

**A SOCIOLOGICAL THEORY
OF COMMUNICATION**

**THE SELF-ORGANIZATION OF THE
KNOWLEDGE-BASED SOCIETY**

Loet Leydesdorff

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- Chapter One: 'Is Society a Self-Organizing System?' *Journal for Social and Evolutionary Systems* 16 (1993) 331-49.
- Chapter Two: 'Luhmann, Habermas, and the Theory of Communication,' *Systems Research and Behavioral Science* 17 (2000) 273-288.
- Chapter Three: 'The Evolution of Communication Systems,' *International Journal of Systems Research and Information Science* 6 (1994) 219-30.
- Chapter Four: 'The Non-linear Dynamics of Sociological Reflections,' *International Sociology* 12 (1997) 25-45.
- Chapter Five: "'Structure"/"Action" Contingencies and the Model of Parallel Distributed Processing,' *Journal for the Theory of Social Behaviour* 23 (1993) 47-77.
- Chapter Six: 'Are EU Networks Anticipatory Systems? An empirical and analytical approach,' pp. 171-181 in: Daniel M. Dubois (Ed.), *Computing Anticipatory Systems -- CASYS'99*. Woodbury, NY: American Physics Institute, 2000.
- Chapter Seven: 'The New Communication Regime of University-Industry-Government Relations,' in: (with Henry Etzkowitz, Eds.), *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations* (London: Cassell, 1997), pp. 106-17; 'Theories of Citation?' *Scientometrics* 43 (1998) 5-25.
- Chapter Eight: 'Sustainable Technological Developments and Second-Order Cybernetics,' *Technology Analysis & Strategic Management* 9 (1997, no. 3) 329-41.
- Chapter Nine: 'Uncertainty and the Communication of Time,' *Systems Research* 11 (1994) 31-51; 'The Complex Dynamics of Scientific Communication,' pp. 163-179 in: Colin B. Grant and Donal McLaughlin (eds.), *Language-Meaning-Social Construction: Interdisciplinary Studies* (Amsterdam/New York: Rodopi, 2001).
- Chapter Ten: 'The 'Post-Institutional' Perspective: Society as an emerging system with dynamically changing boundaries,' *Soziale Systeme* 3 (1997), 361-78.

Chapter One

Introduction

Can society be considered as a self-organizing (*autopoietic*) system? If so, what are the implications of this approach for sociological theory? If social systems can 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, human agency. In modern times, we no longer assume that gods and demigods control our history.

Notions of systems which organize the social process autonomously have been around 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. Ever since Weber, sociologists have attempted to explain social structure and change on the basis of a theory of action (cf., Giddens, 1979; Münch, 1982/1988). The idea of a supra-individual social system which 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 from the study of socially organized cognitive activities like the sciences (e.g., Knorr-Cetina and Cicourel, 1981). Kuhn (1962) proposed understanding the development of the sciences in terms of *paradigms*. He described paradigms as historically emerging from crises in communication. Upon its establishment a paradigm begins to organize a science both

in terms of relevant communications and cognitions, and in terms of underlying communities. Actually, the paradigm seems to trigger a process of co-evolution involving the cognitive science system, the relevant discourse, and the community. Increasingly, scientists working within a specialty have to give way to the further development of the paradigm, at the price of losing their tickets. Eventually, paradigms may fall back into crisis and disintegrate when they lose the competition with alternative paradigms at the supra-individual level.

The concept of paradigms provided the sociology of science—and other fields (cf., Prigogine and Stengers, 1979/1984; Dosi, 1982; Luhmann, 1990a)—with a heuristic model for understanding self-organizing 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 it possible to specify the conditions for a supra-individual system to behave in this ‘self-organizing’ way?

