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MATERIAL SIGN PROCESSES AND EMERGENT ECOSOCIAL ORGANIZATION

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Downward causation and the levels paradigm

Complex, self-organizing systems have traditionally been analyzed in terms of a hierarchy of organizational scales or levels. The phenomenon of "downward causation" can be interpreted as the quasi-effect of higher-level emergent patterning on the dynamics of the lower-level constituents of a self-organizing system. But the significance of such an analysis depends on the assumption that the dynamical processes which constitute the system each operate at a single characteristic scale of space and time. I will call this the assumption of *scale homogeneity*, and I want to question its application to social, and more generally to social-ecological systems. I will propose that when relations of meaning as well as of material interaction co-determine the dynamics of a system, we must take into account *scale heterogeneity* or scale-mixing as well. If system processes at very different scales are tightly coupled with one another, we may need new paradigms for system analysis and a somewhat different interpretation of the meaning and significance of "downward causation".

I want first to summarize the hierarchical or 'levels' description of complex self-organizing systems which emerged in slightly different forms over several years' discussion between Stan Salthe and myself (cf. Lemke, 1984; 1995a, esp. chap. 2, 6, and the Postscript which updates Lemke, 1984). I will then consider the role of semiosis and human-scale, human-interest viewpoints in our description of systems at all levels. To provide an example, I will focus on the process of composition of a written text, and try to explicate the multiple relevant dynamical scales and the problem of modeling them in an integrated and comprehensible account which includes various forms of 'downward causation'. Finally, I will propose some alternative models and metaphors for describing complex social-semiotic ecologies.

Many classes of self-organizing systems can be construed as hierarchical (in the sense of Salthe, 1985, 1989, 1993), where the properties of constituents provide the conditions of possibility for the emergence of higher-level organization, and higher-level patterns represent the net constraints on constituent dynamics from the interactions of all constituents in a highly-coupled system. A radical alternative to the 'levels' approach, recently proposed by Latour (1993, 1996a, 1996b), considerably opens up the discussion, and I would like to sketch out the terms for a helpful synthesis of the two positions.

To anticipate briefly, Latour proposes that traditional systems theory has too narrowly assumed that each descriptive level must maintain a homogeneous dynamical (especially temporal-spatial) scale: that all interactions constituting the same 'level' or 'subsystem' have the same characteristic scale. He notes that many empirical investigations of human social systems, on the contrary, seem to suggest that scale-*heterogeneity* is the norm, and that isolating each scale on its own level makes the problem of integrating levels across scales artificially difficult. I believe that his notion of scale-heterogeneity addresses exactly the same issue as 'downward causation' but in a very different conceptual framework. In brief, I believe that his approach is more natural (but not always necessary) for systems significantly structured by the role of human semiosis and its material artifacts, whereas the 'levels' approach is more natural to elementary physical and chemical systems where scale-homogeneity is a better approximation. Organismic and ecological bio-systems fall somewhere in between, but all complex self-organizing systems which show emergent forms of order are ones for which adequate accounts must involve processes on significantly different dynamical scales. I would like to sketch our available options for performing this feat of analysis.

There is one further important point we must bear in mind in this inquiry. Emergent patterns of organization are identifiable only by privileging certain global system variables over others which *a priori* might equally well be used to describe the system (cf. Hasegawa, 1985). We construct variables which are relevant for our human purposes according to the cultural meaning formations in relation to which certain forms of patterning or order are salient for us. An analysis of the emergence of order in a complex system must always include the observers and their cultural criteria of meaningful patternedness as part of the system to be accounted for (cf. Bohr, 1934/61, 1958; and chapters by Finnemann, Voetmann, and Pattee in this volume). We therefore need a theory of self-organization in "ecosocial systems" (Lemke, 1994, 1995a), in which both material-interaction couplings and meaning-mediated interdependencies in the action of (human, and so also nonhuman) constituents are taken into account. The dynamics and development of ecosystems which contain humans who act according to cultural meaning criteria cannot be adequately described without a description of the meaning-systems in use and how they bias matter and energy flows in ways not predictable from regularities described solely in thermodynamic or biological terms.

These considerations will lead us specifically to the role of semiotic practices as material processes in a complex self-organizing social-ecological system, and, anticipating again, to an account of how typological-categorial distinctions, and the artifacts that mediate them, add new emergent properties to bio-thermodynamic systems which otherwise depend solely on quantitative or 'topologically' varying parameters. This account will be seen to fit very well with Latour's emphasis on the role of symbolic artifacts in the organization of human social interactions across dynamical scales. (For other examples of the complementarity of semiotic and material causation accounts, see Finnemann on artifacts and Pattee on DNA-mediated evolution in this volume.)

Hierarchical organization and emergent order

Let's begin with the 'hierarchical levels' account of self-organization, emergence, and downward causation. Very simply, every level of patterning or order in a complex system is seen as being characterized by units of analysis and their characteristic mutual interaction processes, each with characteristic spatial and temporal scales (within, say, the same order of magnitude) deriving from their dynamics. Taking one such level, L, as 'focal' or 'in focus' for analysis (the focus of our human concern, note for future reference), hierarchy theory proposes that two other levels are also relevant. One is the level immediately 'below' (smaller spatial, shorter dynamical time scales), L-1, where constituents of the units at level L interact with one another to produce these higher-level units. The properties of the L-1 units and their interactions provide the basis for the set of possibilities that may emerge at level L. Units at level L *are* self-organizing patterns of order on a larger spatial and longer time scale than what matters at level L-1. The classic examples are elementary particles interacting to form atoms, atoms to form molecules, molecules to form more complex structures ... on up through various higher levels of organization to cells, tissues, organs and organ systems, organisms, populations and ecosystems. This view presents the classic account of 'upward causation' and is the basis of the so-called 'reductionist program' in natural science: accounting for phenomena at any level by analyzing constituents and their interactions at lower levels.

Nonetheless, however neatly the 'upward causation' model fits with the general political and ideological program of modern Euro-cultural societies (i.e. individuals as more fundamental than communities), we all know that our individual behavior is still profoundly shaped, controlled, or limited in various ways by our interactions with other organisms on our own scale, and since each of these others is also similarly affected, we sum up our net mutual constraints by reference to larger-scale entities like the family, the community, the environment, society, culture, etc. In our scientific models of ecosystems we see again and again that the behavior of organisms and populations, however apparently free and independent when viewed at its own scale, nevertheless collectively repeats the same larger-scale ecological patterns and cycles.

Any entity's L-1 constituents allow it a certain range of possible behavior -- but most often we do not exercise this potential in a vacuum. We adapt to those other L-scale entities which impinge upon us, and they to still others, in ramifying chains of reaction that bind us together as communities, ecosystems, societies, cultures. As we all strive to adapt to one another, only some self-consistent collective patterns are possible for the whole swarm. They are the patterns of emergent order and organization at level L+1, and their effects on us are just as real and material as those rising 'upwards' within us from level L-1. The constraints of mutual interaction at level L, which are summarizable as the emergent patterns of level L+1, produce, when spoken of in the pervasive linguistic metaphors of agency (cf. Pattee, this volume), 'downward causation' effects on us at level L.

While our intuitions of such matters may be sharper for our own human scale, our scientific accounts of even the most elementary dynamical systems with multiple scales (thermodynamic systems, with a micro-scale and a macro-scale) now recognize that the collective order of molar scales (entropy) emerges from *correlations* that accumulate over time from even the random collisional dynamics of the molecular scale (Prigogine, 1980; Prigogine & Stengers, 1984). If I am being jostled closely in a large dense crowd, I can, intrinsically, move in any direction I choose, but if others around me are tending to move in one direction, then I am more likely to be pushed from behind than from this emerging common direction, and I am more likely to encounter an open space to move into in that same relative direction -- and so is everyone else. Locally we self-organize into a micro-convection current, or align ourselves in a local 'magnetic' domain. There may be, in randomly buffeted molecules, an equal probability for reversing any particular motion in isolation, but in the crowd we are not in isolation and the net emergent dynamics of the whole is irreversible and, locally at least, negentropic. Order forms because there are only relatively few solutions to the problem of correlated motions, and when contrasted with an ideal of randomness in which all possible states of motion are equally likely, those few solutions stand out as 'orderly'.

