1

Evolution and Innovation in Sociocultural Systems: A Punctuated Equilibria Model

MARIETTA L. BABA
BERNARD P. ZEIGLER

I. Introduction

How does major cultural change originate and unfold over time? Through the gradual assimilation of incremental change within the fabric of a continuing system? By local innovation and broad diffusion via trade routes and other communication pathways? Through imposition by an economically powerful society upon a less developed system? Cultural anthropologists, with some notable exceptions, have traditionally postulated such mechanisms as the motive forces driving culture change. Indeed, there is little doubt that these mechanisms often play a key role in mediating cultural evolution. But other mechanisms may also be in operation at the same time—mechanisms which are, perhaps, more crucial determinants of the locus, mode, and tempo of evolutionary change.

This chapter proposes and elaborates upon one such potential mechanism; it seeks the locus of innovation in uniquely constituted groups of

INDIVIDUAL DEVELOPMENT
AND SOCIAL CHANGE:
EXPLANATORY ANALYSIS

ISBN 0-12-515620-0

individuals — individuals who are marginal to the stable, dominant systems from which they emerged. It is from the evolutionary paradigm of punctuated equilibria (Eldredge & Gould, 1972) that we draw our central analogy. Rather than seek an explanation for the emergence of new life-forms in the gradual accumulation of beneficial genes in an existing species, this theory seeks mechanisms by which unique combinations of genes are formed in small, peripheral populations, each of which then "tests its mettle" against the rigors of a new environment. In like manner, we seek the cultural locus and mode through which human bearers of new ideas can test these ideas in a multitude of cultural experiments. Just as successful new combinations of genes may be identified by the rapid growth of the peripheral isolate and the emergence of a new species which may then radiate to fill whole new ecozones, so the successful cultural innovation is known through its rapid develoment and possible transformation of the culture in which it sprang to life.

This chapter reviews the contribution of modern evolutionary anthropology to the definition of culture and the characterization of cultural levels or grades and then critically analyzes the conceptual background in which modern anthropology conducts its studies. Exclusive adherence to a narrow form of phyletic gradualism fails to seek systematic explanatory relationships for cultural advance, although evolutionary anthropology has documented the existence of cultural grades. Against this background, the anthropological contribution of Sahlins and Service (1960) and the punctuated equilibria paradigm of Eldredge and Gould (1972) inspire the present work.

In the main body of this chapter, the punctuated equilibria hypothesis is presented and modified for interpretation as a mechanism to explain cultural advance. This mechanism is then elaborated in the context of two examples of techno-economic transformation. The punctuated equilibria model provides an account consistent with that of Flannery (1969) for the evolution of agriculture in the Near East. The model is also consistent with the modern process of technological innovation in which the innovator–entrepreneur and the small, science-based firm may be responsible for the technological transformation of twentieth-century industry.

The ideas presented in this chapter are not intended to suggest that Darwinian selection is anything other than a primary evolutionary force. Furthermore, the argument that strict adherence to phyletic gradualism may unnecessarily limit our understanding of evolution should not be taken as an indictment of Darwinian theory or as a total rejection of gradualism. Recent developments in the literature clearly point out the need to refine and integrate the modes of phyletic gradualism and punctuated equilibria within a general evolutionary framework that can ultimately enhance our knowledge of life's history on earth (e.g., see Schoch, 1982, p. 360). The authors also wish to emphasize that this chapter is not intended as a presentation of formal, empirically testable deductions regarding the punctuated equilibria model or of data which might be used to test such deductions. Our approach is intended to explore the possible applicability of the punctuated equilibria perspective to future studies of culture change and to suggest the potential contribution of this model to the theory of cultural evolution.

Because the ideas presented here have not been rigorously tested, it is not yet possible to determine whether punctuated equilibria is simply a metaphor for certain types of social change or whether it is a fundamental mechanism of cultural evolution. The chapter does propose research paths along which the anthropologist, ethnographer, psychologist, and systems modeler can pursue the issues that have been identified.

