes

But, this can be done only during "stable" periods. Between phase changes, while a system is in a particular dynamical regime, naturally occurring fluctuations and perturbations are damped, and explanation will consist in the back-and-forth interpretive reconstruction of the established dynamics that originated and constrained the behavior, and then in the tracking of the actual trajectory to its terminus in actual behavior. But a phase change itself cannot be explained that way. What needs explaining there is the change itself in the established attractors, the system's transformation into an entirely different dynamical regime. An alcoholic's turnaround cannot be explained in terms of their earlier state of mind. The radical mental transformation itself needs explaining.

A phase change is the qualitative reconfiguration of the constraints governing the previous attractor regime. The shift creates new relationships among the system's components as well as between the system and its environment. Phase changes signal a reorganization of the old dynamics into a new system with renewed relationships among the parts. These new relationships embody new properties and are governed by new laws. Within an established dynamical regime, the components' meaning is given by their contextual setting. There the meaning of individual actions depends on the agent's overall psychological dynamics, in combination with the circumstances in which these are embedded and from which they issued. Determining when or even whether a system will undergo a phase change and switch attractors is even more difficult than reconstructing either the dynamics of an established state or a trajectory through that established regime. Close inspection, however, can at times reveal that a phase change is imminent. When dynamical systems are taken far from equilibrium to a critical threshold, the pull of the established attractor begins to weaken, The landscape begins to flatten out, so to speak. The system accesses states that it would not ordinarily have visited. In human terms, when a person's behavior begins to fluctuate widely such that previously uncharacteristic behavior becomes commonplace, watch out: a psychological crisis is in the offing.

It is impossible to predict with certainty whether an established attractor regime will be able to damp a naturally occurring fluctuation and stabilize; or, to the contrary, whether the system will reorganize or disintegrate. Which critical fluctuation happens to be the one around which the system will reorganize or which perturbation is the one that will destroy the system is often a chance matter. And not just which: *when* is just as important. Timing is crucial: the perturbation that would have taken us over the edge as a child might have only minimal impact today. A full narrative explanation must include all these details. Interpretive explanations of individual actions are therefore always historical and concrete.

INTERPRETATIONS AND SENSEMAKING

The threat of relativism lurking in the hermeneutic circle has often encouraged philosophers to reject it. By drawing the explainer and the explanation into its strange loop, hermeneutics appears to forestall the possibility of any claim to truth and certainty. If we live in a dynamical universe, the novelty and creativity such complex systems display do indeed signal the end of eternal, unchanging, and universal certainty. Unlike modern science, however, dynamical systems theory provides an understanding of both the construction and the integrity of wholes that does not dissolve their unity at that level. According to Gadamer (1985), the resolution to the circularity of hermeneutics is found in Heidegger's recognition that "the circle of the whole and the part is not dissolved in perfect understanding but on the contrary, is most fully realized" (261).

We make sense of persons and their actions through an interpretive dialectic between wholes and parts. From descriptions of the dynamics of a particular instance of behavior, it might be possible to reconstruct the agent's character or personality and therefore the intention that constrained the behavior. We can then examine other examples of that person's behavior to see whether the character that these additional examples suggest corresponds to the personality we inferred earlier. If the test is positive, we reasonably conclude that the first behavior was "in character." As a result, we judge it to have been the agent's action and hold them responsible. From empirically available information of a behavioral output, and taking care to note any interference from noise or equivocation, the explainer attempts to reconstruct the cognitive source from which the behavior issued. The explainer attempts, in other words, to determine the mental dynamics from which a given instance of behavior flowed and the particular intentional attractor that constrained it. The purpose of examining several examples of behavior is to fashion an interpretation of the unknown dynamics (the intention) that constrained the particular behavior in question. The explainer then checks their interpretation of the agent's character by examining whether subsequent behaviors fit that initial (always tentative) interpretation.

PROVIDING EXPLANATIONS

Between phase changes, a complex system's behavior is governed by both the combined constraints of its own internal dynamics and the initial and on-going conditions in which it finds itself. As a result, in contrast to the covering-law model, the direction of explanatory primacy in interpretation is not the usual downward, reductive direction (Wimsatt, 1976). It moves up and down levels, from whole to parts, from inside to outside, and vice versa. This tacking reproduces the inter-level ontological processes that created the explanandum. In contrast to behaviorist analyses that attempt to bypass the subject's actual mental state, moreover, the hermeneutic explainer tries to reconstruct the particular internal dynamics from which the actual behavior issued, not bypass them. Wright (1976) claimed that only the impact of the mental event must be taken into account; this impact, however, could not be determined through commonalities across stimuli-response patterns of behavior over time.

