PROCESS ARCHITECTURE—PART 1:
TOWARD A REDUCTIONIST GENERATIVE CODE

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A. INTRODUCTION

Circa 1980, explaining organizational behavior via evolutionary and process theories gained importance in organization science (Weick, 1979; Aldrich, 1979; McKelvey, 1982; Mohr, 1982; Nelson and Winter, 1982; Pelz, 1985; Gersick, 1991; Singh, 1992; Van de Ven, 1992; Pentland and Rueter, 1994; Pentland, 1995; Baum and Singh, 1994). Process theory imposes a figure-ground reversal on organization science, in which firms are described primarily in terms of processes—with structural units implicit in the background. Though the structural organization chart of a major corporation is quite large, it is insignificant when compared to the quantity and complexity of processes present in a depiction of a large firm. Fully comprehending all of the one- and two-way processes among machines, workstations, people, and entities in the environment of large firms seems unlikely—they could number in the thousands (Mackenzie, 1986: 46).

Process theory remains predominantly reductionist, despite the parallel rise of evolutionary perspectives. Mackenzie (1986) clearly adopts reductionism. Less obviously, other process theorists also take a sequential, linear, deterministic view (Sankoff and Kruskal, 1983), that is often analogous to DNA code sequencing (Abbott, 1990; Abbott and Hrycak, 1990; Van de Ven and Poole, 1990), or to a pre-1980 "early" Chomskyan "rule driven" generative grammar (Weick, 1979; Barley, 1986; Sandelands, 1987, Salancik and Leblebici, 1988; Pentland and Rueter, 1994; Pentland, 1995[1]). Given the reductionist's motto, "Complexity at any given level is a consequence of the operation of relatively *simple rules* one level lower down" (Cohen and Stewart, 1994: 219; my emphasis), process theorists ground their explanations of firm behavior in process phenomena.

Two problems characterize present-day process theory, given its complex phenomena and deterministic reductionist epistemology: 1) Process theory most likely will be unsuccessful if a simplifying architecture is not forthcoming; and 2) Efforts toward elaborating reductionist principles may strike many scholars as archaic, given that the modern sciences from which process theory has drawn its principal lessons, namely physics, biology, and linguistics, all have evolved toward a "contextually activated" treatment of reductionist "simple rules," wherein the influence of the rules is not totally deterministic but influenced by surrounding entities and fields.

I agree. Writing a paper simplifying the architectural complexity of a reductionist process rule system, absent a discussion of contextual activation, does seem archaic. Alternatively, writing about contextual activation makes little sense without further development of underlying process rules. Cohen and Stewart (1994) take nearly 500 pages to demonstrate that *both* reductionist and contextual explanations are important. Space precludes treating both topics in one paper. Consequently, I will present the discussion as one paper with two parts. Readers are invited to consider in Part I the seemingly archaic task of elaborating the rules while keeping in mind that my overall purpose is not fully accomplished until Part II, on contextual activation, is also considered.

Part I focuses on the task of reducing the quantity and complexity of processes involved in explanation and prediction. I begin with a short review and critique of process theory. Then I search for a parsimonious underlying simple rule framework or "code" that might serve as a platform upon which to build a more predictive organizational process science, by developing the architectural elements such a code might entail, drawing mostly from the structure of the DNA and linguistic generative grammar codes. I then propose a generative process code for organizations.

B. PROCESS THEORY

Review. Van de Ven (1992) notes that when a process as a black box or category is opened up it appears as a sequence of events. Abbott (1990) states "every process theory argues for patterned sequences of events" (p. 375). Mackenzie (1986: 45) defines a process as "a time dependent sequence of elements governed by a rule called a process law" having five components:

a) The entities involved in performing the process
b) The elements used to describe the steps in a process
c) The relationships between every pair of these elements
d) The links to other processes
e) The resource characteristics of the elements (1986: 46)

A process law "specifies the structure of the elements, the relationships between pairs of elements, and the links to other processes" and "a process is always

[1] Pentland (1995) is actually a "transition piece" in that it focuses on pre-1980 Chomskyan rule sets (not ever mentioning post-1980 "principles-and-parameters"), while at the same time recognizing contextual influences.

linked to another, and a process is activated by an event" (Mackenzie, 1986: 46). In his view an event "is a process that signals or sets off the transition from one process to another" (1986: 46-47). To sharpen focus and reduce overlap, I define ***process*** as *a set of ongoing events directed toward some purpose* and ***sequences*** as *event orders in which causal flows may be one- or two-way*. Process ***events*** are defined as *observable state changes in whatever is in process—materials, ideas, organizing activities, and so forth*. The discussion continues in terms of ***process/event sequences*** (***PESs***).

Mackenzie's typology of task PESs contains six hierarchical levels: activity, module, bundle, group, area, and macro-logic (1986: 52-56). Various other typologies of PESs exist in the literature. Sankoff and Kruskal (1983) identify two basic kinds of sequences: discrete (an ordered sample of things) and continuous (but they recognize that continuous is analyzed by conversion to discrete). Abbott (1990) mentions temporal and spatial sequences and notes further that similar methods apply to both. Van de Ven (1992) mentions parallel, divergent and convergent sequences. He also discusses life cycle, teleological, dialectic, and evolutionary change sequences. Since Mackenzie's definition of process events amounts to a "grammar," it is important to recognize that alternative process grammars have been suggested (Weick, 1979; Barley, 1986; Sandelands, 1987; Salancik and Leblebici, 1988; Pentland and Rueter, 1994; Pentland, 1995).

Mackenzie recognizes that in an organization

> There are multiple events, chains of events, parallel events, exogenous events, and chains of process laws. In fact, an event is itself a special process. Furthermore, there exist hierarchies of events and process laws. There are sequences of events and process laws. The situation is not unlike the problem of having a Chinese puzzle of Chinese puzzles, in which opening one leads to the opening of others (1986: 47).

Later in his book Mackenzie describes processes that may be mutually causally interdependent. In his view, even smallish firms could have thousands of process/event sequences. Though recognizing the thousands of PESs, and Chinese puzzles inside Chinese puzzles, Mackenzie says, "I prefer deductive, nomological theories based on laws that describe *how* a phenomena occurs" (1986: 272; his italics). As Cohen and Stewart note (1994: 244), reductionists focus on explaining *how*—they try to explain complexity at a higher level by looking for simple laws at lower levels. Mackenzie clearly takes a reductionist approach.

Critique. There are some limitations to previous treatments of organizational processes. First, process theory literature focuses on temporal or spatial sequences of a linear kind. Abbott and Van de Ven limit their discussions of processes to those that are temporal or developmental, that is, sequential. A typical material-processing workflow sequence fits this view, as do the careers studied by Abbott and Hrycak (1990). In firms there are many PESs having more complicated pooled and reciprocal interdependencies than simple sequential ones (Thompson, 1967, Ch. 4) that need to be included before firms can be fully understood by process theory. For example, Weick (1979: 42) bases his entire discussion of organizing on a view of firms as:

> …streams of materials, people, money, time, solutions, problems, and choices. Streams can be a useful metaphor to portray the continuous flux associated with organizations….A stream might be visualized as a single homogenous viscous flow that moves at a constant rate. Such a visualization is unduly limiting as a portrait of organizational processes, and a more appropriate image would be that of multiple, heterogeneous flows of diverse viscosity moving at variable rates. If you can visualize something moving between two points, and then visualize the points also moving, that's what flows in organizations are like.

The addition of pooled and reciprocal interdependencies, variable rates of progression, and changing purposes adds to the already problematic increase in the number of elements to be analyzed as one shifts from a structural unit view of firms to a PES view. *The problem here is too much quantity and complexity*.

Second, as most clearly illustrated in Pentland's (1995) review of process theory and grammar applications, process theorists seem epistemologically confused. Pentland points to Mohr (1982) as the "rallying cry" for process theory (with Mohr using the term "process theory" to refer to an evolutionary approach), yet most process theorists appear to focus on early Chomsky (whose epistemology is reductionist physics) and DNA code sequencing in its more traditional noncontextual rendition, which really fits what Mohr terms reductionist "variance theory." Pentland straddles both paradigms. *The problem here is a confused basis for normal science*.

