Is Society a Self-Organizing System?

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ABSTRACT

Should society be considered a self-organizing ("autopoietic") system? If so, what are the implications of this approach for sociological theory? The concept of paradigms has provided the sociology of science with a mental model for understanding self-organization as an agency at the supra-individual level. In the sociology of scientific knowledge this "anomaly" in sociological theorizing has been elaborated by using the distinction between reflexive and substantive discourses. This essay specifies the conditions necessary for a social system to become self-organizing in terms of communications. "Interpenetration" by action can then be analyzed in terms of structural and operational couplings of the social communication system.

Introduction

"Self-organization" is a mathematically specifiable concept with roots in non-equilibrium thermodynamics (e.g., Prigogine & Stengers, 1979/1984), and neurophysiology (e.g., Maturana, 1978). This concept has also been discussed by many who theorize about society (e.g., Luhmann, 1984), and has also been used more widely (e.g., Geyer & Van der Zouwen, 1991). In the theory of self-organization, macro-level phenomena produced by lower-level units can assume control. If social systems, however, are to be considered as causes of change, this perspective contradicts a central assumption in most modern sociology, namely that social change has to be explained in terms of, or at least with reference to, individual human impact.

In modern times, we no longer assume that gods and demigods control our history. Notions of systems that organize the social process autonomously have been around for a while in social theory, particularly on the Marxist side, but these theories were suspect because of their lack of analytical rigor, and consequently of sophistication in empirical design. (They have also been attacked by, e.g., Popper, on the grounds that they hypostatize hypothetical impersonal forces into positions more powerful than actual people; see, e.g., his *Poverty of Historicism*.) Ever since Weber, sociologists have attempted to explain social structure and change on the basis of a theory of action (see Muench, 1982/1988). The

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idea of a supra-individual social system that actively exerts control may therefore seem to many sociologists an invitation to obscurantism.

The problem of supra-individual control reappeared on the agenda of empirical sociology via the study of socially organized cognitive activities like the sciences (see Knorr-Cetina & Cicourel, 1981). Kuhn (1962) had proposed understanding the development of the sciences in terms of paradigms. As is well known, he described paradigms as historically emerging from crises in communication, with a resultant reorganization of science both in terms of relevant communications and cognition, and in terms of underlying communities. Actually, this process seems to be one of co-evolution, involving the cognitive science system, the relevant discourse, and the community. Eventually the new paradigm may fall back into crisis and disintegrate under competition with alternative paradigms at the supra-individual level.

This concept of paradigms provided the sociology of science—and other fields (e.g., Prigogine & Stengers, 1979/1984; Luhmann, 1984, 1990)—with a mental model for understanding self-organizing social systems at the supra-individual level. But how can supra-individual structure control social action? How can such a theory be given sociological meaning? Is the paradigm only a metaphor useful in reconstruction? Is "self-organization" only a metaphor with reference to the metaphor of a "paradigm?"

In general, discursive metaphors can be generalized to empirical hypotheses via raising of questions like "to what extent" or "for what period of time" one expects the metaphorical description to provide us with a relevant view of the data. For example, one may analyze sciences with respect to the extent to which their development has been guided by paradigms. Analogously, the research question should not be whether "self-organization" is a useful metaphor for describing the function of paradigms, but whether we can specify the conditions required for supra-individual system to behave in this "self-organizing" way. Consequently, I shall first specify more generally the conditions necessary for any system to be considered as "self-organizing," and then raise the additional question of the conditions under which this mechanism might operate at the supra-individual level, i.e. in social systems.

"Self-Organization"

Let me begin by offering the reader an illustration of a self-organizing system—the example of human beings, biologically and psychologically. Then, I'll extend this to social systems, specifying how they differ from biological and psychological systems, and elaborate this specification for the sociology of science. In a further section, I shall extend the argument to general sociology, and indicate why we need to proceed to mathematical specification.

The human operating system itself determines what people can eat, what people can see, and how people can communicate with others or internally. Of course, one can use instruments to see in the infra-red, etc., but this does not invalidate the human condition as a given in all communications, and all processing of information. Furthermore, the human being is a functionally differentiated communication system, both internally and in terms of external communications. We do not see with our ears, nor hear with our eyes; we do not digest with our lungs, nor breathe with our stomachs. After a certain (early) stage in development, there is not a single cell left in the body that does not have

a specific function, although all cells may contain all genetic information. The cells are organized in communication networks that self-organize their function for the system as a whole (see Kaufman, 1991, 1992). The frequency of the operation of organs is controlled by various forms of central memory organized in the neural system.

Once a function is in place, the organ is stabilized against minor lesions, i.e., the operation is self-reproductive, although its organization may always collapse into crisis, both at the physiological and/or the underlying cellular levels. An organ not only needs to be in place, but it also needs to be properly innervated; i.e., the operation of the system needs dynamic control by the neural network as another functionally differentiated system as soon as complexity surpasses certain thresholds.[1] The crucial point is that the system is healthy as long as it communicates what it is supposed to communicate, as long as the subsystems perform their operations at the right moments in time, and as long as each subsystem additionally self-controls its structural organization with reference to its operation. Any self-organizing system will continue to develop and exhibit a life-cycle.[2]

Although we can grasp intuitively the notion of self-organization for a single living system, we have much more difficulty doing so for systems above the individual level. The obvious examples are insects like ants and wasps, which live in communities. But however theoretically and methodologically fruitful our study of social relations via biological metaphors derived from such insects may be, serious questions must be raised at this leap. Firstly, the evolutionary metaphor is uncomfortable, since it has been terribly abused, e.g., in corporatist ideologies. Second, the autonomous momentum of the human will is central to the voluntaristic theory of action that has provided a common basis for sociological theory and research since Weber, and this is by no means accidental. Human beings are in important respects different from insects; social organizations are different from organisms.