Because complex attractors are often implicated in human actions, differences in behavior are sometimes more informative than commonalities. Variations across examples of behavior can reveal a particular intention's complexity in a way that similarities cannot. The back-and-forth tacking of hermeneutics can reveal the convoluted structure of those variations in a way that the covering-law model cannot. By respecting the vectorial nature of the trajectory it is reconstructing, an interpretive narrative does not try to reduce the purposiveness of action to nonpurposive elements.

The whole point of hermeneutical interpretation of action is to show

how meaningful intentions emerge and then purposively to constrain the behavior that flows from them. By recognizing that they are dealing with a unique trajectory, interpretive narratives also take for granted that their account need not apply to other behaviors, even those that appear similar. It is important, nevertheless, to emphasize that interpretation can discover only whether a particular instance of behavior was "in character." That sometimes—perhaps often—it is possible to judge someone's behavior accurately as being "in character," however, should not lull us into believing that we have achieved certainty in judging a particular instance of behavior. That is, when we are dealing with complex adaptive systems, surprises are unavoidable. Because of their sensitivity to initial conditions—due, in turn, to their contextual and temporal embeddedness—complex adaptive systems are characterized by unusual twists and novel turns. We saw the havoc that equivocation and noise can wreak in interrupting and compromising an intended trajectory.

Since we will never be able to specify any dynamical system's initial conditions to the requisite (infinite) degree, *a fortiori* we will never be able to capture all the details and circumstances of anyone's life and background. Given this limitation, we must always keep in mind that reconstructing specific instances of behavior will always be, at best, an interpretation and not a deduction—a much more fallible type of explanation than we had previously hoped was available. Interpretations of human action are always tentative (Metzger, 1995). Absolute certainty about either what the agent just did, or what they will do, specifically, a year from now, is impossible, As the title of Prigogine's last book (1996) announces, the dynamics of complex systems signal the end of certainty. The exact trajectory of any stochastic entity captured by a complex attractor, even between phase changes, is impossible either to predict or to retrodict precisely, even in principle. It cannot be predicted with exactitude in part because of the multiple realizability that self-organized systems support and the mischief that initial conditions wreak, but also because open dynamical systems' control loop runs partly through the environment. The dramatic fluctuations in behavior that strange attractors allow make any hope of predicting a dynamical system's specific future trajectory a futile wish. Knowing that someone is ambitious will not tell you what specific path their behavior will take.

Even though agents are usually in a privileged position to determine the alternatives present in their conscious contrast space and the degree of their awareness of each, extensive reflection and probing may be necessary before they can articulate all the relevant content of that awareness. In the end, the subject's own overall mental state (whose coordinates and dynamics identify the contrast space) parses potential behavioral alternatives from others not even contemplated.

I have claimed that a given instance of behavior constitutes an act-token (as opposed to a nonact) if and only if the information available at the behavioral end was constrained by (not merely contingently connected to) the intention's dynamical attractor. Even after the contrast space of alternatives that the agent had in mind has been established, however, the explanatory narrative must still historically reconstruct the behavior's actual trajectory and show that the intentional source constrained it unequivocally. For it to do so, the explainer must describe at each choice point why the agent took this fork rather than that one: what were the available options, and which was chosen.

Explaining why the agent took this path rather than that after forming the prior intention will require reconstructing the agent's background, circumstances, particular frame of mind, and reasoning, whether self-conscious or not. The cautionary tale of complex dynamics is that we can never be absolutely certain that there is no complex attractor constraining the behavior; we just might not have found it yet. It took a long time for science to discover that chaotic behavior is not chaotic at all. Even worse, what looks like behavior constrained by an intention may in fact have been noise all along. Explaining the agent's convoluted path from one point to the next, therefore, will often require identifying many other internal dynamics and external circumstances involved in bringing about the behavior. When all the intertwined attractors (all the entrained emotional, sociological, psychological, and other attractors) that make up a mature person are taken into account, those labyrinthine explanations we often launch on do not seem so preposterous after all.