Third, processes are often viewed as idiosyncratic in individual organizations by interpretists, postpositivists, postmodernists, phenomenologists, and the like (Berger and Luckmann, 1966; Schultz, 1970; Weick, 1979; Pondy *et al*. 1983; Lincoln, 1985; Sarup, 1988; Hatch, 1993). Further, students of competitive strategy now see idiosyncratic organizational activities as essential to sustained strategic advantage (Wernerfelt, 1984; Teece, 1984; Rumelt, 1984, 1987; Barney, 1986, 1989, 1991; Prahalad and Hamel, 1990; Reevis-Conner, 1991; Teece, Pisano, and Schuen, 1994; Mosakowski and McKelvey, 1995). In light of this, one is left with the reality that much of organizational behavior is not generalizable from one firm to another, raising serious difficulties for conducting normal "scientific realist" science, which includes prediction, falsification, and generalization (Rudner, 1966; McMullin, 1984; Suppe, 1989; Hunt, 1991; McKelvey and Mosakowski, 1995). *The problem here is no basis for normal science*.

To simplify complexity, I will sketch out a metatheory of generative principles for shrinking the vast lexicon of organizational processes into a parsimonious set of generalizable categories and principles. For grammar elements I use Pentland (1995) as a point of departure, but take an explicit post-1980 "later" Chomskyan approach to contextual effects as a logical next step in process theory. I deal with the confused epistemology by clearly separating reductionism (Part I) from contextualism (Part II) before trying to apply them simultaneously. The idiosyncrasy problem I leave to Part II, and invite readers to consider other treatments of this problem (Mosakowski and McKelvey, 1995; McKelvey and Mosakowski, 1995; and McKelvey 1995).

C. THE ARCHITECTURE OF REDUCTIONIST METATHEORY

Consider the possibility that an architectural vocabulary useful for discovering a simplified generative process code might emerge from a comparative analysis of reductionist code vocabularies used in other more successful sciences, specifically biology and linguistics.

1. Reductionism

Schwab (1960) reports the results of his study of some 4000 scientific papers written over the past five centuries, in biological, physical, and three behavioral sciences. He presents a number of "principles of enquiry" guiding these investigations, including *atomic* and *molecular* reduction. Reductionism holds that causality, and thus ultimate explanatory power, resides wholly within an entity's constituent parts. Descartes said, "If a problem is too complex to be solved all at once, then break it up into problems that are small enough to be solved separately" (quoted in Cramer, 1993: 11). This came to be called the Cartesian method, where increasingly profound insights and rules come from the analysis of ever smaller constituent parts. Atomic reductionists take the view that the more powerful and generalizable explanatory rules reside at the lower levels of analysis, ultimately in particle physics.

Molecular reductionism produces two kinds of hierarchies. The first is *intradisciplinary*. For example, within biology, biophysicists are at the bottom, then biochemists, then molecular biologists, then geneticists, then endocrinologists, then parasitologists, ornithologists, and herpetologists, and at the top are the ecologists, paleontologists, and evolutionists. The other is *interdisciplinary*. Each discipline stakes out a part of the overall hierarchy, but at some point draws a line and defers to the more fundamental discipline to explain phenomena below the line, thus: psychology defers to biology which defers to chemistry which defers to physics which defers to mathematics (Oppenheim and Putnam, 1958; Barrow, 1991, p. 189). It is said that mathematicians defer only to God. Biologists investigate down as far as the DNA molecule and nucleotide sequences but leave the details of the atomic particle bonding principles of organic macromolecular formation to chemists (Simmonds, 1992;) and biophysics (Nossal and Lecar, 1991). Chemists investigate down to atoms and electron bonding but leave the analysis of subatomic particles to physicists (Feynman, 1985, p. 5).

Philosophers criticize reductionism (Fodor, 1974; Garfinkel, 1981: Ch. 2), and views of scientific method typically associated with reductionism, such as, logical positivism (Suppe, 1977), logical empiricism (Hunt, 1991: Ch. 9; Hacking, 1982; Boyd, 1983) and determinism (Boyd, 1985; Mermin, 1985; Brody, 1993). In the post historical relativist period, consensus is emerging in favor of scientific realism (Suppe, 1977, 1989; Fine, 1986; Hunt, 1991: Ch. 11; Boyd, Gasper and Trout, 1991; Brody, 1993). Reductionist, positivist, and even scientific realist views are severely challenged in organizational science as well (Berger and Luckmann, 1966; Weick, 1979, 1985; Silverman, 1970; Mohr, 1982; Lincoln, 1985; Harteman, 1988; Perrow, 1994; Van Maanan, 1995). The following discussion meets this challenge head-on.

2. Elements of Reductionist Codes

This section outlines the DNA and generative grammar codes, after a note on intradisciplinary atomic reduction.

a) Intradisciplinary Atomic Reductionist Codes

The *Oxford Dictionary* defines *code* as "A system or collection of rules or regulations on any subject" (Simpson and Weiner, 1989, Vol. III, p. 428). Scientists also believe that reductionist codes should be *algorithmically compressible* in the sense that the code is a shorter, more efficient, expression of information about reality, for example a formula that, when used properly, recreates a more complicated or extensive reality (Barrow, 1991, p. 15). All so-called "successful" sciences (physics, chemistry, biology, psychology, economics) have a code which the more devout intradisciplinary atomic reductionists claim offers a rule system explaining much, if not all, of what the rest of the field is about (Oppenheim and Putnam, 1958). In linguistics, reductionists claim that generative grammar is a formally mathematized rule system that can create the sentences of a language (Chomsky, 1957, 1965, 1986, 1993; Gardner, 1985, p. 187). In psychology, neuroscientists—the resident atomic reductionists—believe that the code governing electrical signaling within and between neurons will connect all learned behavior to neuron firing (Gardner, 1987, p. 282; Levitan and Kaczmarek, 1991). In biology, there is now no question that the code held by the DNA molecule is the rule system behind all life on this earth (Nei, 1987; Li and Graur, 1991; Calladine and Drew, 1992;). In chemistry, quantum electrodynamics (Feynman, 1985), or stochastic electrodynamics (Brody, 1993, p. 179), supplies the rule system underlying chemical bonding (Feynman, 1985, p. 5). Physicists always thought atomic reduction stopped at their doorstep, but now they too may face a molecular reductionist lower bound. The dream of a unified field theory—bringing under one theoretical hat the explanation of gravity, the strong force, electromagnetism, and the weak force, may never come to be (Horgan, 1994; Weinberg, 1994).

Several insights emerge from the foregoing reductionist experiences. **First**, all have a basic code or rule system at the *intradisciplinary atomic reductionist level of analysis* that generates much, if not most, of the substantive material studied by the higher analytic levels within the discipline. The discovery of the code, and unraveling its consequences, comprises the major portion of their activity (Davis, 1990; Li and Graur, 1991; Nossal and Lecar, 1991; Lederman, 1993). **Second**, in some sciences there is a loop connecting the most micro and macro components of the discipline. Thus, cosmologists cannot explain the first second of the Big Bang without fully understanding the behavior of the elementary particles, but at the same time, unified field theorists cannot not explain all aspects of particle behavior without knowing more about what happened in the first second or so of the universe (Carrigan and Trower, 1989; Barrow, 1991, p. 62). In biology, while molecular biologists work at unraveling the code and discovering its consequences on the development and replication of living organisms, they depend on the ecologists and evolutionists to understand the origin of the code in the first place (Mayr, 1982; Nei, 1987; Li and Graur, 1991; Hoffmann and Parsons, 1993). **Third**, sometimes the search for the origin of the code stays intradisciplinary and other times it is interdisciplinary. **Fourth**, codes take numerous forms: gauge theory in unified field theory; Maxwell's equations in physics; rules governing covalent and non-covalent molecular bonding forces in chemistry; nucleotide sequences in biology; price theory in economics; generative grammar in linguistics; neuronal electrical signaling rules in (neuro)psychology. Two of these codes are of special interest: DNA and generative grammar.

b) The DNA Code

The human DNA molecule appears in the nucleus of each cell in our bodies, somewhat loosely wrapped up in a ball about 10^{-7} meters in diameter. The DNA molecule is one of the longest, thinnest things in existence—two meters long but only 10^{-6} meters thick. To get an idea of what this means, imagine that the DNA molecule is the width of a kite string. Now imagine it strung out on the telegraph poles along a railroad track. You would have to take a fast train from Los Angeles to Denver to see the entire molecule! And at 80 miles per hour you would pass 48,000 individual base pair[2] sequence elements every second because there are 3 billion sequence elements of DNA code making up the human genome (Davis, 1990).