1.1 ‘SELF-ORGANIZATION’

Let me begin by offering the reader an illustration of a self-organizing system by using the example of human beings as (biologically and psychologically) self-organizing systems. Then, I extend this approach to social systems, specifying how social systems differ from biological and psychological systems, and elaborate this specification for the sociology of science. In a further section, the argument is elaborated to general sociology, and I will indicate why it is necessary to proceed to mathematical specification. In other words, I shall specify more generally the conditions 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, that is, in social systems.

The human operating system itself determines what people can eat, what people can see, and how people can communicate with others or oneself. 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 other processing. 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 which does not have a specific function, although all cells may contain all genetic information. The cells are organized in communication networks which self-organize their function for the system as a whole, in the very act of operating (cf. Kauffman, 1993). 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, each organ is stabilized against minor lesions, that is, the operation is self-reproductive in terms of its function for a next-order system. However, this 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; that is, the operation of the system needs dynamic control by the neural network as another functionally differentiated system as soon as the complexity surpasses certain thresholds. The crucial point is that the system is healthy as long as it communicates what it is supposed to communicate, as long as its 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.

Such a self-organizing system develops and exhibits a 'life-'cycle. Although it is easy to grasp intuitively the notion of self-organization for a single living system, it is much harder to do so for

systems above the individual level.¹ The obvious examples of supra-individual organization are insects like ants and wasps, which live in communities. However theoretically and methodologically fruitful it may be to study social relations with these biological metaphors, serious questions should be raised at the inference. Firstly, the biological metaphor of ‘survival of the fittest’ is uncomfortable for the analysis of social phenomena, since it has been terribly abused, for example, in corporatist and fascists ideologies. Secondly, it is not incidental that the autonomous momentum of the human will is central to the theory of action which has provided a common basis for sociological theory and research since Weber. Human beings are different from insects in important respects; social organizations are more complex than organisms and/or populations of insects.

What does it mean when these evolutionary models are applied to social systems? Which concepts have to be changed 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 phenomena under study. Whether this view can be considered as provisionally true given the data at hand can only be assessed 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*, however, has provided us with an analytical means of organizing these taxonomies according to a logic. For example, on this basis one is able to specify ‘missing links’ in taxonomic data. A concept like ‘missing link’ is meaningful only for those who have made the inference that there is an evolving system which can be traced in the observable phenomena.

¹ Essentially, a reasoning similar to the biological one can be projected onto the psychological level (Rumelhardt *et al.*, 1986).

Evolution theory places the phenomena in a perspective, and therefore evolution is a concept with a theoretical status. The assumption of evolution helps us organize the data. 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 respect to social dynamics, one does not expect a single hypothesis, but a range of possible hypotheses.

In sociology, these hypotheses have also been called reconstructions. A reconstruction is a line which the analyst draws through the data in order to organize the variation over time. The reconstruction operates with hindsight, and is consequently a specific (theoretical) selection with reference to what actually happened. The specificity of the selection can initially be attributed to the observer/analyst or the author of the description, respectively.

How can one reconstruction be justified in a scientific discourse 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 reflection (that is, reconstruction) can be assessed in terms of whether and how it contributes to each of the previously hypothesized possibilities for identity. If so, the emerging identities begin to stabilize as a yardstick measure. And if they prove to be functional for furthering the communication, they may begin to take over control-functions in justifying 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 by Kuhn (1962) ‘a paradigm.’ Kuhn 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.²

In concrete cases, more than one pronounced core of communication among scholars may emerge. In the sociology of scientific knowledge, these systems of communication have also been called ‘discourses’ (e.g., Mulkay *et al.*, 1983). Differences in communications within and among various research communities can be studied empirically in terms of the variation in their ‘discourses,’ for example, by analyzing repertoires and vocabularies (Hesse, 1980; Law & Lodge, 1984; Leydesdorff, 1995a and 1997). But the boundaries of social communication systems are uncertain, and social communication is failure-prone. Therefore, communication *patterns* remain uncertain, that is, with the epistemological status of a hypothesis guiding the historically contingent observations.

