The Collective Stance in Modeling Expertise in Individuals and Organizations

Brian R. Gaines
Knowledge Science Institute
University of Calgary
Alberta, Canada T2N 1N4

Abstract

This paper is concerned with modeling the nature of expertise and its role in society in relation to research on expert systems and enterprise models. It argues for the adoption of a *collective stance* in which the human species is viewed as a single organism recursively partitioned in space and time into sub-organisms that are similar to the whole. These parts include societies, organizations, groups, individuals, roles, and neurological functions. Notions of expertise arise because the organism adapts as a whole through adaptation of its interacting parts. The phenomena of expertise correspond to those leading to distribution of tasks and functional differentiation of the parts. The mechanism is one of positive feedback from parts of the organism allocating resources for action to other parts on the basis of those latter parts past performance of similar activities. Distribution and differentiation follow if performance is rewarded, and low performers of tasks, being excluded by the feedback mechanism from opportunities for performance of those tasks, seek out alternative tasks where there is less competition. The knowledge-level phenomena of expertise, such as meaning and its representation in language and overt knowledge, arise as byproducts of the communication, coordination and modeling processes associated with the basic exchange-theoretic behavioral model. The model is linked to existing analyses of human action and knowledge in biology, psychology, sociology and philosophy, and is used to analyze the role of information technology in supporting activities in the lifeworld.

1 Introduction

This paper is concerned with the role of technology in supporting human knowledge processes. Some sections may seem to propose that it is necessary to understand the ultimate meaning of life in order to program an expert system or build an enterprise model. It is true that deep philosophical problems surface very rapidly as soon as one attempts to analyze human knowledge processes. It cannot be true that they must be solved in order to progress with the technology. First, the problems are not of a kind that admit to solution. They involve self-reference to a degree which makes for a wide variety of different and self-validating solutions. If there are equations of human existence, they are recursive functions that can evolve in a wide variety of self-consistent forms, each of which can be fitted to human experience by appropriate choice of parameters. Second, the exploration of new technologies is an essential component of our exploration of human nature. Technological action is a powerful form of social action that leads to new human adaptations, and extends the range of human knowledge processes.

From a technological perspective, what is valuable in examining the deeper issues is the rich repertoire of perspectives they make available to us in system design. Expert system research to date has focused largely on the development of overt knowledge structures to model the short-term skilled behavior of individual experts. It is now shifting to apply the same overt knowledge paradigm to the short-term skilled behavior of organizations. What is missing in our existing approaches is an understanding of the longer-term processes whereby skilled behavior is adapted to changing circumstances, the social processes whereby individual skilled behavior is derived from supportive human and technical systems, and the systemic processes integrating individuals and organizations. It may well be that the existing focus in expert systems research on overt knowledge structures is misleading when we attempt to extend the systems to encompass adaptive and social processes.

However, as a discussion of human action, a meta-message of this paper is that practice does not derive from theory, nor theory from practice. Experience and understanding co-evolve, with important interactions but also with inherent autonomy. This paper, while largely discussing theory, is targeted on practice. What insights into system development may be gained by reflecting on the fundamental nature of human knowledge processes? Are there other perspectives on human cognition that are fruitful in stimulating system development?

1.1 Pioneering Systems to Emulate Human Expertise

Like many pioneers, computer scientists have been willing to enter unknown territory with aspirations of achievement despite uncertainties about the terrain. The large-scale research activity involved in the development of 'expert systems' was predicated on the existence of human expertise, and the value of transferring this to computers. Warnings were given, particularly by cognitive psychologists, that human expertise was not necessarily to be valued, not easy to model, and not susceptible to direct transfer (Nisbett and Wilson, 1977; Bainbridge, 1979; Bainbridge, 1986; Broadbent, FitzGerald and Broadbent, 1986). Pioneers, by their nature, have learnt to disregard warnings, taking them as indicating real or apparent dangers to be ignored, faced or bypassed. Expert systems have been built. Methodologies and tools for knowledge acquisition from human experts have been developed. There is an industry of expert systems.

However, expert systems do not exhibit artificial intelligence having the characteristics expected of human intelligence (Dreyfus and Dreyfus, 1986). They are narrow in their capabilities, ineffective in coping with the unexpected, and learn little from experience. They do not have the flexible and adaptive behavior that one expects of an expert practitioner (Schön, 1983). The conceptual foundations of expert system research have also been questioned by those involved in their development, particularly the assumption that underlying expertise is 'knowledge' as a representable and transferable substance (Clancey, 1993). The original objectives of expert system development are themselves brought into question by anomalies in the evaluation of human expertise that cast doubt on the utility of its emulation. Empirical studies of human decision making demonstrate that human decision processes at all levels of expertise are not optimal, and human judgment under uncertainty is often wrong (Kahneman, Slovic and Tversky, 1982). Why then has the transfer of human expertise to the computer so widely promoted and accepted as desirable?

1.2 Expert Systems as Another Information Technology

The foundational problems of current expert systems technology are major impediments to achieving the original objective in expert systems research of emulating human expertise. However, pioneers are also opportunists. Since they are never certain what they will find, they learn to perceive and communicate value in any new territory. Expert systems technology is useful. Knowledge representation systems provide desirable extensions to database functionality. Knowledge acquisition tools provide new means for developing requirements specifications. Information technology is advancing and expert systems research has contributed to that advance. The foundational problems are being bypassed by redefining an expert system to be one that just performs well, rather than one that emulates human behavior or performance. Much current expert systems development may be seen as having the goal of developing decision support systems that emulate the performance we might expect of idealized decision makers, rather than that of human experts. This is reflected in a shift of knowledge engineering methodologies towards software engineering techniques such as KADS which emphasize modeling in general using any source of information, and place no particular emphasis on knowledge transfer from human experts (Wielinga, Schreiber and Breuker, 1992).

The adoption of a technology-centered, rather than a human-centered, perspective in the development of expert systems is a legitimate strategy for practical system development. There are advantages in merging expert systems development with mainstream information systems development. It may well be the most appropriate step for the industry. It recognizes the convergence of many related developments in sub-disciplines where integration of ideas is now highly appropriate. For example, conceptual modeling of databases, object-oriented database development, deductive database development, and knowledge representation for expert systems, have much in common. It is productive to develop systems drawing on the insights of all four research and development communities which, even though they commenced from different cultures, have generated highly related technologies.

1.3 What is Expertise?

Even if expert systems research is recognized as having made a significant contribution to information technology, it would be disappointing if, in common with many ventures in artificial intelligence research in the past, our venture into expert systems development fails to provide any insights into the nature of human knowledge processes. What is expertise, why do we value it, how does it arise, what are the underlying social, psychological and logical processes, what role does it play in the dynamics of the human species, and so on? The notion of expertise is central to the professions, career structures, the health care system, the educational system, and so on. It is at the core of the way in which our society functions, and the basis on which individuals are valued in that society.

Minimally, from the narrow point of view of information technology, computer and communication systems essentially *support* the dynamics of expertise in our society even if they do not as yet effectively emulate or replace it. A reasonable model of expertise would be valuable in the development of such technology, and various tacit models of expertise are implicit in existing developments. As technology develops and society changes, it would be useful to have an overall model of humanity, its processes and products that provides some basis for understanding who we are, where we are going, the interplay of our psychology, culture and technology, and the impact upon all these of personal, societal and technical choices that are open to us. This long-term objective is also assuming short-term significance as the goals of knowledge-based systems research have advanced from emulating the expertise of individuals to those of emulating that of organizations through enterprise modeling (Petrie, 1992).

1.4 A Theory of Expertise

This paper outlines a theory of expertise based on material in the sociology of the professions, the sociology of the science, the nature of neural activity, and existing theories of knowledge processes in society, individuals and computers. It links this to the larger scene in terms of the dynamics of the human species, the nature of society, and discussions of the modern and post-modern eras. It links it to the technological scene in terms of implications for knowledge-based system development. It attempts to provide an overall model for the discussion of the many issues, and levels of issue, involved in the concept of 'expertise'—a model which is very simple in its basic mechanisms, but is able to account for the complexities of knowledge processes as phenomena emerging from interactions between these mechanisms.

2 Notions of Expertise

Specialist disciplines often take colloquial terms and use them as technical terms having a well-defined meaning for discourse within the discipline. This meaning originates from common usage, but can diverge from it to such an extent that there is ultimately little in common between the technical and the colloquial terms. This can cause confusion in discourse that necessarily involves both the technical and colloquial usage. Such confusion is particularly likely when the technology is commercially significant and is marketed to non-specialist communities. It can also become a major impediment to progress in a discipline if the technical definition of the term fails to capture the most valued aspects of the phenomena involved, and even more so if overt definitions attempting to capture colloquial usage do so also.

Before examining the technical usage of terms such as *expertise*, *skill* and *knowledge* in disciplines such as psychology and computer science, it is worth analyzing dictionary definitions attempting to capture colloquial usage of these terms.

2.1 Dictionary Definitions of Expert, Skill and Knowledge

Webster's dictionary definition of *expert* as a noun is:

> *"a person who has special skill or knowledge in some particular field; specialist; authority,"*

and as an adjective is:

> *"possessing special skill or knowledge; trained by practice; skillful or skilled."*

These definitions capture some significant connotations of expertise and it is useful to deconstruct them carefully.

First the use of the terms "has" and "possessing" gives skill and knowledge connotations of a substance that may be possessed. This association of expertise with substance can lead to a perspective that sees that substance as something to be transferred to a computer. It may also given the impression that to possess that substance is to be an expert.

The first association is misleading in the sense that in many cases the only evidence one has for possession of something is that an expert is capable of skilled performance in a task. One may reason that there must be some basis for this performance, and it is a reasonable metaphor to see this as possession of a substance. However, the 'substance' is an imputed hidden variable and hypothesizing its existence gives little insight into the nature of expertise. The metaphor may also be misleading in locating expertise within the expert rather than as a process of interaction between expert and situation.

The association of skill and knowledge in both definitions is part of this metaphor in implying that knowledge is the substance underlying skill. Skill is defined as both:

> *"the ability, coming from one's knowledge, practice, aptitude, etc., to do something well,"*

and as

> *"competent excellence in performance; expertness; dexterity."*

The problem of relating these two definitions of skill, the first causal and the second phenomenological, involves major ontological, epistemological and psychological issues.

Knowledge is defined as:

> *"acquaintance with facts, truths, or principles, as from study or investigation."*

What are facts, truths and principles and how does acquaintance with them lead to competent excellence in performance? Does skilled behavior indicate the possession of knowledge?

The impression that the *possession* of skill is adequate to capture the normal usage of the term expert is also misleading. One would term someone skilled who can perform a task well, but to term someone expert has connotations going beyond mere skill, of being able to perform well in difficult situations, of maintaining the performance in changing, unexpected and novel circumstances. These are the connotations which Schön emphasizes in his discussion of "reflective practitioners" who do not attempt to merely preserve their existing capabilities but to extend them continually in order to match changing circumstances (Schön, 1983).

The difference between the definitions of noun and adjectival forms in the dictionary definitions is also interesting. The noun form defines a *person*, so neither a computer program nor an organization could be termed an expert. However, the adjectival form defines only functions, processes and attributes, so one might well have an *expert program* or an *expert company*.

The auxiliary terms are interesting in suggesting other aspects of expertise. It is *specialist*, not a general attribute like intelligence, and hence can be seen as a situated role that a person can play rather than a general property of that person. Its being associated with *authority* suggests that it plays a social role in that others must allow an expert:

> *"the power to determine, adjudicate, or otherwise settle issues or disputes; jurisdiction; the right to control, command or determine."*

Its association with being *trained by practice* indicates one, but only one, of the many processes whereby expertise is acquired.

2.2 Problems in Definitions of Colloquial Usage

In summary, the major problems with the dictionary exposition of colloquial usage is the definition of expertise in terms of either knowledge or skill, and the definition of skill in terms of knowledge, practice or aptitude, with knowledge being defined as acquaintance with facts, truths, or principles. Notions of skilled behavior as a phenomenon are confounded with notions of what underlies that behavior as a mechanism. In addition the connotations of an expert as a role in society rather than a property of an individual, and as one who assimilates experience rather just exhibits skill, are only peripherally addressed.

