A SELF-ORGANIZATIONAL MODEL OF COMMUNITY EVOLUTION

by

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The purpose of this work is the development of a conceptual model of the interaction of ecological, economic, and social factors in community evolution. The theory of self-organization (Ilya Prigogine and colleagues) is used to relate the growing body of insights into social and societal evolution derived from sociology, anthropology, economics, the community and economic development literature, and other fields to the problems of planning.

A schematic of the interdisciplinary modelling process and a classification of models are developed. The assumptions and goals of the conceptual model presented here are made explicit through the use of a "knowledge vee" (Novak & Gowin, 1984). The conceptual model of community evolution developed here entails eight variables representing the ecologic, economic, and social factors (landscape, land tenure, land use, social inputs, historical inputs, production, consumption, and resources) and four variables derived from evolutionary, non-equilibrium social theory and self-organization theory ("mass," "energy," "tension," and "entropy"). These variables are related conceptually to form a nonequilibrium, self-organizing "model" of community evolution. Several possible examples of self-organization processes in human systems are briefly discussed.

Various implications of the model for planning and understanding community evolution are examined. They include: the process view of evolution, the role of the internal history of the system, the stochastic element in self-organizing processes, the influence of environmental
conditions, the importance of qualitative change, and the mechanisms of long-range order.
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I am grateful to Brahm Weisman, William E. Rees, Norman G. Dale, Ed Levy, and Henry C. Hightower of the University of British Columbia for their comments and suggestions on earlier drafts of this work. I am especially grateful to Scott Carley for encouragement and advice relating to the final chapters. I am indebted to Norman Dale, Peter Boothroyd and Kathy Nelson for suggestions relating to examples of self-organization in human systems. I must also acknowledge the contribution of Muriel Kerr, without whose influence the core of this work might never have included communities. Finally, I am grateful to Eric Higgs and James Kay of the University of Waterloo for discussions and suggestions, past and present, relating to self-organization theory.
CHAPTER I - INTRODUCTION

Whenever human beings are involved, social adaptations and evolution make it certain that trend is not destiny, because life starts anew, for us, with each sunrise.

(René Dubos in Ortner, 1983)

The last several decades have seen the widespread recognition of the existence of societal problems with ecological, economic, and social aspects. Efforts to address these problems are as diverse as those making proposals to address them. One of the more widely accepted of these efforts is the concept of sustainable development — a concept that may be seen as a policy-oriented melding of steady-state economics (Daly, 1973; 1974) and bioregionalism (Dodge, 1981; Sale, 1985). The concept was brought to the attention of decision-makers around the world by the World Conservation Strategy (IUCN/UNEP/WWP, 1980; Croner, 1984) and is gaining acceptance as a policy goal in many areas (cf. Environment Canada, 1984). Yet there are a great many difficulties in the implementation of, or even definition of, sustainable development. Most of the difficulties are a result of the intricacies of the social, ecological, and economic parts of our environment, e.g. the issues of social and economic equity inevitably raised by discussions of environmental conservation.

This work, by developing a conceptual self-organizational model of the interactions of ecological, economic, and social factors in the process of community evolution, seeks to contribute to the understanding of the fundamental, structural relationships of these factors. This approach, with
its use of a relatively new, physical-science-based theory is in contrast to the more usual static, disciplinary, philosophical, ethical, political, and planning approaches to the integration of these three factors (as, for example, in the World Conservation Strategy itself). Self-organization theory goes beyond the usual systems view by focusing attention on a system's internal dynamics and structure.

Self-organization theory describes and attempts to explain the generation of order out of disorder, out of chaos, to use Ilya Prigogine's term, in complex, open systems that are far-from-equilibrium with their environment and which involve positive feedback loops nonlinear processes. Human systems are, of course, such systems and the tendency toward greater structure and order in human systems through history is pronounced, in spite of the seemingly chaotic pattern of events and actors at any given time.

Our task will be to use self-organization theory to examine the interaction of ecological, economic, and social factors in human systems. To this end, a conceptual model of community evolution will be developed to illustrate the process of self-organization in a human system. Finally, the implications for planners and planning of a self-organizational conception of human systems are examined. This thesis is less an experiment or a hypothesis than an examination of the potential usefulness, heuristic value, of a new conception of the functioning of human systems. The goal is understanding, not proof, of the role of self-organizing processes in human systems, e.g., a community.

The course followed is an intermediate one between the two extremes of attempting either to define precisely and reductionistically what is meant
by "factors" and by "community" or the meaningless, if true, exploration of the statement that all these factors interact and intergrade inextricably with each other. The unifying theory of this work is self-organization (Nicolis & Prigogine, 1977). The context is developed from recent work in economic and cultural anthropology, ecosystem ecology, political science and sociology, geography and history, and economic and community development.

The rest of this chapter will make clear some assumptions I have made in delimiting and choosing my topic and my methodology. It will provide an outline of, rationale for, and comparison with some other possible methodologies. This should enable the reader to understand what I have and have not done in what follows. Chapter 2 will present self-organization theory in detail. Here I will merely explain why I have chosen it as the unifying theme of this work. Chapter 3 will review the relationships of community, society, and environment from the perspective of the disciplines mentioned above. This material provides the substance from which the conceptual model of the interaction of ecological, economic, and social factors in community evolution (presented in Chapter 4) is developed. A final chapter discusses the overall usefulness and applicability of the self-organizational view of societal processes presented in this thesis; focusing on the implications of the self-organizing model for community and regional planning.

To elaborate on what I am examining, community evolution describes

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1 A "community" as used in this work may be thought of as a subset of a society in both space and time. Such a subset is much more easily modelled than would be an entire society (e.g., North American society, European society).
the changes that occur in an aggregation of people in a certain geographical location in the course of time — from the formation of that community to its destruction (Martindale, 1964), whether that be five years or five thousand years. During that time, there will be interactions between the community and its natural environment ("ecological factors"): there will be interactions between the community's components and its social and economic environments and, especially as the community grows (in numbers and area), it will develop an internal social and economic structure that interacts with the social and economic structure of the environment — thus the incorporation of "social" and "economic" factors. The latter perspective may be seen as central to socio-economic impact assessment — SEIA — (cf. Leistritz & Chase, 1982). Community development seeks to manipulate the interactions and the development process (while SEIA seeks to assess and evaluate the impacts of such manipulations) in order to achieve a "more desirable" internal structure or environment (e.g., Durston, 1977).

The theory of self-organization, simply put, is a theory of the organization (evolution) of systems in which future states depend non-deterministically on the system's history. It is a result of the work of Ilya Prigogine and his co-workers over the past forty years in the field of non-equilibrium thermodynamics (Prigogine, 1962; Glansdorf & Prigogine, 1971; Nicolis & Prigogine, 1977). Self-organization theory, although developed in the context of chemical thermodynamics, is in fact ideally suited (for reasons made clear in the next chapter) for the modelling of social processes. The prime difficulty, as Nicolis and Prigogine (1977, p.
have noted, is choosing the relevant variables.

This difficulty has resulted in the main applications of self-organization theory to non-physical-science problems being either cases such as urban growth (Allen & Sanglier, 1978; Marchand, 1984), simple population ecology models (Allen, 1976) models of early biological evolution (Eigen, 1971), or social organization of hymenoptera (Prigogine, 1976) where the variables can be chosen fairly readily or arbitrarily; or else purely theoretical discussion of how self-organization might proceed in a human society (Taylor, 1976; Prigogine, 1976; Jantsch, 1980). I attempt to be intermediate to these two.

Self-organization is a systems theory, but it is not a theory of systems. It does represent a general property of systems and perhaps even a unifying principle in science (cf. Prigogine, 1980, 1985). Although it utilizes many systems concepts (cf. Ackoff, 1971) it is not a theory that relates systems but rather one that describes the (irreversible) time evolution of individual systems (Prigogine & Stengers, 1979). This distinction is implicit in Bunge's (1979 - quoted in Mattessich, 1982) mathematical systems theory definition of a self-organization process. Self-organization theory is perhaps intermediate between the "inexpungible craving for generality" and numerous other faults of systems theory as a formal discipline (Berlinski, 1977), and the extreme reductionism of so many classical models of society (e.g., in economics, Solow, 1956). Although involving much more than a simple melding of systems science and physical chemistry, self-organization theory exhibits the characteristics of the contributions of systems science to physics identified by Willems (1984) —
that is a bridging of the descriptive/prescriptive gap and the consideration of dynamic systems with external variables.

The paradigm of self-organization goes beyond the probabilistic systems theory paradigm in several ways. Systems theory is a way of describing the interrelationships of the elements of a system at a given point in time; self-organizational theory is concerned with the internal dynamics and processes of the system and, most importantly, with the system's structural evolution over time. Indeterminacies in systems theory are usually the result of complexity or lack of knowledge, in self-organization theory they are intrinsic to the nature of the evolutionary process. Systems theory is a purely theoretical construct or way of looking at the world; self-organization is an observed phenomenon in chemical and physical systems, with several competing theories to describe it.

The benefits of interpreting a region's or community's history through systems theory are essentially structural: identification of key elements of the community structure, definition of the system boundaries and subsystems, and hierarchial patterns of control and feedback. A fully developed self-organizational interpretation would go further and permit identification of the crucial processes that determine the evolution of the system, identification of critical points in the system's history where minor fluctuations produced major changes in the system, and identification of the conditions in the system that made (and will make) the system susceptible to self-organization events.

Such, briefly, is the background and the context of the work presented.
in the following chapters. Mention should be made of the main previous efforts, of which the author is aware, to look at the interrelationships of society and environment in an holistic and synthetic way. This is the work of Miller (1978, 1982) in modelling a coastal B.C. fishing village. His approach is that of Holling's (1978) applied systems analysis (previously exemplified by Chambers, 1971); the disciplinary background he draws upon is rather similar to that described in Chapter 3. However, Miller's central concern was to develop a model for policy-making in the context of a particular socio-ecological situation (the fishing village) rather than to test the applicability of a general theory (self-organization) in the search for "lessons" about the process of community evolution.

Let us look now at the methodology by which my model is generated. Figure 1 gives a schematic diagram of the process of model generation. First, a conceptual synthesis, or theory, is developed based on extant disciplinary knowledge, in response to needs and objectives, i.e. a problem. Next, a formal synthesis or model is formulated based, for example, on the mathematical techniques of qualitative analysis — that is methods for the analysis of unquantifiable structural change (Katzner, 1983). These include set theory (Dalen et al., 1976, Halmos, 1960), topology (Kelley, 1961), and group theory (Ljapin, 1974). Thirdly, an operational synthesis, or simulation, is prepared and implemented as a program running on a computer. This third step makes possible the last step — that of generation of output or predictions for comparison with "real" systems and the conventional wisdom of disciplinary knowledge — by allowing multiple runs of the model with different data and assumptions.
Figure 1 - Schematic Diagram of the Modelling Process

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Figure 2 - A Typology of Modelling
While this work develops the model to only the conceptual stage, the process outlined above could be applied. The techniques of qualitative analysis could be combined with those of vector analysis — the calculus of directional forces — (Grossman, 1981; Buck, 1978; Royden, 1968) to develop a formal model of self-organizational processes. An operational model could be developed as a model of relatively simple (isolated, small), well documented communities (e.g. in the Northwest Territories: Devine, 1981, 1982, 1984) and compared with an historical model of a larger, older region such as Vancouver. Taking this last step would open the model to evaluation by standard modelling-for-policy techniques (e.g. Majone & Quade, 1980). Additionally, computerization is likely the only way to adequately simulate the complex repetitive processes involved in self-organization and, in addition, presents an interesting programming problem in modelling the parallel processes of society on a sequentially processing machine (Wolfram, 1984).