Thus, by taking the example of theoretical reconstructions 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 its occurrence

² I shall argue (in Chapter Five) that social structure can be considered a result of the operations and interactions of a (set of) self-organizing communication systems, including human actors.

on social developments. Let me repeat the argument more systematically. First, self-organization requires in addition to variation and primary selection (that is, reconstruction) a second-order cybernetics which implies the time dimension. At each moment in time various reconstructions are expected to 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. The reflexive comparison requires that the reconstruction can be stored using a memory function. Since the social communication system cannot carry out these functions—since it is not itself an actor with an active (operational) memory function—the 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 variation 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 it is for modern science historically to have occurred. 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.

In general, the assumption of a feedback—or a coevolution—between the selecting macro-system and the micro-variation potentially closes the evolutionary system in a self-referential loop (Maturana, 1978). The two layers select upon each other, and they generate the variation for each other. Consequently, the category which was specified as the selecting instance at one moment may have to be respecified as generating variation at a next moment, and *vice versa*. ‘Selection’ and ‘variation’ can then be considered as sub-dynamics of this ‘mutual shaping’ or coevolution.

Thus, the differentiation of scientific communication in terms of substantive theorizing and reflexive control potentially self-organizes the scientific paradigm. As we have seen, 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 a result of their interactions. The substance is reflected in the scientific discourse, for example, on the basis of methodological standards. The participants 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 variation, and in terms of relevant selections. The stabilized system operates on the basis of the reflexivity which is physically located in the heads of its participants, but which is shared among them in a reflexive communication system. When either the reflexivity, the sharing, or the underlying communication process breaks down, the system breaks down, and the self-organization of the communication gives way to crisis.

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 continuously has to rewrite its own history. Note the centrality of the reflexivity. Reflexivity at the lower level is a

condition for self-organization at the higher level: by adjusting the available variation reflexively, the constructed system can grasp the possibility to combine its structure with the time dimension and thereby reshape its identity. To the extent that it does so, the control of the communication flip-flops, and the dependency relations among the levels are (partially) reversed. However, the reflexivity of the social communication remains dependent upon the reflexivity of those units which bear the system, *and* on the extent to which the units bring the reflexive dimension into communication within this social system. All arrows represent subcybernetics of the dynamic (super-)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 communicate reflexively, the social system can begin to learn as a distributed network, and therefore perform more complex tasks than each individual system (Simon, 1973a and b). The individual actor is not only related to the network, but also positioned within it, and is reflexively aware of this function. 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 this dual-layered system in the time dimension remains dependent upon the reaction times of the composing units: the social system offers only chances; it does not possess living 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 which 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 reflexively constituted as described above, these systems can (temporarily)

maintain certain functions despite disturbances, that is, they are able to select among the lower-level communications with reference to a higher-order function which is latent to 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 communicate also 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 kept more fluid.

We have developed the notion of reflection at the level of the social system with reference to scientific (that is, theoretical) systems. However, one should be aware that 'reflexivity' can be defined in other dimensions. For example, one can not only reflect cognitively upon one's thoughts, but also feel that one feels, love that one loves, laugh about laughing, etc. (Luhmann, 1984). In general, *reflexivity is the operative capacity of a communication system to apply recursively 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 that if we reflect cognitively upon our feelings, then this is not a recursive application of the specific communication, but reflection of the one kind of communication in terms of the other. The feelings are then the substantive variation, and the reflection only a first-order selection. This reflection provides a horizontal coupling instead of a vertical one. Stabilization and globalization, however, require the feedback of higher-order codifications in the communication.

1.2 SELF-ORGANIZATION REMAINS A HYPOTHESIS

As noted, Kuhn's *empirical* (since historical) hypothesis of a 'paradigm' posed an anomaly to the dominant mode of sociological theorizing, which aimed primarily to explain supra-individual phenomena with reference to human agency. For the substantive understanding of self-organization we have first had to capture reflexively the meaning of this anomaly before we can generalize to other sociological phenomena (e.g., family, organization, etc.). 'Self-organization' was introduced above as a hypothesis for explaining this anomaly.