The basic "rule system" is as follows: Each element of the DNA code consists of a nucleotide composed from a set some 20 atoms, such as carbon, oxygen, nitrogen (Calladine and Drew, 1992, p. 8). There are four different nucleotides, labeled A, C, T, G. They appear in various sequential orders, but only in combinations of three, TTT, CTC, TAG, GGA, etc., to make up the 20 possible amino acids. A gene is a program of varying length composed of nucleotide sequences to produce various amino acids which then comprise a protein; one protein per gene. Proteins are the basic building blocks of living organisms.

One might conclude from all this that the DNA code *determines* the generation of living tissue. Certainly nothings happens without it. But the DNA code is carried in living cells and activated by complicated aspects of cell biophysics (Nossal and Lecar, 1991) and biochemistry (Simmonds, 1992). Thus DNA is activated by certain kinds of physical and chemical "agents" and the cell's "agents" in turn result from DNA—a mutual causal process (Maruyama, 1968). Given live cells and correct cell physics and chemistry, DNA code does in fact determine the generation of tissue after an egg is fertilized, and the growth and replacement of cells thereafter, with a normal error rate of one error per 10 billion base pair replications (Cramer, 1993: 47). The architecture of the DNA code is highlighted in Figure 1.

Insert Figure 1 about here

c) The Linguistic Generative Grammar Code

The lexicon, or dictionary of the English language, contained 550,000 entries that are not names in 1959 (Webster's, 1959). There are several thousand languages in the world (Salkie, 1990: 9). Each sentence in each language contains from two to many of the 550,000 words in myriad sequences. The number of possible combinations and permutations is infinite. Despite this complexity the average two year old child grasps many rudiments of grammatical structure, five year old children converse quite well, and as any college textbook writer is told, most people never progress past the sixth-grade level of reading or conversational ability of an 11 year old child.

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[2] In the double helix, one nucleotide sequence always consists of a pairing of A-T (either order) or C-G (either order), hence they are called base pairs. DNA "sequencing" is now a well developed analytical procedure (von Heijne, 1987; Blackman, 1994).

Noam Chomsky (1965), the dominant figure in modern linguistics, initially defines linguistic science as attempting to find the *rules* by which a two-year-old begins to understand the complexity of language usage. On the one hand the problem is infinitely complex, and on the other a two-year-old can learn the rules. The child's problem is tough enough. Chomsky's problem is far more intractable, how to find out what are the basic rules? Chomsky takes his initial cues from the physicist Weinberg (1976), who discusses what Husserl called "Galilean style" physics: "…making abstract mathematical models of the universe to which at least the physicists give a higher degree of reality than they accord the ordinary world of sensation….We have no present alternative to pursuing the 'Galilean style' in the natural sciences at least" (Chomsky, 1980: 8-9). Chomsky's initial search for a reductionist code results in a complex "rule system," "transformational grammar," and "phrase structure" (Chomsky, 1965).

I initially focused primarily on the 1965 book because Chomsky is more self conscious about his method of inquiry and metatheoretical level of analysis. Then I discovered that circa 1980 and thereafter he abandons much of the rule system in the 1965 book (that is, a large part of its transformational grammar and virtually all of its phrase structure) and replaces it with "*principles and parameters*" (Chomsky, 1986; 1993; Salkie, 1990). By 1986 Chomsky also becomes convinced that much of the basis of human ability to use language is genetic.

Chomsky concludes that as corrections and elaborations were made to the rule system, so that, in Chomsky's (1986: 65-68) terms, the "*deep structure*" (the underlying parsimonious abstracted set of rules) became as complicated as the "*surface structure*" (the words and sentences of everyday utterances). The 1965 approach simply replaced one complex system with another (Chomsky, 1986: 83). It became clear to Chomsky that a two-year-old was no more able to learn the rule system of the 1965 book than she could learn uttered syntactical structure. Consequently, the principles-and-parameters approach pursues an alternative attack (Chomsky, 1986, 1993).

Both early and later approaches are termed *generative grammar*. To understand the meaning of "generate," try extending the following lists:

1. La Cenerentola, Carman, Die Fledermaus, Tosca, Die Oberflauten, Gotterdammerung, Turandot, Les Troyens, Orfeo ed Euridice, Aida, ???
2. Kansu, Assam, Tokyo, Kashmir, Chillan, Valparaiso, Mexico City, New Madrid, ???
3. List of numbers

The idea of "generative," as used by Chomsky, is best understood in terms of the simple rules one might use to generate the foregoing lists or sequences.[3] Inasmuch as sentences are sequences of words, Chomsky's task is to discover the rules or principles by which the sequences are generated. As it stands to date (Chomsky, 1986, 1993), the main architectural units of generative grammar are the rules and principles shown in Figure 2.

Insert Figure 2 about here

d) Common Elements of Code Architecture

Commonalities between the DNA and generative grammar codes are listed below:

1. Both have basic units (molecules or letters), which are combined as intermediate units (nucleic acids or syllables), to make up the basic category of the code (nucleotides or words). See Figure 4.
2. The basic code units (nucleotides or words) assemble as sequences, which constitute the main bulwark of the code—genes or word order in sentences—upon which most of the deciphering activity focuses.
3. Each code has a device for translating the generic message of the code into locally specific messages (the RNA messenger translating the DNA code into specific information for cell construction and replication or, in linguists, translating deep structure into surface structure).
4. Each has a "deep" parsimonious code and an observable building unit (protein or sentence).
5. The explanation of the behavior of each code consists of modular theories that explain certain specific functions, but that also interact in important ways.
6. Both codes are highly abstract, underlying, parsimonious phenomena that both explain and generate incredibly complex target phenomena (living organisms or language usage).
7. Both codes appear to have deterministic and probabilistic elements.
8. Both codes have evolutionary origins over long periods of time; are subject to change in random fashion, and are subject to engineering or change (language perhaps less so, but see Diamond (1994).

We should be encouraged that there are many common elements between the DNA and generative grammar codes. But there is an issue as to whether the commonality stems from the phenomenal reality of the codes, or whether it is due to a common conceptual interpretation made by biologists and Chomsky, that is, are the codes the way they are because that is indeed the way they are, or is it because that is how scientists conceptualize them? Chomsky's model of science comes from Galilean physics. I have found no indication that he "took lessons" from biology, or used the DNA code as a

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[3] 1) Starting with living, alternate well known operas wherein the heroin is dead or alive at the end of the opera. 2) Starting with deadliest, alternate earthquake locations by death toll and magnitude. 3) Show the formula.

model. It appears that the commonality is not an artifact of any common conceptual ancestry, but instead that current conceptions of each code are independent. Therefore the fact of the commonality should not be taken lightly. In view of this, I draw on the common elements in developing a process architecture.

D. ORGANIZATIONAL ATOMIC REDUCTIONISM

Social science levels of analysis are typically defined as societies, organizations, groups, and people, with the disciplines of economics, sociology, and anthropology at the top, social psychology in the middle, and psychology at the bottom. Parallel to these, organizational levels of analysis typically are depicted as environments, organizations, divisions/departments, groups, and employees (Roberts, Hulin, and Rousseau, 1978, Ch. 3). In Schwab's (1960) terms the former is an interdisciplinary reductionism, while the latter is intradisciplinary reductionism.