Figure 2 further clarifies the intention of the model presented here by distinguishing between four types of "modelling" classified along two (space and information) dimensions in a typology developed by the author. The present exercise is intended as a "simulation" in the sense of being spatially restricted and (relatively) informationally comprehensive.

Finally, I will make use of a "knowledge vee diagram" (Figure 3) which, to quote its originators, (Novak & Gowin, 1984) is an heuristic, "a scheme for 'unpacking' the knowledge in any particular field" (p. 55). It is
intended as a final clarification of the conceptual and methodological assumptions and steps implicit in the development of the ideas that form the heart of this work. It compares the conceptual and methodological at different levels of abstraction and forces one to identify the bases of one's methodology. From concepts to theories, on the one side, and records to results on the other, the contents of the figure describe the conceptual framework which the author brings to bear on this work.
CONCEPTUAL ENTITIES


PHILOSOPHY: a belief in diversity of "scientific research programmes" (Lakatos, 1970; Feyerabend, 1970).


PRINCIPLES: non-equilibrium, nonlinear social systems (Diener, 1980; Perroux, 1983) and heuristic value of predictive theories (Friedmann, 1953).

CONSTRUCTS: community, tension.

CONCEPTUAL STRUCTURES: system, mass, energy, environment, entropy.

CONCEPTS: landscape, land use, land tenure, production, consumption, resources, social inputs, historical inputs.

FOCUS QUESTION:

What are the generative forces of community evolution?

METHODOLOGICAL ENTITIES

VALUE CLAIM: as an heuristic in the study of communities and the facilitation of sustainable development.

KNOWLEDGE CLAIM: that the present model represents a new exploration, compatible with present disciplinary knowledge.

INTERPRETATION: of the theory in the context of community and society.


TRANSFORMATIONS: the observations of economists, anthropologists, historians, sociologists, ecologists, and development workers about communities.

FACTS: observed processes of community evolution (e.g., Martindale, 1964; Arndt, 1981; Cottrell, 1976; Bowles, 1981; Blishen et al., 1979).


EVENT: Community evolution.

Figure 3 - Knowledge Vee Diagram of Conceptual Structure for this Work
CHAPTER 2 - SELF-ORGANIZATION

The beginner should not be discouraged if ... he finds that he does not have the prerequisites for reading the prerequisites.

(P. Halmos, 1950)

The theory of self-organization is a large, complex, and highly mathematical subject. The treatment given here is intended to develop the intuitive and qualitative understanding of it necessary for understanding the conceptual model of self-organization processes in community evolution presented later. In what follows I have drawn primarily on Prigogine (1962, 1976, 1978, 1980), Nicolis and Prigogine (1977), Prigogine et al. (1978), and Prigogine and Stengers (1984). Other references will be cited as needed. This thesis follows Prigogine's school of self-organization. Other similar theories which use different mathematical theories (Haken, 1983a,b) or are intended to apply to non-human systems (Zeleny, 1981) do exist but are beyond the scope of this work to consider.

Central to the theory of self-organization are the concepts of isolated, closed, and open systems, and entropy as formulated in chemical thermodynamics. An isolated system exchanges neither matter nor energy with its environment, a closed system exchanges energy, an open system both matter and energy, with its environment. Entropy, S, is defined (by the second law of thermodynamics) as a function of the state of the system (i.e., of a number of specified independent variables assumed to describe the system) and is an extensive property (i.e., defined by the system as a whole as are mass, m, and volume, v). Intensive properties, e.g., p, pressure and T, absolute
temperature are those which take on well-defined values at each point in the system. The change in entropy within a system, $dS$, may be split into two parts, due to entropy production external (e) and internal (i) to the system:

$$dS = deS + diS$$

at equilibrium $dS = deS = diS = 0$ \hspace{1cm} (1)

In an isolated system there is no entropy flow as $deS = 0$ and $dS = diS \geq 0$. If $diS = 0$ then the system is at equilibrium. This situation is irreversible in the absence of exchanges with the system's environment, i.e., entropy is not conserved, it is always positive or zero and, therefore, provides a universal law of the macroscopic (i.e., large-scale, visible in contrast to the microscopic or molecular) evolution of physico-chemical systems. In a closed system:

$$dS = \frac{dQ}{T} = \frac{dE}{T} + pdv; \hspace{1cm} \text{where} \hspace{1cm} E = \text{energy} \hspace{0.5cm} p = \text{pressure}$$
$$T = \text{abs. temp.} \hspace{0.5cm} Q = \text{heat} \hspace{0.5cm} v = \text{volume}$$

that is, the entropy of the system equals the sum of heat (a measure of internal energy) produced in the system plus work (a function of changes in pressure and volume) done at the boundary (of the system). Alternatively,

$$F = E - TS \hspace{1cm} \text{F = Helmholtz free energy} \hspace{1cm} (3)$$

which is the classical statement of the competition between entropy and energy. When $T$ is low, the contribution of $E$ predominates, when $T$ is high, the entropy term dominates. This competition is embodied in Boltzmann's
ordering principle, which applies near equilibrium and, expressed in terms of molecular disorder in an isolated gaseous system, is expressed as:

\[ S = K \log P. \]

\[ K = \text{Boltzmann's constant } 1.38 \times 10^{-23} \text{ J} \cdot \text{K}^{-1} \]

\[ P = \text{Number of complexions} = \text{the number of ways } n \text{ molecules can be divided into } 2 \text{ groups } n_1 \text{ and } n_2 \]

\[ \frac{n!}{n_1! n_2!} \quad (4) \]

The value of \( S = K \log P \) reaches a maximum when \( n_1 = n_2 = n/2 \) -- the normal situation in a gaseous system at equilibrium. Equivalently, in a closed system, \( F \) reaches a minimum when the system is at equilibrium, reflecting the fact \( S \) is at a maximum.

Equilibrium structures, those which commonly result in isolated and closed systems, after a sufficiently long period of time, as a result of irreversible entropic (spontaneous) processes, are dominated by Boltzmann's ordering principle, the competition between energy and entropy -- thus at low temperatures we have relatively ordered structures -- things freeze -- while at high temperatures we have gases. It is, however, open systems far from equilibrium that will be of primary concern to us here. It is here that "dissipative structures" -- structures that are maintained by flows of energy and matter across the system boundaries, that dissipate energy in structural maintenance, appear and the principle of "order through fluctuations" replaces Boltzmann's ordering principle.

An open system can exist in three different forms: thermodynamic equilibrium, linear non-equilibrium, and far from equilibrium when the
constraints on the system maintain it that way. An open system at thermodynamic equilibrium is described by equation 4 above. For an open system in the region of linear non-equilibrium:

\[
\frac{d\Sigma S}{dt} = \sum X_j J_j \geq 0
\]

where the \( J_j \)'s represent the rates (of reactions) and the \( X_j \)'s the corresponding forces (diffusion) of the irreversible or entropic processes occurring in the system.

The forces cause the fluxes and both have a macroscopic order to them (Prigogine & Stengers, 1979). At thermodynamic equilibrium \( J_j = X_j = d_1 S = 0 \) for all irreversible processes simultaneously. An important general result of non-equilibrium thermodynamics is that dissipative structures, and thus self-organization, can only occur in systems far from equilibrium where the processes occurring are non-linear and involve catalytic steps sustained by flows of energy and matter from outside the system (i.e., where equation 5 does not hold).

In an open system \( d_e S = -d_1 S < 0 \) which is to say that a decrease in the entropy of a system can occur as a result of exchanges (flows) of energy and matter over the boundary of the system. While it is possible to describe the entropic evolution of an isolated or closed system relatively simply using the classical methods of equilibrium thermodynamics, or Prigogine's extension of those methods for open, "linear" systems, such a description for an open nonlinear system is very complex, even in theory. Nicolis and Prigogine (1977; Chapter 5) derive general equations for the
time evolution of a chemical system consisting of mass-balance equations:

\[
\frac{\partial \rho_i}{\partial t} = f_i(\{p_i\}) + D_i \nabla^2 p_i
\]

\( D_i \) = diffusion coefficient
\( p_i \) = composition variables of the system
\( f_i \) = describe the overall rate of production of constituent \( x_i \)

(6)

and an equation for internal energy conservation:

\[
C \frac{\partial T}{\partial t} = \text{div} \, \lambda \nabla T + \sum_p (-\Delta H_p) \dot{W}_p(T,\{p_j\})
\]

\( W_p \) = velocity of reaction \( p \)
\( C \) = specific heat of the mixture
\( \Delta H_p \) = heat of reaction \( p \)

(7)

with mathematically appropriate boundary conditions, usually either,

\[
\text{Dirichlet} \quad \sum_{\rho_1, \ldots, \rho_n} \{ \rho_1, \ldots, \rho_n \} = \{ \text{const} \} \text{ or } \sum \rho_i \sum_i \rho_i
\]

\[
\text{Neumann} \quad \{ n \cdot \nabla \rho_1, \ldots, n \cdot \nabla \rho_i \} = \{ \text{const} \}
\]

(8)

(9)

which basically provide a vector calculus evaluation of heat produced and work done at the boundary of the system. Of particular importance in the modelling of a concrete problem are the form of the "chemical" laws determining the reaction rates and the value of such parameters as diffusion coefficients, rate constants, the size of the system (too small a system
will always be dominated by boundary conditions [Hanson, 1974]) and the nature of the applied constraints (Nicolis & Prigogine, 1977).

To return to a more qualitative approach to the problem of modelling the evolution of the structure of an open system far from equilibrium, let us reiterate that as a system moves from equilibrium to far from equilibrium and/or from isolation to openness, it becomes more complex, its internal dynamics become non-linear and, finally, its structure or state, becomes less stable. That group of stable states of the system in a finite neighbourhood of the equilibrium state is known as the thermodynamic branch (branch refers to a "branch" of solutions of the state equations). Beyond some critical value of a state parameter or constraint, however, there is the possibility that the states on the thermodynamic branch become unstable. In such a case, a seemingly minor disturbance, or fluctuation, may cause the system to evolve in a new direction, away from the previous thermodynamic branch — in mathematical terms we have a bifurcation that results in a new family of solutions to the state equations.

The dissipative structure which occurs far from equilibrium manifests itself in all cases by "coherent behavior" at a macroscopic, or supramolecular, level. It results in order, often "new" order, as a result of the amplification of fluctuations (this is the role of the non-linear mechanism of the system's dynamics) in the neighbourhood of a bifurcation point on the thermodynamic branch of the system. In chemical systems, this spatially coherent behaviour may be manifested by the appearance of a time periodicity in a chemical reaction. Thus, Nicolis and Prigogine (1977) describe the evolution of a dissipative structure as a self-determining
sequence. According to their scheme, structure impacts function which impacts fluctuation which feeds back to structure again. The bifurcation introduces history into physics and chemistry (Prigogine, 1980, 1985; Priogogine & Stengers, 1979, 1984). In contrast, the evolution of most chemical reactions is determined by the initial reactions and external conditions, such as P and T.

This approach involves both deterministic and stochastic elements in describing the time evolution of the macroscopic system. At points far from bifurcation the deterministic equations suffice (i.e., equations 6-9), near the bifurcation points stochastic elements become essential in the determination of which fluctuation is amplified and thus what new thermodynamic branch the system will follow. It is here that Thom (1975) parts from Prigogine — by a mathematical simplification he determines the system parameters and founds catastrophe theory. As a methodological aside, I might note that I am using Prigogine's mathematical approach as a guide, rather than catastrophe theory, because of the latter's preferential applicability to systems that maximize or minimize some (potential) function (e.g., entropy or energy, respectively), i.e., optimize some functions (Post & Stewart, 1978). Many societal subsystems (firms, individuals, etc.) may optimize but to attribute such a goal (or even the existence of such a function) to society or community, seems at best premature, at worst a singular instance of hubris on the part of the theorist.