The idea that systems may exist on the basis of interaction *among* units which can empirically be observed independently is more common to sciences like evolutionary biology and cognitive psychology. However, the hypothesized *interaction* systems are not only distributed, but their very existence and identity also remain questions. While in biology and psychology the existence of the subject of study as a system may be taken for granted, sociologists must 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 secondly, one has to specify the relations between this 'systemness' (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?

Would the duality in the hypotheses make the thesis eventually 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). This reflexive analysis has taught us, among other things, that one can no longer accept any transcendental warrant for knowledge; all human knowledge is contingently constructed and continuously reconstructed.

Scientists—including the reflexive analyst him/herself—have to weave a discursive or ‘semiotic’ network. My argument has, however, been that this network is constructed in analytically distinct layers. The reflexive discourse is both substantive and reflexive with respect to the discourse which is reflected, and therefore it adds another dimension to the communication. A crucial question is then whether the reflexive discourse can develop as paradigmatically as the substantive one that is reflected. Under which conditions can it develop into a network which can ‘learn’? If so, with reference to which order? Can communications among reflexive analysts provisionally establish a reflexive order in the communication system which helps to organize the communications to such an extent that in the limiting case the reflexive layer controls the substantive communication? Can this extent be investigated empirically?

In summary, the apparent 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 (Luhmann, 1990a; cf. Woolgar, 1988; Krohn *et al.*, 1990). Note that a radically constructivist epistemology is implied: 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 in principle remains falsifiable.

1.3 A HYPOTHESIS REFERS TO A THEORY

Kuhn (1962) also 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 (e.g., Pinch, 1982). These discourses may evolve, may further differentiate and interact, or may go into crisis. Whatever happens is historically contingent: it is constructed, and can therefore be reconstructed by the historian, the philosopher, or the sociologist.

The reconstruction is always 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, but that 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, but it 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.

The application of the theory of ‘self-organization’ to the social domain raises the question of the contingency of this theory as yet another *paradigm* in science. If paradigms are specific with respect to the communications which they allow, one might well ask what is gained or lost by using this hypothesis instead of, for example, the assumption of the social constructedness of the sciences (e.g., Barnes, 1974; Latour, 1987)?

If one considers the multitude of reconstructions as another empirical domain, one can only make empirical inferences with reference to this domain by specifying another hypothesis. The hypothesis should be empirical, that is, 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. The question of significance, however, brings the methodological issues that were so heavily criticized by post-modernists back on stage, yet at the reflexive level. Methodology is then not a textbook recipe, but a reflexive theory about the quality of inferences concerning the phenomena under study.

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 one has to develop a theory of scientific communications. The notion of a paradigm 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 does not need to explain that the discourse is chaotic, since that is the default. What needs explanation is only that scientists can communicate despite their sometimes esoteric jargon and the unrealistic ('counterfactual') assumptions about the 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 the hypothesis is the degree to which the variation in the theoretical selections under study can be explained by assuming a *second-order* selector—that first itself remains to be hypothesized.

Note that any self-organizing order at the level of the social system has to be a reflexive order: one can only observe the distributions which necessarily contain an uncertainty. Self-organizing social systems of communication remain hypothetical constructs for the sole purpose of serving the process of scientific discovery that is

itself theoretically guided. 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 formulate only hypotheses. Here, I distance myself from Luhmann’s (1984 and 1997a) 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? It is not difficult to specify some heuristics for a special theory of communication, already 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, that is, differentiated into subnetworks.) The next issue is the specification of the *mechanisms* of communication within each of the specified (sub)systems, and of *how* these may interact, that is, 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. Only on the basis of such reconstructions can one raise the question of *when and why* ‘incommensurability’ occurred. 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. However, the various theoretical reconstructions can be examined in terms of whether, how, and to what extent the expected phenomena actually occurred.