The organizational equivalent of Schwab's *molecular lower bound* (that is, the lowest intradisciplinary level—atoms in chemistry, nucleotide sequences in biology, etc.) is Mackenzie's "activity" level. Like atomic sub-particles in physical matter, there could very well be sub-sequences worthy of study, but I avoid this issue for now. McKelvey and Mosakowski (1995) argue that PESs at the activity level are stochastically idiosyncratic and thus offer a suitable molecular lower bound "platform" upon which to develop a scientific realist organization science.

PESs above the particle platform comprise the system of routines and competencies and form a surface structure of idiosyncratic practical application in all different kinds of firms in diverse environments and niches. Using the surface structure originated by the nature of the materials, machines, and services, a firm assembles PESs to produce products and services and therefore harvest resources from its niche. Why a material behaves as it does and requires the kind of processing it does? or why machines work at certain speeds or require certain kinds of maintenance? are questions that move inquiry below the molecular lower bound of firm analysis.

Some organizational scholars may be pessimistic about the prospect of trying to frame organization science around the origin and consequences of deep and surface structures and in searching for an underlying PES code. Firms are often large and very complicated. Might not the code be extremely complex, time consuming, and well beyond our analytical capability? I have highlighted two of the many reductionist codes—the DNA code and the generative grammar codes because the surface structure generated by each code—all living things and all uttered or written sentences—is so vast and varied and the deep structure is itself so complex.

The fact that biologists and linguists have begun to find ways of deciphering their codes is instructive. First, they do indeed study their codes, despite their extreme complexity. It is unlikely that any combination of organizational PESs could approach either of these codes in complexity. If biologists and linguists can find ways to unravel their codes, surely organizational scientists should not be daunted by possible complexities at the organizational intradisciplinary reductionist level. Second, the questions biologists and linguists ask in studying their codes offer insights about how the PES code affects the development of organizational function, structure, and process, and also for understanding how the code comes to exist in a specific form in the first place. It is possible that there are common deciphering approaches and similar metatheories of code architecture.

I am not the first to suggest that organizational form can best be understood by drawing on an underlying framework, or deep structure. Others are quite explicit about drawing on the genetic analogy. Hannan and Freeman (1977, 1989), focus on "blueprints." Aldrich (1979), McKelvey (1982, 1994), Aldrich and McKelvey (1983), focus on "competencies." Nelson and Winter (1982), focus on tacit skills as "remembered" in "routines." Pentland and Rueter (1994) link routines with grammar based process theory. Mohr (1982) and Van de Ven (1992) connect "processes" with evolutionary theory. Many other authors draw on the biological evolutionary and ecology model without being explicit about the genetic component, such as, Miller and Friesen (1984), Tushman and Romanelli (1985), and a host of evolutionists and ecologists (Carroll and Delacroix, 1982; Singh and Lumsden, 1990; Singh, 1992; Amburgey, Kelly, and Barnett, 1993; Haveman, 1993; Miner, 1994; Baum and Singh, 1994; Baum, forthcoming). Other writers have drawn on the grammar analogy (Weick, 1979; Skvoretz and Farraro, 1980; Barley, 1986; Abell, 1987; Sandelands, 1987; Salancik and Leblebici, 1988; Coulter, 1989; White, 1992; Drazin and Sandelands, 1992; Pentland, 1992, 1995; Pentland and Rueter, 1994). It is fair to say, however, that I differ from all of these writers in emphasizing a more explicit intradisciplinary atomic reductionist view of the code and what its role should be for organizational science.

The PES code becomes the basis of most organizational structure and employee behaviors related to organizational goal attainment. PESs may be officially conceived and brought into existence, or they may appear as the result of informal or emergent individual behavior, emergent systemic behavior, or emergent cultural norms and assumptions, and so forth (Scott, 1992, Ch. 3). They may be life cycle, teleology, dialectic, or evolutionarally related (Van de Ven, 1992). PESs and human behavior are inextricably intertwined and revolve around each other, much like stars and black holes in binary star systems—each visible and measurable in different ways. Needless to say, some portion of PESs at any analytical level may be unrelated to any reductionist code.

One may reasonably anticipate some objections to a reductionist approach, given reactions to Chomsky's attempt to find deep structure in grammar. According to Salkie (1990), there are three[4] kinds of challenges to Chomsky's approach relevant to the organizational context.

1. *Indeterminacy*. This challenge comes from Quine (1960) and Wittgenstein via Kripke (1982). In this view language usage is meant to convey meaning. Since the linguist's deep structure leads to surface structure, which is everyday sentence construction, generative grammar would appear to have nothing to do with the real purpose of language, which is to convey meaning. There is nothing in Chomsky's generative code that helps assure that meaning is correctly conveyed. In organizational terms the meaning behind language translates into the human intentions and interpretations lying behind the development of organizational processes. I, along with Chomsky, take a scientific realist response. Language structure and PES structure are observable facts. The underlying rules and principles of the code should bear some relation to these facts; if not immediately then after successive iterations of research. Whether underlying theory relates to the observed facts is an empirical question. Whether either theory or facts relate to someone's "true" intentions is impossible to determine and therefore irrelevant.
2. *Uninteresting*. In this challenge critics take the view that generative codes are possible but not interesting or likely to be very important. Since organizational PESs are created by human intentions for the purpose of carrying out relevant functions, studying them independent of intentions or functional efficacy seems, as Searle (1982) puts it, "pointless and perverse." Chomsky's and my responses are again basically the same—since there is an undeniable relation (though often a loose one), between intentions, observed structure, and function, whether grammatical structure or organizational PESs, it seems even more relevant to ask questions about underlying rules giving rise to the structure, since process structures in many firms are not necessarily direct consequences of specific intentions or functions.
3. *Substantive*. Critics conclude that in principle generative process theory is a good idea but it is being pursued incorrectly. The challenge here is welcome. Current approaches could be challenged and thrown out in favor of a better perspective. There could be a variety of alternatives tried, with many failures, before one begins to see the hoped for consonance between explanatory/predictive underlying theory and PES realities. At this time intradisciplinary atomic reduction appears to be a useful level of analysis, it seems to focus on organizational PESs, and so it may be time to turn some of our collective attention to this topic.

Pentland (1995) cites, as cause for concern, a number of social theorists (Bourdieu, 1977; Fabian, 1979; de Certeau, 1984; Heritage, 1984; Brint, 1992) who object to the idea of a "social grammar." They hold that social action cannot be governed by rules (Heritage, 1984) and that since social norms are often broken, the grammar would have to include rules governing when rules can safely be broken, etc. (Fabian, 1979), leading to an infinite regress. Many postpositivist social theorists object to any notion of positivism or reductionism being applied to social phenomena (Berger and Luckmann, 1966; Glaser and Strauss, 1968; Feyerabend, 1975; Lakoff, 1987) or organizations (Lincoln, 1985; Mahoney, 1993; Perrow, 1994). I note, on the other hand, that philosophers such as Watkins (1991) argue in favor of reductionist explanations of social phenomena, and that others find a constructive role for instrumental prediction (Railton, 1991) or wonder why scientific realism is so quickly rejected by social scientists (Miller, 1983).

In conclusion, codes are not particularly new to organizational scientists, given previously existing binary codes (Gardener, 1985: 17-18), code-like standard operating procedures (March and Simon, 1958) and routines (Nelson and Winter, 1982), and reductionist approaches in other firm related disciplines such as economics, finance, and decision science. Consequently I end this section on the optimistic note that the reductionist code architectures of the biologists and linguists will provide guides for organizational PES deciphering. Therefore, the intradisciplinary atomic reductionism I propose should not take organization science into hostile territory. McKelvey and Mosakowski (1995) suggest this form of molecular reductionism could be a philosophically friendly territory, and could help our field progress toward becoming a more successful science.