What do we mean when applying evolutionary models to social systems? What has to be changed in terms of concepts in order to account for the larger complexities involved? Let me first note that the concept of evolution has been widely used in sociology as a metaphor. A metaphor is useful if it generates a new view of the phenomenon under study. As noted above, whether this view can be considered as provisionally true given the data at hand can be assessed only if one elaborates the metaphor into an empirical hypothesis, which specifies what is to be expected.

In biology, evolution theory has been developed to the level of providing us with testable hypotheses. Without a theory of evolution, one has only taxonomies of fishes, reptiles, trees, etc. Evolution theory provided us with an analytical scheme to organize these taxonomies according to a logic. For example, on the basis of evolution theory one is able to specify "missing links" with reference to taxonomic data. A concept like "missing link" is meaningful only for those who have made the inference that there is an evolving system that can be traced in the phenomena. Since evolution theory places the phenomena in a theoretical perspective, evolution is a concept with a hypothetical status. This hypothesis has been impressively corroborated over the last hundred years.

The straightforward application of evolution theory to social systems in "social Darwinism," however, has been a theoretical and political disaster. If there are common patterns of cultural evolution in social systems, they are not obvious, and probably at variance with one another. Thus, there is not a single hypothesis, but a set of hypotheses with respect to social dynamics. In qualitative sociology, these hypotheses have also been

called reconstructions. A reconstruction is a line that the analyst draws through the data in order to organize its variance over time. The reconstruction operates with hindsight, and is consequently a specific (theoretical) selection with reference to what happened, to be attributed to the analyst.

How can one selection be justified against and in relation to other possible selections? This requires a second-order selection: a given selection has to be compared reflexively with other selections, and over time. As a result of this reflection, the analyst may hypothesize a theoretical organization into one or more cognitive identities (e.g., types). If this reflexive selection is provisionally assumed, each new substantive selection (i.e., reconstruction) can be assessed in terms of whether and how it contributes to each of the previously hypothesized possibilities. If so, emerging identities begin to function as a yardstick, i.e., if they prove to be fruitful, they may begin to take over control-functions in justifying further selections.

Who is the carrier of these selections and stabilizations? In the first place, it is the reflexive analyst. However, if reflexive analysts begin to communicate among themselves not only in terms of how they analyze the data, but also at the reflexive level, e.g., about standards of analysis, the standards may become de-personalized; they begin to circulate in the communication system of this community, and thus begin to form a supra-individual dimension of quality control for the actors (insofar as they acknowledge these standards).

As noted above, the ideal case of this process in science was termed a paradigm by Kuhn. He noted (with a well-known quotation from Max Planck) that once a new paradigm is brought into place, the "old guys" have to die out. This means that their type of communication is no longer recognizable as relevant, and consequently, they are no longer considered members of the relevant scientific community. Note how the delineation of an element of social structure is thus, among other things, dependent on the self-organizing character of this communication system.[3]

In concrete cases, more than one pronounced form of stabilized cores of communication among scholars may emerge. In science studies, these systems of communication have been called "discourses" (see Mulkay et al., 1983). Differences in communications within and among various research communities can be studied empirically in terms of the variance in their "discourses"—for example, by analyzing repertoires and vocabularies (Hesse, 1980; Law & Lodge, 1984; Leydesdorff, 1991a). However, the boundaries of social communication systems are uncertain, and social communications are failure-prone. Therefore, communication patterns remain also uncertain, and historically contingent.

Thus, by taking the example of theoretical reconstruction and the possibility of theoretical reflection as a special case, we have begun to understand the mechanism of the genesis of a self-organizing system at the supra-individual level, and the impact of their occurrence on social developments. Let me repeat the argument more systematically. First, self-organization requires in addition to variation and primary selection (i.e., reconstruction) a second-order cybernetics, which implies the time dimension. At each moment in time, various reconstructions may compete. Stabilization is based on selection among these selections. The next bottle-neck in the social dimension is whether the scholars involved can stabilize a communication system among themselves in which they not only communicate about the various reconstructions—since these communications may then be volatile—but can also compare among communications and over time reflexively, i.e.

by keeping the communications in memory. Since the social communication system cannot itself literally carry out these functions—being not an actor with an active memory function—individuals participating in the communication have to be the physical locations where these reflexive processes occur. By communicating not only about their reconstructions in relation to the variance in the data, but also reflexively about the relevance of reconstructions for the development of the cognitive core of their discipline, the scholars maintain a reflexive communication circuit that is physically distributed and processed among themselves. However, these scholars can function as a scientific community only on the basis of these two levels of communication: they communicate both about the substance of their communications, and about the standards for judging these communications reflexively. Note how many steps are involved, and how unlikely the historical occurrence of science (i.e., the need for the reflexive system to have certain specific qualities). For example, as long as the reflexivity is not communicated in terms of uncertainties, but given normatively (e.g., by religion), the scientific communication system lacks the additional degree of freedom needed for the emergence of patterns of self-organization in scientific communication.

Once the various layers of communication are differentiated, the system can become self-organizing. As we saw in the paradigm example, in a self-organizing system, control flip-flops: the contributors to the genesis and the maintenance of the system are no longer able to control the system's substance, although this substance is logically a result of their interactions. The participants can only contribute to the communication, change it a bit, and reproduce it. They have generated a communication system that communicates what it communicates, and only the communications of those who communicate in those terms are henceforth part of this system. Still the system may change gradually over time, but it is stabilized both in terms of what it regards as relevant variances, and in terms of relevant selections. The stabilized system operates on the basis of the reflexivity that is physically located in the heads of its participants, but which is shared among them in a reflexive communication system. If the reflexivity, the sharing, or the underlying communication process breaks down, then the system breaks down, and self-organization gives way to crisis. (The various forms of degeneration can be more precisely specified.) Furthermore, as long as the self-organizing system endures, it is self-regulating, and thus also self-cleaning with respect to failures in the past. It has continuously to rewrite its history.