The question of ‘why’ requires a reflexive hypothesis. Reflexive analysis can illuminate the ‘why’ of the reconstructed developments

because the hypothesis provides the analyst with an additional degree of freedom for making selections in the time-dimension: the range of possible selections can be specified. At this stage, one is no longer merely describing the paradigms as (hypothetical) self-organizing systems, but one can begin to develop a sociological theory of scientific communication.

Scientific communications require 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' (Popper, 1935). In my opinion, stabilization does not imply transcendence into an idealistic World Three (Popper, 1972), but first stabilization and then globalization as a next-order selection. The theoretical system, however, remains as contingent as the systems about which it theorizes.

The assumption of the self-cleaning potential of a self-organizing supra-individual system does not preclude that a self-organizing system can come into crisis, and contingently disappear. 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 may increase dramatically. The reconstructive analyst of the discourses risks losing track if this chaos can no longer be interpreted as a contingent pathway of the self-organization of the (hypothesized!) system involved.

Thus, *chaos and confusion is no longer 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 can then eventually be only that 'reality' is always more complex than any model. One has to reverse this reasoning: all complexity is contingently contained within communication systems. 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 (for example, by introducing metaphysical notions like Popper's World Three).

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 a hypothesis (based on previous reconstructions) with reference to the system under study. The hypothesis organizes the uncertainty within the theoretical analysis, that is, self-referentially. If it holds, the theory gains in self-organizing identity. If not, it eventually vanishes, that is, it has to give way to another self-organization of the chaos.

1.4 THE 'SELF-ORGANIZATION' PARADIGM IN SOCIOLOGY

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.

The program of study is 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. I wish to argue that the hypothesis of self-organization in communication networks provides us with a reflexive heuristics for (re-)organizing social scientific discourses. Given the methodological objectives, my thesis implies a negative philosophy of science—negative in the sense that is *not* a philosophical but a scientific research program, i.e., a heuristics for empirical research. Scientific communications and their developments, for example, can

be *empirically* assessed from this perspective (e.g., Leydesdorff, 1995a).

Let us begin this enterprise by analyzing sociological theory itself as a potentially reflexive scientific communication system. It is common to state that this system is in deep crisis (e.g., Gouldner, 1970). As noted, we shall henceforth accept crisis as the common state of affairs. The theory of self-organization teaches us that lower-level variation has to take place in history 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 specific 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 possess the theoretical apparatus to understand one's position reflexively. Both theoretically (with reference to the substantive phenomena under study) and meta-theoretically (with reference to the theoretical apparatus) one lacked the semantics for specifying non-reified (that is, hypothetical) supra-individual systems. Therefore, one eventually either had to reify systems meta-theoretically (e.g., the *Capital* or 'cybernetic control') or to reify the phenomena as naturalistically given data or discourses (Mulkay *et al.*, 1983).

On the basis of the hypothesis of self-organization, one is able to appreciate 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 levels: the phenomena are selected with reference to a theoretical understanding, and the implied meta-theoretical system should be considered only as a paradigm. I shall show the theoretical

fruitfulness of this hypothesis in the following chapters of this study, and I shall focus on the epistemological status of my argument in the remainder of this chapter.

The self-organization paradigm in sociology was formulated in 1984 by Niklas Luhmann. Luhmann has made the theory of self-organization into the cornerstone of his work. The classical questions in theoretical sociology were reformulated on this basis (Luhmann, 1984; see also: Luhmann, 1990a). Among the classical sociological questions are those of the relations between individuals and society (e.g., Hobbes, 1651), the relations between subsystems of society and the general system (e.g., the relations between politics and economics; Marx, 1857), and the relations between stratification and functional differentiation (Parsons, 1951).

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 which represent the human beings who carry it. At the nodes, each human actor performs its 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 which is communicated in the network. The social communication system is reproduced by this operation. Sociology has the task of specifying the dynamics of this network system in terms of, for example, functional differentiation, reflexivity, and self-organization.