The problems introduced by attempting to model human action as derived from knowledge have been extensively discussed in the literatures of philosophy and sociology. Gadamer, in his critique of Hegel's theory of knowledge, highlights the fundamental issues underlying the relation of expertise to knowledge:

> *"For Hegel, it is necessary, of course, that the movement of consciousness, experience should lead to a self-knowledge that no longer has anything different or alien to itself. For him the perfection of experience is 'science', the certainty of itself in knowledge." (Gadamer, 1972)*

However, Gadamer argues:

> *"The nature of experience is conceived in terms of that which goes beyond it; for experience can never be science. It is in absolute antithesis to knowledge and to that kind of instruction that follows from general or theoretical knowledge. The truth of experience always contains an orientation towards new experience. That is why a person who is called 'expert' has become such not only through experiences, but is also open to new experiences. The perfection of his experience, the perfect form of what we call 'expert', does not consist in the fact that someone already knows everything and knows better than anyone else. Rather, the expert person proves to be, on the contrary, someone who is radically undogmatic; who, because of the many experiences he has had and the knowledge he draws from them is particularly equipped to have new experiences and learn from them." (Gadamer, 1972)*

In the expert systems literature, Clancey has criticized approaches to expert system development based the assumption that expertise can be captured in overt knowledge, and comes to similar conclusions as Gadamer:

> *"The new perspective, often called* situated cognition*, claims that all processes of behaving, including speech, problem-solving, and physical skills, are generated on the spot, not by mechanical application of scripts or rules previously stored in the brain. Knowledge can be represented, but it cannot be exhaustively inventoried by statements of belief or scripts for behaving. Knowledge is a capacity to behave adaptively within an environment; it cannot be reduced to representations of behavior or the environment." (Clancey, 1989)*

He argues that overt representations of knowledge are only partial models of the knowledge processes underlying human behavior:

> *"**A representation is not equivalent to knowledge***
>
> *A representation of what a person knows is just a model of his or her knowledge, a representation of a capacity. Knowledge cannot be reduced to (fully captured by) a body of representations. Knowledge cannot be inventoried.*
>
> ***The meaning of a representation cannot be made explicit***

Meaning can be represented, but it cannot be defined once and for all, captured fully by representations. The meaning of a representation is open, though there are culturally stable representations of meaning (e.g., word senses).

The context in which a program is used cannot be made explicit

Context can be represented, but the world cannot be objectively and exhaustively described; cultural or social circumstances cannot be reduced to a set of facts and procedures." (Clancey, 1993)

In the artificial intelligence literature *connectionist* systems are proposed as providing the capacity to behave adaptively within an environment (Bechtel and Abrahamsen, 1991), and the reductionist link from mind to brain is a significant alternative perspective to those which emphasize overt knowledge. One problem with this perspective is that it may be presented dogmatically as excluding mental phenomena:

"I am willing to infer that folk psychology is false, and that its ontology is chimerical. Beliefs and desires are of a piece with phlogiston, caloric, and the alchemical essences." (Churchland, 1989)

However, there is no need to adopt such a unitary reductionist position, and the more interesting research question is how to bridge the gap between the physical processes of neural networks and the phenomena of mind. A more fundamental problem is that connectionist reduction focuses on the individual brain and does not address the social context of expertise.

A full theory of expertise has to address overt knowledge representation, adaptivity, and social phenomena within a unified framework. The following three sections address the psycho-social links, how notions of agency arise from modeling the survival processes of living organisms, and how these perspectives may be synthesized into a systemic model of human knowledge processes.

3 Models of Skill and Knowledge

Technology is not a natural phenomenon, independent of our existence, but arises out of human choice. The stance adopted by the designer largely determines the outcome of the design process. Hence, in understanding the current state of expert systems research, it is important to recognize the sources of existing design concepts, and to analyze these sources in relation to their origins and alternative sources.

3.1 Cognitive Psychology and Cognitive Science

The obvious, or most accessible, source of models of expertise for computer scientists has been the literature on cognitive psychology (Baars, 1986; Costall and Still, 1987) and cognitive science (Hirst, 1988; Meyering, 1989; Posner, 1989). This has the attraction of being based on information processing models that resemble processes familiar in the computer.

"Cognitivism is the attempt to explain human and even animal cognition in terms of internal representations and rules. The theory of perception has, for many years, been premised upon the assumption that the perceiver must construct a mental representation of the physical environment. However, technological developments such as cybernetics,

> *information theory, signal detection theory and, most recently, computer science, have encouraged a similar approach to the topic of 'skills.' (Costall and Still, 1987)*
>
> *"A revolution occurred in the 1950s which might crudely be summarized as the overthrow of Behaviourism by Information Processing." (Johnson-Laird and Wason, 1977)*
>
> *"Cognitive science is the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation." (Simon and Kaplan, 1989)*

However, there is a danger that basing the technology of systems that are intended to emulate human expertise on a science that is itself based on a computational model of expertise is a circular and self-justifying process. In particular the science will not be able to provide a critique of what is missing in the technology, and attempts to remedy defects in the technology from within the conceptual framework of the science are unlikely to succeed. Hence, it is useful to widen the perspective and examine other approaches to the understanding of human behavior.

3.2 Cognitive Science and Behaviorism

The position of cognitive science is often overstated because its genesis was a reaction to previous overstatements of behaviorist methodologies that disallowed consideration of mental processes as part of a science of psychology.

> *"Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no part of its methods, nor is the scientific value of its data dependent on the readiness with which they lend themselves to interpretation in terms of consciousness." (Watson, 1913)*

Skinner's "radical behaviorism" adopted a more balanced position:

> *"Mentalism kept attention away from the external antecedent events which might have explained behavior, by seeming to apply an alternative explanation. Methodological behaviorism did just the reverse: by dealing exclusively with external antecedent events it turned attention away from self-observation and self-knowledge. Radical behaviorism restores some kind of balance. It does not insist on truth by agreement and can therefore consider events taking place in the private world within the skin. It does not call these events unobservable, and it does not dismiss them as subjective. It simply questions the nature of the object observed and the reliability of the observations." (Skinner, 1974)*

From this perspective, cognitive science does not involve a revolutionary overthrow of behaviorism but rather a redressing of the balance so that information flows both within and without the organism are considered as parts of an overall model. Operant conditioning is a major phenomenon in human learning and its status as a predictive model of many major phenomena cannot be overthrown. Behaviorism is itself an information-processing model focusing on the relations between sequences of inputs and outputs rather than hypothesizing internal states, and much of cognitive science may be more accurately viewed as an extension of behaviorism.

Skinner does not value cognitive models because he emphasizes prediction and control of behavior, and argues that if one is able to account for the behavior of an organism in causal terms then modeling that system as an intentional agent, while possible, is not particularly useful. His strong hypothesis is that causal modeling is always in theory possible, even though it may be impractical:

> *"behavior is shaped and maintained by its consequences, but only by consequences that lie in the past. We do what we do because of what has happened, not what will happen. Unfortunately, what has happened leaves few observable traces, and why we do what we do and how likely we are to do it are therefore largely beyond the reach of introspection. Perhaps that is why, as we shall see later, behavior has so often been attributed to an initiating, originating, or creative act of will." (Skinner, 1989)*

3.3 Exchange Theory

Skinner's theory of operant conditioning provides an initial platform from which to develop a theory of adaptive processes in human behavior. In artificial intelligence research, reinforcement mechanisms have been incorporated as performance feedback in machine learning programs and in neural networks. Operant conditioning may also be used to model many aspects of social and organizational processes. *Exchange theory* in sociology was developed by Homans as a direct extension of behaviorism to social interactions. Some of his major propositions are:

> *"For all actions taken by persons, the more often a particular action is rewarded, the more likely the person is to perform that action.*

If in the past the occurrence of a particular stimulus, or set of stimuli, has been the occasion on which a person's action has been rewarded, then the more similar the present stimuli are to the past ones, the more likely the person is to perform the action, or some similar action, now.

> *The more valuable to a person is the result of his action, the more likely he is to perform the action.*

The more often in the recent past a person has received a particular reward, the less valuable any further unit of that reward becomes for him." (Homans, 1974)

These appear to be straightforward statements about operant conditioning of individuals, but Homans extends them to social behavior by bringing those who *provide* the rewards into the model, and analyzing social behavior as the *exchange* of rewards.

Homans points out in a review of the status of exchange theory in sociology that these basic behavioral propositions are universal phenomena that are adopted, often tacitly, in most other social theories (Homans, 1987). Exchange theory is not an alternative to other sociological theories, but rather a link from all aspects of social behavior to underlying psychological phenomena. It does not account for all social phenomena, but it accounts for much of their dynamics, and reminds us that an economic perspective is always available. What are rewards, stimuli and values are questions that may be answered in many different ways, but if they can be identified in a particular social model then operant conditioning concepts may be applied because these concepts are inherently involved in the identification. Like Skinnerian behaviorism, exchange theory, viewed in this way can be criticized for the circularity of its definitions, but such criticism misses the point that the phenomena described are ubiquitous in human behavior and in the way we perceive it—operant conditioning is both an empirical phenomenon and a natural explanatory form.

3.4 Cognitive Science, Meaning and Critical Theory

Viewed as a debate over the efficacy of behavioral modeling techniques, the behaviorist and cognitivist positions are complementary rather than mutually exclusive. However, both seem to offer a mechanical model of human behavior that misses a major dimension of human existence—the way in which we attach "meaning" to events and actions. Bruner saw the understanding of meaning as one of the major objectives in developing cognitive science that became lost as information processing analogs of human behavior were developed:

> *"Very early on, for example, emphasis began shifting from 'meaning' to 'information,' from the* construction *of meaning to the* processing *of information. These are profoundly different matters." (Bruner, 1990)*

The point at issue is one that has been most extensively developed by the Frankfurt School in their distinction between scientific theories and *critical theories*. The distinctions may be characterized through three major differences:

> *"Scientific theories have as their aim and goal successful manipulation of the external world. Critical theories aim at emancipation and enlightenment.*

Scientific theories are 'objectifying.' Critical theories are 'reflective,' or 'self-referential.'

> *Scientific theories require empirical confirmation through observation and experiment. Critical theories are cognitively acceptable only if they survive a more complicated process of evaluation, the central part of which is a demonstration that they are 'reflectively acceptable.'" (Geuss, 1981)*

Relative to these distinctions, both behaviorism and cognitive science are scientific theories, and neglect the way in which meaning is imposed on human behavior, becomes part of that behavior, and, like theories of behavior, comes to have major effects on behavior.

Consideration of meaning and the reflective and reflexive nature of behavior involves socio-cultural issues that go beyond individual psychology, and have been neglected in mainstream cognitive psychology:

> *"if the goal is no less than a verified architecture of cognition that can illuminate the full range of human intelligence, the distance yet to go is staggering. Two areas in which these distances are most notable are in the study of cultural differences in cognition and subjective mental experience and the brain." (Posner, 1989)*

3.5 Symbolic Interactionism, Constructivism and Ethnomethodology

In the sociology literature, Blumer's development of *symbolic interactionism* (Blumer, 1969) addresses the role of meaning in behavior. His three basic premises are:

> *"Human beings act toward things on the basis of the meanings that the things have for them.*

The meanings of things arises out of the social interaction one has with one's fellows.

> *The meanings of things are handled in and modified through an interpretative process used by the person in dealing with the things he encounters." (Wallace and Wolf, 1991)*

What symbolic interactionism adds to exchange theory is the notion that the stimuli and rewards involved may be a matter of social convention rather than of physical phenomena, and that the conventions are not rigid but subject to an interpretive process. This is consistent with a constructivist psychology that sees individual and social constructs as generated by experience and subject to change:

> *"Man looks at his world through transparent templets which he creates and then attempts to fit over the realities of which the world is composed.*

Constructs are used for predictions of things to come, and the world keeps on rolling on and revealing these predictions to be either correct or misleading. This fact provides the basis for the revision of constructs and, eventually, of whole construct systems." (Kelly, 1955)

Blumer and Kelly see meanings or constructs as being pre-linguistic, but being capable of having attached linguistic descriptions, so that language can be seen a particular form of symbol system, and one which, as Vygotsky (1934) has stressed, can have a profound and direct influence over behavior.

Skinner would interpret meanings and constructs as hidden variables of little value in predicting and controlling behavior compared with the analysis of the preceding history of operant conditioning. Blumer and Kelly would see stimuli and rewards as meanings and constructs that themselves arise out of experience and social interaction. The behaviorist and constructivist perspectives are not in conflict. One is an external observer's view of the system with an instrumental bias, and the other is a participant's view of the system with an emancipatory bias. Where the perspectives appear to differ most is that operant conditioning is often portrayed as leading to behavioral determinism, whereas symbolic interactionism and constructivism emphasize that situations offer the choice of alternative meanings and constructions, and hence to behavioral indeterminism. In fact, as is discussed later, such indeterminism is also consistent with the dynamics of operant conditioning models.

One major source of indeterminism is the positive feedback introduced when symbolic models of behavior become part of the psychological and social systems in which the behavior arises. Garfinkel's development of ethnomethodology addresses this reflective and reflexive nature of behavior:

> *"Not only does commonsense knowledge portray a real society for members, but in the manner of a self-fulfilling prophecy the features of the real society are produced by persons' motivated compliance with these background expectancies." (Garfinkel, 1967)*

Levis has developed a theory of inter-personal behavior which provides a detailed taxonomy of the pathological phenomena that can result from our negative expectations of others behaviors in themselves coming to generate precisely those behaviors we fear. He deconstructs a wide range of Greek myths as parables providing educational examples of the social power of such inter-personal interaction (Levis, 1977).

The self-fulfilling prophecy aspect of such reflexive processes is the basis of Castoriadis' analysis of the institution of society being strictly *imaginary* (Castoriadis, 1987). We legitimate each age (Blumenberg, 1983). If this is seen to denigrate the nature of meaning then the point is being missed. It is the human capability to fantasize and reify models that are not grounded in our physical environments or biological processes that gives rise to those human characteristics that we most value. It is irrelevant to analyze these activities in terms of survival value, correspondence to reality, and so on.