The stochastic element consists of two parts: 1) The a priori probability for having a certain fluctuation in a complex system, and 2) the probability that this fluctuation spreads and attains a macroscopic range
and amplitude. Diffusion plays an especially significant role in the second of these components by dampening the spread and growth of system fluctuations. Dissipative structures show that long-range (space-time structure) order can be generated by processes at the microscopic level.

Jantsch (1980) summarizes the essence of self-organization quite well when he describes it as "the co-evolution of macro- and micro-cosmos" and calls it an emerging paradigm with three key aspects: "a specific macroscopic dynamics of process systems, continuous exchange and co-evolution with the environment, and self transcendence, the evolution of evolutionary processes" (p. 9).

Two final aspects of self-organization theory need to be clarified here before we proceed to a brief review of the relevance of self-organization theory for modeling of social processes. They are the roles and treatment of stability and stochasticity in the evolution of dissipative structures.

When we talk about the stability of the thermodynamic branch we are concerned with two different kinds of stability -- Lyapounov stability and structural stability. Although there are complex formal definitions of both, the distinction is put simply and succinctly by Hastings (1984) -- Lyapounov stability is concerned with perturbations, shifts in the quantitative state of the system, while structural stability is concerned with the effect of perturbations in the qualitative parameters of the system. Prigogine (1980) expresses structural stability as reflecting the idea of innovation, the appearance of a new mechanism or species that was initially absent from the system. Methods of actually assessing the
stability of a system defined as in equations 7 to 10 above are quite complex, when indeed they exist, and won't be explained here.

Although there is a branch of statistical mechanics known as fluctuation theory, it is not of much use in other applications due to the difficulty of defining the form of the system's probability distribution function. Stochastic theory is of more use to us here. Its basic idea is that the variation of $a_i$ values, as a result of a fluctuation (in an ensemble of variables $\{a_i\}$ determining the macroscopic state of the system) does not depend on the independent variable (time) in a well-defined manner, i.e., is a random or stochastic process. Thus, observation of different members of a representative group of systems results in different functions $a_i(t)$ from which we can define suitable probability distributions such as,

\[
P_1(\{a\}, t) \, \left( da \right) = \text{Probability of finding } \{a\} \text{ within } \{d\}, \quad \{a + da\} \text{ at } t
\]

\[
P_2(\{a_1\}t_1, \{a_2\}t_2) \, \left( da_1 \right) \left( da_2 \right) = \text{Probability of finding } \{a_1\} \text{ within } \{a_1\}, \{a_1 + da_1\} \text{ at } t_1, \text{ and then } \{a_2\} \text{ within } \{a_2\}, \{a_2 + da_2\} \text{ at } t_2
\]

with \( \sum \left( \{a_1\}, t_1 \ldots, \{a_j\}t_j \right) = 1 \) \( P_j \geq 0 \) \( j = 1, 2, \ldots \) \( (10) \)

Probability distributions are often described by a few "typical values" of which the expectation:

\[
\langle a_1 \rangle = \sum_{\{a\}} a_k \left( \sum_{j} P_j(\{a_i\} \, \left( \{a\} \right), t) \right)
\]

\( (11) \)
is the most important. As it does not depend explicitly on fluctuations, however, one must introduce expectations of quadratic or higher order from which variance can be derived (Nicolis & Prigogine, 1977, p. 225). There are three principal distributions: the binomial, Poissonian, and Gaussian (see Pollard, 1977). The binomial and Poissonian arise in cases involving Bernoulli trials; the Gaussian, typically as a limiting case of the law of large numbers. From this and the definition of an extensive stochastic variable it can be shown that the relative importance of fluctuations diminishes as the size (volume) of the system increases (Nicolis & Prigogine, 1977) -- but for nonequilibrium instabilities leading to dissipative structures this ceases to be true and the law of large numbers breaks down (that is to say, that the probability of the sample average and the population mean differing by less than a prescribed amount ceases to approach one as the number of variables approaches infinity). Thus, it has been shown that for nonlinear reactions occurring far from equilibrium the variation (form of the underlying distribution) of fluctuations changes qualitatively as their scale increases. They may be amplified in the presence of instabilities and drive the system to a new and different state.

One approach to obtaining a master equation description of fluctuations is to treat their generation as a Markovian "birth and death" process (a stochastic process in which the future depends solely on the present state) by assigning a set of transition probabilities describing the process in the space of some appropriate stochastic variables (Nicolis & Prigogine, 1977). This approach suffers from its emphasis on collective variables, treatment
of the system as a whole, and the global character of the birth-and-death method. What is needed is a local description of fluctuation in non-equilibrium systems.

Self-organization is a result of the breakdown of the law of large numbers, a result of the fact that nonlinear systems far from equilibrium consist of different macroscopic regions that do not evolve independently but rather become coupled via long-range correlations (of fluctuations). That is to say that the system's behaviour becomes non-Poissonian, although in a small enough region of the system, its behaviour (as the mean-square deviation $<f_x^2>$) can be approximated by a Poissonian (in terms of trials and successes of fluctuations). Thus the system's evolution in terms of the average of some extensive stochastic variables can be described in terms of a macroscopic expression and the deviation from the Poissonian; which deviation ultimately takes over and drives the average to a new macroscopic regime. Thus a chemical reaction exhibiting self-organization will be exhibiting spatially coherent, synchronized behaviour (e.g., regular colour changes) at a macroscopic, visible level (Turner, 1982). Microscopically, at a sufficiently small spatial and temporal scale, the reaction structure will be fluctuating randomly. The essence of self-organization is the selective amplification of certain microscopic fluctuations over a macroscopic range to yield macroscopically coherent behaviour that is fundamentally different from the previous (random) behavior.

This has been an attempt to outline the physical science origins and mathematical methods of self-organization theory. The crucial concepts and mechanisms are those of non-linear, far-from-equilibrium open systems, whose
time evolution along the thermodynamic branch may pass through regions of
instability where microscopic fluctuations can be amplified (by the
nonlinear processes) causing a macroscopic departure from the typically
Poissonian behaviour of such fluctuations, resulting in long-range order via
fluctuations, a new qualitative behaviour of the system. The rigorous
application of these ideas and techniques to simple physical and biological
problems is difficult -- a similar application to social systems is
undoubtedly impossible at the present time. Yet, that is not to say that
nothing can be learned from an application of the theory of self-
organization to social systems.

Nicolis and Prigogine (1977) acknowledged the temptation (as a result
of the widespread presence of "structure" in human societies) to apply self-
organization theory (and especially the idea of structural stability) to
socio-cultural evolution. They noted a couple of examples of applications
(Allen, 1976; Allen & Sanglier, 1978, 1981), and that "it clearly appears
self-organization theory is an emerging paradigm of science" (p. 474).
Self-organization theory is intermediate between the basic laws of classical
and quantum dynamics and the representation of natural phenomena by games of
which "the basic elements are chance and law, . . . and it is the
consequences of chance that are subject to regulation" (Eigen & Winkler,

Prigogine (1976) cited François Perroux's idea of the dialectic between
the mass and the minority in human society in a summary of his description
of self-organization theory as a possible unifying theory in sociology.
Mass represents the average behaviour of man, minority the fluctuations in society which, when they exceed a critical level, influence the average by driving the system to a new average level. From this perspective, he emphasized the nonlinear nature of the evolution of social phenomena, the coherent behaviour of a society, the importance of change in the description of social systems as coherent systems, and the fact that social structure finds its expression in constraints imposed upon the individual. The role of the individual in societal self-organization processes has received prominence in two separate accounts; one from the point of view of economics (Day, 1983), the other from the point of view of cognitive science (Smith, 1983).

Self-organization is, implicitly and explicitly, a major part of Rosnay's (1979) "macroscope" (see also Anthony, 1969; Odum, 1971); a new way of looking at and dealing with modern society (the book might be thought of as a continental answer to how to manage "The Third Wave"). His main achievement is recognition of the characteristics of modern society that make the postulation of self-organizing processes plausible. Balkus (1983) has attempted, in a rather difficult series of papers, to "describe the structure and process of societal self-organization" in terms of social necessity giving rise to organizing forces and thence to functional domains or plans. According to him planning and plans are the vehicles of the societal self-organization process; they identify and amplify fluctuations. This is an idea to which we will return at the end of this thesis in the context of community development and planning.

Clearly, there is some justification and precedent for the modeling of
community evolution as a self-organizing process. Self-organization occurs in complex systems that exchange matter and energy with their environment and at least some of where internal processes are regulated by positive feedback loops. Such a system will be far-from-equilibrium with its environment. The evolution of the system will include times of instability of the system structure or organization when a seemingly minor event within the system triggers a major change in its structure and organization. This new order is the result of the coupling of many minor changes over relatively long distances within the system. This new order is a dissipative structure, the result of self-organization.

What we hope to gain is an understanding of the dynamics of the process to supplement the more usual static description of the steps in the process. There are two crucial problems: the choice of variables (addressed in Chapters 3 and 4) and the question of how to actually model the process that relates the variables (addressed in Chapter 4). The material in the next chapter will form the basis for the actual model.
Art would like to stop being pretense and play, it would like to become knowledge.

T. Mann, Doctor Faustus

The goal of this chapter is to present disciplinary views of the relationships of community, society, and environment and the nature and relationships of their ecological, economic, and social structures and processes. I want to suggest that there are strong common themes among the disciplinary views that emphasize connectedness, stability, discontinuity, fluctuation and evolution and the role of these in determining structures and processes. These ideas are crucial to the elaboration of the conceptual model in the next chapter.

Social structures and processes in human systems may have several manifestations. One of the most important is culture -- the developed social structure of society. Ecological anthropologists see culture as subject to the laws governing living organisms as a result of culture's immanence in living organisms (Rappaport, 1971). Thus, Bennett (1978) argued that most social or human ecological systems, typically open systems, are never in a state of true equilibrium: they "move constantly from one level of organization to another, with the terms of (their) existence constantly changing from state to state" (p. 259). The more (politically) radical cultural and economic anthropologist would take this further and say that the laws to which culture is subject are social as well as ecological (Ingold, 1979), or that the problem is "to conduct the structural analysis
of social relations in such a way that the 'causality of the structures' upon each other could be analysed' (Godelier, 1978, p. 102). Most recently these ideas have begun to be set within a systems framework. Friedman (1979) was explicit in arguing for the use of "dissipative structures" and self-organization theory in modeling social phenomena because "social systems tend to be of an accumulative nature, stable 'cybernetic' cycles are contained within long-term secular trends leading to crises, breakdowns and reorganization" (p. 269). Returning to an ecological anthropologist, Diener (1980) has recently suggested that in order to understand the large-scale evolution of cultural change, it is necessary to concentrate on the "field" of economic and social relations of society, and on the unstable -- for it is in this context that change has occurred in the panorama of history.