This 'levels' model is very elegant, and when combined with the mathematical formalisms of statistical mechanics, renormalization theory, or nonlinear dynamical analysis it enables us to account for the production of order from chaos, the amplification of signals over many dynamical scales, and the emergent attractors of the dynamics of complex systems as descriptions of pattern at higher levels. In most of the cases where such models are applied in physics, chemistry, and biology the assumptions of scale-homogeneity and clearly separable levels are well justified (see Voetmann, this volume). An excellent test of this is the observation by Salthe (1985: 136 seq.) that phenomena characteristic of level L are relatively independent of the detailed dynamics of levels L-2 and below. Phenomena at level L are constituted by interactions of units at level L-1, but the very existence of these units as emergent patternings at level L-1 means that they are already collective 'averages' over the individual behavior of their own constituent units at level L-2. The L-1 units 'filter' at the same time that they organize 'noise' from level L-2, and they thereby 'buffer' level L from noise at level L-2. This is, I believe the correct interpretation of claims such as those of Varela and Maturana that self-organizing systems are 'autonomous'. Systems at level L cannot be autonomous in the sense of insensitive to L-1 or L+1, for they are defined precisely by their *selective sensitivity* (filtering) to these levels. But they are relatively autonomous to noise or detailed phenomena at levels L-2 and L+2 -- *unless* levels L-1 and L+1 for some reason do not perform the filtering of which they are capable (see examples in Salthe, 1984: 142-3).

All this neat layering depends on scale homogeneity and relative order-of-magnitude differences in scale from level to level. Obviously effects from L-2 are already second-order negligible on the scale of level L, as well as buffered by the selective sensitivity and collective homeostasis that are constitutive of the intermediate level L-1. But 'downward causation' effects are not limited to systems for which these assumptions hold strictly.

Beyond levels: homogeneity vs heterogeneity of scale

Most of my human behavior, particularly what we might call my socially meaningful behavior, however much it may originate endogenously in any particular moment, and however much it may be directed to immediate interactions with present surroundings, nevertheless manages to also be quite typical and characteristic of members of my community and my period of history, and of my gender, my age-group, my social class and many subcultures to which I in some sense 'belong'. Even if we grant that dialects, social norms, epochal and community or class 'cultures' are to some extent artificial intellectual constructs produced by recording and comparing many particular momentary behaviors, nonetheless the kinds of abstract similarities and contrasts construed in these ways seem absolutely essential to any adequate account of social interaction or social organization (cf. Lemke, 1995a: chap. 2). When I speak or act in any way, not only my internal constituency and my present surroundings, but my biographical history as a member of many communities or social networks plays a part. More than this, the tools with which and through which I so often act, whether developed as part of my own body (neural nets and maps, muscular habits and skills, immune responses -- none present at birth and all specific to my individual history) or as prostheses produced by others and typical of my community (eyeglasses, hearing aids, clothing, pens and pads), or as something inextricably both (dialects, depictional styles) ensure that the history of my community, and the history of the tools themselves, are also essential for accounts of the full ecological and semiotic signficance of my moment-to-moment actions.

I write a short note to someone in my household and attach it with a small magnet to the door of the refrigerator in our kitchen. In the analysis of the provenience, consequences, and meanings of such a culturally typical activity it is not so easy to cleanly separate different spatial-temporal dynamical scales. There is the basic human reference scale for action, on the order of seconds to minutes of performance of what counts as more or less a single coherent action or activity. Such performances typically span spatial scales of the order of the size of the human body, from millimeters of movement in the writing of the letters to perhaps meters of movement in attaching the paper to the fridge. Even in this there are perhaps three or four orders of magnitude in spatial scale and perhaps three in time. But that is nothing. The words I write may refer to recent past or future events on the order of a day or more distant from the moment of writing. The meanings of those words for me and the person I write for may well have critical dependencies on events earlier by months or years in the history of our personal relationship (a pet-name, for example). And of course the most common meanings of the words were learned by us probably in childhood, and their grammatical and semantic patterns and relationships will have histories of the order of centuries. Shifting to a spatial-extensional view of scale, personal history and community history insofar as it is relevant to the usage of words involves social networks of from several or a few dozen to tens or hundreds of thousands of people.

But even this is only the tip of the iceberg of spatial-temporal complexity of interpenetrating scales. What of the pencil and the paper without which I could not perform this culturally typical action? They too have a history, and that history implies several more scales of dynamical complexity in the social-ecological system in which my action is performable and meaningful. Where did I get them? Who made them? How and from what materials, obtained where and when? How did I learn how to use them? where and when, as part of what eco-social subsystem of cultural practices and material processes? And on what scales do they have their origins and take their present forms in relation to the specific functions they play in my present action? If we say that they are like my own muscular habits and neural memory, substrates for action at the organism level, then we need the characteristic scales of their dynamical processes to be small and fast compared to my human action scale. But they are not; some of the relevant scales exceed the human momentary-action scale. And so also for the magnet, and the refrigerator, and the architectural conventions that define kitchens and their functions and contents, and the cultural habits that make it likely a note placed there will be seen fairly soon by its intended reader. The scale of my partner's daily life routines is also somehow implied in my activity of putting a note on the fridge.

Why is this not also a problem for the hierarchical scaling of biological systems? Perhaps it is. Sometimes the long-term developmental history of particular cells may equal or exceed the typical organismic scale, but this is unusual. For tissue structures and organ systems perhaps it is not so unusual. But the functions of these constituents of the organism as a whole do not depend on their *meaning*. Their significance for the organism is exhausted by their organic functioning. Insofar as their history matters at all, that history is embodied in structural form and operational behavior at the present moment. This is quite unlike the significance that attaches to the history of a word or a visual image, or even a tool. In the days before our present culture of radical commodification, the history of ownership of a famous sword, say, had very definite implications for when and how it would be used as a tool or as a symbol -- implications that could not be derived from properties found anywhere in the object itself, but which were emergent properties that existed for that sword only in the context of a much larger human community with a social history and a social memory.

Scale-heterogeneity based on embodied memory and interpretive history is definitely not a problem for elementary dynamical systems where interchangeability and the absence of non-dynamical properties or degrees of freedom ensure that there is no individuality to which a history can attach. All electrons are exactly the same; no particular one can be labelled or its history accumulated over time-scales large compared to the interactions in which it participates (cf. discussion in Lemke, 1994, 1995a: chap. 6). But as elementary units on any scale interact with many others so that collective properties emerge, we rapidly reach levels of complexity of compound units for which there can be individual identity, memory, and history -- if not yet semiotic significance (see below, and Lemke, 1994, 1995a).

The segregation of distinct temporal and spatial scales of characteristic dynamical processes is a small problem until we reach the threshold of meaning. Once meaning plays a role in material processes, once what humans do in the ecosystem depends on stories and histories, once meaning-categories influence the design of material artifacts which in turn amplify meaning's human-mediated effects on matter, then maximally different scales intersect. If we follow the connections of social practices through links attaching to both the people and the artifacts involved in them, just far enough to account for what happened here and now in terms of both material consequence and semiotic significance, then we will find that social-cultural and material-ecological processes of the widest range of scales are encountered without any clear passage from one scale-homogeneous level to another.

This point has been forcefully made by Bruno Latour in his critiques of macro-social systems theories and his interpretations of empirical studies of the role of artifacts and technologies in human cultural activity (see especially Latour, 1987, 1993, 1996a, 1996b; and studies in Lynch & Woolgar, 1990; Law 1991; Hutchins 1995; and Goodwin 1995). Latour has long argued for a heterogeneity of 'actants' (a term originally from Greimas' semiotics, cf. Greimas & Courtes, 1982) in the analysis of social practices, by which he means a more symmetrical treatment of the roles of material artifacts and human actors, a redefinition of 'agency' away from a paradigm of independently acting agents and towards a model in which all action occurs within systems or networks of human actors and their tools, artifacts, and technologies. But recently he has emphasized that the application of his theory in empirical studies consistently argues for a 'flat' rather than a 'levels' model (Latour, 1996a, 1996b), and the core of his reasoning seems to be that the actant-networks in these studies typically have connections of and between social processes with very heterogeneous spatial and especially temporal scales.

In its current form Latour's argument is essentially that human cultural artifacts and technologies are a way of 'black-boxing' their own origins and histories, so that they can function as if they were units on a smaller scale of spatial extension and temporal process than they truly are. This is another way of saying what I have argued above: that larger-scale processes over more extensive communities and their longer-term histories are always directly implicated in semiotic artifacts, and that this fundamentally changes the scale relations for ecological-semiotic systems as opposed to more purely thermodynamic ones.

I want to argue here that both the 'levels' view and the 'scale heterogeneity' view are important tools for conceptualizing downward causation, i.e. for accounting for how larger-scale, longer-term dynamical processes become relevant for smaller-scale, shorter-term ones. Indeed I believe that a synthesis of 'levels' analysis and 'heterogeneous scale' analysis of complex systems is even more important than a reconciliation of the paradigms of 'upward' and 'downward' causation.