II. The Contributions and Limitations of a Darwinian Approach to Culture Change

> *The expectations of theory color perceptions to such a degree that new notions seldom arise from facts collected under the influence of old pictures of the world. New pictures must cast their influence before facts can be seen in different perspective.*
>
> [Eldredge & Gould, 1971, p. 83]

One of the most significant intellectual events in modern anthropology has been the infusion of evolutionary theory from the biological sciences. This process was initiated by Darwin's formulation of the theory of natural selection and was reinvigorated during the 1950s following the modern evolutionary synthesis of selection theory and population genetics. The evolutionary perspective asserts that there are laws of social change and that the forces described by these laws have produced cultures at several levels of techno-economic productivity (White, 1943, 1945, 1949, 1959).

The explanatory power of an evolutionary framework proved extraordinarily potent in a discipline noted for atheoretical empiricism during the first century of its formal existence (Harris, 1968). This framework has had important implications for the anthropological research program and for the application of more robust methodological tools in sociocultural investigation.

Prior to the advent of evolutionary anthropology, there was no generally accepted definition of culture that described the systematic relationship of cultural components and related the functioning of these components to energy capture and energy–resource flow (Harris, 1968). Culture was

Table 1.1

Evolutionary Series of Cultural Systems

Techno-economic productivity		Socio-organizational complexity
Post-industrial	↑	Modern state
Industrial		Archaic state
Advanced agriculture		Chiefdom—hierarchical
Agriculture-pastoralism		Chiefdom—egalitarian
Incipient agriculture		Tribal level
Hunting and gathering		Band level

loosely defined as a collection of learned patterns of thought and behavior characteristic of a particular population (e.g., Wissler, 1929; Murdock, 1961). Such a normative and particularistic definition did not readily lend itself to the production or organization of a data base from which models could be developed (Flannery, 1967; Watson, LeBlanc, & Redman, 1971). Evolutionary anthropology, by contrast, defines culture as a uniquely human adaptive system designed to capture, harness, and distribute environmental energy and resources for the survival and well-being of its carriers (Steward, 1949, 1955). Following this definition, major components of all cultural systems are described as (1) the techno-economic base that captures materials and energy from an environment; (2) the social structure that organizes individuals to carry out energy production, environmental exploitation, and resource distribution activities; and (3) the ideology that constitutes a set of ideas and values that rationalize and motivate social behavior and the relations of production (White, 1949).

Perhaps the most significant impact of evolutionary theory on the study of human culture was the discovery that cultural systems, much like biological species, represent differing grades of development. These grades are hierarchically ordered according to their level of efficiency and productivity in the capture, distribution, and utilization of energy (Sahlins & Service, 1960; White, 1943, 1959). Table 1.1 lists two generally accepted series of cultural advance arranged according to level of techno-economic productivity and socio-organizational complexity. Following is a list of traditional measures of *quantum cultural advance*, which, for the purposes of this chapter, is defined as techno-economic developments that both require and permit major new forms of social organization as a result of improved energy capture, distribution, and/or utilization.

1. Absolute energy capture
2. Ratio of energy capture to energy expended in capture
3. Systematic complexity (number of components)
4. Systematic integration (linkages between parts)

A. EVOLUTIONARY ETHNOGRAPHY

More than three decades of anthropological fieldwork have now been guided by a Darwinian paradigm of evolution, producing a rich literature describing the reality of culture at varying grades of techno-economic productivity (Fried, 1952, 1967; Lee, 1968; Mintz, 1956; Rappaport, 1968; Service, 1955, 1962; Wolfe, 1957, 1966). The vast majority of ethnographic investigations emerging from the evolutionary school of anthropology thus far have focused upon (1) static, structural–functional descriptions of the ecological niches occupied by cultures at varying stages of evolutionary advance and (2) dynamic adjustment of specific cultures to changing environmental contexts. While these studies have confirmed the existence of energetically defined cultural grades, they generally have lacked concern for the processes of innovation and forces involved in de novo[1] advance to new levels of sociocultural integration.

For students of culture, techno-economic transformation and major sociopolitical reorganization have been viewed primarily as a function of contact between two cultures at different stages of development, with change occurring as the result of forced domination of one system by the other. In such cases, the less advanced system was exposed to new economic pressures or was compelled to participate in the economic structure of the dominant system (e.g., Murphy & Steward, 1955). Studies of this type relegate quantum change to a phenomenon conceived by the deus ex machina of intercultural contact.