From our start in anthropology, we have already introduced two very important implicit concepts -- that of time, of a history (and a future), and that of environment (spatial extent and complexity). History is, of course, very important to us -- its introduction to physical processes is one of self-organization theory's most important contributions. Here a useful distinction can be made between different types of history, different views of the nature of the flow of society and culture over time. Following Braudel (1969) there is the history of man in relation to his surroundings, the "longue durée," the form of history with which we are interested here; there is an intermediate social history of groups and groupings which is the "history" of the anthropologists, and there is the history of events, "l'histoire événementielle". (As an aside, this is the form of history most amenable to the manipulations of catastrophe theory; self-organization
theory, in contrast applies to the "longue durée."

For Braudel the past illuminates the present and history is an explanation of the past, so in a sense, we see the possibility of societal self-organization as a model of history in an analogy between the history of a society and the internal history of a self-organizing system. Additionally, Diener (1980) made much of the role of instability in cultural macroevolution, while Friedman (1979) emphasized the role of cycles, discontinuities and transformation in societal evolution. The evolution and spread of ideas and processes has been shown to fit quite well the logistic equation -- while deviations have often been associated with irregularly infrequent events such as wars, strikes, and economic panics (Montroll, 1978; Marchetti, 1985) that are sources of instability, often cyclical and certainly discontinuous and transformational. Thus, diverse anthropological and historical perspectives on the past suggest the applicability of elements of self-organization theory to social evolution.

Additionally, the wide variety of cycles that may be observed in a diversity of social behaviour (Young & Ziman, 1971) provides not only a parallel with the prevalence of cyclical or oscillatory manifestations of self-organizing processes in physical systems but has proved a major impetus for an important school of spatial geography, the so-called chronogeographic perspective (Parkes & Thrift, 1980). This is an integration of time and space and people, (cf. Hägerstrand, 1971) in pursuit of the goal of understanding the regional patterns of human activity. This linking of time and space and individuals in human affairs is crucial to societal self-organiza-
tion. This approach is in strong contrast to the standard regional science (e.g., Isard, 1975) approaches such as location analysis (primarily space alone), input-output analysis (location/resources/products alone) or economic base analysis (location-time).

One connection that has been recognized by regional science is that between ecology and economics or, better, between society and environment. Although the classic approach to this connection (Isard et al., 1972) is the result of a purely linear, economic science approach (i.e., input/output analysis extended to include ecological resources) others have taken a more general view of the matter. Seddon (1984) went further in recognizing the importance of cultural and ecological properties of the environment in his comparisons of primary human ecosystems (hunter-gather, pre-industrial agriculture, industrial agriculture, post-industrial agriculture) concentrating on properties such as impact, change, diversity, variation, landscape, productivity, energy input, and stability. A similar emphasis may be seen in Statistics Canada's framework for an environmental statistical system (Rapport & Friend, 1979): concern with activities -- especially production and consumption, restructuring, resources, stresses, and responses. Others have identified the importance of the resource concept in an applied, or societal, ecology (Norton & Walker, 1982).

More recently, the concept of a resource as central to plant and animal populations and communities has been given a theoretical foundation:

A resource is an environmental factor that is directly used by an organism and that may potentially influence individual fitness. Resources . . . exist in the environment in a particular abundance and distributional configuration. (Wiens, 1984)
Interestingly, Wicken (1984) makes the opposite argument by using a self-organizing (autocatalytic) view of organismal evolution to emphasize the creative aspects of evolution and liberate the evolutionary paradigm from the need for competition for scarce resources. Resources are necessary inputs to both human and animal/plant communities and the resultant interaction has probably been chronicled best in Cronon's (1983) study of the colonization and development of New England. He describes his goal as that of locating "a nature which is within rather than without history" (p. 15). The crucial components of this 'nature history' which he identifies are the internal and external dynamics of the ecological environment, and society's economic relation to the land (i.e., perception of commodities, commitment of ecosystems to the marketplace, land tenure, and land use). Cronon's prime achievement is the explicit delineation of the interconnections between the economic aspects of a society and the evolution of its ecological environment over time.

Human ecology provides a further perspective on societal structures and processes. It has origins in the study of cities, and particularly, of urban growth. It was originally concerned with the ecology, the social organization and the social psychology of urban life, especially with respect to the interaction of the individual and the organization or institution (Wirth, 1938) -- essentially a geographical human ecology that culminated in Hawley's (1950) tome titled "Human Ecology: A Theory of Community Structure." Human ecology has diversified since its beginnings -- the organizational human ecologists have come to the point where they study "populations of organizations" and internal (e.g., capital investment,
information constraints, political, and historical constraints) and external (barriers to change of organization activity, legitimacy constraints, and constraints of collective rationality) pressures that shape organizations and the individuals in them (Duncan & Schnore, 1959; Hannan & Freeman, 1977; McKelvey, 1982) — essentially a sociological human ecology. Another group has concerned itself with the reciprocal effects of man on the natural environment and of the modified environment on man in large cities -- high population densities together with climatic and atmospheric changes lead to "enduring effects upon human feeling" (Fellenberg, 1984, p. 393) and thus on human social structures such as family size. The patterns and problems created by the interaction between man and his biophysical environment is treated by Dasmann (1984). Some go even further and make of ecology a science of design for human lifestyles (Todd & Todd, 1984).

A similar view of human ecology is to be found in Geist's (1978) normative environmental criteria (based primarily on evolutionary and ecological biology, anthropology, and the health sciences): social milieu, nutrition, physical exercise, intellectual exercise, education, keeping out of doors in natural surroundings, and control of the environment. Ultimately, he argues that quality of life must measure not "user satisfaction but physical, behavioural and social indicators" (p. 423). Rather similar ideas are implicit in Paolo Soleri's (1969) conception of "cities in the image of man" — "architecture ... as the physical definition of a multilevel, human ecology" (p. 31) — that is, housing that is biologically and ecologically suited and designed for human.
Nothwithstanding the unquestionable achievement of human ecology in turning attention to the ecology of humans, one must be careful of the unquestioning application of ecological concepts such as carrying capacity, ecosystem succession, and stability to analyses of human society (e.g., Odum, 1969), because while "ecology can identify significant problems bearing on the biological survival of mankind, . . . it cannot provide the [disciplinary] sociological reasons for their existence" (Cajka, 1980, p. 133). At the same time, Hawley (1973) describes human ecology as a synthetic social science which, while starting with ecological similarities (between individuals, groups, organizations) cannot help converging on, and even becoming synonymous with, social science. What is needed more is a melding or convergence of the ideas of bio-ecology and human ecology.

Another strand in our web is the idea of a "social ecology" as social learning that occurs at both the level of the individual and the level of the group. Such a conception implies crucial roles in society for organization, history, action, information, and interdisciplinary research (Dunn, 1971). This is a dynamic, evolutionary, model of societal change that is readily interpretable in terms of self-organization theory and suggests further that we turn to sociology to inform our perspective on the structure and processes of society.

Carneiro's (1970) theory of the origin of the state in the factors of resource concentration and social circumspection which "intensify war and (redirect) it toward the taking of land" (p. 737) and Flannery's (1972) similar theory of the evolution of civilization which bears striking parallels with ideas from self-organization theory are classic examples of
theories of the evolution of societal structure as a result of the interaction of ecological, economic, and social factors. (For example, "Enough centralization promotion and linearization may move the state toward hypercoherence and instability . . . hypercoherence can lead to collapse and devolution" [p. 423]). Carneiro (1982) has given several examples ranging from the food supply of a Neolithic village to the crash of 1929 of large perturbations in a society that resulted in a reequilibration; a change in the qualitative structure of the society.

That the evolution of societies possesses a structure is implicit in Braudel's notion of the longue durée; that such structure exists has been abundantly illustrated by Braudel's histories of the Mediterranean. Structural sociology sees the explanation of this structure or pattern as a particular conception of causality as manifold, sequential, and cumulative (Abrams, 1982). Additionally, structuralism identifies the importance of differences of time, of the distinction between structure and system in studying the social totality and of transcending simple subject/object dualism (Giddens, 1979). Additionally, in its emphasis on time and space differences structural sociology has important ties to chronogeography. In particular it emphasizes social change as uneven development within social systems, or as critical phases of major institutional, societal change, and a 'leapfrog' idea of change (Giddens, 1979). Structural sociology clearly presents a view of societal change that reinforces our faith in the applicability of self-organization. Structural sociology, too, recognizes aspects of societies that will be important to a view of society as a self-
organizing system.

We have so far been mainly concerned with the society level, let us now turn more explicitly to communities -- societal subsets -- the theory of whose social and economic development may be seen as reflecting many of the themes of the first part of this chapter in the relatively simple, concrete context of the individual and the community and its relatively restricted spatio-temporal context.

What is a community? For our purposes we can consider it "a set of institutions comprising a total way of life" (Martindale, 1964, p. 71). The community arises in order to solve problems of mastering the natural environment, the need for socialization, and the need for social control. It achieves these goals through stabilization, consistency and closure of institutions (Martindale, 1964). This definition is of course functionalist giving rise later to the concept of the "competent" or successful community which was seen as entailing commitment, self-other awareness, articulateness, communications, conflict control, participation, and mechanisms to manage intra- and inter-community interactions (Cottrell, 1976). These concepts were further developed into those of social vitality, economic viability, and political efficacy (Blishen et al., 1979) with the still later addition of the idea of formal and informal sectors of each of these dimensions of community and the idea of integration of all dimensions at the level of both the individual and the community (Mathews, 1983).

Given theoretical definitions of community competence, one is inevitably concerned with its assessment in real life. Blishen et al. (1979) present a list of indicators for each of the three dimensions. For economic
tion, and size; for social vitality — health, support programs, social pathologies, communication, education, and leisure; and for political efficacy — participation in political activities, voluntary political organizations. Heesch (1979) noted similar requirements under the heading of "community facilities and services" as well as observing the need for attention to formal and informal sectors. Others have distinguished areas of concern for monitoring, e.g., factors of production, intermediate products (e.g., social services), objective and subjective welfare indicators (House, 1981) and economic/demographic disaggregators for each area of concern (OECD, 1982). The strong interactions between economic and social aspects of a community have been made clear by various scholars in socio-economic impact assessment (Davis & Webster, 1981; Leistritz & Chase, 1982). A more general approach is to consider the effectiveness of societies in terms of compatibility between components and compatibility with the external environment (Hawrylyshyn, 1980).

Community evolution is not the same as community development — development presupposes to most of us the choice of a better direction, an improvement as a result of development in the quality of life of the community's inhabitants. Evolution of a community may, or may not, include "development" of the community. Nonetheless, insofar as most communities wish some form of development, and it is in the context of development that most community studies are undertaken, we shall examinine some of the relevant community development literature.

The term economic development has its origins in Marx's work (Arndt,
1981) and was introduced to orthodox economists primarily by Schumpeter (1961/26). For much of this century, economic development has been synonymous with growth of labour force and production — GNP in other words (e.g., Solow, 1956; Hall, 1983). In the last few decades there has been a movement to separate the ideas of economic growth (purely quantitative) and economic development (qualitative as well as quantitative) and to put the need for economic development in a global, political, and environmental context (Dadzie, 1980). At the same time as there was a call for a "new international economic order" in the context of economic development, there has been activity at the opposite pole — economic development at a community level, whether in an orthodox, centralized, corporate form (e.g., Brodhead et al., 1981) or a more decentralized, local, unorthodox form (e.g., Nugent & Yotopoulos, 1979).

Economic growth in a region implies growth in production, growth in flows into and out of the region. Economic growth, per se, implies nothing about the magnitude of the tangible or intangible benefits which may or may not accrue to the majority of the region's inhabitants as a result of growth. Economic development, however, implies tangible benefits for the inhabitants of the region in which it occurs, e.g. increased employment, multiplier effects, a wider tax base for regional government. Community development implies, in addition, more intangible social benefits such as development of community identity, social services or recreational opportunities. Development in this sense means "the transformation upward of the entire social system" (Myrdal, 1975).