It is a major role of art to remind us that our humanity is not determined by natural law but depends on our imaginations. Without this insight, morality, ethics and value, may be perceived as derived from the physical world and imposed on us much as a brick wall imposes itself on our perception. As a metaphor, the impenetrability of the wall, and the hurt when we walk into it, may correspond to the force of a moral precept and the hurt when we break it. As an aid to deep understanding, the metaphor is highly misleading. A one-sided emphasis on reductionism that neglects the emergence of meaning from the underlying processes creates an artificial divide in our perception of the world:

> *"The quantification of nature, which led to its explication in terms of mathematical structures, separated reality from all inherent ends and, consequently, separated the true from the good, science from ethics." (Marcuse, 1964)*

Habermas has echoed this in his critique of simplistic analyses of post-modern phenomena:

> *"In everyday communication, cognitive meanings, moral expectations, subjective expressions and evaluations must relate to one another. Communication processes need a cultural tradition covering all spheres, cognitive, moral-practical and expressive." (Habermas, 1985)*

4 An Exchange-Theoretic Model of Expertise

An exchange-theoretic model of the social processes of adaptive systems is sufficient to account for much of the dynamics of the way in which expertise arises in society. Symbolic interactionist and constructivist analyses of the communication and modeling processes involved can then also be used to derive a cognitivist account of expertise.

4.1 Stich and Nisbett's Theory of Expertise

The basic model derives from Stich and Nisbett's theory of expertise that takes account of the sociological factors involved and is grounded in an analysis of the logic of inductive processes. They note:

> *"The role of experts and authorities in our cognitive lives has been all but ignored by modern epistemologists. Yet it is the hallmark of an educated and reflective person that he recognizes, consults and defers to authority on a wide range of topics. We defer to the judgment of experts not only in assessing inference, but on factual questions as well, in medicine, science, history, and many other areas. Few educated lay persons would consider questioning the consensus of authorities on the authenticity of a painting, the cause of an airline crash, or the validity of a new theorem. Indeed, it is our suspicion that one of the principle effects of education is to socialize people to defer to cognitive authorities." (Stich and Nisbett, 1984)*

They analyze expertise commencing with Hume's critique of induction as a process which is not deductively valid, and where it is a circular argument to claim that it is inductively valid (Hume, 1739). Goodman proposed that we accept the circularity but note that it involves a dynamic equilibrium between data and inference rules:

> *"A rule is amended if it yields an inference we are unwilling to accept; an inference is rejected if it violates a rule we are unwilling to amend." (Goodman, 1973)*

Rawls in his theory of formal justice as induction from informal moral behavior terms this a *reflective* equilibrium (Rawls, 1971).

Stich and Nisbett argue that there are flaws in Goodman's analysis in that individuals do not necessarily behave rationally in their own behavior relative to known good practice. They repair them by proposing that the equilibrium is social not individual:

> *"a rule of inference is justified if it captures the reflective practice not of the person using it but of the appropriate experts in our society." (Stich and Nisbett, 1984),*

This gives an operational definition of the role of experts within an overall social learning process as referential sub-systems managing the process in specific sub-domains.

4.2 Positive Feedback Processes Generating Expertise

This analysis is remarkable in capturing the adaptive nature of expertise, socially situating it, and linking it to formal models of induction. What it does not address is how particular individuals become charged with managing the reflective equilibrium of a particular domain. Gaines shows that a simple exchange-theoretic model can model a society of, initially identical, adaptive agents becoming functionally differentiated into 'experts' each managing learning in a particular sub-domain (Gaines, 1988). He notes that if tasks are themselves viewed as resources that are allocated by a client community to a problem-solving community, then there is strong positive feedback present in that clients will allocate tasks to agents on the basis of their past performance, while improved performance results from performance on tasks:

> *"Experts trade the skills based on their knowledge for access to problems providing them with new material for the inductive process. The formation of expertise is functional in general because it leads to division of labor in the management of knowledge acquisition. The development of an individual expert is a random process brought about by strong positive feedback loops in the social process; for example, that a proto-expert with superior performance is brought more problems and hence has a greater opportunity to learn and improve that performance. A diversity of such positive feedback processes operate in the professions and sciences with little relation between them except their overall effect in promoting the formation of expertise." (Gaines, 1988)*

Such positive feedback processes within the scientific community have been documented in a number of sociological studies (Hagstrom, 1965; Merton, 1973; Blume, 1974). For example, in terms of individual human expertise, a patient with a difficult condition will be routed the specialist with the best track record of having dealt with similar conditions in the past. That specialist is thereby given the best opportunity to learn more about these conditions and hence to further enhance his or her actual and perceived expertise. Merton coined the term the "Matthew effect" for those features of the reward system in research that were biased towards allocating greater credit for the same discovery to those with an already established reputation (Merton, 1968). Similar considerations apply to the award of scholarships, invitations to scientific congresses, and so on (Blume, 1974). They also apply not only to individuals but also to social units such as a company subject to government procurement procedures that are heavily biased to contractors with 'prior experience' and with whom the government agency has 'prior experience.' Analytical and simulation models show that this positive feedback is sufficient to account for an initially uniform population becoming strongly functionally differentiated (Gaines, 1988).

4.3 The Need for Deeper Models

At this point, one might be satisfied to propose that a general theory of expertise can be developed in terms of a the dynamics of a society of socially situated adaptive agents, with operant conditioning as a basic mechanism and knowledge arising as a constructed system of symbolic meanings imposed on, and becoming part of, the basic behaviors. However, it is possible to develop a broader perspective from which this theory may be derived, and where the relations between the behavioral and symbol systems, and between individuals and organizations, are more clearly defined.

Some reasons for going deeper are apparent in Stich's later repudiation of the reflective equilibrium model in his book *The Fragmentation of Reason* (Stich, 1990). He argues against it as a solution to the problem of induction rather than as a phenomenological account of expertise in society. At one level his argument can be seen as deriving from Hume's original analysis of induction as neither deductively nor inductively valid. However, Stich also argues against more specific justifications in terms, for example, of an evolutionary process that filters out agents whose behaviors are non-anticipatory for the environment in which they happen to exist. These arguments are important in suggesting that one should not be satisfied with an account of expertise that takes for granted the phenomenon of operant conditioning with the implicit assumption that the organisms involved have solved the local problem of induction in being able to adapt their behavior to anticipate their particular environment.

5 Modeling Autopoietic Systems

There is a very general systemic model of the behavior of any living system that allows the properties of socially situated adaptive agents to be derived in a way that gives new insights into, and much greater generality to, the exchange-theoretic model of expertise. In particular, one can show that neither general solutions to the problem of induction, nor evolutionary functionalist arguments are necessary. Notions of agency and expertise arise out of presuppositions made in modeling living systems. They are artifacts of modeling, but highly significant ones because they are socially accepted artifacts that have become reified as part of the processes of human living systems.

5.1 Autopoietic Systems and Agency

The most fundamental properties which we impute to any system are its existence and persistence over time. A system is identifiable as not having existed before some time, of definitely existing after some later time, of persisting in existence until some later time, and of not existing again after some later time. This coming into existence, persisting for while, and going out of existence again is a common property of all systems. It applies to both living and non-living systems, and in living systems it applies at all levels from cell to species.

What characterizes living systems are the recursive activities of self-replication underlying their persistence, that they actively and continually *create* the conditions for their persistence.

Maturana (1975) has proposed that this is the fundamental distinction between living and non-living systems. Autopoietic systems:

> *"are systems that are defined as unities as networks of production of components that (1) recursively, through their interactions, generate and realize the network that produces them; and (2) constitute in the space in which they exist, the boundaries of this network as components that participate in the realization of the network...a living system is an autopoietic system in physical space." (Maturana, 1981)*

It is these activities of autopoietic systems that are necessary to their persistence that we see as some form of goal-seeking and model through notions of agency.

However, there is no notion of agency in Maturana's definition, and no ascription of intrinsic intentions or goals to living systems. The notion arises because a modeler finds it convenient to adopt an *intentional stance* (Dennett, 1987), but there is no necessity to assume that the properties of the model introduced by this stance are present in the system being modeled. A reactive persistent system in itself has no goals or intentions. It reacts to its environment through mechanisms that tend to maintain its persistence despite changes in its environment. An external observer may model this behavior as goal-directed because that provides a simple predictive explanation. That is, if an autopoietic system when disturbed, regardless of what state it is triggered into, seems to return to its original state, it is naturally modeled as goal-seeking.

If the system's environment happens to contain other systems like itself and the system's activities include observation and modeling, it may model the other systems as goal-directed, and then by analogy come to model itself as goal-directed. This is a natural outcome of autopoiesis in a social environment. The notion of agency arises as we impose notions of modeling upon the phenomena of autopoietic systems.

5.2 The Genesis of Autpoietic Systems

As well as not reading too much into models of autopoietic systems, it is important to note that we can ascribe very little to their *existence*. A chaotic universe has a probability of producing any system including autopoietic systems. Once such systems exist and are modeled properties emerge (Sharif, 1978). As Peirce remarks:

> *"Law begets law; and chance begets chance...the first germ of law was an entity which itself arose by chance, that is as a First." (Peirce, 1898)*

Jantsch (1980) and Prigogine (1984) have developed detailed models of how organization emerges from chaos. Gould has analyzed the fossil record and modeled the genesis and extinction of a wide variety of species as low probability random events (Gould, 1989). Monod has given a biochemical model of life as an improbable phenomena that, once it exists, follows deterministic laws (Monod, 1972). When a living system comes into existence it acts to persist, but, from the systemic perspective advanced by Maturana, this is the definitional property by which we recognize its existence as a living system, not an additional property going beyond active persistence.

Barrow and Tipler have analyzed the remarkably narrow physical conditions under which life as we know it can exist (Barrow and Tipler, 1986), and when one examines the mechanisms by which a living organism narrows these conditions even further in order to persist it is natural to ascribe purpose to its activity. For example, Cannon terms such activity homeostasis and part of

The Wisdom of the Body (Cannon, 1932), and Ashby in analyzing homeostasis as part of his *Design for a Brain* models it as a goal-directed process (Ashby, 1952). However, he also shows how such apparently goal-directed behavior arises in any system with many states of equilibrium. The utility of an intentional stance stems from simple systemic considerations, and one has to be careful in reifying the notion of agency to realize that the additional assumption of the existence of some reified 'agent' is also a matter of utility, not of existential proof or necessity.

5.3 Chaotic Behavior in Autopoietic Systems

In Ashby's day a system that reacted to its environment by acting until it arrived in a new mode of equilibrium would be seen as not only counter-acting the effects of the environment but also arriving at some state that was determined by those effects, that is, apparently targeted upon them. Nowadays, with the realization that *strange attractors* are prevalent in all forms of physical system (Ruelle, 1989), and particularly in biological processes and their higher-order manifestations such as brains (Basar, 1990), societies (Dendrinos and Sonis, 1990) and cultural phenomena (Hayles, 1991), it would be realized that the final state may be one of very many that have the equilibrating effect but is neither determined by the effects of the environment nor targeted upon them.

In particular, the definition of *fitness* of a species in evolutionary terms is merely a restatement of the species' persistence in terms of the environment in which it persists. As Ollason argues:

> *"Biologists use the concept of fitness as the explanation of the truly inexplicable. The process of evolution is exactly what the etymology of the word implies: it is an unfolding, an indeterminate, and in principle, inexplicable unfolding. (Ollason, 1991)*

A species is fit to exist in an environment in which it happens to persist. As noted in the previous paragraph, this does not mean it was targeted on that environment or that there is a determinate relation between the nature of the environment and the species that happens to have evolved. The environment acts as a filter of species and those that persist are fit to survive. There are no teleological implications, nor moral implications that the species has more right to survive. Neither does this model give survival-directed behavior any greater probability of leading to persistence than any other behavior. Gould details the random phenomena that have made particular species fit to persist for a while in the fossil record (Gould, 1989). Bickerton argues that there is no evidence for what we deem to be high-level human traits to have survival value—intelligence and language have at least as many disadvantages as advantages, and may be seen as of negative value to the survival of the human species (Bickerton, 1990).

Thus, in adopting an intentional stance it is important to remember that one is selecting a modeling schema for its simplicity, convenience and utility. Notions of expertise, the connotations that come with them, and the psychological and social behaviors we associate with expertise are part of a modeling schema that we impose upon certain phenomena of our species. It is not only relevant to ask what is this modeling schema and how does it operate, but also why is it simple convenient and useful. One can then also extrapolate this line of thought and propose other modeling schema that may be even simpler and more convenient and useful.

5.4 Models of Autopoietic Systems

In explicating modeling one becomes involved in a reflexive process because one has to state how the notions of modeling arise from the models adopted of autopoietic systems. However, the notions involved are naturally recursive, and involve the same logic of existential assumptions as in the previous section—one has to assume the existence of modeling processes before the notion of modeling itself can be analyzed.

In modeling the persistence of an autopoietic system despite changes in its environment, one finds it convenient to classify the unobservable state of the system by the observable state of the environment. That is, even though the actual state of the system is not determined by the environment, it is convenient for purposes of explanation to group together internal states by their effects in enabling the system to cope with particular states of the environment. Given that the system persists, as its environment changes, it will be seen as generating a trajectory of states each one of which is indexed by the state of the environment. It is in this sense that an observer imputes to the system a 'model' of its environment. This is the argument form of the result in cybernetics that "every good regulator of a system must be a model of that system" (Conant and Ashby, 1970). The classification of the system's state in terms of that of its environment also makes an 'intentional stance' self-justifying—the system, if it persists, by definition comes to be in a state that compensates for that of its environment.