Salthe (1985, 1993) has made some interesting efforts to reformulate Aristotle's classic 'four causes' to fit the 'upward and downward' causation paradigm of his hierarchical levels model of complex biological systems, and he has commented there as well about the limitations of the reductionist paradigm. I would like to close this section by noting a different but related view of the reductionist program, from within a 'levels' perspective.

How is it possible in principle for a component at level L-1 of a system at level L (or spanning a number of levels) to model the levels above it? How can human organisms model the higher levels (ecosystems, cities, societies) whose downward causal influence we feel? How has it come about that we appear to be adapted by evolution to do just this?

That some modeling of higher levels is adaptive can be seen again by scale considerations. An organism has a limited capacity to sample its environment, limited in scale of spatial extension and limited in time-scales. In any given interaction on the normal human scale we sample the environment over a period of seconds or minutes (before moving on to another interaction, perhaps in a different locale) and in a volume of a few cubic meters, or perhaps on somewhat larger spatial scales if we count distance vision and auditory input as interaction. But the ecosystem to which we belong, and which matters to our survival and the survival of our progeny, extends over much larger spaces and may have on-going processes on much slower time scales which require sampling over much longer time periods to assess. Our first asset in the struggle to know the opportunities and dangers of our habitat is memory: our bodies dynamically recreate past sampling interactions and (at least with, and perhaps even without semiotic mediation) can overlay these on top of present interactional circumstances so that we can 'see with hindsight' and act with foresight or planning. We cumulate our sampling over space and time, we comparatively register invariances and divergences.

Our second asset is communication. With symbolic resources comes the possibility of collective memory and pooling our samplings of the environment over much wider times and spaces. When the troupe travels together this effect is somewhat minimized in space but augmented in time as informational patterns are passed across age-cohorts and generations. When some members typically wander far afield and return, or when troupes exchange information, spatial extension also grows.

The key lesson here is that our means of modelling higher levels are fundamentally social and collective, and our models are built with group means (languages, vocal or gestural) and by collective actions (comparing and accumulating records and accounts). The role of writing in this activity (cf. Olson, 1994, and see Lemke, 1995b) and in the construction of other sorts of stable visual artifacts (e.g. navigational charts, scientific data archives, cf. Latour, 1987, 1990) has often been noted. Individuals do not construct detailed maps of a continent, nor could we do so without artifacts-as-records (cf. Latour's 'immutable mobiles').

In all this, we have adopted the habit of constructing the properties of wholes from samplings of their parts. Confined to the human scale in our specific interactions with the here-and-now, but benefitting from overlaying these with models of the there-and-then, we have had to learn to make sense of higher levels by piecing them together 'from below'. When this same adaptive strategy was turned to the analysis of levels below us (anatomical studies, mechanical and chemical theories) we found first that we were well-served by our technologies (our machines, built by assembling pieces into wholes), and then that we had to sample still lower levels, where changes happened too quickly for our eyes and where units were many. But we still thought in terms of aggregation and piecing together, we sampled and constructed always 'as if from below', our ancient phylogenetic trick, for which our symbolic systems of communication and representation were themselves long adapted. We were, not very surprisingly, most successful as reductionists.

But in order to make the reductionist program work it was essential that we leave *ourselves* out of the picture. For once we see our representations of the levels below as actually models of our human-scale relationships *to* phenomena at those levels, then the neat homogeneity of scale that defines the separability of levels is broken. This paradox was of course at the heart of the great philosophical debates over quantum theory: if the data only existed because of the measuring apparatus, and so as part of the human-scale (and larger cultural-scale) experimental program, then events on our scale somehow were critical for events on the atomic scale, and vice versa (cf. the infamous lives and deaths of Schroedinger's cat). Niels Bohr's 'complementarity principle' was born from a rethinking of the reductionist program that admitted extreme heterogeneities of scale, mediated by human artifacts and technologies, in the measurement interaction itself (Bohr, 1934, 1958).

Bohr was the first to recognize that the new quantum theory presented us with a view of experience in which different interactional arrangements resulted in complementary perspectives that need not be logically consistent, compatible, or commensurable, and in many critical cases *could* not be so. The reductionist trick was predicated on the assumption that the different 'pieces' or views from different perspectives could always somehow be neatly fit together. But we now know that material processes cannot be comprehended, cannot be exhaustively described within any one single self-consistent formal discourse. They always overflow the limited possibilities of our semiotic models of them. It is only by building more and more semiotic-discursive models, each internally self-consistent, but not limited by requirements of mutual consistency with each other, that we can, by adding together such 'complementary' views, attain to the most complete possible account of material phenomena, including semiosis itself. Thus we still come back to a version of 'assemblage' but hopefully a more sophisticated one, one that takes into account our own role and perspective as observers, as well as the material means by which we observe, compare, and assemble -- the material mediation of our semiotic practices.

The inclusion of the observers and our technologies, and the viewpoints we embody, in the analysis of the dynamics of systems across many scales (from apparatus to electron) are also discussed in Voetmann (this volume) and in some ways extended by Bickhard (this volume) to the later field-theoretic models in physics, which are again inherently non-local -- that is, they do not necessarily respect scale: events remote in space and time become interdependent, even without any energy passing between them to communicate information. Kruse (this volume) provides us with fascinating accounts of the historical and contemporary forms of material 'holism', an alternative to reductionism which assumes that the same sorts of patterns will be mirrored on all scales and that there is a material unity of the universe that transcends divisions into scale-homogeneous levels of analysis.

Materiality of Sign Processes and Scale Heterogeneity

So we are now building up a picture of material artifacts and the artifact-like (i.e. embodying culturally learned patterns) properties of our own bodies as accumulators of information sampled on larger-than-human, greater-than-here-and-now time scales, from those of the family and extended communities to those of personal biographical trajectories and wider social history. The importance of these artifacts lies foremost in their mediation of the role of meaning in human actions, actions which are always also material processes entrained in the larger dynamics of ecological-social systems. In ecosystems-with-humans, meaning matters to material dynamics because humans act in terms of semiotic categorizations and evaluations as well as in direct biological and thermodynamic response to their material environments.

Meanings are collective phenomena; their impact on the material ecosystem is large exactly to the extent that the same categorizations and evaluations are relevant to the behavior of many individual human agents. And meanings are shared to the extent of and because of common past history of interactions. At the level of the individual organism this is the phenomenon of social and cultural learning, but at the level of the community it is an emergent phenomenon, one of the small number of possible solutions to the self-consistency problem of myriad cross-coupled interactions among humans, mediated by signs and artifacts, and between humans and all material Nature. The common meanings of words, the common structures of language, the shared ideologies and genres of communication and social activity generally -- all of these emerge as characteristics of communities or subcommunities, and all of them change on time-scales long compared to cogent human moments, or even lifetimes, and as part of larger-scale ecosocial processes.

Linked through the role of meaning in the material dynamics of ecosocial systems, human organisms and natural or artifactual objects are the irreducible participants in the local dynamics of interaction. But the characteristic scales of the dynamical processes which engender them, determine how they participate in various interactions, and control how they change, develop, or evolve are often very different for organisms and for artifacts. If we construct our models of ecosocial systems by following the chain of linkages -- which agents and objects are essential here and now, which processes put them here, now, and in a form suitable for the interaction, what other agents and objects were in turn involved as essential participants in those processes, ... and so on in indefinite regression -- then our models will be 'flat' with no distinct levels, they will be like complex intersecting networks of interactional processes with all the auto-catalytic and cross-catalytic feedback which engenders non-linear self-organization, and they will be heterogeneous in dynamical scale in the specific sense that the processes so linked will be consitutive of and constituted by systems with widely different characteristic spatial extensions and time-scales.

This view foregrounds the new feature of complex systems with semiotic as well as biological and thermodynamic processes: tight linkage across scales. But it will not serve our human purposes if it is our only model. If there are no intermediate levels of organization and order between the total ecosocial network and the human scale of organisms, artifacts, and activities, we will be at a loss to usefully model the many kinds of order that we do indeed find in language, culture, social structure, ideology, historical change, etc., or to account for these larger-scale patternings in the mutual interactions of myriad constituents at the human scale. I believe that we are adapted for survival as a species-in-an-ecosystem partly by our ability to piece together collective pictures of systems larger than our own scale of moment-to-moment living. The 'flat' models of scale heterogeneity, however, do provide for one key notion of intermediate organization: artifacts themselves.