Development is a complex process requiring basic structural changes in
the distribution of societal goods. This notion reaches an extreme in bioregional theory in which the social, ecological, and spiritual are conjoined to produce a new form of economic development (Dodge, 1981; Sale, 1985). Development involves social and economic, spatial and temporal, local and national actions; as well as techniques for popular participation (for development as a sociological process, see Western, 1977). It is a continuing process aimed at meeting development needs (Durston, 1972).

Self-organization has been reflected in both the theory and practice of community development — epitomized by Perroux's (1983) definition of community development as evolutionary, active, consisting of linked growth of sectors in irreversible time, together with resultant structural changes or shifts; or by Jane Jacobs' view of economic development as "improvisation," as import replacement by city economies "that sparks other cities" and then trading networks, which all have a catalytic effect in inducing further development further afield.

It is more difficult to define indicators of development than to choose indicators of community competence. This has been recognized for almost thirty years (Perloff, 1956) and stems from the need to consider not only the present state of things (much the same as for community competence) but also the potentialities for development in the future.

If development has its origins in economics and the ideology of growth, economists have also been the source of some of the more innovative notions concerning economic development: Georgescu-Roegen's (1971) linking of the concepts of entropy and economy led to one of the first formal suggestions
of some "limits to growth"; then Daly's (1973, 1977) suggestion of the steady-state, sustainable, largely closed (in terms of resources) economy as a necessary goal of society.

The authors and disciplines cited above all contribute to the postulation of self-organizing processes in human systems in general and communities in particular. From anthropology, we have the recognition of human systems as open, never in a state of equilibrium, as involving ecological, economic and social components, and including cycles of "crises, breakdowns, and reorganization". The Annales historians contribute recognition that there is both a (microscopic) history of events and a (macroscopic) history of system structures. From geography and ecology we have the importance of (ecological) resources and population patterns in creating patterns of activities and behaviour in time and space; Cronon, especially, links the economic and ecological components of the human system. Human ecology takes us further, extending ecological methods to the social characteristics of human systems on the one hand, while elaborating the impacts of the ecological environment on the social component of human life on the other.

The sociological views presented return to the dynamic, evolutionary nature of human systems and the existence of catastrophes, discontinuities, and re-equilibrations in human societies throughout history. From the experience of community development we learn of the synthesis of social vitality, economic viability, and political efficacy into community, and their indicators. Economics and economic development further elaborate the relationship between the ecological, economic and social aspects of development and, especially, the need to consider these aspects as defining
a system.

This chapter has aimed to develop our understanding of the self-organizational aspects of, and the interconnectedness of, the social, ecological, and economic components of human systems. The next chapter will use this understanding to develop a conceptual model of the evolution of one particular type of human system — the community. It is not a working model that "runs"; it is a conceptual, written description of a structure and process that self-organization could follow in a community. It is intended as an aid to cognitive understanding of self-organization in community systems.
"Seek simplicity, but distrust it." - Alfred North Whitehead

In previous chapters, we have examined Prigoginian self-organization theory and a variety of disciplinary views of human systems which support the view that self-organization occurs in human systems. The goal, here, is to present a conceptual model or scenario of community evolution that explicitly includes self-organization processes. It is not claimed that self-organization in any particular community or human system proceeds in the manner here described. Rather, the model is intended as an heuristic device to aid our understanding of self-organization in human systems.

It is postulated that the human system the earth has become possesses three main subsystems -- the ecological, the economic, and the social subsystems. Distinct societies (e.g., the North American) form other, horizontal, subsystems. A community, in turn, is a subsystem of a society. A community is defined in a relatively localized place and evolves irreversibly -- that is, history does not repeat itself, there is no inevitable end state. There is a boundary that separates it from its environment. The forces that shape the community derive from properties of its ecological, economic, and social components. At the level of a community we speak of components rather than subsystems because at this level one is not dealing with entire subsystems but only parts of the ecological, economic, and social subsystems of the human system. This is the core of our model, and formalizes ideas expressed by Martindale (1964),
Matthews (1983), Blishen et al. (1979), and Perroux (1983).

The model consists of eight structural variables which represent the ecological, economic, and social components of community structure, and four process variables which attempt to characterize the state of the process of community evolution. Each of these variables inevitably subsumes within it many specific characteristics of actual communities; they are idealizations representative of the many elements that make up each component. Therefore, I also speak of indicators and give a few examples for each variable, which are actual, observable community characteristics subsumed by the variable.

There is no purely objective way to choose eight variables by which to represent community structure. I have made my choice on the basis of what I perceived to be the common themes among the authors cited in the last chapter (especially Blishen, et al., 1979; Cottrell, 1976; Cronon, 1983; Geist, 1978; Hannan & Freeman, 1977; Martindale, 1964; Matthews, 1983; Rapport & Friend, 1979; Wiens, 1984) as well as on the basis of a need to include in the model both macroscopic and microscopic, extensive and intensive variables. This because the goal of the model is not to reductionistically describe a community but to construct a dynamic, self-organizing model. Eight structural variables, explained further below and in Figure 4, were chosen: landscape (ls), land tenure (lt), land use (lu), resources (re), production (pr), consumption (co), historical inputs (hi), and social inputs (si). The variable names do subsume much. Rather than coin a neologism, common terms have been chosen and specific definitions given below and in the Glossary (Appendix I).
Landscape is an holistic variable that represents the overall integrity of the community's ecological component as indicated by, for example, ecological diversity and complexity, naturalness, or resilience. Land tenure corresponds to the system of determining land ownership and use with indicators such as the hierarchical level at which the system operates and the relative role of governments, organizations, or individuals. Land use is the site-specific use of land and its resources; indicators including the intensity of building or grazing on the site, the number of wells, the amount of resources extracted from the site. Resources refers to the quantity of resources on a site and their distribution within it, as indicated by, for example, the absolute amount of the resource, its quality, and the ease of extracting it.

Consumption refers to the using up of renewable and non-renewable resources; with simple indicators such as the quantity used (degraded). Production refers to the results of resource extraction and processing and the economist's consumption -- generation of useful products for later consumption and non-useful wastes; indicators such as the amount and types of products, the relation between useful and waste products. Social inputs are the effects of the community social structure on the social, ecological, and economic components of the community, indicated by, for example, number of conflicts within the community, the number and stability of social groupings, the stability and cohesiveness of community membership. And finally, historical inputs are the impacts of past social structure in the form of myth, ritual, and tradition, with indicators including the
importance of myth and history in community life, the relative strictness of tradition, and social rules.

Landscape and resources represent the ecological component of the community; consumption, production and land use the economic, and land tenure, social inputs and historical inputs the social components of a community.

The extensive variables are emergent properties of the whole system, do not take on specific values at each point in the system; the intensive variables are specific characteristics of the system itself, are defined at each point in the system. The macroscopic variables serve to characterize the state of the entire system; the microscopic variables are meant to represent the internal structures that determine change in the macroscopic variables. Extensive/intensive refers to the way in which the variables may be defined; macroscopic/microscopic refers to the scale at which they are significant. Microscopic variables are an intermediate step between macroscopic determinism and random "emergent" properties (Klee, 1984).

Land tenure and landscape are macroscopic because they refer to characteristics of the system that are manifested at the level of the entire system; similarly resources and land use are used to describe the entire system. The latter are intensive, however, as they are defined at each point in the system, while the former are not. Historical inputs and social inputs are extensive, not readily definable at each point in the system, while consumption and production, intensive variables, are so definable. These four variables are microscopic because 1) they are representative of the internal structure of the system rather than its external, macroscopic
form, and 2) they are major determinants of large-scale characteristics such as land tenure, landscape, resources, and land use. The classification represented in Figure 4 has been useful to the author in choosing and defining the variables. It is represented, implicitly, in the model itself by the placing and relationships of the variables.

The eight structural variables trace their origins to the main themes present in the literature in disciplines from ecology to planning to history anthropology. The four process variables, to which we now turn, have their origins in the main themes of the theorists presented in the last chapter. These variables serve to relate (as will be shown below) the structural variables and to represent some characteristics important in a self-organizing conception of communities. The decision on how the variables relate is the author's, based on his knowledge of self-organization theory, the materials presented in the last chapter, and more conventional sources such as mainstream economics and political science.

From Rappaport to Giddens to Jacobs, we have read of the importance of evolution, adaptation, and change in cultures and societies. Others have reported on the shift away from the dominance of the concept of equilibrium (K. Jacobs, 1984) of which Lorenz' (1963) paper on the role of instability and non-equilibrium in meteorological processes was one of the earliest examples in the natural sciences. Moreover, J. Jacobs (1984) suggested society may fear cultural or economic stagnation as a result of structural inflexibility. This view of social evolution is the basis of the four process variables postulated here.
EXTENSIVE VARIABLES

MACROSCOPIC
- land tenure (lt)
  the system of determining land ownership and land.
- landscape (ls)
  ecosystem integrity:
  ecological dynamics, diversity, naturalness, connectedness, resilience.

MICROSCOPIC
- historical inputs
  the legacy of past social structure: information and ritual, rationality, legitimation, tradition.
- social inputs (si)
  social structure: social milieu, socialization, stabilization, consistency, closure, conflict resolution.

INTENSIVE VARIABLES

- resources (re)
  abundance and distribution.
- land use (lu)
  use of land and its resources on a site-specific basis.
- consumption (co)
  use and harvest of renewable and non-renewable resources.
- production (pr)
  generation of useful products and non-useful wastes and energy on a site-specific basis.

Figure 4 - The Conceptual Model's Structural Variables: Indicators and Classification
First "mass," m, a measure of community structural inertia or stagnation, defined as structural rigidity plus social conformity. In a community mass or inertia measures the resistance of community institutions, administrative structures, and citizen's groups to change. This will be a function not only of organizational structure but also of the attitudes of those within them. It will be a relative measure and best evaluated via an historical study of structural change in the community. In a given community one might look at the rate of acceptance and date of introduction of such innovations as electricity, telephone, the automobile, radio and television; or at the existence and/or change in time of the community's governing bodies; or at the diversity and modernity of the forms of entertainment existing and popular in the community.

"Energy," E, represents adaptability and innovativeness. It can be defined as the extent of learning (negative feedback) relative to opportunity, plus the rate of innovation relative to other similar communities. The energy or adaptability of a community is the opposite of mass. It measures the community's ability to generate innovation and to learn from and anticipate change. This will be a function of the education and experience of community members and more particularly of their willingness to accept new ideas and experiment with different ways of organizing their community and using its resources. E is ability to respond, m is resistance to change. The relation between E and m is unlikely to be constant, although probably basically inverse, as change will be discontinuous due to particular stresses and responses.
For example, a small rural community that finds itself being drawn into an urban agglomeration will usually initially resist the changes this implies (high m). In time, as pressures for assimilation increase, so too will energy in the form of proposals for assimilation, until a bifurcation occurs with the inevitable assimilation being accepted. At this point, mass is increased considerably and energy decreased as the strictures of metropolitan living are accepted and many alternatives to urbanize foreclosed. Once the community is fully integrated into the city, energy may be increased and mass decreased. Between bifurcations, mass, and energy may move together; over the long-term, including bifurcations, they will not.