Note the centrality of the notion of reflexivity. Reflexivity at the lower level is conditional for self-organization at the higher level: in this step the constructed system attains the possibility of combining its structure with the time dimension and thereby forms its identity. To the extent that this occurs, the control of the communication flip-flops, and the dependency relations among the levels are (partially) reversed. However, the reflexivity of the social system also remains dependent upon the reflexivity of those units that bear the system, and upon the degree to which the units bring the reflexive dimension into communication within this social system. All arrows represent subcybernetics of the dynamic operation.

On the one hand, the emergence of such a complex system may seem highly unlikely, but on the other hand, if the actors do also communicate reflexively, the social system can begin to learn as a distributed network, and therefore perform more complex tasks than each individual system (see Simon, 1973). The individual actor is not only related to the network, but also positioned within it, and reflexively aware of this function. The

tasks are now no longer distributed only physically, but also functionally. Once in this reflexive mode, the social system's communication can also recover from the failure of a couple of the units involved, by replacing them with functional equivalents.

The development of the system in the time dimension remains dependent upon the reaction times of the composing units: the social system offers only chances; it possesses no physical memory. Therefore, it cannot process independently; it remains structurally coupled and thus dependent on the underlying communications among the actors involved. However, at each moment in time, it offers chances that are distributed as a result of previous rounds of communication. The ongoing communications not only inform the communicators, but also update the distributions in the communication system. When parts of this communication system become (temporarily) reflexively constituted as described above, these systems can maintain a certain function despite disturbances, i.e., they are able to select among the lower-level communications with reference to a higher-order function that is latent in the lower-level systems, although the latter may be reflexively aware of this process. The maintenance of reflexive communication systems within society is thus directly related to functional differentiation. Furthermore, self-organization can imply also the time dimension if lower-level units also communicate in this dimension reflexively. For example, in the case of a scientific specialty, frequencies for textbooks, reviews, conferences, research-articles, etc. may be developed. These frequencies can become structurally sedimented into conventions or can be kept more fluid.

We have developed above the notion of reflection at the level of the social system with reference to scientific (i.e., theoretical) systems. However, one should be aware that "reflexivity" can be defined in other dimensions. For example, not only can one reflect cognitively upon one's thoughts, one can also feel that one feels, love that one loves, laugh about laughing, etc. (Luhmann, 1984). In general, reflexivity is the capacity of a communication system to recursively apply the communication to the communication of this system. As far as this can be done, and then be communicated, the higher order communication system may begin to exhibit self-organization. Note, however, that if we reflect cognitively upon our feelings, then this is not a recursive application of the specific communication, but reflection of one kind of communication in terms of another. The feelings are then the variance, and the reflection only the first-order selection. Stabilization, however, requires a second-order cybernetics.

Self-Organization Remains an Hypothesis

As suggested, meta-theoretical understanding of reflexive theorizing as common in the modern sciences provided us with an understanding of this special theory of scientific communication, and this was not incidental. Remember that as an empirical hypothesis, the "paradigm" posed an anomaly to the dominant mode of sociological theorizing, which primarily aimed at explaining supra-individual phenomena with reference to human agency. For a substantive understanding of self-organization, we first have had therefore to capture the reflexive meaning of the anomaly before we could generalize to other sociological phenomena (e.g., family, organization, etc.). "Self-organization" was introduced as an hypothesis for explaining this anomaly.

The idea that systems may exist on the basis of interaction among units that can be empirically observed independently is more common to sciences like evolutionary biology and cognitive psychology. However, although the hypothesized social systems may be distributed, their very existence and identity remain questions. Although in biology and psychology the existence of the subject of study as a system may be taken for granted, sociologists have to proceed reflexively in this respect. "Self-organization in social systems" can therefore not be taken as a characteristic of the system, but has to remain a hypothesis in two respects: first, one has to assume "systemness" or a pattern of communication in otherwise chaotic data, and second, one has to specify the relations between this "systemness" (see Giddens, 1984) and "self-organization." This double hypothesis further complicates the matter theoretically: which of the two hypotheses can be tested against observational data in which instances?

Does the duality in the hypotheses make the thesis untestable? Can we distinguish the various notions of substantive organization from reflexive self-organization, and specify the conditions under which each of these hypotheses can be falsified and/or corroborated? As noted, the study of the dynamics of science in terms of paradigms as pursued in the sociology of scientific knowledge has provided us with the semantics to understand processes of construction both at the substantive and at the reflexive level (e.g., Mulkay et al., 1983; Callon et al., 1986). But in the sociology of scientific knowledge, the analysts reflected mainly with reference to themselves as knowing subjects (see Woolgar, 1988). As Luhmann (1990) has noted, this reflexive understanding failed to formulate the meaning of the systems under study being increasingly considered as constructed communication systems. The possibility of reflexivity and self-organization in the social communication structures ("discourses") should first have been specified.