Latour conceives of artifacts in part as 'black boxes', as material condensations of the histories and processes that gave rise to them and determine their functional potential, but at the same time as units of interaction at the human scale for which it is normally possible to ignore what is boxed up 'inside' them. If we generalize, as Latour himself usually does, from artifacts to technologies, conceived as practices in which these artifacts play a part (as tool, as product, as raw material), then we can regard artifacts as points of possible connection, points of possible relevance of the there-and-then to the here-and-now. From the viewpoint of the global actor-object-network, the dependency is very real. From the viewpoint of the human actor, the key question is whether the meaning of the object does or does not go beyond its form and function in the present circumstances. If we use the object without regard for its history and origins, i.e. for the larger systems and time scales its existence implies, then it remains a black box, an unanalyzed instrumentality. But we *can* always open this black box, or try to, and we do so typically when it fails to function in the expected manner as an instrumentality for here and now, or when we wish to challenge its suitability or value, or when we wish to change it for new purposes, and so on. Then our interactions with it and through it will begin to depend quite critically on larger-scale processes in which it, and now we, participate.

In this sense artifacts are the very material reality of 'downward causation' in social processes: not only the means through which larger scales of dynamical organization impinge on each moment, but also the means by which, in the production of artifacts, we both produce and model these larger scales. Latour (1987, 1990) notes, for example, that we produce artifacts such as data archives and maps as the tools by which we sum up over many sampling interactions with the environment at the human scale, and so build up more global models. At the same time, in using them, we become able to carry out different kinds of material human practices (mid-ocean navigation, global trade) that in turn alter the world on larger-than-human (as well as human) scales.

But if we also maintain the 'levels' perspective we will suspect that artifacts can hardly be unique in this respect, though they may represent an especially salient case. It is not at all clear, for example, whether language as an abstract structure, or even the sets of systematic relations in how people use language, are artifacts in the same sense as material tools or objects, but certainly they have all the same functional properties which Latour requires. Nor is it likely that one needs technological artifacts as such, since natural environmental objects can also function semiotically in addition to their biological and thermodynamic functions. Indeed the human body itself can function in this way (perhaps even pre-semiotically) insofar as it carries within itself its own history of previous interactions (cf. Bourdieu's, 1990 notion of *habitus* as embodied dispositions for action).

The key linkage seems to be that between matter and meaning. An artifact, a twist in the gut, or a tree outside my window may be just a tool-of-habit, just an enteroceptive sensation, just a source of shade from the sun ... or these things may also be more: the tool a shame to its maker, the twist in the gut an associative focus for a germinating and still unarticulated idea, the tree a totem of my clan planted by a particular ancestor. Material interactions and the entities we construe from them are inexhaustible sources of meaning: they overflow the terms, categories, and sets of properties that any semiotic system can assign to them. We may collectively or individually assign them only their minimal common functional meanings, or we may open them up as black boxes, or begin to pack them with links to new interactions -- including our semiotic tales about them -- even if they had none before.

Meaning is the link between matter and history; making the material meaningful potentially links the scale of humans, artifacts, and other same-scale ecological partners to the larger scales of their diverging histories and the dynamical processes that determine those histories.

Topological vs Typological Semiosis: Emergence of Ecosocial Systems

In order to further develop the perspective outlined in the last section, we need to see how our descriptions of ecosystems must change qualitatively when semiotic processes are at work in them. Our goal will be an account of how categorizations and valuations of material processes, by producing artifacts and other meaning-implicated material forms, transform the dynamics of ecosystems and lead to the emergence of new system properties.

The essential point is that our meaningful material interactivity in the world arises from two kinds of interdependence among specific interactional processes: a 'topological' interdependence, based on continuously variable phenomena, which is primary and characteristic of thermodynamic and biological systems without human culture, and a 'typological' interdependence introduced by those forms of human semiosis that operate in terms of discrete contrastive categories. The former tend to preserve separations of scales and allow more faithful and complete descriptions in terms of 'levels', while the addition of the latter tends to favor scale-heterogeneity. In particular, by filling the ecosocial world with artifacts designed at least partly according to typological semiotic principles, subsequent use of these artifacts in activities that further shape the world materially leads to an avalanche or cascade, a sort of chain reaction by which typological meaning colonizes the topological world. (For a fuller discussion of the 'typological' vs. 'topological' distinction, see Lemke, in press-c.)

We need, most basically, an understanding of semiosis as a material process in an ecological system. Our own cultural traditions in the centuries since Descartes have too radically disjoined the material and (under the older name of the 'mental') the semiotic. We have one set of discourses for talking about matter in the languages of physics, chemistry, and biology, and a completely different set for talking about meaning in the languages of semiotics, linguistics, and cultural anthropology. Yet we know that every sign has a material phenomenon as its representamen (sign-vehicle, signifier, carrier), that every process of semiosis is not just a social and cultural practice, but also a material activity in which not just humans but also non-human elements of the ecosytem participate.

From the ecological standpoint, we know that when an ecosystem contains a human society, we cannot account for the dynamics of the total system unless we take into account the beliefs and values of a human culture. Which trees are cut, which crops are cultivated, what kinds of raw materials transported where, depends not simply on the physical, chemical, and biological properties of human organisms or other components of the ecosystem (biotic and abiotic), but also on the cultural values assigned to actions, constructions, and objects. These phenomena depend on the beliefs of a community, depend on purely cultural customs. These customs must be consistent, in some broad sense, with the other material aspects of the ecology, but there is still such broad latitude for differences of culture, for differences of meanings made that affect matter moved, that we cannot hope to account for the changes, for the total dynamics and trajectory of such an *ecosocial* system unless we take culture and semiosis as well as physics and biology into account.

What kinds of material systems can support semiosis? This will depend on how broadly or narrowly we define the making of meaning. If we take the broadest possible definition, the most inclusive one, then we have the opportunity to examine how semiosis itself has evolved with the processes of self-organization and complexification of the cosmos (cf. the similar project of C.S. Peirce who saw the processes of human semiosis as continuous with, and a veritable extension of the general tendency to self-organization in the evolution of the cosmos, which he referred to as matter's propensity of 'habit-taking' ; Peirce, 1992: chaps 19, 24). We can also examine the degrees of complexity of various classes of material systems with an eye to imagining how close they might come to what we would be happy to call semiosis *sensu stricto*.

I have tried to do this following Salthe's notion of a specification hierarchy (Salthe, 1985, 1989, 1993; Lemke 1994, 1995a: chap. 6). This is a formal scheme of nested classification in which each class of system is a subclass of the previous one, from an outermost class of systems whose dynamics can be adequately accounted for with the fewest assumed properties or characteristics, in the simplest discourses with the fewest number of primitive terms, to those which successively require more complex descriptions, adding to the descriptive apparatus needed for the less specified or more generic systems further properties which are newly relevant. This model would map smoothly onto an evolutionary model in which systems of greater complexity arise from systems of lesser complexity by successive differentiation, and by the emergence of new properties by processes of self-organization and symmetry-breaking within a matrix system possessing only the more general properties. Whether cosmological evolution, seen from the human viewpoint, follows the sequence of a specification hierarchy or not, the latter is still a very useful way to formulate the degrees of complexity in observable types of systems, and this suits our present purpose very well. (Emmeche et al., this volume, seem to assume that historical emergence follows the specification hierarchy, but I believe this view needs to be somewhat modified from an 'ascent' to ever higher levels to a *progressive interpolation* of ever more specified kinds of systems *between* less specified ones above and below; see Afterword below.)

The simplest dynamical systems we know are the ones I will call elementary dynamical systems. They are typified by the elementary particles of physics and their interactions. For purposes of describing their possible dynamical participation in an interaction, quantum theory requires that only a small number of properties be specified. Moreover, it appears that these systems can have no other properties than these essential dynamical ones. The number of degrees of freedom, the number of ways in which such a system can be identified by its behavior, is completely exhausted by the properties necessary to account for its fundamental interactions. For this reason, modern physics says that electrons have no individuality, no history, no culture that matters to their potential behavior under any and all circumstances. Every electron in the same quantum state will behave the same way with the same probability as any other electron. When two electrons collide, one cannot trace their identities from before their interaction to after it. Each could as well have taken the role of the other, and the experimental results agree only with this otherwise strange assumption.

Electrons and other constituents of elementary dynamical systems are truly simple, truly minimal in their complexity. They are not really even individual entities in the sense we expect for macroscopic systems like ourselves. Electrons and atoms do not age. They have no history, no individuality, no youth, maturity, or old age. They are generic, and their science is a science of the generic.