E. ELEMENTS OF AN ORGANIZATIONAL PROCESS ARCHITECTURE

Architects work within a set of principles governing artistic, functional, and safety considerations in building design. They also have the problem of applying these principles under idiosyncratic local constraints such as hillside lots, sandy soils, earthquake zones, and owner preferences. The overall objectives of process architecture are essentially the same as for building architecture: 1) A search for the criteria of "good" architecture, termed ***optimal logical form***; 2) A recognition that the exigencies of local sites call for modifications in how principles apply, termed ***application structures***; and 3) the actual development of a parsimonious ***code system*** of "simple rules" or principles, which if followed, would serve to produce effective process design. The components of the ***code system*** are syntactical structure, principles, and parameters. In what follows my intellectual debt to Chomsky is obvious, but readers should also be aware that I have adapted his scheme in many ways to better fit the organizational context.

1. Optimal Logical Form (OLF)

Both the DNA and generative grammar codes

[4] Salkie enumerates four challenges. Since his first two focus on meaning, I collapse them into one.

have objective functions, respectively, of accurate and appropriate replication of specific kinds of cells, or effective communication of meaning. OLF is an equivalent objective function. That is, process theory should provide a means whereby scholars and managers can agree about what the *best* process design for a given task might be (Chomsky's "competence"). OLF, to be effective, should offer generalized process design principles one step removed from the idiosyncrasy of specific local applications. And any effective local application should easily fit within the outline provided by the OLF. For example, in this view, while there might be wide variation in the observed PESs for installing components inside laptop computer cases, one could reasonably expect that each variation, if effective in the sense of producing reliable laptop functioning after shipping, months of use, and occasional drops, would fit within the OLF generated by a relevant process design theory. This view places more emphasis on the normative objective than does Pentland (1995).

2. APPLICATION STRUCTURE

By including a component termed ***application structure*** (Chomsky's "performance"), I recognize that each local modification of the OLF could differ as a result of idiosyncratic local conditions. This raises two problems: 1) How does the OLF arise from the idiosyncratic local variants? and 2) How to allow local modifications while still keeping honest with respect to the OLF? First, McKelvey and Mosakowski (1995) build on the resource-based view in recognizing that, under competitive conditions, firms have incentives to attempt to generate idiosyncratic PESs and protect them once created. But, under competitive conditions, there also are coevolutionary forces causing idiosyncrasy to eventually erode toward widely known, nonidiosyncratic "best practices." Even though "coevolutionary" and "best practice" process designs could have local variants because of differing personalities, geographic locations, national cultures, and so forth, the forces of competition create common parameters governing the range of effective local idiosyncrasy. Best practice "benchmarking" (Boxwell, 1994) also implies that, in principle, there is one best way to carry out a particular application such as, for example, feeding a punch press, powder-coating file cabinets, or handling point-of-sale inventory control. Consequently an infinite number of application structures does not in any way negate the possibility of broader OLFs. The second problem is dealt with later in terms of the "parameters" aspect of code structure.

3. SYNTACTICAL RULE SYSTEM

In outlining the syntactical structure I draw on the development by Pentland (1995), with some reference to Mackenzie (1986). My revision extends Pentland's analysis by pursuing an organizational application of the principles-and-parameters approach of later Chomsky (1986, 1993; Salkie, 1990) which sets the stage for the contextual analysis in Part II of this paper. Given the reductionist view that principles are defined as "simple rules," the following distinction is important: 1) S***yntactical rule systems***, consist of invariant ***R-principles*** that are unchanging no matter what the local context; and 2) ***Contextually sensitive C-principles***, the parameters of which allow modifications to meet contextual demands. I discuss each below.

The syntactical rule system consists of, 1) a ***base*** of PES "building blocks" consisting of the ***basic lexicon***, ***primary category***, and various categories in between, in which PESs might be grouped, and 2) those basic ***modification R-principles*** not affected by local circumstances, that govern alterations in the ordering of lexical elements within the standards of OLF.

a) Base

(1) Basic Lexical Elements for Process Theory

In linguistics, the lexicon appears as dictionaries of words, each of which is defined. Words are broken down into alphabets and phonemes or syllables. Although the term, organizational, has fourteen letters of the English alphabet, and six phonemes or syllables, in terms of the lexicon it appears as one element—a word. Words form the basic category for linguistic generative grammar. One of the tasks for process theorists is to decide which PES elements comprise the equivalent *basic* lexical category and which, if any, smaller constituent parts might play roles equivalent to letters or phonemes. Grammarians also talk of **morphology**, which is the structuring of word combinations, such as "decision making," "decision-making, or decisionmaking." Process theorists seem to have ignored this issue to date, and so will I.

Another lexical problem is, How many different organizational process lexicons are there? Is there one for each kind of technology? One for each country or language area? One for product or market areas? Is there a universal version of the lexicon that might apply to all organizations around the world, with various local versions that most managers might work with? Following Pentland (1995), I presume that process theory will develop in terms of local versions of the lexicon, possibly by industry population, technology, geographical or language region, or by product or market, though the specific nature of this development remains to be seen. Even though lexicons might materializes in local versions, I differ somewhat from Pentland in that I believe lexical differences should not negate a universal process theory, since the primary focus of generative grammar is on categories *higher* than the lexical category.

Pentland (1995) argues that "*moves*" (assign, transfer, refer, escalate, etc.), are the most advantageous *basic* lexical process elements. He draws on Goffman's (1969, 1981: 24) concept of moves which have "distinctive unitary bearing on some set or other of the circumstances in which participants find themselves." Mackenzie's (1986: 52) "*activities*" (ensure, unload, pile, inspect, count, approve, refuse, document) seem equivalent to Pentland's moves.

It is important to establish that "moves" and "activities" are indeed one level *above* what McKelvey and Mosakowski (1995) define as the molecular lower bound and thus are worthy of explanation. For biologists nucleotides are the basic level of explanation, with base pair atoms the "particles." For linguists, words are the basic level "terminals" in syntactical graphs of sentences, with alphabet letters and syllables treated as particles that are there, but not explained. To satisfy this condition, moves or activities have to be the basic elements of sequencing, with little if any explanatory interest focused on their constituent process elements. Further, there have to be a wide variety of subelements or particles: thus, any oxygen molecule is okay for being part of a base pair biomolecule; any symbol is okay to stand for a vowel or consonant. Judging from examples given, of specific behaviors of each (Pentland, 1992: 537; Mackenzie, 1986: 52), both conditions are satisfied: 1) Each move or activity "verb" (assign, escalate, unload, inspect, etc.) can be "behaved" in a variety of different ways not of interest to organization scientists; and 2) Moves or activities are clearly components of sequences in that they affect subsequent PESs. *Basic* process lexical elements may be defined as *observable PES actions (the component behaviors of which are stochastic and unworthy of explanation), contributing to an OLF, conditioned by effects imposed by other PES elements in the sequence.*

(2) The "Compseq" as the Primary Category for Process Theory

How are basic lexical elements best classified and grouped? In grammar, the sentence category has syntactical constituents (words and word groupings) like nouns, noun phrases, verbs, verb phrases, particles, and so on (Cook 1988; Freidin, 1992). Most of grammar focuses on the proper ordering of these categories within sentences, for example, nouns come before verbs in English, adjectives come before nouns, and so forth. In language, words appear in a nested hierarchy, for example, noun and verb phrases in sentences; sentences in paragraphs or conversations; paragraphs in sections. Words, sentences, paragraphs, and sections have well established and clearly discernible, differentiated functions. Nevertheless, *most* of the effort in linguistics focuses on what comprises "complete" sentences that convey meaning. Thus, there are both horizontal and vertical dimensions of analysis.

Similarly for the DNA code. Horizontal units are sequences of varying length, separated by "cleavage sites." Hierarchical units are nucleotides, amino acids, genes, chromosomes, and DNA macromolecules. Genes appear most analogous to sentences in that genes hold the code for creating specific protein molecules—incomplete or faulty genes create nothing or injurious proteins, while amino acids compare rather well with syntactic constituents such as noun or verb phrases, with nucleotides as the basic lexical category. It is important to establish that, as primary categories, sentences and genes have a definite "sense of ordered completeness" as the criterion by which their soundness may be judged.