The reflexive analysis has taught us that one can no longer accept any transcendental warrant for contingent knowledge; all knowledge is contingent. Indeed, scientists—including the reflexive analyst him/herself—have to spin a discursive or "semiotic" network. My argument has, however, been that this network is constructed in analytically different layers. The reflexive discourse is substantively reflexive with respect to the discourse that is reflected, and thereby may add another dimension to the communication. The crucial question is whether the reflexive discourse can develop as paradigmatically as the substantive one that is reflected. Can it be a network that can "learn"? If so, with reference to which order? I have argued that conditions can be specified under which communications among reflexive analysts can provisionally establish a reflexive order in the communication system that helps organize the communications to such an extent that in the limiting case it controls the communication. The extent can be investigated as an empirical hypothesis.

In summary, the presumable anomaly of the paradigm as a supra-individual agency provided the sociology of scientific knowledge with a gateway to the understanding of science as a specific form of producing reflexive order out of chaos. Note the implied radically constructivist epistemology: scientists have to make assumptions, but the assumptions are in need of revision both in terms of the statements about the subject of study, and with respect to the analytical categories. The reflexive analysis itself is as contingent as the substantive discourse, and therefore remains falsifiable. This holds true at each next level of reflection: the analysis proceeds both at the substantive and at the reflexive level.

An Hypothesis Refers to a Theory

The application of the concept of "self-organization" to the social domain raises the possibility of this theory as yet another paradigm in science. If paradigms are specific with respect to the communications that they allow, one might ask what one gains, and what one looses, by using this hypothesis?

Kuhn (1962) emphasized the "incommensurability" among paradigms. Incommensurability means that whatever can be communicated within one paradigm cannot be communicated outside it except at the price of a different meaning. Consequently, paradigms have sometimes been identified as Wittgensteinian language games (see Pinch, 1982). [Editor's Note: But see Popper's "The Myth of the Framework," in Freeman, E., ed. *The Abdication of Philosophy*, LaSalle, IL: Open Court, 1976, for an argument on behalf of meaningful communication among paradigms, namely, by rationality that transcends paradigms. For more on universal rationality, see "Rationality and Evolution" in my *Mind at Large*.—PL.] These discourses may evolve, may further differentiate and interact, or may go into crisis. Whatever happens is historically contingent: the process is constructed, and can therefore be reconstructed by the historian, the philosopher, or the sociologist.

The reconstruction is necessarily based on a deconstruction, and this process has to be carried out by an analyst. The crucial lesson from constructivism, discourse analysis, and post-modern sociology has been that there is never a single pattern in the complexity of the data; rather, any reconstruction by one analyst can be deconstructed from a wealth of other perspectives. In my opinion, this does not imply that there can be no structure in the multitude of possible reconstructions; this rather supports the above thesis that higher-order structure cannot be taken for granted. If it exists, it is latent; it requires a second-order reconstruction of the reconstructions, and has to remain a hypothesis.

If one considers the multitude of reconstructions as another empirical domain, one can make empirical inferences with reference to this domain only by specifying an hypothesis. The hypothesis should be empirical, i.e., should eventually allow for testable consequences. Hypotheses, however, remain ad hoc if they are not stabilized in a theoretical system. This theoretical system should, for example, enable the analyst to specify criteria for distinguishing among the reconstructions in terms of their significance. This brings the methodological questions that were so heavily criticized by post-modernists back on stage, but at the reflexive level. Methodology is then not a textbook recipe, but a reflexive theory about the quality of inferences concerning the phenomenon under study. (If the methodological discourse is solidified into a normative theory, the theoretical communication degenerates again.)

I have argued that in order to achieve sociological understanding with respect to the concepts of paradigm and the incommensurability among paradigms, one has to reformulate these concepts in terms of discourses, and thus as communication systems. The paradigm notion refers to the possibility of self-organization in these communication systems. In my opinion, there is no a priori reason to exclude sociological reasoning at the meta-theoretical level from this general mechanism. This inference leads to the hypothesis of self-organization as the general form of scientific discourse. One need not explain that the discourse is chaotic, since that is the default. What is in need of explanation is that scientists can communicate despite the sometimes esoteric jargon and the unrealistic ("counterfactual") phenomena under study.

As noted, the question of whether these theoretical and/or meta-theoretical discourses exist and can endure remains empirical. The test for this hypothesis is the degree to which the variance in the theoretical selections under study can be explained by the hypothesis of a second-order selector that first has to be specified. Note that any self-organizing order has to be a reflexive order: one can only observe the distributions. Self-organizing (theoretical) systems remain hypothetical constructs for the sole purpose of serving the process of scientific discovery. Whether actual organization found in the data is a consequence of self-organization or not can be decided only on the basis of ex ante specified expectations. Consequently, one may always wish to ask questions like to what extent can this system be considered as self-organizing, and for what period of time? The sociological analyst should abstain from the reification of "self-organizing systems," and should formulate only hypotheses. Here, I distance myself from Luhmann's (1984) more speculative insights into these matters.

Hypotheses embedded in systems of theoretical expectations challenge empirical researchers, since they refer to some empirical distributions and not to others. How can one delineate the hypothetical communication systems in empirical research? Specification of some heuristics for any special theory of communication is not difficult, even at this stage. The first question in an empirical design concerns the substance of the communication, since communication systems can differ, and thus be distinguished, in terms of what they communicate. This substance can be multi-dimensional, i.e., differentiated into subsystems. The next issue is the specification of the mechanisms of communication within each of the specified (sub-)systems, and how these may interact, i.e., make selections with reference to one another. As was shown above, the addition of a second-order selection in the time dimension is necessary to explain why certain selections can be stabilized.