How complex, and complex in what ways, must a system be to show the history, individuality, and diversity characteristic of cultures and meaning-making systems? We know from the work of Ilya Prigogine (1961, 1962, 1980; Prigogine & Stengers, 1984) on irreversible thermodynamics and complexity theory that statistical ensembles of elementary dynamical systems begin to have histories that matter. They are systems for which we need to define an entropy. They break the time-reversal symmetry of elementary dynamical systems. Macroscopically they are still not truly individual, though microscopically perhaps they are. They do not yet have individualized macro-developmental trajectories. They suffer the irreversible effects of history, they are 'in time', but they do not yet have unique individual biographies, trajectories which matter to their dynamics. This further step is taken with the next more highly specified class of systems in our hierarchy, the so-called 'dissipative systems' which export entropy to their environments and feed on the order in those environments (on the maintenance of a gradient between system and environment) in order to self-organize, to increase their internal dynamical and morphological structure, to develop along a trajectory typical of their system type, from one dynamical regime to another. Such systems as flames and tornadoes, hurricanes and Rayleigh-Benard convection cells (see Table 1).

Table 1. Specification hierarchy nesting ecosocial systems

System Types	Additional Properties
Elementary Dynamical Systems (electrons, atoms, small molecules)	
	Energy, mass, identicality
Complex Systems with Irreversibility (paper clips, balloons, water droplets)	
	Entropy, memory, aging, identity
Dissipative Structures = Dynamic Open Systems (flames, dust-devils, hurricanes)	
	Emergent organization, individuality, developmental trajectory
Autocatalytic Self-Organizing Systems (Cairns-Smith clays, Eigen-Schuster hypercycles)	
	Autocatalytic-crosscatalytic interdependencies
Epigenetic-Developmental Systems (Salthe dust-devils, ...)	
	Recapitulation of evolvable type-specific trajectory
Genetic Evolutionary Systems (Ecosystems > organisms; A-life configurations)	
	Recombinant, transferable genotypes
Ecosocial Systems (Ecosystems-with-cultures > semiotic practices-with-persons)	
	Meaning-construal-dependent material activities

These systems develop, but they do not conserve the information acquired through interactions with an environment which shapes their development, nor transmit it to future generations. There is as yet no epigenesis, no evolution. There is, however, already one feature which will later prove crucial to our analysis of semiosis in ecosocial systems: the dynamics of the system as we ordinarily define it cannot be defined in terms of processes strictly internal to the system: the dynamics is always transvective, it always crosses the boundary of what we call 'the system'. Indeed the maintenance of the structural or dynamical integrity in terms of which it is possible for us to define it as 'a system' depends directly and critically on processes of exchange of matter, energy, and information with an environment. In this sense while it may be defined as an individual, it is not in any sense autonomous. It is, in fact, merely an isolable component of a larger dynamical system. It is always a subsystem, and to understand its dynamics, we must always examine the supersystem of which it is an integral part. It cannot exist apart from its participation in this supersystem.

The properties of each class of systems we are describing are inherited by all the subsequent subclasses of the specification hierarchy (see Table 1). A dissipative system is a thermodynamic system, a thermodynamic system is a physical system with the same parameters and degrees of freedom of elementary dynamical systems. As we shall see directly, an organism is a dissipative system, and so is an ecosystem. Indeed they are two levels of organization in the same system, and that system belongs also to the class of dissipative systems, and to all the classes above it in the specification hierarchy, *a fortiori*.

Where are we headed in this sequence of classes of systems? Obviously the concentric circles of subclasses of more highly specified types of systems is converging on the point from which it is being drawn: on the cultural systems in which humans and their ecologies make meanings about classes of systems. Along the way, we hopefully will gain some further insights into what makes meaning-making possible in a material system.

An *epigenetic system* is a developing system that recapitulates the major stages along a developmental trajectory typical of its kind. It is a system that develops according to its kind, recapitulating a sequence of bifurcations in its dynamics that may have evolved over many generations of its predecessors. I hope it is clear that while we have for some time now been using the language of living systems, that at no point in the specification hierarchy that we have been defining (complex systems with irreversibility, dissipative structures, developing systems, epigenetic systems) is there a clear transition to Life, as such. Hurricanes are alive in many significant ways; so is the Planet as a whole. Organismic life as we know it is based on a very specific strategy (DNA-mediated epigenesis), but ecosystems are also alive and use a different strategy. What is special about the class of epigenetic systems is that the developmental trajectories of individuals recapitulate a prior evolution of the trajectory of their type.

How is recapitulation possible? Epigenesis further specifies the nature of development: epigenetic development is development guided by an environment which is approximately the same for different individual systems and which changes relatively slowly compared to the lifetime of these systems. The sequence of bifurcations, of development, cannot be left entirely to chance, to random fluctuations, if there is to be recapitulation. Random fluctuations must be harnessed and guided by an external source of information, regulation, and control, and that can only reside in the environment of the developing system. An adequate analysis of a developing system must not only be extended in time, it must also extend beyond the system itself to examine system-environment interactions: it must extend to the immediate *supersystem* that contains both the system under focus and its immediate environment (cf. Lemke, 1984, 1995a: 159-166).

In epigenetic systems, a new bifurcation in the developing dynamics of an individual leads to effects on the environment that favor similar bifurcations in other individuals. A series of "accidental" dust-devils in a narrow defile might erode landscape surfaces in a way that produces contours which favor the formation of other very similar dust-devils in that same place (cf. Salthe, 1993 p. 42-43). Globules of organic polymers in a tidal pool, engaged in autocatalytic chemical reactions (i.e. proto-life), might modify the surrounding silicate clays (their external, proto-DNA) in ways which tend to favor recapitulation of their latest chemical innovations when future globules develop in the same pool. In each case, along with epigenesis comes a supersystem (dustdevils-plus-landscape, globules-plus-clays-in-tidal-pool) and a hierarchical relation of system and supersystem. That hierarchical relation is one of *scale* (cf. Salthe, 1985, 1989, 1993, who clearly distinguishes scale hierarchies from specification hierarchies), in which the supersystem is more stable, changes more slowly, and exerts a regulatory influence on the dynamics of the now "sub" -system. In the case of organismic lifeforms, the relatively stable "environmental" molecules (RNA, DNA) were eventually internalized, incorporated into the supersystem which became the modern *cell*.

But epigenesis depends only on a system's being integrated into a supersystem which can in turn regulate the subsystem's development. It depends only on the possibility that innovations by individual subsystems can be recapitulated because information about them (or leading to them) is stored in the long-term "memory" of the supersystem environment. The DNA strategy of organismic life is only one specific way in which this can happen. Epigenesis is simply development under an environmental guidance that enables recapitulation of type-trajectories in individual development. (For a more complete picture of how development and evolution are linked by DNA, including the complementary roles of 'typological' , semiotic constraints and 'topological' dynamical ones, see Pattee, this volume. For a complex account of subsystem-supersystem relations and the interplay of type-specific equifinality and individuation along particular developmental trajectories, see the account of language acquisition in Hirsh-Pasek, Hollich & Tucker, also in this volume.)

My simple account of things (like many accounts of the origin of organismic life) is a bit backwards: there have always been supersystems, there have always been ecosystems, there has always been a planetary dynamical system. Particular self-organizing units always came into being in the context of supersystem environments. Life did not begin with micro-organisms that eventually got together to form ecosystems that eventually united into the living planetary system ("Gaia" after Lovelock, 1989). There was always Gaia, even before organic life, and there were always the chemical, atmospheric, oceanographic, and geological precursors of biological ecosystems. What has happened in the history of the planet is that new *intermediate* levels of organization have emerged *between* the total Gaia-system and her molecular subsystems (cf. the discussion of this issue in Moreno & Umerez, this volume). Ecosocial systems and the human cultures they sustain form one of those intermediate levels. These levels of organization, each on a different scale of physical size and mass, rates of change, energy transfer, etc. are (partially) regulated by their integration into the larger ones that contain them, and in turn (partially) regulate the smaller-scale ones that they contain.

All epigenetic systems belong to regulatory subsystem-supersystem hierarchies of this kind across a range of scales from the molecular to the planetary. At or near the human scale, organismic lifeforms are not the only epigenetic systems, there are also ecosystems.

Ecosystems are individuals. Their biographies partly recapitulate during ecological succession (Odum, 1983; Schneider, 1988) the trajectory of ecosystems of their specific type. Unlike organisms, ecosystems do not seem to die, but to undergo continual processes of local decay, replacement, and variable succession, resulting in a whole, a supersystem which is a mixed-age aggregate, a mosaic of ecological patches, each of which is itself an individual on a smaller space-time scale. Human communities exist as patches, and networks (see below), within natural ecosystems. Our communities are parts of larger ecosystems, and even our most artifactual cities show all the properties of ecosystems as a class. Any architectural survey will show the mixed-age mosaic, the mixed-use patches, the local diversity of 'species' types (person-types, artifact-types, natural types), in intimate dynamical interdependence.