As a concrete example, consider the process whereby sand takes up the shape of an irregular container. One can examine the end result and say that the sand has 'modeled' the container. However, one would find no modeling algorithm in the grains of sand, and the existence of the model itself is a construct of the observation that the sand and the container now match one another globally—it is only in a very remote sense a property of the sand. If one wished to expedite and improve the process—to *educate* the sand—one would be foolish to attempt to aid the local modeling process by moving individual grains of sand. Instead one would shake the container to provide an environment of maximum opportunity for the sand to settle into the shape of the container. One would shake roughly at first and then increasingly gently. This is exactly the *modeling* process of the Boltzmann machine and its management through simulated annealing (Aarts, 1989). It also corresponds to Gibson's *ecological* model of perception in which we model the world by the brain coming into equilibrium with the stream of incoming sensation (Gibson, 1979).

The theoretical foundations for the relation between an autopoietic system and its apparent modeling capability can also be given a simple interpretation. If we consider a perfect system that is able to match every change in the environment, then an observer modeling each of the two systems through a behavior-structure adjunction will ascribe the same minimal structure to both up to an isomorphism (Gaines, 1977). Because the observer obtains the same model of both system and environment, it is a reasonable metaphor that the autopoietic system contains such a model of its environment. For example, an operator controlling a linear mechanism apparently has an internal linear model despite the discrete 'bang-bang' nature of the neuro-muscular process precisely to the extent that his or her control is optimal (Gaines, 1969).

The symmetry of the models derived by an external observer of a coupled system and environment may appear paradoxical. If the models obtained are the same, then it makes as much sense to see the environment as containing a model of the system as it does to see the system having one of the environment. The symmetry can only be broken by presuppositions about the nature of the coupled systems, or by additional information about one or both of them. If the observer has access to other sources of information about one of the systems that enables its behavior to be modeled as causal dynamics responding to observable inputs, that model will be preferred to the less predictive one of autonomous agency. If such information is available to others but a particular observer cannot access it and model the environment causally, and hence takes an intentional stance then more informed observers may find this inappropriate and term it unnecessary *animism*. A behaviorist will see an intentional stance as animism even when applied to a person.

5.5 Luhmann's Systemic Sociology

Luhman's systemic sociology (Luhmann, 1987) provides a very detailed analysis of the way in which socially meaningful behavior arises out of the dynamics of autopoietic systems. He commences his analysis of the symbolic concepts of trust and power with a simple behavioral model and its interpretation:

> *"The world is overwhelmingly complex for every kind of real system... Its possibilities exceed those to which the system has the capacity to respond. A system locates itself in a selectively constituted 'environment' and will disintegrate in the case of disjunction between environment and 'world.' Human beings, however, and they alone, are conscious of the world's complexity and therefore of the possibility of selecting their environment—something which poses fundamental questions of self-preservation. Man has the capacity to comprehend the world, can see alternatives, possibilities, can realize his own ignorance, and can perceive himself as one who must make decisions.*
>
> *...we invoke a whole new dimension of complexity: the subjective 'I-ness' of other human beings which we experience (perceive) and understand. Since other people have their own first-hand access to the world and can experience things differently they may consequently be a source of profound insecurity for me." (Luhmann 1979 p.6)*

Crespi criticizes Luhmann's statement in terms of it being based on an intentional stance that is not made explicit:

> *"the concept of complexity reduction which forms the basis of Luhmann's theory implies reference to an active principle of selection, which can be understood only as the negative capacity of consciousness in its relation to objectivated forms. Luhmann, even though he recognizes the importance of negation in the concept of complexity reduction, does not relate the latter to subjectivity but to the social system itself, thus attributing to the system a quality that can only be specific of an individual." (Crespi, 1989)*

However, chaos is maximally complex and complexity reduction corresponds to the emergence of organization. The logic of Luhmann's statement can be reformulated to avoid any apparent imputation of intentionality. A chance fluctuation in complexity is sufficient to account for the emergence of the system-environment relations he specifies. Thereafter, modeling and multi-level reflexive modeling lead to the phenomena he describes, including those that Crespi ascribes to the subjectivity of conscious individuals. The essence of the arguments in this section is that there is no conflict between Crespi's and Luhmann's positions, both of which are developed in their works into rich analyses of significant phenomena in the social behavior of living systems.

This compatibility is apparent in Crespi's affirmative quotation of Touraine's analysis of the autonomy of action:

> *"the sense of an action can neither be reduced to the adaptation of the actor to a more or less institutionalized normative system, nor to the expression of the mind through a social activity" (Touraine, 1965)*

The actions of an autopoietic system are prior to, and independent of, such considerations, which belong only to the interpretive act of modeling the system. They are an interpretation, not a derivation, of its behavior.

6 Constructs of Modeling

The preceding section has argued that the behavioral phenomena of an exchange-theoretic model of expertise derive from the presuppositions made in modeling autopoietic systems, in particular, the mutual models of interacting autopoietic systems. This section addresses the other aspect of cognitive modeling of such systems, how notions of meaning arise out of the modeling process. It does so by deconstructing an abstract model of general modeling processes. The argument is again a reflexive one, that it is the way in which we model modeling that leads to our notions of higher-level cognitive processes.

6.1 Modeling Modeling

Klir has analyzed the processes involved in any modeling system and developed an infrastructure for them that can be instantiated in different ways to encompass many different modeling schema (Klir, 1976, 1985). His basic constructs form a hierarchy of systems: a *source system* providing a descriptive terms, a *data system* providing descriptions in these terms, a *generative system* providing a regeneration of these descriptions in terms of a *structure system* providing theoretical terms, itself described through *meta-systems*, *meta-meta-systems*, etc. Figure 1 shows this modeling hierarchy expressed in terms of a primitive process of forming a construct by making a distinction (Gaines and Shaw, 1984). Thus, a general modeling system may itself be modeled as a process that makes distinctions in the world, gathers data in terms of those distinctions, selects from a repertoire of representations those which best generate the data, analyzes relations between the structures of such representations, and recursively repeats such analysis to generate higher levels of the hierarchy. The term *anticipation* is used for the output to capture both prediction and action. It is not necessary in general to distinguish whether the system anticipates correctly by passive prediction, or by actively changing the world to be predictable.

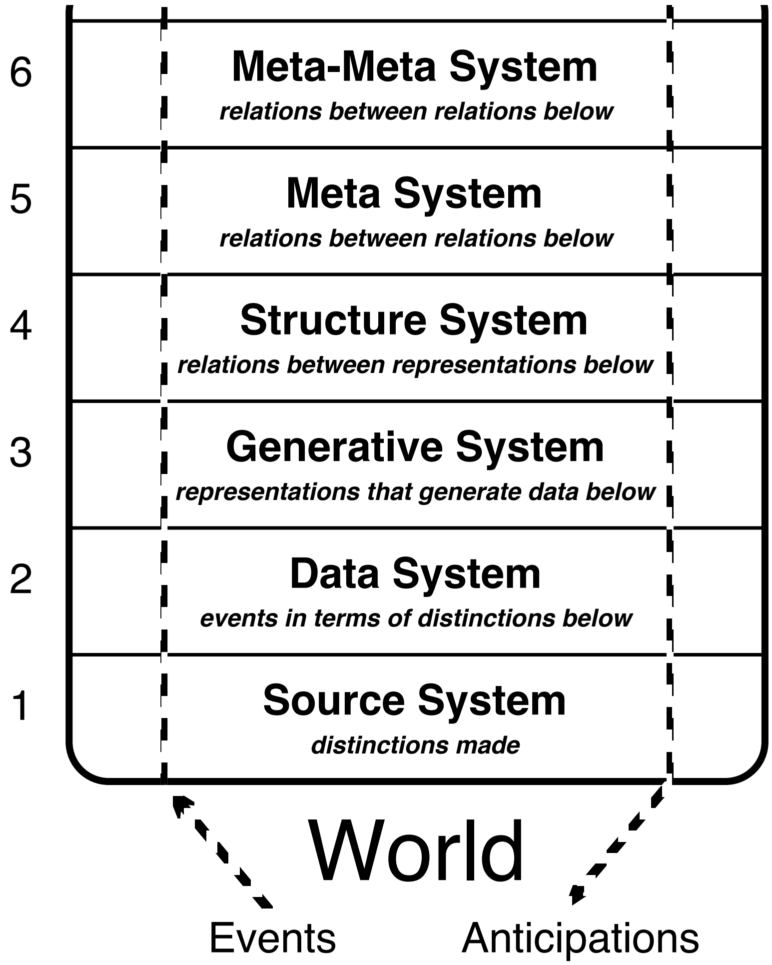

Figure 1 Klir's modeling hierarchy

The instantiation of this hierarchy with particular data description languages, model classes and measures of model complexity and model-data approximation has proven in practice to account for the wide range of mathematical modeling techniques (Gaines, 1977; Klir, 1985). It is interesting as an account of generalized adaptive processes since it makes clear the presuppositions necessary for modeling to take place—a *tabula rasa* cannot begin to model and some degree of 'innateness' is required. The trade-off between the amount of data needed in learning and the innately 'assumed' constraints upon the world can be investigated (Gaines, 1976), as can that with the socio-cultural filtering of data to improve its support of learning (Gaines, 1989). Fodor-style arguments about the innateness of cognitive processes (Fodor, 1986) can be investigated in terms of the presupposed structures at each level of the modeling hierarchy, together with the possible cultural mechanisms for ensuring that the presuppositions are correct and met in experience. In essence, one can operationalize Kant's *synthetic a priori*, the phenomenon where we bring to our apprehension of the world presuppositions that do not become effective until they are used to model experience:

> *"though all our knowledge begins with experience, it by no means follows, that all arises out of experience. For, on the contrary, it is quite possible that our empirical knowledge*

is a compound of that which we receive through impressions, and that which the faculty of cognition supplies from itself." (Kant, 1781)

Pope has noted that distinction-making hierarchies such as that of Figure 1 are common in a wide range of different cultures, and that they have another dimension in that the recursive upward-building process may be seen for what it is and transcended (Pope, 1984). We may interact with a world, begin to make distinctions about it, begin to make distinctions about these distinctions, and then recognize the distinction-making process. This does not necessarily prevent us from continuing to build the hierarchy but it does also allow us to step outside it and reflectively treat our own modeling processes as phenomena which we are able to model. This reflective step, of 'modeling the modeling' is distinct from the abstractive set of subsuming more and more modeling within a unified framework.

If the world being modeled is a socio-cultural world of other modeling agents there is an intrinsic instability in the model process. My model of you is affected by your model of me, and by my model of the modeling processes underlying your model of me, and by my model of your model of the modeling processes underlying my model of you, and so on. Lefebvre uses this mutually referential framework to develop a formal basis for ethical systems based on remarkably sparse logical primitives (Lefebvre, 1982). It is also the basis for ethnomethodological analyses of the essential reflexivity of society.

6.2 Cognitive Processes in Modeling

One may instantiate the modeling hierarchy in a number of different contexts using the vocabularies of psychology, anthropology, organizational science, education, artificial intelligence, and so on, to develop systemic architectures for modeling processes in a wide range of systems. Figure 2 shows a variant of this hierarchy emphasizing the cognitive processes involved in modeling the world and their definitions in abstract, systemic terms (Gaines, 1989):

- To *recognize* at the lowest level is the capability to notice recurrence of the 'same' events in the world when they recur. This is already a significant cognitive act because 'same' is subject to personal definition, and the concept that events recur is a strong presupposition. Recognition is fundamental to any modeling system but is in itself a weak operation since it is dependent on the recurrence to make use of the data.
- To *recall* at the next level is the capability to regenerate the distinction used in recognition internally so that it is itself an 'event' that may be processed. This facility to recreate events in the 'imagination' is fundamental to the existence of the cognitive process, detaching human knowledge processing from the immediacy of experience.
- To *represent* at the next level is the capability to derive the distinction used in recognition and recall from other distinctions that may themselves not relate directly to experience. This facility to 'represent' events in terms of distinctions that relate only indirectly to experience is again fundamental to the efficiency of the cognitive process, allowing novel distinctions to be developed that efficiently encode wide ranges of otherwise unrelated experience.
- To *reconstrue* at the next level is the capability to derive one distinction from multiple models. This facility to move between modeling systems is fundamental to the adaptability of the cognitive process, and the human species, allowing a wide repertoire of anticipatory sub-systems to be developed to cope with the variety of the world.

- To *abstract* at the next level is the capability to detach distinctions from their sources and make the relations between models themselves subject to study. This facility to study the world of modeling as if it were a world of experience is fundamental to the externalization and growth of human knowledge as a cumulative by-product of the anticipatory process. It makes the expertise of the species largely independent of that of existing individuals.
- To *originate* at the next level is the capability to treat the distinction making process itself as a human activity, subject to choice and change, and to generate distinctions in themselves. This freedom raises many questions as to the nature of 'reality', of the 'wisdom' of certain distinctions, and of the relationship of the distinction-making, cognitive and knowledge processes to the nature of the individual and the survival of the species.