For example, by pursuing the reconstruction, the analyst attempts to understand how the paradigm has developed, and how it differed from other paradigms. However, only on the basis of such reconstructions can one raise the question of when and why "incommensurability" occurred. On the one hand, neither the paradigms nor the incommensurability are a given for the sociological analyst; they are to be understood as historical constructions which can be deconstructed in the theoretical reconstruction. On the other hand, the various theoretical reconstructions can be examined in a second-order cybernetics in terms of whether, how, and to what extent the expected phenomena actually occurred. The question of "why" requires a reflexive hypothesis. The reflexive analysis can illuminate the "why" of the reconstructed developments because it provides the analyst with an additional degree of freedom for making selections in the time-dimension: one is then no longer merely describing the paradigms as (hypothetical) self-organizing systems, but beginning to develop a sociological theory of scientific communication. Theory requires not only selection, but also (provisional) meta-selection. If both selection and meta-selection are corroborated by further research, stabilization may provisionally occur.

Traditionally, the difference between volatile knowledge claims at the research front and reflexive meta-selection has been expressed by contrasting the "context of discovery" with the "context of justification." However, contingent stabilization does not imply transcendence into Popper's World 3 (see Popper, 1972). The theoretical system remains as contingent as the system about which it theorizes. Additionally, the assumption of the

self-cleaning potential of a self-organizing supra-individual system does not preclude a self-organizing system coming into crisis, and contingently disappearing. For example, a paradigm may come into crisis with respect to unresolved inconsistencies and biases in its initial assumptions. Anomalies may indicate such problems, particularly if they "don't go away." During crises the chaos and confusion increase dramatically. The reconstructive analyst of the discourses risks losing track if he/she is no longer able to interpret this chaos as the contingent pathway of the self-organization of the (hypothesized) system involved.

Thus, chaos and confusion is not to be taken as an endpoint or a degeneration. That position would reify the rationality in the reconstruction to a normative a priori. The conclusion could then eventually be only that "reality" is always more complex than the model. One has to reverse this reasoning: all complexity is contingently contained within a communication system. If it is not, we cannot communicate with it, and therefore we cannot test our empirical hypotheses with respect to it, but only speculate about it. The development of uncertainty in (hypothesized) empirical systems can be used as information to disclose the development of this system. However, the theoretical system of the analyst contains ex ante only an hypothesis (based on previous reconstructions) with reference to the system under study. The hypothesis organizes the uncertainty within the theoretical analysis, i.e., self-referentially. If it holds, the theory gains in self-organizing identity. If not, it eventually vanishes, i.e., it has to give way to another self-organization of the chaos.

Sociology as a Complex Theoretical System

In the previous example, the system of reference was the social communication system of science, and not any of the specific scientific paradigms under study. As noted, I took the sociology of science here as an entrance point, since in this specialty one has had to distinguish between the scientific discourses under study and the meta-theoretical discourse. Thus, one has had to specify reflexivity in relation to theoretical discourse. However, our program of study will be to understand all social systems as special communication systems, and to examine them in terms of the question of whether and to what extent they can be self-organizing.

Let us begin this enterprise by analyzing sociological theory itself as a potentially reflexive scientific communication system. This system is commonly said to be in deep crisis (see Gouldner, 1970). As noted, we shall henceforth accept crisis as the common state of affairs. The theory of self-organization teaches us that the lower-level variation in history has to take place in order for the emergent system to be able to organize itself (if it emerges at all). Only a reflexive understanding of the contingent history can guide the further specification of the emerging system of reference.

Can one discern reflexively a pattern among the existing theories? By using one metaphor or another, this is often not too difficult, but would the hypothesis of "self-organization" help in understanding sociology as a theoretical system? In my opinion, much theoretical and methodological effort in the past century has been sensitive to crucial issues within the theory of self-organization, although one did not have the theoretical apparatus to understand one's position reflexively. Both theoretically (with reference to the social phenomena under study) and meta-theoretically (with reference to the theoretical apparatus) one lacked the semantics for specifying non-reified (i.e., hypothetical) supra-

individual systems. Therefore, one eventually either had to reify systems meta-theoretically, or reify the phenomena as naturalistically given data or discourses (e.g., Mulkay et al., 1983). However, on the basis of the hypothesis of self-organization, one may wish to understand reflexively and with hindsight the half century or so of crisis in sociological theorizing as mainly a struggle to understand the socially constructed and yet empirically identifiable nature of both: the phenomena are selected with reference to a theoretical understanding, and the meta-theoretical system should be considered only as a paradigm.

The "Self-Organization" Paradigm

More than any other sociologist, Niklas Luhmann has made the theory of self-organization into the cornerstone of his work. He made a serious attempt to reformulate the classical theoretical questions in sociology on this basis (Luhmann, 1984; see also Luhmann, 1990). Among the classical sociological questions are questions like the relations between individuals and society (cf. Hobbes, 1651), the relations between subsystems of society and the general system (e.g., the relations between politics and economics; cf. Marx, 1857), and the relations between stratification and functional differentiation.

According to Luhmann (1984), the concept of self-organization requires a paradigm shift for sociology. The crucial point is that society should no longer be considered as composed of human beings, but as consisting of communications. The communication network is added to the nodes that represent the human beings who carry it. At the nodes, each human being performs his/her own self-referential loop; one only communicates within the network as far as one performs social action. Action can be considered as a local event that is communicated in the network. The social communication system is reproduced by this operation. Sociology has the task of specifying the dynamics of this system in terms of, for example, functional differentiation, reflexivity, and self-organization.

Luhmann thus specified the social communication system as the proper domain of sociology, and sociology as a special theory of communication. Obviously, the major issue in relation to older sociologies is the interfacing between social and individual systems in the individual act of social communication. Using Parsons' terminology, Luhmann (1977, 1978a, 1984) studied this problem under the heading of "interpenetration." However, Luhmann did not elaborate his theory into the quantitative terms that are nowadays available. Although his claims about systems and their operations are sometimes amazingly precise, his semantics essentially remain speculative. For example, notions of probability and variance hardly play a role in his studies. The "self-organization" of the social system is taken as a given, not explained as a hypothesis. Furthermore, Luhmann is consciously aware of the crucial function of stabilization in the time dimension, but he has never systematically addressed the variance in this dimension.