But the dynamics of such an *ecosocial system* (Lemke, 1994, 1995a) depends not just on the volume and biotoxicity of wastes, the nutrient needs of the population, the structural properties of building materials, the available arable land; it depends also on cultural food preferences, on building styles, on technological histories, on political structures and social values. It depends on the activities by which humans not only move and transform matter and energy but also assign value and meaning. It depends on the critical link between activity and language (cf. Vygotsky, 1963; Leontiev, 1978), action context and meaning.

How can we describe this ecologically? Human networks of activity, like many of the dynamical subsystems of an ecosystem, are not strictly space-time localized 'patches'. As Latour has emphasized and his co-workers shown in so many cases (Latour, 1987, 1993; Law, 1991), networks of activity have a different topology from localized subsystems. I discuss this in more detail below (see also Lemke, in press -a), but the critical point for our purposes is that humans and the non-human species and material forms that co-participate in ecosocial and cultural practices and processes within a network interact over long distances and even at considerable removes in time more intensely in many cases than they do with objects and persons close at hand but not in that network. Our transport networks, our information and communication networks, our economic trade-routes of exchange, have always had a 1-dimensional reticular network topology spread through a three-dimensional ecosystem. This is true also of the food-webs and carbon-exchange cycles even of ecosystems that lack human participation.

One of the functions of our network subsystems, one of the kinds of activities that takes place in them is semiosis. But we have in mind now not semiosis *per se* in some idealist sense, not some mental processes with no consequences outside an immaterial 'mind'. We are concerned rather with a view of 'cognition' more like that of Gregory Bateson (1972) or of the situated cognition models of the last decade (e.g. Lave, 1988; Kirshner & Whitson, 1997; Lemke, 1997), in which the material substrate of semiotic processes extends always beyond the organism, is always in fact a process characteristic of the supersystem, and not internal to an organism (cf. Smith & Thelen, 1993; Lemke, 1996). We are not concerned with 'thought' that does no work in the ecosystem, because there can be no semiotic process uncoupled to the material systems which are its dynamical basis. Every 'thought' is part of a material activity, and its form and its consequences depend on the material systems and processes through which it occurs. These are only partly neurological (and neurohumoral) processes: they are also active, efferent and motor processes. From perception to memory to reasoning, all human neural activity includes both afferent and efferent connectivities (even if pre-emptively inhibited and/or re-entrantly diverted, cf. Edelman, 1992), and most human meaning-making occurs in the context of immediate motor activity. Our perception is the product of our action: the Umwelt made by our specific way of participating in the ecosystem (cf. Gibson, 1979 on affordances; von Uexkull, 1926; Smith & Thelen, 1993).

We need to represent semiosis as an integral part of activity in an ecosystem. Integral in that it is engendered by such activity, evolved to function as part of such activity, is shaped moment-to-moment by the activity, and has its consequences in the activity. In Bateson's famous example (1972: 458), the chain of differences that make a difference, which constitutes cognition or semiosis, is one aspect of activity itself, and its moment-to-moment trajectory derives from the loop of action (hefting an axe), consequence (interaction of axe and tree), feedback (perception of recoil), and modification of action (the next swing). However ethically questionable this murder of trees may be, it readily situates itself within the larger activities and networks of activities of an ecosocial system. The axe is swung initially as part of a larger activity (tree-killing) which depends on an economy, on cultural values for certain kinds of wood, on a technology (for use of the wood as well as for cutting the tree), on the people who will buy the wood, those who will use it, those who forged the axe-blade, and so on. Semiosis is always *in medias res*, plunging into the midst of events, at once material and social-cultural. There is no 'mind' outside of an 'ecology' which makes it materially possible and culturally meaningful. (Bateson's title is *Towards an Ecology of Mind* in this sense.)

Meaning-making is a material process in a material ecosystem. Its forms have evolved and are dynamically shaped from moment-to-moment as aspects of human-mediated activities in network subsystems of ecosystems. Materiality is as fundamental to an understanding of semiosis as is social function. Indeed these two are inseparable in a model of ecosocial dynamics. Every social practice is also a material process. As social practice it has semiotic relations to other social practices, construed by the semiotic activities of human communities. As material process, it participates in material, eco-bio-physical interactions with other process of the ecosystem. It is this double-connectedness that gives to ecosocial systems their enormous increase in complexity over other ecosystems. There are so many more possible couplings of processes/practices through the mediation of semiotic relations as part of the activities of humans (and non-humans) in the system.

Finally, we can begin to characterize the materiality of semiosis in two complementary ways (see also Lemke, in press-c). In the first, more general perspective (analogous to Peirce's, see above), which I will call the 'topological' one, semiosis arises in any self-organizing system to the extent that there are differences that make differences, and that what difference a given difference makes in turn depends on some other feature of the system (for this 'meta-redundancy' view of semiosis, deriving from Bateson, see Lemke, 1984, 1995a: 166-174). This kind of semiosis is quantitative. It need not depend on categories or contrasts, it rules in the domain of the analogue and the continuously varying -- a domain in which all material systems are situated, including our ecosocial ones. The mathematical descriptions of classical physical science developed precisely to describe this sort of quantitative covariation.

But mathematics itself initially grew out of a very different sort of semiotic resource: language, for which meaning arises by discrete (not continuous) covariation of categories and types. Classical semiotics, deriving from Saussure (1915/1959, but see Thibault, 1997 for a re-appraisal in relation to dynamical systems and topological semiosis), foregrounded the principle of *valeur*, according to which the meaning of a sign is a function of its place in a system of contrasts with other signs. *Which* other signs it is relevantly in contrast with depends on the wider context of its occurence, a fact which leads again to Bateson's differences that make a difference in a fully contextual and relational model of semiosis (see Lemke, 1984, 1995a: Postscript).

This is perhaps not the place to attempt an analysis of how typological semiotic practices can arise from a topological substrate; certainly it seems plausible that this phenomenon is itself akin to self-organization in complex systems, to the emergence of attractors of the dynamics of a 'topological' system which then bifurcate into two regimes, each of which stands in potential 'typological' contrast with the other. Of more relevance to our immediate concerns here is what happens when human collective interaction in the ecosystem becomes self-organized in such a way that linguistic and other semiotic categories play a role in human material actions in the larger system.

There are two particularly important cases, I think. One is the role of human semiotic valuations in determining what species we favor or disfavor, what materials we accumulate or disperse, and the differential ways we treat various categories of our fellow humans that are also grounded in such valuations. The other, coming full circle to Latour's arguments and the foregoing extensions of them, is the role of human semiotic categories and categorial-conceptual reasoning in the design and engineering and modes of use of our 'artifacts'. Whether we merely reshape the 'natural' environment (foraging, primitive gardening) or construct more completely artificial 'kinds' (mechanical and electronic devices) with no prior history in the ecosystem, we are providing the material means for still further human activity predicated on the use of these artifacts, and in most cases predicated also on the adoption of the categorial-conceptual logic of their functioning and use (if not always also of their design and production). Each new artifact, from a myth or a speech genre (cf. Bakhtin, 1953/1986) to a container or a computer, enables patterns of human activity in the ecosocial system that tend to multiply and project typological meaning into other domains. Typological semiosis is contagious, and artifacts are among its primary vectors.

One very simple way to appreciate the pervasiveness of the consequences of this chain reaction in which typological distinctions in one domain or material medium beget typological differentiations in others is to consider how insulated from the systems of cultural categories a child growing up in our ecosocial system could remain? Even in the absence of formal education or explicit family or peer tuition in such matters, merely as a result of operating the pervasive gadgets and technologies of daily life, categorial culture comes with participation in material-artifactual culture. The typological, conceptual-categorial dimensions of our culture are built into our artifactual worlds, inescapably.

Textproduction: Linguistic Technology and Scale Heterogeneity

Are *words* artifacts? Certainly *documents* are, because of their obvious materiality, artificiality, and the role they play in our technologies of communication and representation beyond the scale of the immediate here-and-now. Spoken language is rather more evanescent, especially inner speech, which verges on thought itself. But materially the spoken word is a cultural modification of a natural feature of the ecosystem: of breathing and grunting, of cries of pain and danger, of vocalizations more topologically determined. Presumably for long periods prior to the spread of literacy technologies, oral traditions played an equivalent role to documents; and spoken dialects are examples of emergent features of on-going collective interaction, relevantly describable only for scales of systems well beyond the individual organism or the momentary dyadic interaction. The dialect we speak very certainly shapes or constrains the kinds of things we are likely to say or think -- one of the most powerful of all the examples of 'downward causation' (for this neo-Whorfian view see for example Hasan, 1986, 1990, 1992a, 1992b; Silverstein, 1979, Lucy, 1992) .