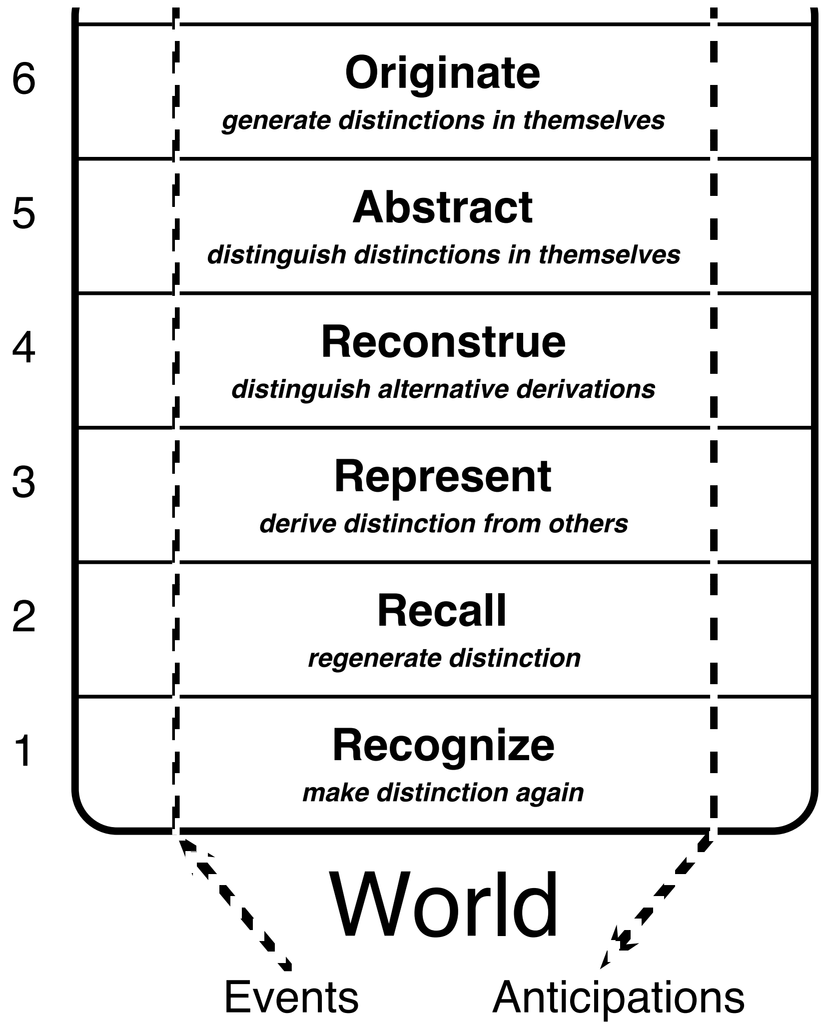

Figure 2 The modeling hierarchy in a psychological instantiation

6.3 Information Flows in Modeling

The information flows in the hierarchies of Figures 1 and 2 are very significant. In anticipation the key distinction is to what degree a level accounts for the information flowing through it and hence this distinction may be termed one of *surprise* (Gaines, 1977). Surprise goes in opposition to the degree of membership of an anticipated event to an actual event and the expected surprise is a form of entropy. Surprise at the lowest level of the hierarchy corresponds to distinctions being inadequate to capture events; surprise at the next level to inadequate variety to experience events; at the next level to inadequate approximation to predict events; at the next level to inadequate simplicity to explain events; at the next level to inadequate comprehensiveness to account for events.

The formal theory of modeling is one in which models are selected at each level down the hierarchy to minimize the rate at which surprise is passing up the hierarchy. The criteria for model selection independent of the data are generally thought of as being ones of simplicity/complexity: of two models which fit the data equally well choose the simplest. However, notions of simplicity/complexity are not well-defined nor intrinsic to the class of models. The simplicity/complexity ordering is arbitrary and in its most general form is just one of preference. In situations that are mathematically well-defined, such as determining the structure of a stochastic automaton from its behavior, such a model schema gives the correct results (Gaines, 1977). Conversely, the success of the schema in stabilizing with regard to a given world defines the characteristics of that world.

Thus the basic modeling schema for adaptive behavior is one in which surprise flows up the hierarchy and preferences flow down. In primitive organisms only the lower levels of the hierarchy are developed, surprise and preferences are linked directly to experience, their mechanisms are genetically determined. In higher organisms the modeling process generalizes both surprise and preference to cope with novel environments. Human life has developed the upper levels of the hierarchy and detached surprise and preference from direct experience and from their genetic roots. Surprise can flow up from a level without flowing into it from below because the processes at that level have generated novelty. Preference can be generated at a high level detached from experience and flow down to affect the relations of the organism to the world.

There is physiological and behavioral evidence of the existence within the brain of the two channels of communication shown in Figure 2 (Tucker and Williamson, 1984). The *arousal* system passes surprise upwards to the cortex from the limbic region when unexpected events occur. The *activation* system passes preferences down from the cortex to the motor regions. Emotion also has a direct interpretation in terms of these information flows. Melges notes that:

> *"the normal function of emotions is to attune the person to overall discrepancies between the present and the future so that he adjusts his plans of action to his future images." (Melges, 1982)*

Thus emotions may be seen as derived from surprise with the type of emotion varying according to circumstances. The deviation from the model may be construed as having adverse or beneficial consequences, being distracting, requiring attention, investigation, action, and so on. This is consistent with Kelly's notion that negative emotions arise through the violation of core constructs (McCoy, 1981). In the modeling hierarchy such core constructs are distinctions that we prefer not to change. From a systemic point of view human feeling tones are signals directing the inductive inference process. This is the basis of Gray's insight that emotions structure cognition and memory (Gray, 1979)—a modeling system does not need to store what it can anticipate, and hence changes in a system's model that we interpret as 'memory' processes correspond to failures in anticipation which are associated with emotions that are the system's cognitive interpretation of surprise.

The analysis of modeling and its infrastructure have generated a perspective in which the emphasis on information flows in cognitive science is natural and expected. However, there is nothing that has been assumed that differentiates the modeling processes of the person from those of any other cognitive system. Notions of autopoiesis and modeling apply as well to organizations as to people. Even notions of emotion are applicable to organizations, not as metaphors, but as an interpretation of the evaluation of discrepancies in the modeling process. The following section generalizes the analysis of autopoietic systems and modeling developed so far to apply also to organizations.

7 Humanity as an Autopoietic System

The analysis to this point has been couched largely in terms of individual human agents because this gives the concepts involved a conventional grounding and allows them to be evaluated in terms of familiar intuitions. However, the interaction between individuals involved in the exchange-theoretic model of expertise has been treated as a different construct from the information flows within an individual, and organizations have played no essential part in the discussion. The final step in the argument is to change perspectives once again and adopt a *collective stance* which considers the human species as a single autopoietic system. This allows a unified treatment of individuals and organizations, and of information flows within individuals, between individuals, and between individuals and organizations. The phrase collective stance is chosen by analogy with Dennett's (Dennett, 1987) intentional stance, because its primary justification is one of utility.

7.1 The Human Species as a Single Organism

To allow the social dimension of expertise to be treated as an integral feature of human activity it is convenient to consider humanity as a single organism. This is intended as a perspective rather than a deep ontological commitment. It does not involve teleological issues such as the ascription of agency or goals to the species because neither agency nor goals will be treated as causal variables for any organism. They, and many other related descriptive terms will be treated as terms within modeling vocabularies, but no particular class of models will be taken as primal. The same considerations apply to notions such as causality. The universe is taken to be something which exists and exhibits phenomena, and the initial descriptions from which notions of expertise are derived are intended to be read phenomenologically. That is not to say that they are intended to be theory-free, but rather that they are about *what* happens, not how or why.

How humanity came to be regardable as a single organism is not a major issue for this paper. One could assume that it has always been so, and that we tend not to see it so because egocentric perspectives emphasizing individual humans are more useful in our everyday lives and cultures. One could assume that it was not always so but that humanity has evolved to be more naturally and usefully regarded as a single organism. Again, such considerations involve no deep issues since no such assumptions are necessary to the argument, and both these perspectives and their associated vocabularies will be treated as legitimate models. In particular, notions such as fitness will not be taken as explanatory variables but rather as post-hoc rationalizations.

The basic mechanism of evolution is that organisms change in ways that are influenced by its environment. The phenomenon is one merely of change, not of direction. If it is modeled as a process of improvement then this modeling process may itself be modeled as one of defining what is meant by improvement. Teilhard de Chardin's (1959) enthusiasm for the phenomenon of the evolution of humanity as a single organism is because he brings to it a value system that sees it as desirable, not because the phenomenon itself has, or can have, any intrinsic value. As a parallel, the beauty and infinite variety of complex forms we perceive in the fractal patterns generated by the chaotic equation underlying the Mandelbrot set (Mandelbrot, 1977) is diagnostic of our processes of perception, not of hidden meaning in the simple equation itself.

From a phenomenological point of view, the way we explain the universe involves circular arguments, and where we chose to break the circularity is arbitrary in itself but significant in leading to our world-views. Ultimately the world-views that we happen to have are just that—the world-views that we happen to have. If we wish to derive them from arguments relating to their appropriateness to the universe that we happen to exist in, then those arguments presuppose a world-view that we happen to have that lets us do so. The circularity is inescapable but it does nor make the whole process of modeling meaningless. Rather, it gives us a choice of perspectives and the basis for changing perspectives should we chose, and the possibility of persuading others that the change is worthwhile in terms of some world-view.

7.2 Recursive Partitioning of Humanity in Time and Space

The organism that is humanity will be assumed to exhibit certain phenomena. First, that it may be recursively partitioned to some depth, and that the parts exhibit much the same phenomena as the whole. Second, that the parts and the whole are distributed in space and have limited extents in space and time. Third, that the parts and the whole interact with environments which may include the parts or the whole. Fourth, that the parts, the whole and the environment change as they interact. Fifth, that some such changes may be evaluated as improvements.

What is being defined here is a vocabulary for describing phenomena of an organism that may be regarded as partitioned into a variety of sub-organisms interacting with environments and exhibiting performance change. If this vocabulary already appears to involve strong presuppositions and to be theory-laden, then three comments may be applicable. First, it is very difficult to develop any description of humanity encompassing normal models without the presupposition that such a descriptive vocabulary may be used. Second, if these presuppositions are taken as themselves being derivable then an alternative framework is being proposed. For the purposes of this paper, the terms are being presupposed as applicable primitive descriptions. Third, the questions of what are space and time, how the partitioning is done, what are the environment, interaction and change, and how improvement is evaluated, are all as significant as they may appear. However, it is not necessary to answer any of these questions to use the framework. That is, the answers are arbitrary for the purposes of this paper. Differing answers to questions such as these can generate very different world views.

Pepper's analyzed such views as *world hypotheses*, defined as unrestricted products of knowledge which cannot reject anything as irrelevant. He proposes that someone desiring to understand the world will take an area of commonsense fact and use this as a basic analogy with which to understand other areas. The structural characteristics of this *root metaphor* become the categories for that person's basic concepts of explanation and description. His analysis is that:

"I. A world hypothesis is determined by its root metaphor;

II. Each world hypothesis is autonomous;

III. Eclecticism is confusing;

IV. Concepts which have lost contact with their root metaphors are empty abstractions." (Pepper, 1942)

Pepper considers four root metaphors underlying common world hypotheses: *formism*, *mechanism*, *contextualism* and *organicism*. However, these are only some of an infinite range of possibilities. From a systemic point of view, world hypotheses are complete, autonomous, non-comparable and can completely account for one another. They are cognitive perspectives on the world not competing theories. If they compete it is in their attractiveness and utility, not in their truth.

7.3 Expertise as a Positive Feedback Phenomenon

The overall thesis developed in this paper is that the systemic mechanism underlying the phenomena of expertise is a simple positive feedback process within an autopoietic system that generates complex behavior subject to many interpretations according to the parts and levels of the systems involved. An account of expertise involves first giving a concise description of the systemic mechanism and then examining how, and why, it may be interpreted in many different ways. That is, what are the presuppositions underlying different perspectives, what models of expertise arise given these presuppositions, and why is each set of presuppositions reasonable in some sense? While this approach is integrative, there is no reason to suppose that the differing perspectives will lead to commensurable accounts, or a uniform theory applicable to all phenomena. In fact, the contrary will be argued, that the essential characteristics of expertise are those of a variety-generating mechanism. From a functionalist perspective, such a mechanism supplies an organism with a reservoir of behaviors with which to cope with an uncertain environment.

Notions of expertise arise because the organism adapts as a whole through adaptation of its interacting parts. The phenomena of expertise precisely correspond to those leading to distribution of tasks and functional differentiation of the parts. The mechanism is one of positive feedback from parts of the organism allocating resources for action to other parts on the basis of those latter parts' past performance of similar activities. Distribution and differentiation follow if performance is rewarded, and low performers of tasks, being excluded by the feedback mechanism from opportunities for performance of those tasks, seek out alternative tasks where there is less competition.

The organism thus conceived has a potential for adaptivity through functional evolution and differentiation that derives from changing relationships between its parts rather than changes in their bio-physical substrate. No one part is crucial to the functioning of the organism, but the experience of any part can contribute to the adaptivity of the whole because of the discourse between parts. In other words, the system can be said to support *cultural evolution* (Boyd and Richerson, 1985) through a variety of *memetic* (Dawkins, 1982), rather than genetic, processes. A major difference between cultural and genetic evolution is that parts which fail in genetic evolution only contribute indirectly to the success of others whereas those that fail, even to destruction, in cultural evolution can communicate information that contributes directly to the success of others.