SUMMARY

Nineteenth-century hermeneutics failed to take into account that the explainer, as much as the phenomenon explained, is embedded in time and space. Twentieth-century students of hermeneutics, in contrast, have finally come to appreciate that interpretation is doubly historical. The phenomenon being explained has a history, and so must be understood within that history; but interpreters, too, are situated within history, within a tradition, which their interpretation both reflects and influences. This double historicity affects the pragmatics of explanation. When the subject is planetary orbits and billiard balls—that is, when interactions can be ignored—the role of interpreter recedes in importance; not so when the subject is either quantum processes or human actions, Dynamical systems have therefore brought the interpreter back into the pragmatics of explaining action (if not into the metaphysics of explanation, as quantum processes have).

In dynamical terms, the tradition in which interpreters are situated is itself an attractor. As social beings, interpreters are embedded in its dynamics. As Gadamer (1985: 216) notes, "The anticipation of meaning that governs our understanding of a text is not an act of subjectivity, but proceeds from the communality that binds us to the tradition" that frames our interpretation. This fact, on which even the popular media harp, need not lead either to paralysis or to the deconstructionist's conclusion that any interpretation is as good as any other. As Umberto Eco (1990: 21) insists and our discussion of top-down constraints has shown, context constrains the range of plausible interpretations: "A text is a place where the irreducible polysemy of symbols is in fact reduced because in a text symbols are anchored in their context."

I submit that two contexts provide an action's "literal" meaning: the historical background and contextual setting in which the action was performed, and the context established by the "small world" of the action itself. Two contexts likewise frame the meaning of a hermeneutical explanation: the historical background and contextual setting in which the interpretation is offered, and the context established by the "small world" of the interpretation itself. Hermeneutic interpretation, within a narrative framework, thus comes closest to the logic of explanation advocated by David Lewis (1973a). Twenty-five years or so ago, Lewis argued that causes should be analyzed in terms of counterfactuals: if x had not occurred, y would not have. Despite the potential objection—"What underwrites the counterfactual itself if not causality?"—thinking of y in terms of its dependence on x can be helpful in capturing the way meaning flows from intention into action.

Within stable periods, the system's dynamics do much of the causal and explanatory work: the initial conditions account for the particular twists and turns within the behavior's attractor. The less complex the system, the more explanatory work the dynamics do; the more complex the system, the more the initial conditions do. Between phase changes, on the other hand, it is first necessary to reconstruct the process that drove the system far from equilibrium. Did the agent's own internal dynamics drive them to a threshold point? Or was it more a case of external perturbations driving (the agent's) weak internal dynamics to an instability? There is no one-to-one relationship between the dynamics in place before the phase change and those that appear after. The direction that a stochastic dynamical system's bifurcation will take cannot in principle be predicted even by ideal, omniscient observers. The precise path that the phase change takes can be explained only after the fact.

Such explanation must take the form of a genealogical narrative that reconstructs the bifurcation by painstakingly describing (1) the inter-level and contextual interactions that took the system far from equilibrium in the first place, (2) the particular fluctuation or perturbation that drove it over the edge, and (3) the specific pathway that the bifurcation took (as opposed to other possible alternatives). Phase changes cannot be explained in terms of the dynamics from which they issued. The reason, to repeat, is that phase changes mark a qualitative, catastrophic transformation in the dynamics themselves. Across phase changes, therefore, what requires explanation is how the meaning that governed one stable state is transformed into qualitatively different dynamics governing a different space of possibilities with a different frequency distribution.

Phase changes embody essentially incompressible information. That is, there exists no law or algorithm more concise than the process itself that can capture and describe what happened. That is why fiction and drama, bible stories, fairy tales, epics, novels, and plays will always be better than deductions or formulas for explaining personal transformations of this sort. The rich, vivid descriptions and reenactments that these genres provide represent meaningfully for the reader and spectator the processes that precipitate such personal transformations. They do so by paying special attention to the role played by both the agent's internal dynamics and the particular environmental perturbations that drive a system far from equilibrium. Stories and dramas also show the reader and viewer how random, unrepeatable events and circumstances can be responsible for either destroying people or renewing them at a different level. Often insignificant in themselves, these unique events can be the proverbial straw that breaks the camel's back.

Had the characters in those novels and dramas not been near a crisis point, of course, those unique events would not have had an impact. By interacting with background conditions far from equilibrium, unique events provide the turning points along a singular trajectory. Reenactment, which is what both simulations and theatrical performances offer, is even more explanatory than narrative, because we get to see how the tensions of living with Torvald Helmer, George Tiesman, and Charles Bovary drive Nora, Hedda, and Emma to the edge.

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