In his study of the science system, Luhmann (1990, pp. 405 ff.) suggested that scientific theorizing can gain sufficient degrees of freedom for self-organization precisely on the basis of the co-evolution of theory and methods. Methodology and mathematization, however, are not tools to be added to a qualitative theory; reflection in this respect requires a reformulation of theory with reference to methodology.[4] A methodologically reflexive theory is capable of systematic learning because, on the one hand, neither the theory, nor

the data, nor the methods are reified. On the other hand, the dynamics of the organization of these elements must be hypothesized in substantive terms, i.e., with reference to what one might be able to learn from subsequent observations.

Both theory and methods can profit from the reflexive turn in relation to one another. On the methodological side, the exploration of the research question forced me, for example, to be more specific about the conditions for "self-organization" than previous authors. As argued, the occurrence of this phenomenon cannot be taken for granted in social systems, of which additionally the existence and delineation cannot be taken for granted. On the substantive side, the main gain from such a reformulation will be clarification, and a more encompassing theory. The level of abstraction will provide us with opportunities to cover more complex ground, and particularly to address the important topic of time (and thus operation, process, and interaction) more systematically. Notably, system-interdependencies and interference among systems can be analyzed in more detail.

"Interpenetration" as a Critical Example

The founding fathers of sociology as a discipline (e.g., Weber, Durkheim, Parsons) achieved a profound qualitative understanding of the processes of differentiation and institutionalization. Parsons developed a general systems theory for these processes. "Interpenetration" is used by Parsons as a general concept for the zones of interaction between systems and subsystems,[5] and at other places more emphatically with reference to the ways in which the personality internalizes cultural and social objects.[6]

Parsons assumed that these two processes (the relations between subsystems of society, and the internalization of cultural and social objects into the personality) can be understood in terms of the same cybernetic relations among all stable systems of social interaction. For example, Parsons (1968, p. 473) formulated:

> The phenomenon that cultural norms are internalized to personalities and institutionalized in collectivities is a case of the interpenetration of subsystems of action, in this case social system, cultural system and personality .... Here the critical proposition is that institutionalized normative culture is an essential part of all stable systems of social interaction. Therefore, the social system and the culture must be integrated in specific ways of their interpenetration.

With hindsight, discussions among students of Parsons reveal that the relations between the social system and the cultural system are in important respects also systematically different from those between the social system and personality. Although Parsons noted the specificity of interpenetration among systems, he did not distinguish sufficiently among these various kinds of interpenetration.

As noted, Luhmann (1977, 1984) specified the relations between the social communication system and what he called "individual consciousness systems" (i.e., actors) as "structurally coupled:" the social communication system cannot operate without individuals who communicate, but only the message (i.e., the action) and not the actor is communicated. The action will thus have different meanings for the sending actor, for the receiving actor, and for the social communication system, since they are different systems of reference. The various systems interact in the communication. Furthermore,

more than one structurally coupled interaction is involved. The first is an interaction between the sending system and the transmitting system, but since this involves the operation of the social communication system, subsequent reception of the message can occur at other ends. (The question of how to delineate the addressees of the communication is technically a different one.)

The crucial point is that in Luhmann's theory the social system does not include the actors, but actors and social (communication) systems exchange information through interpenetration, i.e., by means of action. The social system then has its own dynamics. In reaction to this redefinition of "interpenetration," others (e.g., Muench 1982/1988) have emphasized with reference to Weber's sociology of religion that "interpenetration" refers primarily to the interpenetration of subsystems among one another (e.g., to the interpenetration of cultural meaning and power in society), and with the social system at large, since particularly this type of interpenetration should be considered as constitutive for Western modernity.[7]

Relations among subsystems (e.g., the social system and culture) are not structurally coupled, but structural: the subsystems are expected to be contained within a system. Coupling therefore is of another nature: subsystems are operationally coupled. Operationally coupled subsystems are expected to update in relation to one another if this is functional for the system that contains them. However, in this tradition, the social system is defined as the Parsonian action system, and thus the social system operates by actors taking action. If one additionally accepts Luhmann's distinction between actors and the social communication system, action is in itself already a form of interpenetration. If in action the subsystems of the social system have additionally to be coupled, the two subsystems have to be made relevant for one another in the same action. Thus, the communication is internally differentiated, in addition to being a communication in the two structurally coupled systems; it integrates the specified internal dimensions of the relevant subsystems operationally, and the two systems that are coupled structurally. Note that the two systems (i.e., the social and the psychological one) may internally process the two dimensions in this communication differently. (The next question is whether the two meanings for the actor involved may again be reflexively combined into one.) A single two-dimensional information content of a message can be decomposed in various ways (see Theil, 1972; Leydesdorff, 1991b).

If we add subsequently the time dimension to this complex, different frequencies may be involved for the self-referential update within each subsystem. Remember that the social system cannot operate except by action at local nodes. However, not all actors can be involved in each update. In other words, the systems may update with a spectrum of different frequencies. For example, relatively small economic transactions can have a cumulative impact on change in political power-relations, but the latter may go (temporarily) unnoticed for some of the actors involved. On this occasion, the actors coupled structurally with the communication system by acting, but their actions failed to couple operationally.