The phenomena of expertise correspond to a society of relatively undifferentiated adaptive agents becoming functionally differentiated through decentralized systemic processes. From a functionalist perspective, many other phenomena may be analyzed as byproducts of this process. The partitioning in time corresponds to the limited life and fragility of the parts, and the coordination of the parts over space and time gives rise to phenomena of discourse, language and overtly represented knowledge. Such an organism seems well-fitted to an ecological niche involving a greater variety of conditions and greater changes in conditions than those for other known animal species. In particular, it may be capable for some time of supporting a growth in biomass that is very high in relation to the available natural resources, and such that the growth itself is the primary cause of radical changes in the environment of the species.

The limited capacity for activity and limited life of the agents in whom expertise is focused makes it desirable to encourage them to replicate that expertise by any means possible. Hence the dissemination of expertise is itself rewarded and social mechanisms such as apprenticeship, and oral and written communication of the basis of expertise are developed. The general increase in levels of specialist expertise as the organism as a whole adapts means that new parts have an increasingly long trajectory of adaptation to become competitive, leading to social mechanisms such as universal education.

7.4 Neural Structures, Individuals, Groups and Organizations as Different Partitions

The model developed can be applied integratively to analyze the relations between levels. What are people as components of organizations and societies? What are neurons as components of people and cultures? If we return to the species perspective for a moment, and consider the cognitive unit to be the biomass then in terms of territory, diversity and risk it makes sense for that biomass to distribute itself in such a way that severe damage to its parts has little effect on its whole, yet models generated by its parts may be shared by the whole—a formula for distributing the whole brain among small mobile sculls. Our folk evolutionary biology may tell us that is not how it happened, but our systemic analysis will tell us that it does not matter too much if our model is not historically sound provided it is a good model of the system now. An analysis of the psychological processes of individuation arising out of the extreme dependence of the child on the mother and the resultant primate nurture practices may suggest that our naive model is not so wrong after all.

The simple model that the distributed intelligence making up the biomass has people as functional units, however, misses much of the richness of the processes involved. We are egocentric and have somehow located our egos in our skulls. This view has been supported by enlightenment philosophy from Descartes through Husserl to Sartre—*cogito, ergo sum*—the ego turning toward the object—the nothingness within me providing the gap by which I may become cognizant of others. The first person singular is the cognizing agent, and yet there is no fundamental reason for this. Only in Hegel do we find a clear systemic model that does not locate cognitive processes in individuals (Hegel, 1816). However, his terminology is usually misappropriated to apply to *our* being, not that of an arbitrary system, being and reflecting upon its being.

From a systemic point of view any cross section of the modeling hierarchy may be a possible partitioning of the agents in a distributed cognizant system, whether organization, group, person, role, module or neural complex. Simmel made this inter-relation of wholes and parts the central theme of his sociology:

> *"Society strives to be a whole, an organic unit of which the individuals must be mere members. Society asks of the individual that he employ all his strength in the service of the special functions which he has to exercise as a member of it; that he so modify himself as to become the most suitable vehicle for this function.…man has the capacity to decompose himself into parts and to feel any one of these as his proper self." (Simmel, 1950)*

Simmel's insight that the group member is always a fragment of a person, a role created precisely to enable the person to enter the group has been developed extensively by Wolff with his notions of *surrender* and *catch*:

> *"From the standpoint of the world of everyday life, the mathematician, as we often put it, lives in the 'world of mathematics', dealing with 'nonreal' elements, notably numbers, whose relation to 'real' things, to 'reality', is not part of his concern. Analogously for the logician. What makes our subject-object approach to this attitude misleading is the fact that the subject, the student of mathematics or logic—his or her individuality, including motives and attitudes—is irrelevant for our understanding; the only thing that counts is the pursuit, with its results and questions." (Wolff, 1976)*

He makes the key point that not only does the real world, the object, disappear to be replaced by the world of mathematics, but also that in entering into this world the person doing mathematics, the subject, also disappears to be replaced by a new entity, the mathematician.

Wolff was not alone in these insights and there are two further models which develop and complement his. In terms of his *subject* Pask's concept of *P-individuals* as coherent psychological processes capable of engaging in conversations (Pask, 1975) is a useful representation of the results of Wolff's *surrender*, particularly when we note that several P-individuals may execute within a single processor. Thus 'the mathematician' may engage in conversation with 'the physicist' or 'the statesman' all of whom happen to use the same brain for their processing. In terms of Wolff's *object* Popper's concept of a *third world* of *statements in themselves* (Popper, 1968) is a useful representation of that which we *catch*, emphasizing the distinct ontological status of Dawkin's memes:

> *"I regard the third world as being essentially the product of the human mind. It is we who create third-world objects. That these objects have their own inherent or autonomous laws which create unintended and unforeseeable consequences is only one instance (although a very interesting one) of a more general rule, the rule that all our actions have such consequences." (Popper, 1974)*

Pask goes beyond Simmel in conceiving that a P-Individual is not just what we conventionally term a role within a person (which he terms an *M-Individual*, or mechanically characterized individual) but may itself be composed of a number of roles coming together to form a unity that we conventionally term a group or organization:

"a P-Individual...has many of the properties ascribed by anthropologists to a role, in society or industry, for example. A P-Individual is also a procedure and, as such, is run or executed in some M-Individual, qua processor. However, it is quite exceptional to discover the (usually assumed) one to one correspondence between M-Individuals and P-Individuals." (Pask, 1975)

Shaw has developed Pask's notions to show how personal construct psychology may be used to account for the psychological processes not only of individual people but also for that of functional groups such as a nuclear family or a product executive (Shaw, 1985).

7.5 Roles, Organizations and Species

The human species as variously distributed intelligence may be analyzed within the framework of the modeling hierarchy already developed. Figure 3 shows how the species itself may be treated as an anticipatory system with various imputed modeling processes that may be seen as carried out by various levels of sub-organization, themselves constituted through roles within individuals. From this perspective organizations are cross section of the representation of the overall anticipatory system within the modeling hierarchy, and roles are cross-sections of organizations within the same framework. Communication and coordination processes occur at every level of the hierarchy, and can be analyzed in terms of the forms of representation and activity defined at each level.

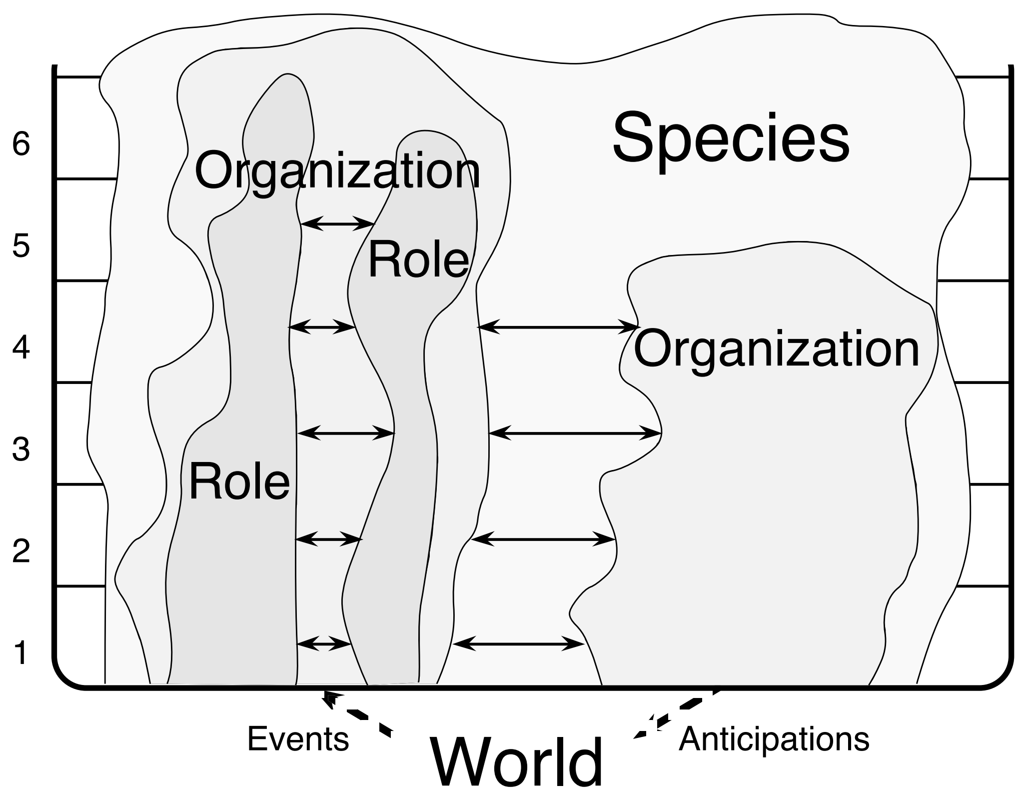

Figure 3 Psychological and social organizations as cross sections of the modeling hierarchy

In particular, this analysis suggests that theories of cognitive agencies should be applicable to all levels of intelligent organization, not just the human person. It draws attention to the potential artifacts inherent in perspectives that place undue emphasis upon the individual, reifying one aspect of localized cognitive activity and neglecting its embedding in a larger context. Figure 3 emphasizes that the boundaries placed around cognitive entities are themselves part of the process whereby we model them, and different placements will lead to different, but related, models. When we study the inter-model relations in cultural, organizational and social psychology, it is illuminating to see them generated by distinctions that are themselves part of the processes being studied. We cannot escape the modeling process but we can attempt to make overt its current preconceptions, deconstructing not just our theoretical frameworks but the personal, cultural and social environments in which they have been developed.

7.6 Language and Knowledge

We can gain new insights into the nature of language and knowledge within this framework of Figure 3. If the biomass is partitioned into semi-autonomous, physically distinct units, how does it coordinate the activities of its components? Systemically, language may be seen as a by-product of such communication. What functions language has in a particular situation will depend on what levels within the hierarchy coordination is required. In ethnomethodological terms, language and knowledge have to be seen as *situated* in the total context of activities within the lifeworld (Garfinkel, 1967).

At the lowest levels of the modeling hierarchy it is not the symbolic aspect of language which is relevant. We coordinate reflexive actions at the lowest level by mimicry. We coordinate rule-based conformity at the next level by reinforcement. These are the levels of Hall's *informal* and *formal cultures* respectively (Hall, 1959). It is only at the next level that his *technical culture* and overt knowledge constructs comes into play. As we go up the hierarchy our linguistic needs become more abstract and what is communicated becomes less associated with experience and more with the way in which we communicate our models in themselves. These are the levels of Popper's third world of objective knowledge. Figure 4 attempts to capture these concepts by showing the modeling hierarchy on the right in terms of connection between events and anticipations at each level, and on the right the coordination, communication and knowledge transfer mechanisms involved across society.

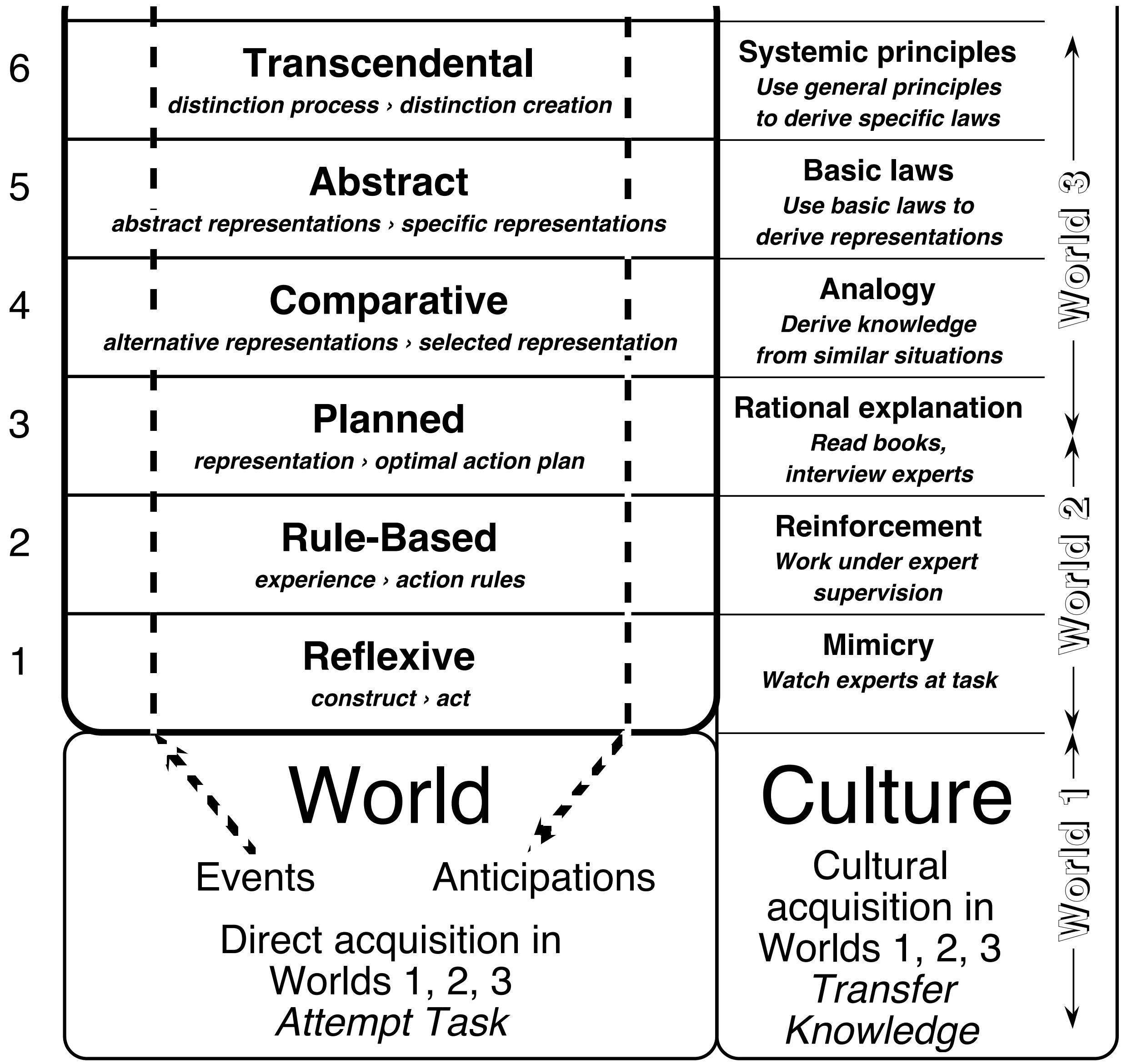

Figure 4 Control and coordination in the modeling hierarchy

Thus language and knowledge can be seen as byproducts of distributed agency. The work of Vygotsky (1934) and Luria (1961) on the role of language in aiding the performance of perceptual-motor skills fits within this framework as communication between two roles, or Paskian P-Individuals, within one head. However, the framework bypasses, as I think it should, the role of language in the mental processes of the individual. Language may be needed for internal communication between Simmel's fragments that we have created in order to play roles in society. Because it is needed for external coordination it may well become used for internal coordination. However, there is no systemic reason for this to happen universally. Most of our mental processes may be not so much pre-linguistic as utterly independent of language. This is a matter for empirical study.