Luhmann thus specified social communication as the proper domain of sociology, and *sociology as a special theory of communication*. Obviously, a major issue in relation to older sociologies is then 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 which are nowadays available. Although

his claims about social systems and their operations are sometimes amazingly precise, his semantics remained speculative.

For example, the notion of probability hardly plays a role in Luhmann's studies. The 'self-organization' of the social system is taken as a given, not explained as a hypothesis (Blauwhof, 1995, at pp. 154f.). Furthermore, Luhmann is consciously aware of the crucial function of stabilization in the time dimension, but he has never addressed the methodological problems when one studies variation in this dimension.

In his study of the science system, Luhmann (1990a, at pp. 405 ff.) suggested that scientific theorizing can gain sufficient degrees of freedom for self-organization precisely on the basis of a 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. 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, that is, with reference to what one might be able to learn from subsequent observations.³

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 (above), for example, to be more specific than previous authors about the conditions for 'self-organization'. As argued, the occurrence of this phenomenon cannot

³ At other places, Luhmann (1990a) indicated that a more complex cybernetics would have to study those questions which he considered beyond the scope of his qualitative articulation. E.g., at p. 340: 'The differentiation of society changes also the social system in which it occurs, and this can again be made the subject of scientific theorizing. However, this is only possible if an accordingly complex systems theoretical arrangement can be specified.' I return to this problem in the next chapters.

be taken for granted in social systems whose existence and delineation also 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. In particular, system-interdependencies and interference among systems can then be analyzed in more detail. Let me provide an example.

1.5 AN EXAMPLE: 'INTERPENETRATION'

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,⁴ and at other places more emphatically with reference to the ways in which the personality internalizes cultural and social objects.⁵

⁴ '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 and Platt, 1973, at p. 36).

⁵ '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, at p. 432). However, Parsons considered society as a *category sui generis*, that is, a dimension of the general system, and

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, at 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, however, reveal that the relations between the social system and the cultural system differ also in important respects 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' (that is, actors) as '*structurally coupled*:' the social communication system cannot operate without individuals who communicate, but only the message (that is, the action) and not the actor is communicated. In general, action is expected to have different meanings for the sending actor, for the receiving actor, *and* for the social communication system, since these are different systems of reference. As Luhmann noted, various systems interact in the communication. Luhmann, however, proposed to define

not as a different system. See also: Jensen, 1978; Luhmann, 1978a.

communication in terms of the *unity* of sending information, message, and understanding.

In my opinion, more than one structurally coupled interaction is involved in the reflexive understanding of a message containing information. The first is the interaction between the sending system and the transmitting system. Since this interaction 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 social system has its own dynamics: it operates by redistributing opportunities for action at local nodes. Reception at different nodes (and thereafter potentially ‘understanding’) can be distributed differently from these opportunities, and this difference matters for the further development of the social system since it changes the distribution of a next round of actions and/or communications.

If the social system is defined as the network of links which does not include the actors at the nodes but only their actions (in a distributed mode), actors and social (communication) systems exchange information through interpenetration, that is, by means of action. In reaction to this (that is, Luhmann’s) definition of ‘interpenetration,’ others (e.g., Münch, 1982/1988) have emphasized—with reference to Weber’s sociology of religion—that ‘interpenetration’ refers primarily to the interpenetration of social subsystems among one another (for example, 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.⁶

In contrast to ‘structural coupling’ between actors and communication systems, however, relations among social subsystems (e.g., the economy and science) are *operational*. Subsystems are not structurally coupled, but *a structural part* of the

⁶ Münch (1988), at p. 204; translated from Münch (1982), at pp. 480f.

system: the subsystems are expected to be contained *within* a system. Coupling therefore is of another nature. *Operationally coupled* subsystems are expected to update in relation to one another if this is functional for the system which contains them.