How quantum cultural innovations arise, why they occur, and what systemic relationships may be operative during each change are some of the major questions which may be raised concerning the process of evolution. Such questions have been seriously investigated only by archaeologists (particularly those influenced by systems theory), who have concentrated upon the origin of major cultural innovations that produced new grades of social organization (e.g., Flannery's "broad spectrum revolution" in the Near East, 1969; Carneiro's origin of state-level civilizations in the New World, 1970). For such investigations, the most fascinating questions have centered on new quantum developments in the techno-economic base and on the resulting transformation of sociopolitical systems, settlement patterns, and population density. One reason for archaeologists' concern with processes of

[1] For the purposes of this essay, *de novo* is defined as the original invention of an idea, artifact, structure or process within a particular cultural context. The term *de novo* implies that the new entity was invented within the cultural context in which it appears and was not borrowed or transplanted from another cultural system. De novo entities may, of course, be invented independently in two separate cultures, entirely without diffusion or borrowing.

change may be the nature of their discipline, which views culture over tens of thousands of years. Trends leading to major social change may leap more readily to view from this telescopic perspective than when viewed from the microscopic perspective of ethnographers, who typically witness change over a much shorter period of time.

Among cultural anthropoloists, Sahlins and Service have contributed significantly to the modern school of evolutionary theory championed by Leslie White. Their collection of essays entitled *Evolution and Culture* (1960) explicitly challenges ethnographers to apply three laws of general cultural advance to the study of modern societies. Of these three laws, two deal with the origins of quantum social change (the Principle of Stabilization and the Law of Evolutionary Potential), while the third treats change as a function of culture contact (the Law of Cultural Domination). Although Sahlins and Service's book is required reading for many undergraduates, subsequent generations of fieldworkers have not taken up the challenge; for the most part, they apply only the Law of Cultural Domination in their exploration of social change.

B. DARWINIAN BIASES

One factor that may have contributed to the failure of ethnographers to consider processes which account for the emergence of cultural innovation is the presence of certain biases inherent in the Darwinian perspective. Darwinian selection has been the dominant paradigm in evolutionary biology for more than 100 years. Darwin's own discussion of selection theory and the interpretation of this theory by evolutionists that followed included some very distinctive notions regarding the tempo, mode, and locus of evolutionary change — notions which have had an important influence on evolutionary anthropology.

1. TEMPO OF EVOLUTION

Darwinian selection has been viewed by many students of evolution as a gradual, step-by-step process linking ancestors and descendents through an unbroken chain of transitional, intermediate forms (see Eldredge & Gould, 1972). According to this viewpoint, evolution is a "stately unfolding" of change over time; small, incremental steps of change lead imperceptibly to new forms of life. All parts of the life system slowly adjust to modified conditions, and sudden leaps or saltations are not expected.

Anthropologists have also expected cultural change to occur in a gradual fashion. Indeed, "evolutionary" change in the social sciences has come to mean gradual, incremental change and is contrasted with "revolutions" during which rapid, disruptive shocks cause serious social and economic imbalance. Such rapid shocks are viewed as aberrant phenomena and are not typically the subject of mainstream research. In the process of focusing upon gradual, incremental change, anthropologists may have inadvertently missed some evidence that supports quantum social transformation.

2. Mode of Evolution

Darwinian theory asserts the primacy of selection as the creative agent of change (Gould, 1982). Selective forces operate on the basis of relative "adaptive fits" between organisms and specific ecological contexts. From such a selectionist paradigm, the small-scale adjustments or "adaptive strategies" of living societies in response to environmental change would be identical with processes generating macrolevel transformations to new grades of organization. In the cultural application of this paradigm, a study of cult formation as an "adaptive" response to economic domination by a foreign power or an investigation of "adaptive" social structure shifts associated with the forced transition from food-gathering to market economies would be treated as theoretical examples of cultural evolution.

Yet while natural selection and adaptive shifts in environmental pressure are important parts of cultural evolution, other forces may be at work in the emergence of true cultural innovation. In macrolevel change, selection may exert its creative influence in concert with both stochastic processes and dynamic relationships inherent within sociocultural systems. These additional forces may be sufficiently different from those of gradual adaptive change to warrant the hypothesis that new quantum developments cannot be reduced to the action of microlevel selection or to adaptive responses to environmental change.