The Re-Entry of Time into the Theoretical Representation

Obviously, if one uses interpenetration to refer to specific relations between subsystems of the social system (Muench 1982/1988), this frame of reference is different from

Luhmann's, who used the same concept for the relations between the social system and actors. Both concepts are derived from Parsonian theory. However, Parsons' theory—using a more traditional format derived from evolution theory—abstracted from the contingency and asynchronicity of individual actions, which were then analyzed as specific instances of a single cybernetics with an unequivocal time dimension.[8] In this sense, his systems theory was grandiose architecture.

The difference between the concepts of interpenetration among, on the one hand, social subsystems, and on the other hand, between the social system (and its subsystems) and actors, can be given an unambiguous interpretation by a more abstract specification of the difference in mechanism between operational and structural coupling as processes. In the simulation, one can even specify the (limiting) conditions under which one would not be able to distinguish the two mechanisms in terms of the resulting phenomena.

In the abstract, bringing the two concepts again under one denominator is no problem. Conceptually, one then refers to a general system that includes both actors, on the one hand, and society and its subsystems, on the other. In this case, however, one first has to specify how these different subsystems of the general system interact among one another, and this leads to the same results, although they are more difficult to intuitively understand, since the system of reference has been complicated. Some systems—but not necessarily all to the same degree—are again composites of subsystems. Without a precise specification of the levels in this hierarchy, one may acquire a feeling of understanding the mechanism by using a single word (e.g., "interpenetration"), but at the price of losing the empirical reference of the hypothesis. Consequently, the theoretical description may degenerate into a metaphorical narrative.

The problem of having to specify operations differently with reference to a system than with reference to its subsystem or its super-system has been signalled in the discursive tradition, but it has not been sufficiently appreciated. For example, Teubner (1987) made an impressive attempt to distinguish, in addition to operating cycles of self-organizing systems, "hypercycles" and "ultracycles." However, even he will run out of terms with increasing complexity. Mathematics are not a tool, but a discourse that enables us to address more complex questions, to distinguish various meanings, and if necessary to label them with words. For example, given the noted differences in the coupling mechanisms, we can reasonably use two different words for the two different concepts covered by the original concept of "interpenetration," and not add to the confusion by proliferating discourse with respect to the single traditional term.

In other cases, one has to use Occam's razor to reduce different words to their single underlying concept. Sometimes, different contexts of similar words indicate a different semantics. This may be useful for theoretical purposes, but not necessarily in methodological terms. For example, in symbolic interactionism, "communication" and "interaction" are made central categories, but semantics other than systems and information are attached to these concepts. In this tradition, central questions concern how meaning can be attributed to, and also used for, the construction of identity. These are dynamic questions, in the sense that they require a series of operations, whereas the various processes of "interpenetration" in the above discussion can in principle be studied at one moment in time. Thus, in symbolic interactionism, differences in time spans, differences in time horizons, and various forms of communication of time are made central, whereas from other (e.g., systems) perspectives the focus has been on the variety of meanings of a given act as an event.

Both in the time dimension, and in the (analytically discrete) multidimensional construct, sociological theories have hitherto made theoretical selections. However, the combination of selections in the variances in the multi-dimensional construct and in the time dimension is crucial to the theory of self-organization. The system can be organized both in the multi-dimensional instance and along the time dimension, but only the operation of these two selections one upon another can provide us with stabilization. Focus either on systems- or historical-reconstruction is not sufficient; we need both.

The specification of how systems and subsystems communicate, how their coupling can be structurally different, and how this complex varies over time would provide us with both the conceptual apparatus to profit from the various theoretical specifications and with an escape from scholastic debates about the assumptions underlying them. Such a specification requires algebra, since spatial representations provide us either with static pictures of the multi-variate complex (like snapshots) or they depict the trajectory of a system using a geometrical metaphor (see Shinn, 1987; Haraway, 1988). One cannot represent change in the data and in the relevant dimensions for organizing the data without changing one's reflexive position, and this leads to confusion unless the representation itself can be made dynamic (as in a movie). The use of algebra enables us to reintroduce the time dimension in the representation by specifying observables in relation to fluxes. Algorithms can be used for coding computer simulations; the theoretical assumptions underlying different hypotheses can then be programmed as conditions that reduce the complexity in the expectation.

At the theoretical level, Giddens (1979) introduced the concept of a "duality of structure" to surmount the deep division between systems theoretical and situational approaches in sociology (cf. Giddens, 1981). The "instantiation" is considered as both conditioned ex ante, and reshaping ex post facto an otherwise "virtual" structure. However, Giddens (1984) eventually left the reflexive analyst the task of relating the two sides of structure, and therewith reduced the duality of structure to the question of how to handle this complexity in the discursive interpretation. Structure, however, is dual—or perhaps of higher order—because it operates as a flux that an analyst can perceive only in terms of instantiations through reflexive deconstruction and reconstruction. As soon as more than one flux is involved, we have difficultly conceptualizing the interactions and co-evolution among the systems without the use of algebra. The price we may have to pay for the algorithmic approach is a sacrifice in terms of common sense language. One can always explicate the results at length for the interpretation, but the discursive reconstruction in "natural" language has a heuristic function only for the further development of theory; it cannot warrant the inferences.

In summary, I have argued that some dichotomies both in theorizing and in methodologies of the social sciences point to underlying problems that cannot be resolved without the theory of self-organization. The study of "order out of chaos" requires the specification of algorithms for computer simulations. Previous theories can with hindsight be understood as provisional and often programmatic solutions for problems unsolvable at the time. Given these historical contexts, important problems could be addressed—for which nowadays, however, new problem formulations can be proposed, since the implied assumptions can be clarified as conditions, and then be reflexively communicated, for example, as code.