Language is a phenomenon of seemingly inexhaustible complexity, and every linguistics has had to pay attention to only some of its manifold aspects. For present purposes it is perhaps best to think of language as the sum total of all resources for verbal meaning. That includes not just the words themselves and the typical grammatical patterns that link them into phrases, clauses, and sentences, but their systematic semantic relationships (synonymy, contrast, hyponymy, etc.), the typical ways-of-speaking about various topics in a community (thematic formations, speech genres, discourse voices -- see discussions in Lemke, 1995a, in press-a, and references therein), and even the typical stories told in those ways (cf. Threadgold & Kress, 1988; Lemke, in press-b). It also includes the meaning shifts associated with the intonations and pacings with which we speak the words ... and much else.

Now here is our central mystery: How does it happen that a particular writer (or speaker) produces, word by word, and sentence by sentence, a text, that is not predetermined in detail by any explicit plan (perhaps only by some general goals or an on-going activity of which the writing forms a part) -- and which indeed quite often actually surprises us when we see what we've wound up having written -- and yet, in almost every case the resulting text can be seen as quite typical of a particular genre of a particular culture and subculture in a particular historical period? For all the creativity and indeterminacy of the process of textproduction itself, certain 'constraints' of genre and discourse conventions will nonetheless supervene from larger scales of the ecosocial system. (For a discussion of the historical evolution of written genres through their dynamic integration into larger social-political systems, see Andersen, this volume.)

If we open the black box that is the finished and completed document, we expose the processes of its production: the other times and places, the other participants in the larger-scale systems of text production as a process. This reminds us that documents are not produced solely at the human here-and-now scale we imagine, that the relevant system in which production as a total process takes place is not limited to this scale. Somehow the larger-scale social systems are speaking through us, as in Bakhtin's metaphor of 'ventriloquation'. Bakhtin (1935/1981, 1953/1986) offers us a germinal insight into these processes in his more general notion of the pervasive 'dialogicality' of language in use. Every word, every expression form, is something that we appropriate from another, and with it comes a history, a collective memory of its uses in others' mouths and texts, which fills out its connotative meaning and cannot be ignored in any use we make of it. No word is entirely our own, and the richness of meanings in the words we appropriate depends precisely on their partial otherness.

From Bakhtin's basic insight Kristeva (1980) and others (see references in Lemke, 1985, 1995a) developed the notion of 'intertextuality'. As a principle, intertextuality reminds us that the meaning of each use of language here and now depends in part on how we connect it to other uses of language there-and-then. The relevant 'intertexts' of any given text are those which echo in its meanings as we read and interpret it, but they are also those whose resonances contributed to the original selection of words and form in our production of the text. (Naturally many texts only imply and do not explicitly state, in footnotes or by citations, the intertexts of their production, so that interpretation may bring to bear still other intertexts, resulting in further meaning possibilities.)

As I write I consult my notes, another text. I switch windows on my screen to view other papers I have written, and bibliographies, and half-formed essays to be incorporated here. I have stacks of books and papers by my side to which I refer, and some I cite for you here and some I do not. I recreate in memory the outlines and key expressions of still other texts I have read, and I do so under the stimulus of some of the materially present intertexts I have before me, as well as of my re-readings of this very text as I have written it so far. Later this first draft of my text will become an intertext for future drafts.

In all these ways the extent, the spatial and temporal scale, of this present text-production exceeds the immediate processes of here and now. But there are also more intermediaries of an artifactual sort. In addition to fully formed texts here present and remembered highlights of texts past, there are also the accumulated dispositions of my body and its memory, my 'know-how' for writing this academic style, for shaping the conventions of this genre, and less consciously, for writing my dialect of English in this historical epoch. Do I write as a man? in a masculine manner? with the semantic orientation of the upper-middle class? with the interests and emphases of an academic trained as a physicist? widely read in linguistics, ethnography, semiotics, philosophy? And can we say simply that all these dispositions are solely to be regarded as operating on the scale of my organism in isolation, as Bourdieu (1990, 1991) sums them in his notion of *habitus*? Yes, my bodily processes play critical roles -- but insofar as I-as-writer am concerned, the *agency* of this writing is distributed more widely across a larger material system and longer time-scales than any which are characteristic of me-as-organism.

I cannot write without keyboard, display screen, and all that mediates between them, or without motor-facility with pen, and paper of the right sort. My writing is as much in my fingers as in my brain, for the feedback loops between them and my eyes' sight make it no longer possible to ascribe exclusive originary agency solely to one part of this integrated system (cf. Bateson's tree-and-axe loops above). Here the differences that make a difference, however, are not simply perceptual forms and tactile feedback as simple stimuli, but rather, American radical behaviorism notwithstanding, in human action and all the systems in which humans participate, their *meaning* matters as well. I do not write from a preformed plan straight through to completed text. At each step I read what I am writing, read back what I have written, and new associations are made. Meanings reinterpret what the words say, differently or more richly perhaps than they meant as I first wrote them; these meanings evoke still other intertexts, still newer meaning possibilities for re-writing and editing what I just wrote, and for writing a new next phrase or sentence that I would not have planned to write before (see Lemke, 1991). My own text as growing artifact before me also has co-agency with my body and brain in this activity, not simply material co-agency, as the black boxes hidden in the writing loop do, but semiotic co-agency as well: contributors to developing meaning. The system in which meaning is being made is the larger supersystem. (Togeby, this volume, seems to suggest that text is *analyzable* in terms of fixed sets of goals; this may indeed be possible and useful, but I do not believe text is in general *produced* in this way, even though many of us probably believe it should be.)

My partners in writing include all those material intertexts I have already mentioned, and through them their agents of production, all the remembered and imagined texts, and the very dispositions to write in particular ways and utilize particular themes and ideologies, that enter in through my body's writerly habitus. I am saying very literally that my internal organism cannot be the sole author of the texts that get written by my hand, that textproduction is a process across all these system scales. The text is not being produced solely as part of a process on the scale of a meter or so around about me and over times of the order of each attack on the keyboard or the composition of each sentence or paragraph. The text is also being produced as part of processes on much larger scales that operate over much longer characteristic times -- as part of the evolution of a discourse formation or a genre in a subcommunity (cf. Andersen, this volume), as part of the evolution of a dialect. Textproduction belongs also to community- and ecosocial system-scale processes, as well as to organism- and artifact- scale processes.

(See also in this connection Togeby's insightful discussion in this volume of textual coherence as a phenomenon across time.)

This rather radical picture of a process like textproduction has an even more radical implication for human consciousness. Textproduction is a special case of meaning making, and so of what we loosely call 'thought'. Together with the more topological material ground of consciousness (our being-in-the-world interactively, much of which is also scale-heterogeneous), this analysis implies that meaning-making consciousness need not be considered as a process confined solely to the organismic scale. Our meaning-awareness, and perhaps a good bit of our primary awareness prior-to-meaning, are also aspects of larger-scale on-going processes. Consciousness is a cross-temporal phenomenon; it exists on multiple time-scales simultaneously, and some of those scales may be very long indeed.

New paradigms for the study of complex systems

What I have proposed here is an effort to extend our usual paradigms and metaphors for understanding complex self-organizing systems from those which assume strict scale-homogeneity of levels of organization to ones which also allow us to think, when needed, in terms of scale-heterogeneity.

A great deal of further discussion and elaboration of these issues will be needed. I believe that it will be very fruitful to examine, across the widest range of different kinds of empirically researched systems, the extent to which the assumption of scale-homogeneity is justified and the extent to which it is helpful to supplement it with views that emphasize multi-scale processes and strong cross-scale linkages. I would like to end here by mentioning a useful, if slightly simplified, set of metaphors for thinking about levels and scale-heterogeneity.

Our classic view of hierarchical levels in general systems theory models each level or dynamical domain on a sphere: a three-dimensional region with a definite spatial-extension scale, in which processes on this characteristic scale take place with some corresponding characteristic time. Our view of subsystems at lower levels models them as spheres or three-dimensional regions of smaller spatial-extension scale within the larger spheres, and so on up and down the hierarchy. There are two intimately related assumptions in such a prototypical view: (a) that there is a single definable spatial and temporal scale for the processes identifiable within the sphere, and (b) that points which are nearer in space, and events which are nearer in time, are more likely to be linked by interactions, more likely to be co-participants in larger events, more likely to be constitutive components of the next larger system level, than those which are remote (and so far outside the characteristic sphere).