These two variables are closely related to a third, tension, T, (somewhat akin to "temperature" in a physical system). Tension represents "goodness of fit"; it is a present-oriented structural concept, defined as the appropriateness of community structure to given external constraints (pressures). The worse the goodness of fit, the higher the tension. Community tension reflects incompatibilities between the community and its environment (i.e., other communities and the broader society) that are reflected internally as a function of community disorder or entropy. Tension may be assessed by an analysis of the differences between the community and its environment in terms of the structural variables land use, land tenure, production, consumption, and social inputs (by, for example, the indicators of these variables listed above); together with, of course, an assessment of entropy as described in the next paragraph. Qualitative and quantitative differences in these characteristics of sufficient degree
and certain type (i.e., incompatible differences) will result in tension.

As an illustration consider a community with a low intensity of land use, equitable land tenure system, low and balanced consumption and production, and stable and adaptive social inputs, and resulting low entropy. Tension could be expected to result if this self-contained community were to find itself surrounded by a larger society, or in the "shadow" of a major urban agglomeration with a high land use intensity, centralized and inequitable land tenure system, high and unbalanced consumption and production, and resulting high entropy.

And finally, we must consider community entropy, $S$, a measure of disorder. It can be considered a result of the inefficient or ineffective use of the system's resources, and defined as deviation from that "ordered" structural state necessary to meet the needs and goals of the system or community. Social disorder or entropy is a result of inefficiencies in the community such that inadequacies in the use and distribution of resources result, which in turn cause the needs of some members of the community to not be met. Inefficiency and inadequacy are simply defined relative to the needs and goals of the community. These individual inefficiencies lead to community-wide inefficiencies which are reflected in the output and structure of the community as a whole -- e.g., low production, innovation, and/or learning in comparison to other communities. The individual internal inefficiencies will be reflected in the incidence of social pathologies, or the proportions of the populations existing below some poverty line etc.

For all of the process variables the actual characteristic or
phenomenon that is assessed will depend not only on the particular situation but also on whether or not the situation is pre- or post-bifurcation, i.e., before or after a perceived discontinuity in the community's evolution. For example, before the Stock Market crash of 1929 one might have measured T by the great demands placed on the fiscal structure of the economy by so many having great (paper) wealth; after the crash tension would better be measured by the great demands placed on the system by so many with no wealth, and a very few whose wealth survived.

Tension and entropy are characteristics of the evolutionary process, mass and energy are characteristics of the system that directly influence the process. Tension and entropy are likely to be directly proportional but not directly related, as were mass and energy inversely. "Tension" and "entropy" should tend to reinforce each other, with "energy" the main countervailing force (remember free energy = internal energy minus absolute temperature times entropy from Chapter 2). Tension is defined by reference to the system and its environment, entropy is purely internal to the system.

S and E can also be related through the notion of system equilibrium and nonequilibrium. Were the community system at equilibrium its structure would be static, there would be neither change, nor progress, nor development, and the change in energy and entropy would both equal zero while mass might be high or low and tension low — self-organization would not occur. A community system would be at equilibrium if it was not subject to tension as a result of internal disorder generated by differences between it and the community's environment. The community would be fully integrated economically, socially, and ecologically with its societal environment.
Clearly, this is an exceedingly unlikely event. Alternatively, the system may be in a nonequilibrium state (for all practical purposes the only possibility) in which the structure is dynamic, changing, "evolution" is occurring, the changes in entropy and energy are not equal (one is greater than the other) and mass and tension (within self-organization cycles) will likely be decreased as a result of the system's evolution. If the change in entropy and energy were equal, but not equal to zero, then the system would be internally stable but moving towards a bifurcation as a whole. The system is, by definition, far-from-equilibrium with its environment. Self-organization would not occur in an equilibrium system.

Assuming that each of the process variables could increase, decrease, or remain the same, there are 81 possible combinations. That is too many to examine individually. We will, however, use hypothetical examples to illustrate three cases — those where change is a result, respectively, of high entropy, high tension, and high energy — to demonstrate relationships and the fact that in any given case certain variables may be important and others not.

Consider a community characterized by high entropy — poor social organization, lack of cohesiveness, dissatisfied community members — perhaps a town where the economic base has been eroded or lost. It will likely have low energy as a result of poor organization to take advantage of opportunities, and a loss of sources of new ideas or opportunities to other communities. Mass in the community will likely be low — everyone recognizing the need for change. Tension may or may not be high. If it is
high, as a result of obvious contrasts with the environment or perhaps other outside pressures (e.g., to close down the town), the community may "self-organize" its way to lower entropy and higher energy. If tension is low, the community may stay trapped in disorder and decline.

A community typified by high tension would be one, such as that discussed above under the definition of energy, that finds itself increasingly in an urban shadow. Tension, energy, and mass are likely all to be high, while entropy is low; the first two as a result of the conflict situation, the third is typical of most rural communities. After the self-organization that changes the community from being rural to suburban, its energy and tension will decline as it is assimilated into the metropolitan region and the conflict and tensions ease, its inhabitants homogenized; while mass and entropy will probably increase.

A high energy community might be one such as Silicon Valley where change is the order of the day, creativity and ideas the definition of merit. In this example, community entropy (in contrast to corporate entropy) would be high as a result of the instability of community composition. Mass would be low as the diversity of ideas negates any fixity with which they are held. Tension is high both because of the differences between this community and those around it and because of the inherent instability of the high-tech industry and those in it (when compared to almost any other). Depending on the ability of the outside world to support it, this community may persist or it may self-organize into a more normal one of lower entropy, tension and energy, and high mass.

Throughout these examples one should bear in mind that the
(microscopic) patterns of change in the variables between bifurcations is not the same as the (macroscopic) pattern over several bifurcations. The latter is the major, structural effect of self-organization. For example, tension and entropy may well decrease immediately following a bifurcation, but over time and several bifurcations, both are likely to increase. (See also p. 54 and Rifkin, 1980, p. 241.)

Next we shall describe the model in more detail -- in particular the interactions between the variables paying special attention to the occurrence of the characteristics of self-organizing systems, i.e., openness, nonlinearity, far-from-equilibrium, fluctuations, and periodic instability.

We will begin, as self-organization begins, with the distinction between the system and its environment and the flows between the two. These flows reflect the fact that the system is open and far-from-equilibrium with its environment. In the community system these flows will consist of raw resources, produced goods and wastes, and information in the form of ideas, knowledge, and people. Evolutionary biology has come to recognize that the units of evolution "both make and are made by their environment" (Lewontin, 1983). Communities evolve similarly. These flows will have their main impacts in the entropy, energy, and tension variables. Mass, being a characteristic of the system determining the process, is not affected directly by transboundary flows. The present community structure will reflect historical inputs and, especially, past interactions between the community and its environment. Pressure for change will be the result of
demands for, for example, resources, production, changes in social structure, from the community's internal and external environment. The community's ability to respond will firstly be the result of its social and historical inputs which are synthesized in the process variables energy (system adaptability and innovativeness) and mass (resistance to change).

In some cases ability to respond to stresses will also be a function of the ecological or economic components of the system — e.g., the ability to change consumption or production levels, land tenure systems with their concomitant impacts on land use and resources. This process of change, of adaptation to stress, will inevitably involve feedback loops and nonlinear processes. We can identify two here: the first, between social inputs, land tenure, and consumption reflects the tendency of the community's social and economic structures to coevolve or reinforce each other. The second, between consumption, production, resources, tension and mass, reflects the mutual interdependence of the ecological and economic components of the community and the ratchet effect of people's expectations for consumables. As the stress on a community increases its structural rigidity and conformity and its consumptions of resources also usually increase (cf. Tuchman's [1984] review). Ultimately, the effect of the stresses and system's responses will be seen in the variables landscape and entropy — the community ecosystem's integrity and disorder. The entropy of the system will increase, community social and other structures will lose their stability. As tension and entropy increase so too may the system energy (especially in the sense of innovativeness) as community members (individuals and organizations) search for solutions.
Clearly, few social structures, least of all human communities (disregarding a few regulated, usually religious communities) are homogeneous. Disorder and tension, the search for solutions, encourage the appearance of informational fluctuations; encourage the individuals and groups whose ideas, goals, and/or actions are, if not in opposition to, at least a contradiction of the existing community structure, to make their ideas known. More importantly, it results in the other members of the community giving consideration to their ideas. This is the source of fluctuations of potential forces for re-organization that self-organization can seize upon. The frequency of fluctuations can be expected to vary in response to the community's energy, tension, and entropy, increasing as all three increase.

When the tension and entropy of the system pass a certain point, the community structure will become highly unstable and the probability of a bifurcation in the system's structural history will be high. A bifurcation will occur as a result of self-organization when one of the fluctuations, alternative solutions to the impending crisis, is widely recognized as the solution. In self-organization theory one speaks of the amplification of a fluctuation to create long-range, macroscopic order; in the human community it is communication, both individual and via the mass media, that will result in this crystallization of opinion and new order. Just which fluctuation (alternative) will be amplified is a random event but the existing historical and social inputs, environment, and system of production and consumption could be expected to influence the outcome. The result will
be a reduction of tension in the community but quite possibly an increase in mass and social and historical structures as connectedness increases necessitating management of more stresses and responses. Concurrently, transboundary flows will increase, as will energy and its rate of change, in response to greater opportunities for, and demands for, adaptation and change as the community becomes more complex. Rifkin (1980, p. 241) makes a similar point.

Several pages back some brief examples of the effects of self-organization on the process variables were given. Here, I want to expand on the example of the rural community that finds itself increasingly in the urban shadow of a metropolis in order to further illustrate the use of both self-organization theory and the model variables. The metropolis will differ from the rural community in almost all the descriptive variables: production, consumption, resources, land use, landscape, and social inputs; land tenure and historical inputs may be relatively similar. These differences, especially those in production, consumption, resources, and land use are what lead to the pressure (stress) on the community to become a part of the metropolis. The community is valued for its land and as an access point to the hinterland behind it.

Tension in both will be high — in the metropolis due to its dependence on its environment for resources; in the community due to its resistance of integration into the metropolis. Entropy in the community will be low, in the metropolis high. Both community and metropolis will be out of equilibrium with their environment but this is especially true of the metropolis which dissipates (or degrades) vast amounts of energy and
material in order to maintain its (dissipative) structure. Energy and mass will probably be high in both community and city initially; in the latter because of its complexity and diversity, in the former because of the tensions it faces and its relatively closed past.

As time passes the stress on the community will increase, as the metropolis continues to grow. More of the young leave to work in the metropolis or get an education, land values skyrocket pushing for land use changes, there is more traffic of people and goods through the community and so on. These changes will induce other changes in the community through positive feedbacks: the more people who leave, the more others will be tempted to leave; the more who sell their land, the more others who will sell; new and different people come into the community and the greater the changes in community composition the less able will the community be to present a united front against assimilation into the metropolis. Tension will increase, so will entropy as cohesiveness is lost and the metropolis intrudes. Mass will tend to increase as the people left behind in the community become more stubborn in the face of the inevitable. Energy too will increase as new people and ideas flood the community, as people seek to find solutions (zoning) to the dilemma of rural life vs. city life -- these are fluctuations.

Ultimately, this situation will become unstable -- too many accumulated minor changes in the environment, too much tension -- and the self-organization process will be completed with a bifurcation triggered, perhaps, by a community leader's decision to sell and leave. Most of the
community members follow suit. Now we have a suburb. It too will be subject to change, perhaps other bifurcations will result in its becoming part of the downtown or a ghetto. But for the present it is stable, relatively homogeneous. Tension and energy have been decreased. Mass and entropy probably increased. The "community" will be much more closely connected to the city, will involve much higher flows of people, energy, matter between it and its environment. Its patterns of production, consumption, land use, landscape, resources, and social inputs will be very different from what they were before the discontinuous (compared to past changes) change that was the result of self-organization and assimilation into the metropolis.