At this time organizational process analysis also shows horizontal and vertical dimensions, though there is little agreement on what leads to OLF. Pentland's (1995) analysis shows three levels: "*moves*" (words), "*performance programs*" such as "standard operating procedures" (noun or verb phrases), and "*processes*" such as task unit processes (sentences). By linguistic analogy, performance programs consist of rarely disassociated chunks of process behavior, but which do not complete a task. In Pentland's scheme, most of the horizontal analytical emphasis in categorization focuses on the task process level—what I will label ***compseqs***, a special term to signify their primary role in process analysis as "sequences in some sense complete." It is not unreasonable to expect that theories of OLF pertaining to levels above or below the compseq level would be less elaborate and less well defined. Only with compseqs would one have a set of components offering a sense of completion. Needless to say, in any firm a number of compseqs might be strung together, as are sentences in a paragraph or genes in a chromosome. In contrast, Mackenzie's hierarchical analysis forms its groups by *common predecessor*—all process elements having a common predecessor are grouped together. This is equivalent to saying that all the words defining any given sentence are those logically following from the first word—"this" in this sentence. Mackenzie's logic is fundamentally different from generative grammar and DNA logic where "completeness" as to elements and meaning dominates predecessor-successor sequences.

Completeness vs. predecessor—which approach might best apply to a theory of task PESs? "Completeness" is an output effectiveness driven logic in that a PES shows OLF—its output has a sense of entitivity and meets the input criteria of a follow-on stage. "Predecessor" is an input driven logic in that OLF for a PES is defined by elements having a common predecessor. I think most theorists would favor "completeness" since the "predecessor" approach has no effectiveness criterion. To take Mackenzie's example, "rail receiving," an OLF of this PES would normally be evaluated by how efficiently and accurately are goods checked in, palletized, and readied for the next processing stage, not simply by asking, "What happens after the car shows up?"

This analysis (summarized in Figure 3) suggests that, 1) several nested analytical levels are involved, 2) the primary focus of process theory will be at the compseq analytical level, 3) that an output effectiveness criterion such as "completeness" is essential, and 4) that the logic of the DNA and generative grammar codes fits firms better than Mackenzie's predecessor logic.

Insert Figure 3 about here

b) Modification R-principles

Within sentence or compseq categories there is the question of what the proper order is, and may words or moves making up a sentence or routine appear in different orders without failing the completeness (effectiveness) criterion? There do not appear to be modification rules within the DNA code itself—any change in the order of base pairs is a mutation, most of which are errors—though the DNA message activated for different kinds of cells may be transformed by RNA messengers, and other aspects of cell biophysiochemistry. An elaborate transformational grammar rule system dominates early Chomsky but in later Chomsky this gives way to a generalized transformation principle termed, *move* α,[5] which follows Edmonds' (1976) "structure preserving principle. The *equifinality* concept from general systems theory (von Bertalanffy, 1968) has long symbolized social scientists' views that diverse sequences may all produce the same outcome.

Process theorists have not focused explicitly on modification rules, even though grammar oriented theorists draw mostly on early Chomsky. For the time being, I will assume that there are some broad R-principles implicit in the OLF that allow order modifications. For example, in the primary value chain when there is high isomorphism between engineering and organizing rules, an R-principle, "any order modification of organizing process categories that does not undermine the performance outcome created by the order of material flow engineering categories," may be acceptable. Since my approach draws heavily from later Chomsky, specifically his principles-and-parameters approach, I defer further discussion of modification to the following section.

4. Contextually Variant Principles and Parameters

a) Definitions

Contextually Variant Principles. Stop for a minute at the next tall building you see and consider how much of its design might be due to (materials) engineering rules, safety codes, architectural rules, personal artistry of the architect, or the good or bad taste of the owner. Engineering and safety rules are well understood and fairly long lasting, except in California where they change after every major earthquake. Good architecture also has rules, though most may be less robust than engineering rules. Clients may or may not have good vision or taste. Process architecture is parallel to building architecture. Consider a tuna canning plant. There are a variety of well understood engineering and health principles assuring that tuna packing is efficient and not likely to introduce bacteria, and that the tin cans are strong enough and won't have leaks, and so on. There are well understood sociotechnical systems principles (instead of architecture) governing the design of organizational processes, though they may not be as universal or well corroborated as the engineering principles. Finally, there are personal design approaches of the engineers and managers building the packing line. In both examples the effects of enduring codes of a more universal nature are mingled with the transient effects of local context: the nature of the site, function of the building or process, and "tastes" of the local designers and users, and so on.

Contextually variant C-principles are "simple rule" components of the reductionist code that come with attached parameter "trade-offs" and "switches" that, based on local context and experience determine how the principle applies. Principles are expected to be, 1) relatively stable, 2) more universal in application, and 3) relatively few in number. In firms, the engineering code's effects are intertwined with the effects of the code governing good organization process design. Given the early state of process theory development, principles as I have defined them have yet to emerge from studies of process phenomena. Emergent principles should govern, 1) appropriate overlaying of organizing process code onto engineering code, 2) effective process design elsewhere, and 3) the relation between various contexts and parameter definitions.

Parameters. At this point it is important to distinguish between two ways in which C-principles exhibit contextual flexibility via parameters. First, in both the building and tuna plant, ***T-parameters*** set up various trade-offs. Thus, the C-principle+T-parameter, 'Heat loss is a function of the amount of insulation and glass used' imposes a trade-off decision between cost of heat loss and cost of insulation or loss of natural light and views. Second, ***S-parameters*** may have alternative modes that may be switched on or off. Thus, the C-principle+S-parameter, 'Clear measurement and feedback improves performance' offers a designer a choice between two modes, 1) behavioral measurement, or 2) output measurement, but not both at the same time. Possibly, for situations involving process event ordering, S-parameters are most important (switching parameters are what Chomsky focuses on for word order in sentences (1986: 146). However, since process theory, as implied by the modular theory approach below, properly includes

[5] A reasonably accessible treatment of *Move* α appears in Salkie (1990: 44-47.

more than just PES ordering logic, both T- and S-parameters may prove essential.

Parameters arbitrate context driven choices by suggesting criteria that, 1) Govern choices as to the form in which principles might be applied in different settings, 2) Govern design when local effects or constraints are probabilistic, such as whether the effects of tornadoes and earthquakes should be accounted for in building design, whether feedback loops should built in to various points in a sequential line, or whether union strikes, materials shortages or variability, or employee absences should be accounted for in process design, 3) Govern optimal points in trade-offs among principles when they are not definitive, 4) Come into play when principles are less sound, questioned, or not fully understood, possibly because of bounded rationality (Simon, 1957), and 5) Place limits on local judgments prone to excessive variance.

In this view, principles are reductionist and parameters make them contextual. Since this Part focuses on reductionist issues, I will focus on principles, leaving contextual issues till Part II.[6]

b) A Modular Process Theory Approach

The modular approach recognizes that there are several interdependent process theory foci, each of which has its own purpose, underlying theory, C-principles, and internal coherence. Focusing on modules also helps theoretical prioritizing in that the amount of prior work on each module becomes more apparent.

(1) Category Theory

Much of organizational process theory has focused on sequence order, but before ordering theory makes any sense a taxonomy of intermediate categories has to exist—there are presumably more than just lexical and compseq categories. Otherwise ordering theories might be based on noncomparable categories. As outlined by McKelvey (1982), any taxonomy has to have a taxonomic theory. Clearly, to date there is no consensus on categories, even within fairly narrow technological or other process delimitations, though in fairness little work has been done.