In this sociological tradition, the social system has been defined as the Parsonian action system, and thus the social system operates by actors taking action. If one accepts, however, Luhmann's additional distinction between actors and the social communication system, action is in itself already a form of interpenetration, notably the *structural* coupling between the actor taking action and the communication network system in which the action can be considered as a communication. If the subsystems of the social system have additionally to be operationally coupled, the two subsystems have to be made relevant for one another in this 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 which are coupled structurally. Note that the two systems (that is, the social and the psychological one) may internally process (that is, decompose) the two dimensions in this communication differently. (A next question is whether the two meanings for the actor involved can again be reflexively recombined into one.) A single two-dimensional information content of a message can be decomposed in various ways (cf. Theil, 1972; Leydesdorff, 1991a).

For example, the specific function of scientific communications for social communication at large makes the problem of 'science and society' so difficult to understand. The 'socio-cognitive (inter-)actions' of the scientists under study operationally couple two communication systems (e.g., the 'social' group and their 'cognitive' field of science as a codified communication system). However, the social system cannot operate without actors doing so contingently, and thus the scientists involved are structurally

coupled to the socio-cognitive communication in both dimensions. Each 'interpenetration' has therefore at least four meanings: one has to *cross*table actor(s) and communication networks as systems of reference versus the dimensions of differentiation in order to explain the interaction as a result.

Thus, the student of issues of 'science and society' analyzes two problems at the same time, *viz.* the sociological question of the dynamic relations between individuals and society (social action and social structure), and the epistemological question about the relations between the knowing subject and the sciences as cognitive communication structures. 'Socio-cognitive' communications contain both substance and reflexivity, and thus the observed data can be attributed to more than one dimension of the differentiated system. Consequently, there is reconstructive flexibility in the attribution of action over the social and the cognitive contexts (Hesse, 1980).

Additionally, the update frequencies in the time dimension can be specified. Both the research groups and the scientific fields are part of the larger social system. In a hyper-cycle the various cycles, that is, the one of the individual and society, and the other of the knowing subject and scientific truth, can be integrated into one (super-)system, but with potentially different frequencies. The (sub-)systems constitute at a next-higher level the units for a second-order cybernetics which reproduces their differentiation, and thereby also secures the integrity of the lower-level units (Maturana & Varela, 1980; cf. Simon, 1973a).

Different frequencies are expected 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 have coupled structurally with the communication system by acting, but their actions failed to couple operationally.

1.6 THE RE-ENTRY OF TIME INTO THE REPRESENTATION

Obviously, if one uses ‘interpenetration’ to refer to specific relations between *subsystems* of the social system (Münch, 1982/1988), this frame of reference is different from Luhmann’s, who used the same concept for 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.⁷ 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, between the social system (and its subsystems) and actors, could be given an interpretation above by a more abstract specification of the difference in mechanism between operational and structural coupling as processes. Using simulations, one can specify the (limiting) conditions under which one would not be able to distinguish observationally the two mechanisms in terms of the resulting phenomena. In terms of the abstract mathematics of systems theory, it is also not difficult to bring the two concepts of ‘interpenetration’ again under a single denominator.

Conceptually, one then refers to a *general* system which includes both actors (as subsystems), on the one hand, and society and its subsystems, on the other. In this case, however, one has first to specify how these different subsystems of the general system

⁷ ‘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, at p. 45.])

interact among one other, and this leads to the same results, although the terminology of subsystems, systems, and supersystems may become more difficult for the intuitive understanding, since the system of reference has been complicated.

Without a precise specification of the levels in the 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. Some systems—but not necessarily all to the same degree—are again composites of subsystems.

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 signaled 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 may run out of terms with increasing complexity.