7.7 Modern and Post-Modern Perspectives

Figure 3 may also be understood in terms of Heller's analysis of modern society in terms of three Weberian *spheres*: the fundamental sphere of 'objectivation in itself'; the institutional sphere of 'objectivation-for-and-in-itself'; and the transcendental sphere of 'objectivation for itself'. She discusses the fundamental sphere in the following terms:

> *"What is the social* a priori *that must be dovetailed with the genetic* a priori *in order for any single human being to be able to join the great chain of living creatures?..I have termed this cross-segment 'the sphere of objectivation in itself'. It is, so to speak, the first sphere of the social universe. Without having stepped into this sphere and thus having become a person of a particular social universe, one cannot step into other spheres. What has been acquired here is the foundation of the person's communicative, cognitive, imaginative, creative and emotive possibilities" (Heller, 1990)*

She introduces the need for the transcendental sphere in the following terms:

> *"The sphere of 'objectivation in itself' provides men and women with* meanings*, as a complex of rules, norms, signs and contextual signification, cross-significations. It is precisely meanings (in the plural) that it provides. What it does not provide, however, is meaning in the singular—the meaning of the whole enterprise, of its very existence, of life and of our own life, of everything that it implies. Viewed from this perspective, the human condition includes and presupposes the very existence of another sphere of signification as its necessary (ontological)constituent. I term this sphere one of 'objectivation for itself'". (Heller, 1990)*

She introduces the institutional sphere in the following terms:

> *"This third kind which I have termed the sphere of 'objectivation-for-and-in-itself', since it has resulted from the differentiation of the former two, is the sphere of socio-economic-political institutions. Institutions establish their own sets of norms and rules of communication, action and procedures...Where the institutional sphere is dense, institutions behave like systems within the environment of other systems." (Heller, 1990)*

In terms of the discussion of this paper, and its summary in Figure 3, Heller's distinctions may be seen as based on the relations between role, organization and species, and on the rich symbolic interactions involved in this differentiation. In this paper her transcendental sphere of 'objectivation for itself' has been presented as one of chaos. This is consistent with existential positions that see this very absence of ultimate meaning as providing the void which can be filled with any meaning that one chooses (Sartre, 1943). As Heller notes:

> *"The sphere of 'objectivation in itself' comprises all kinds of narratives, mythologies of various provenance, speculations, visual representations of all sorts and much more." (Heller, 1990)*

Heller's book is rich in insights into the dynamics of roles, organizations and species. In particular, her insight about the significance of the growth in the *density* of the institutional sphere is important in characterizing the transition through the modern to the post-modern age. The past 300 years has seen the growth in the biomass and its spatial density resulting in a massive growth of the institutional sphere to the extent that it has become of equal status with the others. In terms of Figure 3, the post-modern age is one in which gaps between roles and organizations and between organization and species have been filled by a very high density of richly related, coherent, nested partitions of the overall human organism. Rather than seeing it as the ‘death of the subject’ one may better see it as the growth of the subject to become integrated with the whole, or the individuation and wakening consciousness of the species as a whole.

These considerations may seem far removed from the information technology objectives of this paper. However, in coming to understand and development future generations of information systems and it may be highly productive to adopt the perspective of Figure 3. Computer and communications technologies been essential to providing the environment in which the current density and complexity of organizations can exist. The growth of the internet (Quarterman, 1990), and the increasing impact of it on human knowledge processes (Gaines, 1993) can only be fully comprehended from such a perspective. Like language and overt knowledge representation, information technology is not what is driving evolutionary changes in the nature of humanity, but rather an essential byproduct of the occurrence of those changes. Increased understanding of modern and post-modern social phenomena is essential to the design of future generation information and communication systems.

8 Implications for Information Technology

The following sub-sections return to the technological questions of the introduction to this paper and review them from the perspective of a collective stance.

8.1 Neurology and Connectionism

The potential for neurology and connectionism ‘in the large’ is particularly exciting. Why bound our studies of the brain at a particular physical discontinuity in the tissue determined by the skull when we do not at other discontinuities, and when that particular discontinuity is bypassed by so many communication mechanisms. The perceptual organs are brain tissue turned outwards to the world. Why not see them as bridging the discontinuity between tissue in different skulls? There will be differences between intra-skull and inter-skull communication, but are they as significant as we seem to believe? Probably not, but we will never know unless we think seriously about neurology in the large.

Connectionism in the large is a natural extension of current approaches. Smolensky has been a major proponent of neural modeling not as a ‘bottom-up’ reductionist strategy of explicating the mind through its physical mechanism, but as a ‘top-down’ strategy of characterizing a task in a way that allows the mathematical *derivation* of mechanisms that perform it:

> *“My claim is not that the strategy leads to descriptions that are necessarily applicable to all cognitive systems, but rather that the strategy leads to new insights, mathematical results, computer architectures, and computer models that fill in the relatively unexplored world of parallel, massively distributed systems that perform cognitive tasks. Filling in this conceptual world is a necessary subtask, I believe, for understanding how brains and minds are capable of intelligence and for assessing whether computers with novel architectures might share this capability.”(Smolensky, 1986)*

There is a parallel, massively distributed system in the network of individual brains as well as in the network of neurons, and the two systems may be better modeled as one.

8.2 Long-term Perspectives on Information Technology

This paper has emphasized the fundamental and long-term significance of expertise in biological and cultural evolution, and the role of information technology in supporting continuing cultural evolution. One of the problems of keeping pace with the rapid growth of information technology is that we focus on discontinuities in the rapidly changing technology in the short term and lose sight of continuities in information technologies over much longer time periods. If, instead, we examine information technology as the latest byproduct of evolving practice in human discourse it emphasizes its continuity with past changes over the millennia and particularly with the post-enlightenment changes that led to the modern period. For example, Beninger has analyzed the technological and economic origins of the information society as a *control revolution* taking place from the 1830s:

> *"The Information Society has not resulted from recent changes, as we have seen, but rather from increases in the speed of material processing and of flows through the material economy that began more than a century ago. Similarly, microprocessing and computing technology, contrary to current fashionable opinion, do not represent a new force only recently unleashed on an unprepared society but merely the most recent installment in the continuing development of the Control Revolution." (Beninger, 1986)*

When one examines development in expert systems and enterprise modeling in relation to the evolution of computing technology itself, significant new perspectives become available. Why have we not always thought of computer applications as 'expert systems'? Virtually every task that has been programmed for the computer from the very beginning was previously performed by people. We have always been involved in the transfer of human expertise to the computer. What has been different in the recent 'expert systems era'?

The most publicized difference has been in the use of artificial intelligence programming languages, initially production rule systems, and now more elaborate knowledge representation systems. However, if one looks back to MYCIN (Shortliffe, 1976) as the breakthrough application there is no reason why the rules could not have been programmed in decision tables in Cobol. The significant paradigm shift in medical diagnosis that MYCIN initiated was away from attempts to develop Bayesian models based on analysis of large numbers of case records to an attempt to program the diagnostic system directly through discussion with experts.

When expert system technology became of commercial interest, the development of the early shells based on MYCIN coincided with the advent of the personal computer and graphic workstations. This confounds the claims made for the significance of these shells in applications development, since the greatly improved human factors through speed of processing and graphic interfaces has probably played as great, if not greater, role than the programming capabilities of the shells.

From a longer term perspective the convergence of conceptual modeling of databases, object-oriented database development, deductive database development, and knowledge representation for expert systems, is not surprising. They are all technologies for operationalizing increasingly rich representations of the world. The need for such representations derives from the increasing involvement of information technology in general in supporting human knowledge processes. One does not have to take an 'artificial intelligence' approach to develop what may become seen as artificial intelligence technology. It is a natural outcome of developing information technology to play a significant role in human social and knowledge processes.

8.3 Cutting Edge Artificial Intelligence Research

Even though mainstream information technology inevitably comes to subsume technologies as routine that were initially developed from an artificial intelligence approach, there will for the foreseeable future remain a cutting edge of information technology developments generated by taking this approach. The knowledge level perspective has been subsumed first because overt knowledge representation has always been central to information technology, and there has been a natural evolution from the numeric to the algebraic and hence the symbolic. There are many aspects of human intelligence addressed in this paper, however, which are not subsumed in the knowledge level.

Part of the logic of the collective stance may be seen as addressed by the growth of research on distributed artificial intelligence and societies of communicating agents (Bond and Gasser, 1988). The primacy of action and the behavioral basis of adaptation leading to skilled performance without imputation of a knowledge level is being addressed by research on situated agents (Maes, 1990). Minsky's (1985) *society of minds* model analyses individual cognitive activities in terms of an internal society of agents, and the collective stance suggests that this can be taken not as a metaphor but as a particular partition of the lifeworld. It would be interesting to see the ideas in his model applied to groups working closely together where the multiple roles in individuals combine to form a composite agent. The collective stance also provides new insights into issues such as the functions and mechanisms of memory, and these are being addressed in studies of social memory and mentalities (Fentress and Wickham, 1988; Connerton, 1989; Lloyd, 1990).

The reflective nature of human knowledge processes is one of the most important topics that is still primarily the domain of artificial intelligence research. The role of Lisp as the primary programming language in artificial intelligence research arises simply from the fact that Lisp programs are also Lisp data structures making reflective processing intrinsically available. While MYCIN could have been programmed in another language, it would have been far more difficult to provide the interactive debugging environment of TEIRESIAS (Davis, 1982) without the reflective capabilities of Lisp. Such reflection has not been provided in most commercial expert system shells, and knowledge acquisition has been treated as a separate task from skilled performance. The split is a natural one in terms of standard information technology, between 'programming' and 'operation', but is a very unnatural one in human terms. Reflective architectures in artificial intelligence are a topic of research (Maes and Nardi, 1988), reflective capabilities are available in more recent programming languages such as Prolog, and LIFE (Aït-Kaci, 1991), and technology supporting reflection will provide the link between situated agents and the knowledge level.

8.4 Expert Systems

The notion of an 'expert system' as an emulator of human expertise remains a stimulating research challenge and it would be useful to retain it, with current systems being seen as limited in their capabilities rather than as constituting a *de facto* redefinition of the term. This leaves open the objective of enhancing expert systems to emulate the adaptation as well as the skilled performance of human experts.

Emulating human adaptive capabilities is not primarily a matter of machine learning as we know it today, although it has a role to play. The relevant human adaptation processes are those of the social learning of a professional community. Individual experts in such a community are each likely to be conservative in their willingness to change their behavior. It is the reflective equilibrium of the community as a whole which is referential for their behavior, and entrepreneurial behavior deviating too far from this is subject to sanction. The individual acts as a data gatherer and anomaly detector providing input to the community. Those individuals who obtain critical information are usually not the same as those empowered to make critical decisions regarding the reflective equilibrium.

It is the community as a whole which adapts, and the partitions managing different parts of the reflective equilibrium are generally specialist sub-communities rather than individuals. However, every individual involved in action has the potential to be the primary contributor of new information leading to change. When computer-based expert systems play a role in this process currently the anomaly detection is usually left to their human users. However, the system itself has capabilities to detect certain forms of anomaly with greater sensitivity and clarity of information than its users. For example, every rule that states "if A then B" also has a corresponding anomaly detection rule that "if A and not B then report anomaly." There will generally be many more such consistency checking rules than there are performance-oriented rules, and hence their inclusion adds to the development effort required. However, the result is a system able to play a much more effective role in the adaptive processes of a community of experts.