In Chomskyan architecture, category theory is part of the syntactical rule system, meaning that linguistic categories are fairly rigidly and universally determined. This seems much less true for process categories. Consequently, I assume that category theory best fits under C-principles rather than R-principles. In some contexts, however, category theory may approach universality. For example, consider how parallel are organizing process categories to engineering process categories. My assumption is that most of the time engineering principles (and categories) come first, with organizing aspects overlaid on top. Frequently, organizing categories may include several engineering categories. For example, file cabinet painting might include metal preparation, priming, painting, and oven baking—four compseqs based on engineering principles, yet the organizing compseq might be one task process, painting. In small firm OLFs it could be true that organizing categories would vary in how they bundle engineering categories—meaning that C-principles govern. However, in large mass production OLFs, one might find that (in the painting example) four organizing categories exist, one for each engineering compseq—R-principles govern. It could be true that in large mass production firms organizing categories are isomorphic to primary value chain engineering categories. In addition, engineering categories may have a large effect on organizing categories for the primary value chain, but not for the support chain. Thus, for a task such as curriculum redesign in a business school, there may be no "engineering" type principles that might help resolve the category taxonomy—other criteria become more important.

(2) Sequence Theory

Given categories, sequence theory becomes relevant. Sequence theory clearly dominates both DNA and generative grammar codes. Most existing process theory and grammar applications have also focused on sequence theory, though it is in very nascent form. Sequence principles primarily generate the preferred ordering of syntactical categories nested within the compseq category—the OLF. Sequence theory has four important submodules:

(a) Limit Theory

Consider again Mackenzie's example of the railcar unloading sequence, shown in Figure 4. Compseq (1) is as given by Mackenzie, based on his observation of a supermarket. Let us suppose that compseq (2) is the OLF. Locality theory focuses on what the limits are as to how far an element of a sequence can be relocated while still staying within the bounds of OLF. The advantage of compseq (1) might be that the loading dock is kept more orderly and theft is less if goods are quickly palletized. The advantage of compseq (2), the OLF, is that it is more general and does not suffer the risk that inspection may be impossible after palletizing. In this example there is one OLF, but limit theory specifies how much deviation may be allowed.

(b) Function theory

For a compseq to be complete or effective, a number of functional roles may have to be "played" by

[6] Even with the parameter approach a portion of application structure will remain stochastically idiosyncratic, with effective structures varying according to some distribution within the OLF framework, and ineffective structures totally at odds with it.

various elements comprising the sequence. From the general systems literature we know that there are input, throughput, and output functions. Each of these would be played by some element within a compseq, and a compseq would not be judged as complete without all three roles represented and in the correct order. Thus, in compseqs (1) and (2) unloading plays the input role, document plays the output role, and everything in between is part of the throughput. Mackenzie did not include a "move pallet" element, which could also be an output, or perhaps in Mackenzie's analysis "move pallet" is considered the input to the next compseq. Output-to-input adjacencies might be useful cleavage sites separating compseqs one from another. I have identified one set of functional roles elements might play. Perhaps there could be others.

(c) Binding Theory

Consider the "inspect, count, check quality" sequence. It is intact in both compseqs (1) and (2), but is disrupted in compseq (3). Binding theory sets out rules wherein some elements of a sequence are always attached to some other element. In this example, inspection, counting, and checking quality always must be bound together as a single unit. However, palletizing is not really bound to any other element in that it could fit several places in the compseq.

(d) Governance Theory

Governance theory focuses on the co-relation of changes among sequence elements. Thus, in compseq (2), suppose that the initial inspection method of "eyeballing" and writing on a form with a pencil is changed to counting bar codes with a wand. In this example, once the inspection element is changed, the count element is also changed, the document element changes from pad to computer file, and the check quality element changes to some other electronic method of recording when an item passes the quality check. Thus, the way in which counting, checking quality, and documenting are carried out are governed by the inspection process is conducted.

(3) Interdependence Theory

Principles in this module generate preferred delineations of one- and two-way causal flow patterns leading to OLF. There could be categories where the causal flow is not dictated by engineering principles. Design, production, and marketing/selling of automobiles could be seen as linear or mutually causal. Information flows up and down or laterally within an organizational hierarchy may optimally take one- or two-way causal paths. Process theory in this module would generate code for what the OLF of interdependencies and causal flows might be for a given technological or international differentiation when the causal flows of organizing processes are not dictated by material flow. It would also specify conditions governing the nature of causal flow. Process theory to date focuses primarily on linear, one-way sequences. In Mackenzie's (1986) terminology, these are "half-channel" communication flows, as between A, B, C, D, E in Figure 5a. There could be full channel interdependencies between some elements and there could be reverse interdependencies via loops that skip over intermediate elements, as in Figure 5b. Principles governing choices among half-channel, full-channel, and loops are not yet developed in a form that would allow application in less than universal, but broader than idiosyncratic firm, settings.

(4) Parameter Theory

As Chomsky uses principles and parameters, the logical form of universal grammar is switched (via the parameters) from one form to another as one switches from one language to another. Thus principles for verb positioning are switched, say, from English to German where verbs are at the end of sentences. Languages are clearly major differentiations of universal grammar; parameters, therefore, are not meant to be sensitive to intralanguage differences as might occur with dialects, local town, or individual usages. For firms the question is, What are the major differentiations in OLF that should be recognized and differentiated? Possibly technological differences between, say, chemical, electronic, and physical processes could be worthy of parameter recognition. Would international differences be recognized? Would intranation cultural differences be recognized? Would parameters recognize corporate cultural differences? Would size differences call for a parameter switch? As mentioned earlier, in smaller firms several primary chain engineering processes might be subsumed within one organizing compseq, but in large mass production firms each engineering process, such as metal preparation, priming, painting and oven baking, might each have a parallel organizing compseq attached.

Trade-off parameters, which occur frequently in most physical and organization design processes add another component to parameter theory that is outside the concerns of linguists. Trade-off parameters could be much more detailed than Chomsky's concept of switching parameters—relevant differences could extend down well below major differentiations in technology or international cultures. Possibly, trade-off parameters could usefully and manageably reflect experience differences among populations, but not among firms within a population.

Parameter theory seems totally absent in current process theory, yet it seems unlikely that rigidly applied reductionist principles will work for organizational processes, given the existing level of idiosyncrasy characteristic of most process designs. The development of principles of OLF may make little headway without a theory of how the more universal principles may be idiosyncratically modified to better accommodate major differences among technologies, cultures, and populations. The present state of organization theory does not appear to support parameter theory in any way, given that organization scientists tend to fall into either reductionist/positivist (uniform, universal principles) or nonreductionist/postpositivist (no principles) camps.

(5) Adaptation Theory

Principles in this module generate the preferred change processes that keep all of the foregoing principles, which comprise the OLF, in a state of appropriate adaptive progression relative to a changing environment. Unlike DNA or grammar codes, which exist in relatively stable contexts, organizational process theory has to accommodate the fact that organizations typically exist in rapid paced evolutionary settings. As Nelson and Winter (1982) point out, for organizations there have to be higher order routines that serve to change the lower order routines.

F. CONCLUSION

As they say of streets in Boston, process theory appears to have followed the proverbial cowpath. Ignoring early epistemologically undefined references to "process" by March and Simon (1958) and Parsons (1959) among others, "process theory" was first aligned with evolutionary epistemology by Mohr (1982). Then it took an unmistakable reductionist turn with Mackenzie (1986). Given analogic focus on DNA sequences and pre1980 Chomskyan generative grammar, it stayed deterministic reductionist with Salancik and Leblebici (1988), Abbot (1990), and Van de Ven and Poole (1990), even though both of the analogic sciences had moved toward increased contextual sensitivity. With Van de Ven (1992) and Pentland (1995) process theory has at least partially reconnected with the evolutionist/contextual path.