The main example of the preceding pages has been that of the assimilation of a community into an urban centre or metropolis. The process by which the community is assimilated is described as a self-organization process. The actual event of assimilation is but a part of the much larger process termed urbanization. No attempt is made to describe this larger process for there is a vast literature dealing with it, and many aspects of its, such as its general spatial and economic form are both predictable and planable. This does not, however, preclude the usefulness of applying self-organization theory to certain critical points in the vast phenomenon of urbanization: in particular, to the process that determines the course (rate, ease) of assimilation of a specific community. This process, with its characteristic flows between city and community, its nonlinear feedbacks, and central role of individual (microscopic) actions is a classic example of self-organization in a human system.
In contrast, for example, the impact of the private automobile, per se, on urban form is not a self-organization process. The growth of the road and highway network is such a process (and indeed is one of the earlier applications of self-organization theory, e.g., Allen, et al., 1978-80) as is the evolution of urban form as a function of many economic, social, and technological forces. Innovation or the spread of new technology is not self-organization. The former is purely random, the latter an example of exponential or logistic growth (see, for example, Montroll, 1978).

Self-organization occurs in every community. It is the inevitable response to the dynamic nonlinear nature of a social community and the stresses, or tensions, that exist within a community as a result of both internal and external processes. There is no typical community in which self-organization occurs for it will happen sooner or later in all communities. The timing and rate of the process will be affected by the tension of the community, by the rates of communication both within the community and with its environment, and by the history of the community. At some critical point the internal and external tensions will become such as to prevent the community from functioning with its existing structure. The existing structure will become unstable and an alternative structure will appear as a result of the selection and amplification of what had, until then, been only an informational fluctuation. One of the many possible alternative community structures (or responses) is adopted as a consequence of communication of information from outside the community and, later, as a result of spread of the information (alternative) within the community. The
change in structures due to self-organization should lower tension and increase energy.

I am often asked for an example of a self-organization event in a human system, or asked whether such-and-such is an example. By considering some of these suggestions, and giving some examples of my own, I hope to make clearer my conception of societal self-organization. One suggestion was that the organization, education and motivation of U.B.C. SCARP Planning students in the face of the possibility of the School being terminated was a self-organizing process. It is not, at least in the sense I use the term, because of the central role of several individuals in initiating and maintaining the process and because it was a purely internal, individual process that did not result in new structures — it was merely a short-lived fluctuation.

Another suggestion was that of a neighborhood group organizing in order to gain control of its environment and to develop a sense of community among its component individuals. This is a better example in that it is likely to include all the elements of a self-organization process that were identified earlier but the results of the process will at best affect social structures, just one component of the total human system.

The best suggestion was that of the process that might occur in an area were it proposed to build a major industrial plant on a site where it would destroy an ecological resource crucial to the residents of the area. Here, the resulting self-organization could easily involve social, ecological and economic processes and structures, but this example, like the previous two, suffers from one key problem. All these examples imply the existence of
macroscopic human-directed self-organizing processes. This is a faulty use
of the idea. Self-organization is not a tool of the planner but rather a
characteristic of the systems within which he or she works. Each of the
situations described above might trigger a bifurcation, but will not
necessarily do so and is not, itself, self-organization in the sense used in
this thesis. Self-organization is the key only to the broad structure of a
system, not to its particulars.

Self-organization processes in human systems will be detectable in the
same way that such processes are detectable in chemical and biological
systems — by their effects, by the spatio-temporal patterns they produce.
These are, broadly speaking, discontinuously changing structural patterns,
such as cyclical waves in chemical systems. Detection of self-organization
processes in human systems will, however, be complicated by the larger-scale
at which the processes display their effects. At any level, the patterns of
self-organization may be obscured by the passage of time or the clutter of
historical detail, or be subject to conflicting interpretation. Proof of
self-organization in human systems, if such is ever possible, may have to
await a better understanding, and modelling, of the processes that shape the
human system. Meanwhile, I will offer two possible examples of the effects
of self-organization processes at a global, societal level: the first, the
shifting pattern of political and economic dominance of the globe over the
last five centuries, the second, an impending bifurcation, in the clear
tensions (and incipient demise) of the international banking system's
position between the developed and the developing nations. Self-
organization is a process that takes place in a system. Revolutions alone are not examples of self-organization — they are the idealizations of catastrophe theory.

Self-organization is the vehicle of rapid revolutionary change in a community or society, becoming manifest only at critical points as a result of the accumulation of tension and instability. Self-organization proceeds in a manner akin to that of the saltational or punctuated equilibria model of biological evolution (Gould & Eldredge, 1977). Self-organization is not the result of changes in one or even a few community (system) characteristics. It cannot be reductionistically predicted. It is the result of a synergistic interaction between the community and its environment. As the next chapter should make clear, self-organization theory represents a qualitative change in our way of viewing the world, as fundamentally new as was once the systems approach.
CHAPTER 5 – DISCUSSION AND CONCLUSIONS

It will long offer to those who pursue it the comfort that to journey is better than to arrive.
C. Sherrington (quoted in Lewis, 1981)

Ultimately, the sources of the conclusions we are to discuss in this chapter are a model and a theory. The model is a conceptual one, of the structure, relations, and dynamics of a subset of the comprehensive entity we term society. This model, or simplification, of community evolution is supported in its parts by the views of scholars in a number of fields yet, as a whole, it is a hypothesis, perhaps unique to its author (as are all large-scale social-systems models -- Meadows, 1982). The theory is Prigoginian self-organization. A further stage in the development of this model and theory would be to simulate the self-organization/evolution of a community or society using data from, for example, the work of historians such as I. Wallerstein and F. Braudel, land-use studies such as those of the Canadian Lands Directorate (e.g., Fox & Macenko, 1985), and social planning studies such as those of Blishen et al. (1979).

Fundamentally, what has been achieved here is the development of a model which includes "microscopic" structural components that not only allow the development of self-organizing processes but also suggest how such processes arise in a social, community system. This is a step beyond previous societal models such as those of Taylor (1976) or Prigogine (1976) which limited themselves to a qualitative discussion of where self-organization might and does arise. Additionally, an effort has been made in
Chapter 3 to identify the characteristics of human systems that support the applicability of self-organization theory.

If the model of the last chapter has any usefulness as such, as opposed to as an heuristic aid to understanding how self-organization may occur in one particular human system, that usefulness likely lies in the process variables — energy, entropy, mass, and tension — and the dialectical view of the interactions of human systems that they suggest.

What do a self-organizational view of human societies and the model of community evolution presented here have to say about and for community and regional planning? This chapter draws primarily on the general implications of self-organization theory rather than the specific model of Chapter 4 because the latter was intended to illustrate the process of self-organization, not to generate specific lessons for community development. The most important lessons may well be the most general. That is, that self-organizational processes in human society are transformational — that is, they bring about non-linear, non-cumulative changes. Referring back to Prigogine's schema (p. 16) of structure/function/fluctuation it is fluctuations (ideas, innovations, revolutions) that alter structure (i.e. legal, economic, political, and moral/ethical institutions) which then impact on societal functions which feed back into the generation and amplification of fluctuations. The result of self-organization is structural and functional change that transforms the community. Several recent works on social and societal change have recognized this, most notably Marilyn Ferguson (1980), but also Morris Berman (1981) and Robin
Morgan (1982) with their discussions of social implications of new physical science paradigms. Anthropologists too have recognized the transformational nature of human society, most notably in the development and role of myth in human communities (Prigogine & Stengers, 1979; Luc de Heusch in Baudson, 1984). Finally, Prigogine and his theories have even gained mention in several recent science fiction books (e.g., Attanasio, 1981). Let us look in more detail at some of the components of this model before returning, at the end of this chapter, to the global, transformational, theme.

Self-organization is a process. A self-organizational view of community evolution shifts the emphasis away from particular states during the evolutionary process toward considerations of the process as a whole. Complementarily self-organization implies a dynamic conception of community evolution and continuous, dynamic process that is never at equilibrium, never static or stationary. Planners need to be planning the process, observing, discovering its macroscopic manifestations rather than endeavouring to plan its state or structure at a point in time — an attempt that is doomed to have temporary success at best.

A self-organizational view of community evolution implies the importance of understanding that the internal history of the system is deterministic at the level of a point in the system but stochastic at the level of the system as a whole. The system's history can imply the appearance of certain structures, processes, or changes (Prigogine & Stengers, 1979). This historical determinism is most apparent perhaps in the form of certain of the world's great, old cities such as Rome (Ilya Prigogine and Serge Pahout in Baudson, 1984). This historical determinism
works primarily through affecting the timing of bifurcation (the onset of instability), the time at which self-organization (bifurcation) is initiated, and through effects on the outcome of the process as a result of selective amplification of fluctuations. Thus, the planner should be aware of the internal, structural history of the community and, through knowledge of the self-organizing process, consider how it may affect the future of the community.

One of the most surprising results of self-organization theory was that near bifurcation the law-of-large-numbers breaks down (Glansdorff & Prigogine, 1971). That is to say that the probability of macroscopic events becomes non-Poissonian; instead of the average driving the mean, individual fluctuations do so in an \textit{a priori} unpredictable way. This was and still is a shock to science, which has hardly become accustomed to the statistical formulation of thermodynamics or the implications of the Heisenberg Uncertainty Principle. More practically, for us in the study of community evolution this aspect of self-organization emphasizes the ultimate unpredictability of community evolution and the non-linear nature of the processes of that evolution. One must remember that the community is always "in time", changing, never "out of time", or static (Prigogine, 1985). The planner must learn to think of community evolution differently than he has in the past. Community structure is unpredictable, apt to evolve non-linearly, and most importantly, after bifurcation occurs may be incomparable to the previous structure (Allen, et al., 1985).

Two other more technical results on nonequilibrium chemical structure
suggest another interesting possibility. Such systems have been found to be sensitive to weak gravitational or electric or polar or chiral fields (Kondepudi & Prigogine, 1981; Nicolis & Prigogine, 1981). A self-organizing system at the point of bifurcation is able to be influenced by environmental conditions and to select as a result spatially asymmetric solutions. In communities it is likely that there will be forces on the community analogous to the physicist's fields (e.g., economic — Dyckmann, 1984) which will influence the subsequent structure of the community — quite probably toward asymmetry in time (i.e., a qualitatively different regime) with resultant implications for social and physical infrastructure planning. That is an infrastructure suitable for the present city structure may be totally inappropriate in the future. This symmetry breaking has been perceived and shown by many artists over the last few millenia (Gregoire Nicolis in Baudson, 1984).

Self-organization implies an emphasis on qualitative change (Allen, 1982; Allen et al., 1985) and on time (Umberto Eco in Baudson, 1984; Prigogine, 1985), which is often notably absent in both science and planning. Fluctuations are innovations, ideas. They are non-rational, creative and as such the unpredictable precipitators of bifurcations and self-organization. Planning too must be creative, innovative, even non-rational to the extent that the goals and actions of the members of a community may be non-rational, if it is to have any hope of anticipating or influencing a bifurcation. Planners too must study and plan first of all for qualitative changes in structure — not more or less of the same but something completely different — if they wish to keep up with the evolving,
self-organizing community. This, on a vaster scale, is Braudel's (1984) point when he says, apropos of the world economy:

Are not the day-to-day remedies proposed to meet the crisis completely illusory? For the reversal of the secular trend is a structural crisis which could only be resolved by thorough-going structural demolition and reconstruction. (p. 618)

Systems ecologists (Clark & Holling, 1979) too have recognized the importance of qualitative structural change in real world situations (the spruce budworm).