3. Locus of Evolution

Darwin's work emphasized gradual change in large, interbreeding populations that occupy contiguous geographical space. The focus was upon the *entire* species and its change *as* a species over time. Darwin did not select certain parts of species as the lead agents of change nor did he look to certain parts of a species' geographical range as the primary site of change. Evolutionary change swept up all interlocked demes in its path.

Anthropologists also perceive intact cultures as the primary units of evolution and search for patterns of change which may originate anywhere within these units. If certain parts of a culture fail to change, this failure is viewed as a "maladaptive" phenomenon (Turnbull, 1972). If the cutting edge of change regularly originates in specific parts of the system, then a holistic focus on total patterns may filter out significant transformation events.

C. PHILOSOPHICAL BIASES

The choices made by evolutionary ethnographers in selecting research topics and their focus on change as a consequence of culture contact may also be influenced by philosophical biases in modern Western thought. Gould and Eldredge (1977) noted this:

> The general preference that so many of us hold for gradualism is a metaphysical stance embedded in the modern history of Western cultures: It is not a high-order empirical observation, induced from the objective study of nature. The famous statement attributed to Linnaeus — *natura non facit saltum* (nature does not make leaps) — may reflect some biological knowledge, but it also represents the translation into biology of the order, harmony and continuity that European rulers hoped to maintain in a society already assaulted by calls for fundamental social change. (p. 145)

Furthermore, evolutionary theory was reintroduced into the discipline in the late 1940s and early 1950s, a period during which anthropologists were sensitive to the links between nineteenth-century evolutionary anthropology (e.g., the work of Lewis Henry Morgan) and the writings of Marx and Engels. In the McCarthyist era of the early 1950s, evolutionists might have unconsciously (or consciously) chosen the comparatively safer course of describing systematic relationships within cultures at varying grades of advance rather than focusing upon the forces which drive evolution from one stage to another. The latter approach might well have led to considerable discomfort for scholars, since the official state philosophy of the Soviet Union was (and is) founded upon "dialectical materialism" — a theory of quantum social transformation that seeks the motive force of change within systemic relationships.

III. Paradigm Shift: The Punctuated Equilibria Model

> *The importance of peripheral isolates lies in their small size and the alien environment beyond the species border that they inhabit—for only here are selective pressures strong enough and the inertia of large numbers sufficiently reduced to produce the "genetic revolution" that overcomes homeostasis.*
>
> [Eldredge & Gould, 1972, p. 114]

In his book *On the Origin of Species by Means of Natural Selection*, Darwin noted that new species can arise only as the result of two processes: (1) phyletic evolution, whereby a total population is transformed to a new state and (2) speciation, in which an ancestral lineage splits into more than one descendent line. However, Darwin may have blurred the distinction between these processes in much of his own work by holding that speciation and phyletic evolution both occur as the result of slow, gradual adjustments of populations in contiguous geographic regions (Mayr, 1959).

Darwin's gradualistic vision of lineage-splitting shares certain features with the sympatric model of speciation, a model which has not been the preferred view of modern population genetics (Eldredge & Gould, 1972).[2] Most contemporary biologists and geneticists favor the allopatric model of speciation. In the allopatric model, subpopulations "bud off" the main ancestral species and enter new and frequently marginal geographic regions. The establishment of reproductive barriers between the main population and the "spin-off" groups, together with the pressure of different selective forces operating in frontier environments, creates conditions favorable to the emergence of distinctive gene pools and eventually to the formation of new species.

Since 1970 some paleontologists have begun to question the Darwinian conception of evolution as a gradual process and have advanced the model of punctuated equilibria to explain some perplexing "anomalies" in the fossil record. Eldredge and Gould have suggested that the famous "gaps" in the fossil record may not be the result of imperfect preservation of prehistoric life forms but may reflect the actual process by which most evolution has taken place (Eldredge, 1979; Eldredge and Gould, 1972; Gould and Eldredge, 1977). According to Eldredge and Gould, proper emphasis upon the process of speciation over the past 3 billion years generates a new paradigm of evolutionary change.