But this view fails to some extent even in non-artifactual systems. Two ecological zones within the same watershed, or riparian zones along the same river, or regions within the influence of the same oceanic current, are more likely to interact with one another than they are with many points that are nearer in three-dimensional space but are not linked by these natural quasi- one-dimensional networks. Pollution dumped into a stream may have effects far down-river but none a few meters inland from the dumpsite. The relevant scale here is the long distance along the one-dimensional network link, and not any three-dimensional sphere with that (or any other) characteristic spatial-extension scale. Artifactual examples include railway and road transport networks, and telephonic and signal-cable system nets (including today the global Internet). I am far more intensively in interaction (for some purposes) with individuals in Italy, Denmark, and Australia than I am with most neighbors in my own town or street. From the viewpoint of a scale-and-levels model of the 'spherical' type, these network artifacts produce scale-inhomogeneities in processes which are both local and global.

More generally there are always a number of different co-dimensional manifolds that can be embedded in a space of N dimensions. In 3-dimensional space, in addition to three-dimensional regions, typified by the interior of spheres with a single spatial scale parameter, there are also what we will call 'networks', which are of co-dimension one. They are reticula in 3-space which are one-dimensional 'internally' even as they spread out through two- or three- dimensional regions in space (i.e. one moves along *lines* that connect points, which may be quite different distances apart, inducing the external scale-heterogeneity).

Finally there are, not surprisingly, though much less often taken as prototypical, also what we can call 'lamina', which are of co-dimension two in our three-dimensional space. These are sheet-like regions, with one characteristic scale (the thickness of the sheet), such that points within the same sheet are more likely to interact with one another (either locally or across many scales of distance) than with points which are off or outside the thin sheet. Ideally, of course, lamina are internally 2-dimensional (the limit of zero 'thickness' of the sheets), just as networks or reticula are 1-dimensional. Real network connections (cables, rivers, roads) of course are characterized merely by a very large ratio between their length scales and any other spatial extension, and real lamina by the large area of the layer compared to its 'thickness'. There are again certainly natural laminar systems, such as the layered zones of lakes and seas by depth (and so also by salinity, temperature, pressure, and light levels), and perhaps also such phenomena as 'canopy ecologies' in rainforests, or layers of soils, etc. Artifactually, there is some isolation of connected underground levels of cities vs the surface and perhaps in some cases also of elevated levels.

In the case of lamina, there may be a single set of parallel laminar surfaces, in each of which interactions across both short and long distances within the sheet take precedence over interaction with nearby points outside the sheet. There may also of course be more complex 2-dimensional manifolds, the analogue of reticular grids, but I cannot off-hand think of ecological or artifactual examples, though there may be such phenomena in the complexly folded tissues of organisms (neural sheets?).

Extending the repertory of our prototypical images and metaphors of organizational complexity to include networks and lamina as well as spheres can help us to integrate both the 'levels' perspective and the 'scale heterogeneity' perspective in our analyses of self-organizing systems. My examples here have been based on the easily visualizable models of spatial scale relations, but of course dynamic temporal scales are equally if not more significant. One could generalize the embedded manifolds view of connectivity here from 3-dimensional space to an Einsteinian space of three spatial dimensions and a fourth one for time, but I will not explore this interesting approach here. It is sufficient to see that multi-scale and cross-scale temporal processes, as well as space-scale heterogeneity, are implied by the generalized models sketched in this section and elsewhere in the paper. We need many more detailed empirical studies to help us build up a repertory of means for representing how processes on different characteristic temporal as well as spatial scales (deriving from common dynamical scales) are intimately relevant to one another. Where we identify such cross-scale phenomena against the background of relative separation of levels, we may speak of 'downward causation', but I think it should be apparent from the arguments advanced here that this notion has an even wider generalization and signficance when we consider systems characterized by scale-heterogeneity.

Afterword

Throughout this chapter I have made cross-reference to other contributors to this volume. Most of the contributors met near Aarhus in 1997 to discuss their draft chapters and the unifying themes of the volume. I want to add here a few notes to place the perspectives of this chapter in the context of some of the other issues raised by the volume as a whole.

In their Introduction, Emmeche et al. offer a useful categorization of views on downward causation. I believe that my own approach most closely corresponds to their 'medium-strong' position rather than to their 'weak' version. I do believe, in agreement with Finnemann, and Bickard, that in the processes of emergent self-organization the very most fundamental laws of a system are produced and changed. The development of a system over time and through interaction within an environment can lead to dynamical possibilities in principle unpredictable from a knowledge of the system at any one time. (Self-organizing, open dynamical systems cannot in general be analyzed at single moments of time. They exist in a sense only over-time, and across many temporal scales; they move or die.)

This is a much stronger view than the 'preformationist' perspective, according to which all the possible futures of a system are fixed by its composition, i.e. from below. If emergent organization in the dynamics of a system can be represented by attractors of the dynamics, as Emmeche et al., Finnemann, Andersen, and many others have proposed, then my position is that in at least some forms of emergent organization for sufficiently complex systems the attractors themselves change as the systems' processes become entrained in interaction with still larger-scale processes. Along the historical developmental trajectory of such systems the very ground of dynamical possibility moves. This can happen, as chaos theorists have observed, because non-linear systems amplify 'noise' from levels below, turning it into information. I would only add that what kind of information it gets turned into also depends on the larger-scale processes of the environment within which the system is itself a constituent.

I also agree with Bickhard's response to arguments such as those summarized by Kim: a physics in which non-local fields or dynamic processes, rather than entities, are primary does not require that the behavioral possibilities of (process) constituents be independent of the organizational patterns in which they may be included. This is more obvious perhaps at the social level. People have radically different behavioral possibilities because they live in a complex technological culture: possibilities which *were* not available to our remote ancestors not simply for lack of the technologies and social institutions, but also because our species' bodies and brains have evolved, and our individual bodies and brains now develop, in the context of these larger ecosocial systems and they now have different potentialities as well. In both Bickard's argument and mine, non-locality, or violation of the assumption of separable scales for constituent processes vs. aggregate processes is fundamental. A focus on entities, be they particles or organisms, makes scale-homogeneity seem more realistic than it actually is. 'Things' always fit neatly inside some sphere at some definite scale; fields and processes do not. Many arguments against 'downward causation' depend on the assumption of definite, separable scales. (So, of course, do many formulations of what 'downward causation' is.)

Such arguments also seem to depend on a synoptic perspective, that is, one that stands outside of time and ignores both history and change-in-progress. This is the temporal-scale analogue of non-localizability. Over time, the distinction between different scales which seem obvious at a single moment can become quite blurred (as in the example above of ecosystem effects on the evolution and development of brains, not to mention the role of changing brain capacities in altering ecosystems). Not only don't systems of the kind we are interested in really exist in single instants of time, the processes which constitute them are not confinable to characteristic time-scales.

I do still want to qualify my support for the medium-strong version of downward causation in two respects. First, like Patee and Moreno & Umerez, I do not believe that the metaphor or paradigm of cause-effect itself can be applied in an unrestricted way to the analysis of all phenomena. I believe it reaches the limits of its usefulness precisely (a) for systems of sufficient complexity that they must be treated as individuals with irreversible histories (and so for which there can be no question of same antecedents, same consequents) and (b) for cases where phenomena result from self-organization among many components and it is pointless to single out some of these as causal agents. I would rather say that the dynamics of constituent processes become entrained in the dynamics of larger-scale processes than that a larger-scale system simply 'causes' its constitutents to behave in novel ways.

Secondly, many arguments about downward causation assume a two-level model, whereas I believe that useful accounts must always consider at least three levels simultaneously. Processes at level L+1 represent selectional constraints on the possible ways processes at level L (in focus) can deploy the affordances they have by virtue of their constituents at level L-1. Historically, developmentally, phylogenetically, and probably cosmologically, we do not climb up from isolated quarks (or whatever) to complex organisms and ecosystems as the two-level, rung-to-rung model suggests. Instead, there is always already a higher level of organization (or at least of interaction; a quark soup, not just single quarks; ripples in the hyperdimensional continuum on many scales, not just the particle scale) and emergent self-organization produces more organized, more specified *intermediate* levels of order. We do not go from A to B to C to D ..., but from A-Z to A-L-Z to A-G-L-Q-Z .... In this view what should be meant by 'causation', either upwards or downwards, may thus ultimately have more in common with notions such as material and formal cause than with the classical notion of efficient causation.

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