Finally, we may observe that while it is fluctuations that drive the mean near a bifurcation, they do so because one or a few of them have attained a macroscopic "coherence length" and begun to generate long-range order. This is evidence of communication, in the broadest sense of the word, and even learning (Allen et al., 1985) within the system. Fluctuations are amplified, as a result of communication and learning in order to generate macroscopic order. Communication and learning are the key so we should not be surprised to see a paper giving a self-organizational model of an urban system in the report of a "Symposium on Cities and Regions as Non-linear Decision Systems" (Allen, 1983). The planner need concern himself with the substance and process of communication at two levels. Within the community where communication will have a primary effect on the growth and spread of selected fluctuations (cf. Watzlawick, et al., 1967 on the systems theory of group communication) and between the community and its environment where the primary effect will be on the selection of fluctuations and the rate of their spread (amplification) — cf. Toynbee
(1968) on the role of such communication in breaking down the barriers of national sovereignty — perhaps the ultimate social bifurcation.

I want to conclude with some general remarks on self-organization and planning. In Chapter 1, we noted the idea that planning and plans are the vehicle of the societal self-organization process. In view of the roles of choice and structural change in self-organization, this cannot be true for it implies an ability to predict and manage a process that by definition cannot be predicted. The belief in society's ability to predict and manage the broad form and detail of its own future is today one of the least tenable of the human conceits. The possibility that self-organization theory will bring about a revolution in the way we think about the human environment (as scientists or planners or citizens) is one of the more promising and important of the theory's implications (Prigogine & Stengers, 1979). Though we manage on a short-term, contingency basis now, we never have and probably never will be able to guide the long-term evolution of human society.

Planning theorists have a tendency to favour either a social science-based approach or a natural science-based approach (with many variations of each and little unanimity on which is best). Ozbekhan (1968) even suggested planning was the core of social science (in contrast to the more intuitively likely opposite). Most planning theorists, however, have had a predictive, rational management orientation (notable exceptions include Friedmann & Weaver, 1979; Schöhn, 1983). It is this which must, most of all, change in the face of a self-organizational view of community evolution. Community
and regional planners will still work with citizens, with local and other institutions, trying to meet community needs and goals, but they will have to do so bearing in mind the characteristics of the self-organization process (complexity, nonlinearity, discontinuity) and the different goals this will force on them: management of change, of communication, of stability and instability, awareness of history, always with an eye to the occurrence of the next bifurcation, how they might influence it and what structural changes it will bring. As Higgs (1985: p. 45) put it, "Careful design will serve to match existing and potential environmental conditions of the system with its specific self-organizing properties."

As the theory and application of self-organization are further developed it should become possible to identify impending bifurcations by attention to the sources and magnitudes of increases in tension, instability, and entropy in the system. At the levels of communities and societies, planners may well be in the best position to recognize these signs and to identify measures internal and external to the system capable of influencing the self-organization process. Such measures might include measures to facilitate the flow of materials and information into and out of, and within, the community; attempts to encourage particular structural changes within the community; and efforts to track the pace of change through the use of computer and information technologies.

Self-organization theory asks the planner to face the broad, long-term pattern and evolution of the systems in which he works, as well as its day-to-day functioning. It is not simply a matter of developing a systems view -- everything connected to everything else -- but a more complex view that
emphasizes the dynamic evolution of human systems -- as we have endeavoured to present in the preceding pages. At the level of communities and societies self-organization theory requires, and provides the framework for, the planner to expand his understanding of the evolutionary processes of these systems and to take a role in the development of the theoretical understanding of human systems -- by himself looking at and working with this new conception of the nature of the evolutionary process.

This is the approach necessary if we are to make sustainable development a reality. It is a learning, adaptive approach that aims to elucidate inter- and intra-system relationships through an immediate and continuing combination of theory and applications. Self-organization theory, by its emphasis on structure, change, and processes, may in time provide one way of uniting ecological, economic, and social structures in human systems and thus facilitate sustainable development planning.

In Chapter 1, I compared the systems and self-organizational interpretations of a community or regional history. The difference was that between structural description and dynamic process description. Here I want to examine some of the implications of this difference for planning and planners.

While the self-organizational view of human systems implies a basic indeterminacy in the evolution of the system, this is no argument not to plan -- precisely the opposite. At small spatial and chronological scales plans and planning may be little affected. But the "big" plans, the regional scale and larger, over longer time periods, must change. Not
abolished, but made to incorporate uncertainty and the likelihood of discontinuous change, to recognize the nonlinear processes that generate change, and to have built into them the monitoring functions necessary to track the process of change and to be prepared for the unexpected (cf. Goldberg, 1985).

At this level, the role of the planner will be monitoring change and manipulation of information and communication in an effort to guide the self-organization process. That is information in the sense of inputs to and outputs of the processes underlying the self-organization structure, and communication between the elements of the self-organizing system whether individuals, organizations, or computers. This is a role that will require the melding of the scientific skills of the systems theorist and information scientist with the understanding and sense of direction of a good community planner and organizer.

Of course there is much still to be learned about human systems and about self-organization within them. We can think of the typical systems view of a community as like the basic series of fossils that trace the form of a species' evolution, while the self-organization view is like the efforts of the paleoecologist and paleobiologists to establish the external ecological environment and the internal genetic environment that shaped the evolution of those forms with which we are familiar. The first is of historical significance and descriptive (classificatory) usefulness but only the latter can explain the process and hold any hope of predicting the future -- or understanding what Milan Zeleny (1985) has called the existence of "spontaneous social orders." We may not be able to control self-
organizing processes and bifurcations, but like the changes involved in the transition to an information society (Cordell, 1985) we can attempt to understand it and to manage its effects in order to make the most of the benefits and to minimize the disbenefits. A self-organizational interpretation of societal evolution may not permit prediction of the results of self-organization but it may permit its preemption.
REFERENCES


APPENDIX I - GLOSSARY

Note: the names of variables in the model are capitalized.

amplification — increase in magnitude; here to increase in spatial scope. e.g., amplification of microscopic fluctuations to create long-range order.

autocatalytic — the situation when one of the products of a process enhances the rate of the process which produces it.

bifurcation — an abrupt (discontinuous) change between the way things have been and the way they will be in future. e.g., a bifurcation in the evolution of the state of a system.

closed system — from thermodynamics; a system that exchanges energy but not matter with its environment.

community — a cohesive assemblage of individuals and their institutions in a relatively localized place and time, cf. society.

community structure — the total of the ecological, economic, and social structures that constitute a community.

component — a major constituent part of a (sub)system that is not, at the level of complexity under consideration, itself a system; a determinant of community structure.

connectedness — a property of systems; implies that a change in a characteristic of one system will affect characteristics of those systems to which it is connected.

CONSUMPTION — the actual using up (degrading) of renewable and non-renewable resources.

deterministic — a system is deterministic if its future state can be predicted on the basis of given initial conditions and a knowledge of the forces acting on it.

discontinuity — a break in the structure of a system; a qualitative change in the fundamental nature of a process or structure.
dissipative structure — Prigogine's term for the structures that result from self-organization as a consequence of the nonlinear, catalytic processes within the system that dissipate matter and energy in creating and maintaining system structure.

dynamic — a property of systems; the opposite of static; implies a complex, changing pattern of structures and processes within the system over time.

dynamic properties — properties of systems that appear spontaneously once a certain level of complexity has been reached.

ENERGY — system adaptability and innovativeness; defined within a given system as the extent of learning (negative feedback) relative to opportunity plus the rate of innovation.

entropy — in thermodynamics, a measure of the disorder of the system; a measure of the energy available to do work.

entropy — a result of inefficient or ineffective use of a (human) system's resources; defined within a specific system as deviation from that ordered structural state necessary to meet the needs and goals of the system.

environment — all those components of the human system that are not included in the particular subsystem being considered.

equilibrium — a system is in equilibrium if the forces acting on it sum to zero; i.e., if in the absence of a change in the forces acting on it, it undergoes no structural change.

evolution — the process of continuing change in the nature of a system as a result of forces external and internal to it.

extensive — defined by and extending homogeneously over the entire system; e.g., mass and volume in physico-chemical systems.
far-from-equilibrium — a state, far from that which would otherwise result (equilibrium) that is maintained by flows of energy and matter over the system boundaries.

fluctuation — a small change in the value or nature of some system characteristic which, under most circumstances, will disappear rapidly.

force — that which changes the state of a system from what it would have been in the absence of the force.

functionality — usefulness; of or pertaining to what a system, structure, or process does or should do.

HISTORICAL INPUTS — legacy of past social structure in the form of myth, ritual, tradition, etc.

human system — the total system of the earth or some part of it involving the ecological, economic, and social subsystems.

indicator — actual, observable community characteristics subsumed by a variable.

information — fact, knowledge; anything which justifies a change in a plan or structure.

intensive — defined at, and often taking on a different value at, each point in a system, e.g., pressure and temperature in physico-chemical systems.

internal history — the history of the structures and pressures within a system in contrast to a history of the system's relations with its environment, e.g., the spatial pattern of a city over time.

irreversible — a process is irreversible if its past is not knowable from a knowledge of its present state and the forces acting on it.

isolated system — a system that exchanges neither matter nor energy with its environment; a theoretical ideal useful in thermodynamics.

LANDSCAPE — the overall integrity of the ecological component of community.

LAND TENTURE — the system of determining land ownership and land use.

LAND USE — the site-specific use of land and its resources.

macroscopic — large-scale; visible; of the same order of magnitude as the entire system.
MASS — a measure of community structural inertia and stagnation; defined as structural rigidity plus social conformity.

microscopic — small-scale, invisible; of the same order of magnitude as the constituents of the system; e.g., molecules are microscopic, a gas cloud is macroscopic.

nonlinear — a nonlinear reaction or process is one which involves catalytic steps or feedback loops.

open system — a system which exchanges both energy and matter with its environment.

parameter — characteristics (constants or other terms in a mathematical equation) of a system that distinguish it from fundamentally different ones.

PRODUCTION — the result of consumption; generation of useful products and non-useful wastes.

qualitative — concerned with quality; the nature of a thing, rather than its quantity.

quantitative — concerned with the magnitude or quantity or measurement of a thing rather than its fundamental nature or quality.

reductionist — attempting to reduce complex phenomena to the simplest terms possible; i.e., the usual method of the physical sciences.

RESOURCES — the actual amount and distribution of resources on a specific site.

reversible — a reversible process is one whose past is knowable from a knowledge of its present state and the forces acting on it, e.g., the trajectory of a dropped ball in classical mechanics.

self-organization — the generation of order in an open, nonlinear system as a result of processes internal to the system.

social — of or pertaining to the interaction and organization of individuals in their relations with other individuals.

SOCIAL INPUTS — the effects of the community's social structure.

social structure — the formal (e.g., governments, laws) and informal (e.g., classes, castes) mechanisms by which the relations of the individuals of a society are regulated.
society — a collection of communities and individuals with a common social structure.

stochastic — a stochastic process is one whose evolution is determined by random events.

stress — a force for change in a system; most often, but not always, originating outside the system.

structural change — change in the structure, in the mode of functioning, of a system.

structural stability — stability of a system in the face of structural change — does the change take over the system or is it resisted.

system — a complex whole consisting of things, parts, individuals, structures, processes, and systems.

TENSION — goodness of fit; defined as appropriateness of community structure given external constraints. The worse the goodness of fit, the higher the tension.

variable — the actual components of the model which represent the ecological, economic, and social components of community.