The punctuated equilibria model holds that most evolutionary change is concentrated in very rapid spurts of speciation, a process occurring most frequently in small, peripheral populations existing at the geographic margins of habitation for the group in question. According to this paradigm (which draws some of its features from the allopatric model of speciation), the main body of a population will remain genetically stable over long periods of time because of the homogenizing forces of gene flow and the operation of homeostatic mechanisms in developmental and genetic systems (Gould, 1982). The main population will experience minor fluctuations in gene frequency but will not demonstrate the long-term directional change associated with speciation.

[2] Mayr (1963) notes that the sympatric model of speciation is actually pre-Darwinian. This model holds that an interbreeding population will develop isolating mechanisms *within* a single geographic region as the result of ecological forces. The sympatric view may be contrasted with the geographic, or allopatric, model of speciation. This latter model holds that "a population, which is geographically isolated from its parental species, acquires during this period of isolation characters which promote or guarantee reproductive isolation when the external barriers break down" (Mayr, 1942, p. 155).

Genetic stability of large ancestral populations is usually attributed to one or both of the following mechanisms:

1. Gene flow among interbreeding demes, which exerts a homogenizing influence "to counteract local ecotypic adaptation by breaking up well-integrated gene complexes" that might otherwise tend to form new species (Mayr, 1963); and
2. Developmental and genetic homeostasis, or self-regulation, in which natural selection acts to favor heterozygotes rather than extreme genetic types (Lerner, 1954; see Gould, 1982).

Developmental homeostasis (or ontogenetic self-regulation) occurs because heterozygotes possess a greater ability to stay within the range of canalized development; genetic homeostasis means that populations with a larger number of heterozygotes will display a greater overall reproductive fitness.

The locus of change in the punctuated equilibria model is the small, isolated subpopulation which "buds off" the main ancestral body to form a deme at the margins of the ancestral species' geographic region. Peripheral isolates form as the result of "population push" from the optimal environment inhabited by the ancestral group and move into a variety of suboptimal microenvironments. The spin-off population is genetically variable but small enough to constitute a unique nonrepresentative sample of the total ancestral gene pool. The advantages of a small, unique gene pool reside in the heightened possibility of successful new genetic recombinations and the ability to increase the frequency of a favorable gene very rapidly. The isolate population carries with it most of the genetic features that may eventually become hallmarks of a new species status, although these features may exist in very low frequency at the outset.

Genetic isolation of the spin-off group must persist until enough change has taken place to ensure that gene flow will not occur between the isolate and the ancestral species. Genetic isolation, and the reduced genetic variability of the isolate, disrupts the homeostatic equilibrium which prevented speciation in the ancestral population. It is the unique combination of genes, freed from homeostatic restraint and within the context of a stressful new environment, that permits speciation to occur.

Isolate formation may be viewed as the establishment of genetic experiments. Certain ancestral populations will continually spin off, or peripheralize, isolates, with each possessing a unique gene pool and entering a relatively new microenvironment. A number of futures are possible for any given isolate, including extinction, resorption into the main body, survival at a low level of density, and successful speciation followed by increasing density and range. Stochastic processes determine which few unique gene pools will succeed. Most experiments will surely fail, and it will be difficult to predict success. Where gene pools are well matched to the demands and opportunities provided in marginal microenvironments, speciation will occur very rapidly.

The theory of punctuated equilibria focuses closely upon the process of evolutionary transformation. Why species do or do not emerge, the mode by which speciation takes place, the location of a locus or cutting edge of genetic change within a population—these are the key questions addressed by the punctualist model. This approach sharpens the focus of research upon specific *loci* of change and specific *modes* of change rather than pointing to all living populations and all forms of adaptation as probable sites of and processes critical to evolution. Such a sharpening of focus may improve the testability of evolutionary hypothesis and help to satisfy some of the objections which have been raised concerning the "nonfalsifiability" of Darwinian hypotheses.

IV. A New Paradigm of Sociocultural Innovation

A. THE CONTRIBUTION OF SAHLINS AND SERVICE

> *Evolution is usually diagrammed as a tree with the trunk representing the "main line" of progress, as though the advance from the highest form at one stage to the new form at the next were phylogenetically continuous. It is an inappropriate and misleading picture, however, and the recognition of the discontinuity of advance is an important element in the understanding of some major problems.*
>
> [Sahlins & Service, 1960, p. 97]

Sahlins and Service's book, *Evolution and Culture* (1960), is an important contribution to the theory of quantum social change. This treatise identifies two key rules governing change in cultural systems that foreshadow the central premises of punctuated equilibria introduced by Eldredge and Gould nearly a dozen years later. Sahlins and Service call these rules the *Principle of Stabilization* and the *Law of Evolutionary Potential*. These rules represent a significant break from Darwinian tradition in cultural studies and suggest a different mode, locus, and tempo of evolutionary change.