The mathematics and the methodological rigour of systems theory are not a tool, but a discourse which enables us to address more complex questions, to distinguish various meanings, and if necessary to label them parsimoniously with words. For example, given the noted differences in the coupling mechanisms, it makes sense to use two different words—‘structural’ and ‘operational coupling’—for the two different concepts which are covered by the original concept of ‘interpenetration,’ and not to add to the confusion by proliferating discourse with respect to the single 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 other semantics are attached to these concepts than systems and information. In this tradition central questions concern how *meaning* can be attributed, and used for the construction of identity. These are dynamic questions, in the sense that they require a series of operations, while the various processes of ‘interpenetration’ in the above discussion can in principle be studied at a single 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, while 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 multidimensional construct at each moment in time, sociological theories have hitherto made specific selections. However, the *combination* of selections in the multi-dimensional variation 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 reflexive operation of these two selections upon one another—that is, reorganization—can provide us with stabilization and globalization. A focus on either systems or historical reconstruction is not sufficient; one needs both.

Spatial representations provide us either with static pictures of the multi-variate complex (like snapshots) or they depict the historical trajectory of a system using a geometrical metaphor (e.g., 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 specification of how systems and subsystems communicate, how their coupling can be structurally different, and how this complex varies over time, requires a calculus (Bar-Hillel, 1955). The use of algebra enables us to reintroduce the time dimension into 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) has been the first to consider society itself (and not only action) as an operation. He introduced the concept of a ‘duality of structure.’ The ‘instantiation’ is then considered both as conditioned *ex ante*, and as reshaping *ex post facto* an otherwise ‘virtual’ structure. However, Giddens (1984) eventually left it to the reflexive analyst to relate 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 a higher order (Leydesdorff, 1995c)—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 difficulty conceptualizing the interactions and co-evolution among the systems without the use of algebra. The algorithmic specification may 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. The price we pay for the algorithmic approach is a sacrifice in terms of common-sense language. However, one can always explicate the results at length for the interpretation. The discursive reconstruction in ‘natural’ language has an heuristic function for the further development of theory, but each reconstruction implies a perspective, and it cannot itself warrant inferences about the significance of the approach.

In summary, I have argued that some dichotomies both in theorizing and in methodologies of the social sciences point to underlying problems which may be resolved with 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 new problem formulations can be proposed, since the implied assumptions can be clarified as conditions, and can then be communicated reflexively, for example, in terms of computer code.

1.7 THE PROGRAM OF STUDIES

The question of whether society should be considered as a self-organizing system has led me in this introductory chapter 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 an 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 can also be analyzed in terms of various network (sub)systems which may couple in action at local nodes. To the extent that each network is self-organizing, it escapes temporarily from chaos, since self-organization means the ability to learn systematically, that is, to counteract upon the uncertainty of the communication within the system by using another subdynamics.

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

Shannon's (1948) mathematical theory of communication provides us with an information calculus (Theil, 1972). 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), but a 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 (Leydesdorff, 1995a).

A mathematical theory of communication is by definition void of empirical substance. *The system of reference for the communication has thus to be additionally specified.* Obviously, the thermodynamic system of reference is completely different from the social system. Analogously, the biological system of reference is different from the social system. Substantive knowledge about what the system communicates when it communicates, how it selects from these communications and eventually may be able to stabilize not only structure, but also under certain conditions tends to self-organization at the global level, has to be elaborated in each special theory of communication with reference to the substance of the system under study. For example, one is able to draw on writers in the sociological tradition to develop a special theory of communication for the social system. However, the various concepts will have to be reorganized within the framework of a sociological theory of communication.

Since one 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 which are not in equilibrium, that is, without jumping to a physico-chemical interpretation. For example, we must specify in these other contexts what 'self-organization' means in relation to weaker concepts like 'self-referentiality' along a trajectory and the 'eigen-dynamics' of observable systems.

In summary, the reflexive nature of sociological theorizing challenges us to specify more consciously what it means to ‘apply’ the mathematical theory of communication to the social system as a special case. The natural sciences assumed that variation in the data were 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. The sociological theory of communication, however, is able to understand itself reflexively as a specific communication system.