Conclusion

The original research question of this study (whether society should be considered as a self-organizing system) has led me to the specification of what reflexivity means for the social system as a system of reference different from the individual subjects who may participate in it. I used the notion of "paradigm" as the anomaly, and the sociology of scientific knowledge as a model system for the distinction between substantive and reflexive discourses. Like the dissolution of the originally monolithic concept of paradigm into the study of relations and life-cycles of discourses, the social system also has to be analyzed in terms of various subsystems that may couple in action at local nodes. As far as each network is self-organizing, it escapes temporarily from chaos, since self-organization means the ability systematically to learn, i.e., to incorporate the uncertainty of the communication into the system.

Self-organization, however, requires reflexivity, and thus differentiation between the instance of reflection and the reflected substance (see Maturana, 1978). It is therefore an evolutionary achievement: the temporarily stabilized substance is constructed, and the latter's reflection is correspondingly in flux. None of the sub-cybernetics can be taken for granted; they rather need to be explained. The explanation has to be theoretically guided by the hypothesis of self-organization, specified and elaborated for the system(s) of communication under study, and methodologically warranted by a mathematical theory.

Fortunately, Shannon's (1948) mathematical theory of communication is available. However, since this theory uses the notion of (probabilistic) entropy, its results have often been given a physical (i.e., thermodynamic) interpretation. As argued, we need a mathematical (i.e., probabilistic) non-physical interpretation of the concept of self-organization, although we share with non-equilibrium thermodynamics a common interest in the emergence, stability, and evolution of highly unlikely configurations.

In summary, the reflexive analysis of the research question of this study enables me to specify the following analytical tasks:

1. Since we cannot take for granted that self-organizing social systems exist or endure, the mathematical theory of communication has to be extended beyond non-equilibrium thermodynamics to other systems that are not in equilibrium—without jumping to a physicochemical interpretation. For example, we must specify precisely what "self-organization" means in relation to weaker concepts like "self-referentiality" and the "Eigen-dynamics" of systems. Simulations are the principal method for mathematical specification. The results of simulations alert us that structural properties are always at variance, and therefore simulation helps to "de-reify" any structural interpretation (including the biological one).
2. A mathematical theory of communication is, however, by definition still void of empirical substance. The system of reference for the communication has thus to be additionally specified. Obviously, the thermodynamic system is a completely different system of reference from the social system. Analogously, the biological system is a different system of reference from the social system. Substantive knowledge about what the system communicates when it communicates, how it selects from these communications, and eventually how it may be able to stabilize not only structure but also under certain conditions how it tends to self-

organization over time, has to be elaborated in each special theory of communication with reference to the substance of this system. As noted, one is able to draw on writers in the sociological tradition for developing a special theory of communication for the social system. However, the concepts may have to be reorganized within the framework of a sociological theory of communication.

3. The reflexive nature of sociological theorizing challenged us to specify more consciously the meaning of "applying" the mathematical theory of communication to the social system as a special case. The natural sciences assumed variance in the data to be given by "nature," evolutionary biology assumed the selection environment to be "natural," and psychology shares with sociology a radical understanding of the reconstructive nature of knowledge, but sociology is able to understand itself reflexively as a specific social communication system (see Leydesdorff, 1992). (Aspects of linguistic philosophy, epistemology, and media theory also are able to "reflexively understand" themselves as communication systems—e.g., Russell's theory of logical types, news media creating news by their very coverage of events, etc.) This reflexivity with reference to the constructed system may provide us with a passage point for further clarifying the possibility of a more general theory of communication. The latter might encompass systems theory, evolution theory, and action theory. A crucial prerequisite for this development seems to be that the generating communication system, i.e., sociology, be developed reflexively with reference to the hypothesis of itself as a science, i.e., its evolutionary, and therefore formalizable, constructedness as a theoretical system.

Notes

1. The degree to which and the conditions under which the nervous system can be controlled reflexively by the brain implies the analysis of a next evolutionary variable.

2. Essentially, a similar reasoning can be projected onto the psychological (sub-)system (see Rumelhardt et al., 1986).

3. More generally, social structure can be considered a result of the operations and interactions of a (set of) stabilized self-organizing communication systems, including human actors.

4. At other places, Luhmann (1990) indicated that a more complex cybernetics would have to study those questions which he saw as beyond the scope of his qualitative articulation. E.g., on p. 340: "Die Ausdifferenzierung verändert auch das System der Gesellschaft, in dem sie stattfindet, und auch dies kann wiederum Thema der Wissenschaft werden. Das allerdings ist nur möglich, wenn man ein entsprechend komplexes systemtheoretisches Arrangement zugrudelegt."

5. "Institutionalization gives rise to a zone of interpenetration between the cultural and the social systems, the two components of which, though composed of parts of both systems, crosscut one another and constitute one subsystem. Thus, the parts of two interpenetrating systems are more intimately related to each other than the parts of the two primary systems which do not interpenetrate. For example, the moral-evaluative subsystem of the culture interpenetrates primarily with the fiduciary subsystem of the society. Interpenetration means that the cognate subsystems at each of the four-system levels constitute zones of 'overlap' and thus affect each other across these boundaries" (Parsons & Platt, 1973, p. 36).

6. "Whereas Freud, from a biological starting point, arrived at the recognition of the distinctive property of social systems, Durkheim began with the conviction that clear distinctions between social and personal systems are essential; in his famous phrase, society was a reality sui generis" (Parsons, 1968, p. 432). However, Parsons eventually considered society as a category sui generis, i.e., a dimension of the general system, and not as a different system. See also Jensen (1978) and Luhmann (1978a).

7. Muench (1988, p. 204); translated from Muench (1982, pp. 480f).

8. "The first implication is that an act is always a process in time. The time category is basic to the scheme" (Parsons, 1937, Vol. I, 1968, p. 45).

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