The communication of experience is critical to the social processes of adaptation, and next generation expert systems should be designed as part of a social network so that they function as data gathering and anomaly detection agents within a community. This also entails follow-up procedures providing performance feedback as to the consequences of adopting the systems' advice.

8.5 Maintenance

If the use of terms such as expertise and knowledge in regard to aspects of computing technology somewhat distorts colloquial meaning, the use of the term 'maintenance' is a blatant abuse. Software does not wear out, and the analogy with hardware maintenance is patently incorrect. Requirements change, the environment changes, and software must adapt. It has been an error in computer science to treat software maintenance as a commercial phenomenon deriving from inadequate specifications or imperfect coding. A more profound view of maintenance as analogous to human adaptation rather to than to the wear of mechanical parts might have led to radically different objectives for expert systems. For example, as self-maintaining information processing systems rather than, or as well as, expert performance systems.

The knowledge acquisition literature has emphasized that acquisition is not just akin to requirements analysis, but also akin to software maintenance in that acquisition is required throughout the life-cycle of a knowledge-based system. This may be rationalized in terms of an essential feature of knowledge-based systems compared with ordinary data-based systems which is that the knowledge base is inherently subject to change. However, all software is subject to such change. Payroll programs have to be continually 'maintained' as governments change the basis of tax calculations year by year and are ever inventive of new modes of taxation. Any information technology that plays a significant role in society is subject to the adaptive or evolutionary processes in that society. It is not surprising that one of the most powerful techniques for knowledge acquisition for large-scale rule-based expert systems was originally developed primarily in response to maintenance issues (Compton and Jansen, 1990).

A realistic continuation of expert systems research should treat so-called maintenance issues as seriously as knowledge representation issues have been treated in the past. They are essentially issues of knowledge transfer to information technology, and machine learning, knowledge acquisition, programming, and so on, are all processes of knowledge transfer. Future generations of knowledge engineering cannot depend on knowledge level solutions alone. Techniques for program verification will be effective to the extent that requirements may be specified as overt and complete knowledge structures, but such specifications will be the exception rather than the rule. A realistic approach to practical software engineering for the requirements that society will place on future information technology must look to human adaptive behavior for its inspiration. It will have severely limited impact if it is modeled only on that small part of human knowledge that is overt, axiomatic and subject to deductive proof.

8.6 Situated Action and the Knowledge Level

The collective stance leads naturally to a situated action perspective. We do not have to make the step of re-situating what we have perceived as an autonomous and isolated agent, because we are aware in dividing the system into parts that conceptual boundaries have been created which are artifacts of the subdivision. Each agent is intrinsically situated, and the question reverses to become one of asking what we might be able to say about an agent independent of its situation.

In some literature the situated action perspective has been taken as negative towards a knowledge perspective, as if the knowledge construct became less significant or valuable from a situated perspective (Sandberg and Wielinga, 1991). The contrary is true. The situated perspective provides a metric within which all forms of the knowledge construct can be analyzed and their relations understood. Defining knowledge as a state variable imputed to underlie the performance potential of an agent for a particular task does not denigrate knowledge. It emphasizes that we have to estimate the hidden state in terms of the available measurement of performance of tasks which is standard practice. It also allows situational support of performance to be treated within the same framework as if it provided a short term change in the knowledge state. This provides an integrative conceptual framework in which we can view the knowledge being used by the agent as partially internal and partially external, as a combination of agent and situational knowledge.

The basis of the analysis is operational and behavioral. Relative to a coherent class of agents we may define a partial order of difficulty and transfer on tasks which is inverse to the partial order of performance by agents of those tasks. That is, agents will be expected to have a lower performance on more difficult tasks and to transfer adaptation to one task to adaptation to tasks near in the partial order. Thus, the hidden variable of knowledge is indexed by the overt measurement of performance of tasks, and the partial order on tasks defines one on the knowledge state of agents.

This partial order may also be used to index the knowledge level and other environmental factors affecting either the agent's knowledge state directly, or supporting it indirectly by enabling better performance than would be expected from the knowledge state. If an agent's performance potential may be changed by some means other than adaptation we may measure this by the equivalent change in the knowledge state variable. Thus, knowledge becomes a measure of support systems. If the support system is something that changes the knowledge state of the agent we call it *transfer of knowledge*. If is a physical system that provides a permanent change in the agent's knowledge state we call it *overtly represented knowledge*. If it is another person that provides a permanent change we call it *teaching*. If is a physical system that provides a temporary change in the agent's knowledge state we call it a *tool*. If it is another person that provides a temporary change we call it a *service*.

8.7 Computer-Supported Cooperative Work

If the buzzword of the 1980s was expert systems then that of the 1990s has become computer-supported cooperative work. A focus on supporting the social component of human knowledge processes is clearly appropriate within the framework developed in this paper. However, current research on computer-supported cooperative work is falling into many of the same traps that have been analyzed for expert systems research. It emphasizes the novelty of the problem rather than the role that information technology has had from the beginning in supporting human collaboration. For example, corporate databases have always been seen as a collaboration technology supporting the coordination of activities in an organization (Nolan, 1983). The growing ubiquity and increasing speed of networks now offer new possibilities for supporting direct human interaction while collaborating in the solution of a problem, but this is only an incremental addition to collaborative practice. It is valuable to make the collaborative aspects of all information technology more overt as part of seeing them embedded in human social knowledge processes, but this does not necessarily involve a radical change in the technologies themselves.

There is already evidence of the over-emphasis on the knowledge level that has been noted in the development of expert systems. The natural role for information technology to play in group communication is to support multimedia interaction. Fiber-optics networks offer adequate bandwidth for large numbers of television-quality interconnections supporting remote transmission of the non-verbal components of human face-to-face discourse. However, the system's role is then restricted to being a carrier of content only, and having no information about the meaning of that content. It is tempting then to put in facilities for the users to classify their discourse in enable to enable the system to play a more active role. For example, *information lens* has users classify their email message types and *object lens* provides templates for customizing such classification (Lai, Malone and Yu, 1988). It will be very interesting to see whether users make effective use of such classification given the nature of normal human discourse which is action-based with very little conscious awareness of intentions. One would expect some form of content analysis to be a more useful approach to message classification since it does not add meta-monitoring activities to the discourse itself. In particular, techniques such as SYMLOG for the modeling of small group behavior (Bales and Cohen, 1979) could be carried over to computer-mediated discourse and provide participants with information about their interactions that is not normally consciously available.

8.8 Enterprise Modeling

Enterprise modeling is another term of increasing frequency of occurrence in the information systems literature. In the detailed enterprise models being developed in the computer-integrated manufacturing literature the term can be seen as referring to the integration of accounting, inventory, manufacturing, and so on, databases to support information systems at all levels of operation (ESPRIT Consortium AMICE, 1989; Scheer, 1989). However, in terms of the discussion of this paper it would be appropriate to classify such ‘models’ as enterprise behavior monitoring, rather than enterprise modeling. That is, current databases track the activities of the enterprise but do not generally model that behavior in terms of underlying meaning—the basis of symbolic interaction and understanding in human activities is missing.

The collective stance allows us to see the enterprise in the same terms that we see the individual. Notions such as intentions and emotions are applicable because they are state variables we impute to a living system. Emotions arise as interpretations of information flows corresponding to unexpected effects. It may not be particularly valuable to use the vocabulary of human emotions in the context of organizational information flows, but it may be very important to model the significance of the underlying phenomenon. For example the loss of a major and expected contract may lead to organizational ‘disappointment,’ but the significance of this is in the activities that should result. Currently, the non-event may not even be recorded in the database. Most major organizations prepare detailed medium-term plans containing forecasts which correspond to human expectations. A knowledge-base that represents these plans and then tracks them against actual activities can provide a commentary on the significance of events.

The management literature contains some richly developed frameworks for organizational modeling that could be used as a basis for information system development based on a collective stance. Scott’s (1992) analysis of organizations from three perspectives, as *rational*, *natural* and *open* systems, covers many of the issues raised in this paper using the more specific terminology of organizational theory. Tracy’s (1989) analysis of organizations as living systems, based on Miller’s (1978) system-theoretic model of a hierarchy of living systems from cells to supranational systems, adopts a vocabulary in which individual and organizational behaviors have close parallels. The operationalization of these frameworks in information systems would lead to systems that might reasonably be termed enterprise models. The problems of implementation will be difficult for similar reasons to those noted for groupware, that organizations are action-oriented and the overt meta-monitoring of activities would detract from their activities. Intentions will have to be inferred from action and context rather than assumed available as entered data. However, it seems feasible to build models at the symbolic interaction level through imputation of intentions to the activities of organizations much as we build models of one another, and of ourselves. This is the major challenge for future generations of enterprise models.

9 Conclusions

The main outcome of this paper is a recommendation to adopt a *collective stance* to humanity and see it as a single organism, a neural network, a giant brain, that is distributed in time and space by recursive partitioning into parts similar to the whole.

The phrase *collective stance* is chosen by analogy with Dennett’s *intentional stance*, because its primary justification is one of utility. A collective stance provides a convenient perspective from which to view phenomena of human existence, including behavioral and knowledge processes, and the specification, design, application and impact of technological support systems.

It is surprising that we have not already adopted this stance in neurology, psychology, sociology and information technology. It seems to have no adverse effects, unless undermining our egocentricity is seen as negative, and it provides an integrative framework for many significant phenomena.

The parts into which the human organism is recursively partitioned include societies, organizations, groups, individuals, roles, and neurological functions. Many concepts that apply to individuals may be applied to social systems, not as metaphors or analogies, but because, from a systemic perspective, its is the same concept that is being applied to different partitions of the system.

Notions of expertise arise because the organism adapts as a whole through adaptation of its interacting parts. The behavioral mechanism is one of exchange of reinforcement through some parts allocating tasks to others. The preferential allocation of tasks to those parts which have performed well previously also gives those parts access to experience enabling them to adapt and perform better in the future. This positive feedback leads to functional differentiation of the parts and the distribution of activities.

From a functionalist perspective, the coordination of the activities among the parts leads to phenomena of communication, discourse and language. The short lives of individual parts would lead to loss of knowledge by the organism as a whole unless compensated by social interactions supporting knowledge transfer, including the generation and storage of overtly represented knowledge.

The improved performance resulting from adaptation may be modeled as the part involved having acquired a model of its task. Reflective processes in which parts model the behavior of other parts including themselves leads to a hierarchy of models of increasing abstraction, and detachment from direct experience.

The modeling of human activity in terms of behavioral contingencies and its modeling in terms of symbolic interactions are complementary analyses of the same phenomena. There will be some situations which are more richly represented by one of the analyses and poorly by the other. Many of the phenomena of human action and expertise are behavioral and do not involve significant symbolic representations.

The Copernican revolution greatly simplified our model of the solar system by dropping an earth-centered stance and adopting a sun-centered stance—we ceased to place ourselves at the center of the physical universe. The call for a collective stance proposes a similar revolution that simplifies our model of the human system by dropping an individual-centered stance and adopting a collective stance—we cease to place ourselves at the center of the cognitive universe.

However, the emphasis on the need to escape from egocentricity in this paper does not suppose that individualism can be sensibly replaced with larger abstractions. The group, the organization, the culture, the species, have just as much life about them as the person—they are not empty abstractions. The enlightenment sought to free us of a unitary culture that dictated our thoughts and modes of being. To some extent the modern age did that, although it has replaced it with a unitary culture that is no less oppressive for being based on economic reward than divine punishment. It also promoted an excessive emphasis on individualism that attempts to center all explanation upon the ego—we have swung from undervaluing the person to undervaluing the lifeworld.

Systemic perspectives can redress the balance, but not if they are seen as empty abstractions. The danger in attempting to use them to see the larger scene is that we reify our abstract models and are then alienated from the world that we conceive:

> *"the reification of abstract phenomena can be interpreted in psychiatric terms as schizophrenia, that is, as a kind of logical disease in which man constructs an abstract world but treats it as if it were real and concrete." (Zijderveld, 1970)*

We have to use the systemic models, the knowledge level, as means to our destination and not as ends in their own right:

> *"Leave us to ourselves, without our books, and at once we get into a muddle and lose our way—we don't know whose side to be on or where to give our allegiance, what to love and what to hate, what to respect and what to despise. We even find it difficult to be human beings... and are always striving to be some unprecedented kind of generalized human being…Soon we shall invent a method of being born from an idea."(Dostoyevsky, 1864)*

Kohak captures the role of technology in this context in his remarks:

> *"Technology is the human's achievement, not his failing—even though the use he chooses to make of it may be fallen indeed. If the products of human techne become philosophically and experientially problematic, it is, I would submit, because we come to think of them as autonomous of the purpose which led to their production and gives them meaning. We become, in effect, victims of self-forgetting, losing sight of the moral sense which is the justification of technology. Quite concretely, the purpose of electric light is to help humans to see. When it comes to blind them to the world around them it becomes counterproductive. The task thus is not to abolish technology but to see through it to the human meaning which justifies it and directs its use." (Kohak, 1984)*

The perspectives presented in this paper are intended to be both emancipatory and instrumental—to lead to reflectively acceptable knowledge that also provides the power to transcend some of the limitations of existing information technology that derive from the limited utility of the way we currently conceive it. What we do with this power is a matter of individual and social choice—or of blind chance. It is the relationship between these two forms of explanation that provides the dynamics of our existence.

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