Following Cohen and Stewart (1994), I argue that process theory benefits from a clear exposition of both reductionist and contextual epistemologies. In Part I, I focus on a possible architecture for a reductionist organizational process/event sequence code, leaving further development of contextual aspects to Part II. Several arguments are developed in Part I:

1. A review and critique of process theory concludes that a successful process theory needs a simplified underlying reductionist code architecture that is contextually sensitive.
2. The architecture of contextually sensitive intradisciplinary reductionist codes is developed by reviewing reductionist logic and the architecture of DNA and generative grammar codes.
3. Despite social science critiques leveled against reductionism, observed commonalities between DNA and generative grammar codes suggest an equivalent code architecture may be appropriate for process theory.
4. An architecture for such a process theory code is outlined in Figure 6. It is influenced primarily by post-1980 Chomskyan generative grammar, with the primary category labeled the "compseq."
5. If Figure 6 is taken as a research agenda, the conclusion is clearly that process theory has barely scratched the surface, as compared to research on the DNA and grammar codes, and has many challenges ahead.

The main contribution of Part I is in trying to set up the epistemological foundation of an organizational reductionist process code. If process theory is to become a central part of a more predictive organizational science, an essential feature necessarily will be a contextually activated reductionism. Given the pervasive negative attitudes of many social scientists in general, and many organizational scientists in particular, toward any form of reductionism pertaining to social phenomena, this argument is timely and fundamentally important to the success of a reductionist process theory. It cannot flourish if its epistemology is confused.

This contribution is limited, however, because my analysis stays at the metatheoretic level. In particular, the further development of process lexicon, category and sequence theories (including limit, function, binding, and governance), and especially parameter theory, seems critical. Without rapid development of modular theories, process theory may not fulfill its promise. With respect to parameter theory, of particular importance are parameter switches related to major differentiations in optimal logical form, such as by technology or international cultures. That these differentiations may be important is an assumption that needs testing, otherwise process theory will appear inconsistent and development will slow. Empirical corroboration remains at issue as well.

If the process theory architecture shown in Figure 6 is taken as an outline of the research agenda, some topics have received fairly specific attention while others are totally ignored. Mackenzie (1986) has chapters covering aspects of syntax and interdependence and adaptation theories. Salancik and Leblebici (1988) focus intensely on sequence theory. Pentland (1992, 1995) and Pentland and Rueter (1994) focus directly on syntax and category theory. Though Kruskal and Sankoff (1983) and Abbott (1990) discuss sequence analysis, it is not specifically related to sequence theory, as sequences are taken as given. As constructive as these and other studies have been, they are stories about journeys scattered across a land where no map exists. Consequently one cannot put them in relational context and cannot tell if parts of the land are well described while other parts are unexplored. Progress would improve if future contributions were carried out in the context of a process theory map such as the one I have outlined. Would it not aid overall understanding of this strange land if process theorists were to travel and talk about their travels in terms of the same map? And if the proposed map itself is inaccurate, as it easily could be, should they not attempt to correct it in addition to describing journeys within the map?

Organizational process theory has the potential of offering new insights into organizational functioning.

It could become a fruitful basis for explaining and predicting superior competitive performance among firms. Pentland and Rueter (1994) make a link between process theory and the routines of Nelson and Winter (1982). The resource-based view adherents in strategy have made a like between internal SBU routines and sustained competitive advantage, that is ***competitive organizing***. To move further in this direction, however, the vast complexity of firm processes needs to be narrowed and focused and directed toward those processes most critical in leading to superior competitive performance.

Besides suggesting that most process grammar should focus on the "compseq" category (defined as sequences in some sense complete), perhaps the most novel outcome of this paper is parameter defined principles. Normally principles are true or not true, apply or do not apply, depending on contextual effects—UNDER CONDITIONS *C*, *X* CAUSES *Y*. Methods are designed to allow tests of this kind of principle. In this usage, as the context changes, so does the principle. But in Chomsky's principles-and-switching-parameters, and in my addition of principles-and-trade-off-parameters, the principle becomes, UNDER CONDITIONS *C*, ARRAY *X* CAUSES ARRAY *Y*, WITH DIVERSE ELEMENTS X_{ij} AND Y_{ij} ACTIVATED BY PARAMETERS. The number of required principles reduces by the array size, yet any given user needs only to learn the array element relevant to her context. This is why, in Chomsky's view, two year old children can learn the principles of proper language usage so quickly. I think this approach is well suited to process theory and organization science in general—not because managers are child-like, but because of the array-size reduction factor. Even though organizational contexts are incredibly idiosyncratic, creating a large array, Y_{ij}, the number of relevant principles might be relatively small and highly predictable, making for a much more tractable science.

The array effect means few principles as traditionally defined, so how does one deal with predictability, falsifiability, and generalizability—hallmarks of good science—if the array element Y_{ij} differs for each empirical site or population? This could be overcome if the operational measures of X_{ij} and Y_{ij} are defined uniquely to each site or population *in advance*, which does not seem too intractable. This approach might seem vulnerable to misuse (anything→anything), but on the other hand, if the array of acceptably defined elements is public knowledge, it is subject to the same level of critical review as with any other empirical study. A possible illustration of this approach may be drawn from Pfeffer's (1995) "principles," shown in Figure 7. Based on half a dozen very well performing companies, Pfeffer argues that the principles listed are keys to competitive advantage. In essence he says that even though the X_{ij}, Y_{ij} operationalization details vary in each firm, nevertheless, the principles apply across all firms (leaving "all" somewhat undefined for now) and therefore may stand as good examples of the "principles and parameters" approach. Thus, *incentive pay* (X_{ij}) *leads to competitive advantage* (Y_{ij}), where X_{ij} and Y_{ij} are diversely operationalized but equally calibrated to have a standardized effect and idiosyncratically activated across firms (one element per firm) (subject to normal auxiliary hypotheses and controls).

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Figure 1. Architecture of the DNA Code

1. Basic code elements are very simple—they are binary
2. Only four base pair code elements (A, C, T, G); infinite sequence combinations
3. Horizontal sequence groupings of different lengths
4. Hierarchical structure (e.g., atoms, nucleotides, genes, chromosomes)
5. Code Replication:
   a. Nonerror based differences (normal sequencing produces different members of species)
   b. Error based differences (errors enter in to produce abnormal functioning members)
   c. Low error rate (1 error per 10 billion base pair replications)
6. Same code for all cells; activation differs by cell function
7. Contextually activated:
   a. Physical means
   b. Chemical means
   c. Mutatations (random or otherwise (e.g., radiation effects))
8. Code creates bases of activation (e.g., DNA creates the physical and chemical "agents")
9. Code controls timing of activations (e.g., injury healing cells turned on, then off)

Figure 2. Architecture of Chomsky's Generative Grammar

I. **The rule system consists of**:
   A. lexicon
   B. syntax
      1. categorical component
      2. transformational component
   C. phonetic form component
   D. logical form component

II. **The principles consist of**:
   A. bounding theory
   B. government theory
   C. θ theory
   D. binding theory
   E. Case theory
   F. control theory

Figure 3. Unit Comparisons Across the Codes

Genes	Sentences	PESs
Nucleic acids	Noun/Verb phrases SOPs	
Nucleotides	Words	Moves/activities
Chemical molecules	Letters	Behaviors

Figure 4. Example PES Sequence

(1)	unload	palletize	inspect	count	check quality	document
(2)	unload	inspect	count	check quality	palletize	document
(3)*	document	count	palletize	check quality	inspect	unload

Figure 5. Interdependencies

a) A → B → C → D → E → F

b) A → B ↔C → D ↔E ↔F

Figure 6. The Architecture of an Organizational Process Theory Code

1. Optimal logical form
2. Application structure
3. Synctactical rule system
   a. Base
      1) Lexical elements
      2) Primary category
   b. Modification rules
4. Contextually variant modular principles and parameters
   a. Category theory
   b. Sequence theory
      1) Limit theory
      2) Binding theory
      3) Function theory
      4) Governance theory
   c. Interdependence theory
   d. Parameter theory
   e. Adaptation theory

Figure 7. Possible Incentive Principles*

1. Employment security
2. Selectivity in recruiting
3. High wages
4. Incentive pay
5. Employee ownership
6. Information sharing
7. Participation and empowerment
8. Self managed teams
9. Training and skill development
10. Cross-utilization and training
11. Symbolic egalitarianism
12. Wage compression
13. Promotion from within

*From Pfeffer (1995)