The Principle of Stabilization asserts that "a culture at rest tends to remain at rest" (Sahlins & Service, 1960, p. 54). The authors note the following:

> A culture is an integrated organization of technology, social structure and philosophy adjusted to the life problems posed by its natural habitat and nearby and often competing cultures. The process of adjustment or adaptation, however, inevitably involves specialization, a one-sided development that tends to preclude the possibility of change in other directions, to impede adaptive response to changed environmental conditions. While adaptation is creative, it is also self-limiting. The tendency toward stability is, empirically speaking, thoroughly familiar to anthropologists. The his-

> toric, archaeological, and ethnographic records attest to numerous instances of the persistence, "survival," or "inertia" of cultural traditions, particular cultures and elements or traits. (pp. 53–54)

This corollary of the Principle of Stabilization is well demonstrated by the numerous field studies of "adaptive" evolution mentioned earlier in which the successful adjustment of cultural components to external pressure without development of true technological or social innovations is documented. Sahlins and Service themselves suggest several examples of the operation of this principle, including the stability of food procurement techniques at the end of the Pleistocene in Europe, the adaptation of the Siberian Yakut to northeastward migration, and the elaboration of wampum use by the Iroquois to maintain confederacy organization.

The Principle of Stabilization may represent an original anthropological contribution to evolutionary theory. The notion that central populations tend to remain genetically stable over long periods of time does not appear to have been a prominent concept in evolutionary biology in the late 1950s nor did the authors borrow this perspective from the then-embryonic field of systems theory. Rather, it appears that Sahlins and Service developed this principle as a result of observing records of human behavior.

Sahlins and Service moved beyond recognition of cultural stability to define the locus of true cultural innovation. The Law of Evolutionary Potential states:

> The more specialized and adapted a form in a given evolutionary stage, the smaller is its potential for passing to the next stage. Another way of putting it which is more succinct and more in conformity with preceding chapters is: Specific evolutionary progress is inversely related to general evolutionary potential. (p. 97)

Several important corollaries of the Law of Evolutionary Potential are identified by Sahlins and Service. These include:

1. *The local discontinuity of progress.* As the result of stability, ancestral lines will not typically give rise to new forms of organization. The emergence of new grades of development is more likely to occur in areas that are removed or separated from the ancestral type.
2. *The privilege of backwardness.* Cultural innovation is more likely to be created or adopted by societies or groups that are not as energetically advanced as the dominant cultural form of the time. Such "backward" groups may have more to gain from the adoption of new social or economic structures and less vested interest in the current dominant structure.
3. *The direct relationship between rate of change and extent of discontinuity.* The more rapid the process of change, the more distance will separate dominant ancestral populations from those less dominant groups engaged in innovation.

The operation of these corollary principles is described in a number of fascinating examples, including the occurrence of a socialist revolution in Russia, the development of a cult of youth in the People's Republic of China, and the rapid development of a strong industrial economy in the United States.

The Principle of Stabilization and the Law of Evolutionary Potential closely parallel basic concepts in the punctuated equilibria model developed by Eldredge and Gould. The Principle of Stabilization is similar to the punctualist tenet of genetic homeostasis in central populations. "The norm for a species during the heyday of its existence as a large population is morphological stasis, minor non-directional fluctuation in form, or minor directional change bearing no relationship to pathways or alteration in subsequent daughter species" (Eldredge & Gould, 1972, p. 117). While Sahlins and Service did not identify specific mechanisms of social homeostasis, the punctuated equilibria model provides some useful insights into such causes and mechanisms (punctualist contributions in this area were discussed in Section III).

Sahlins and Service's Law of Evolutionary Potential also bears some resemblance to the punctualist notion that speciation occurs in small subpopulations which are isolated from the main ancestral body. However, in their analysis of those cultural loci holding most potential for change, Sahlins and Service used the criterion of specialization, or narrow adaptation to a particular niche, as a marker of low innovative potential. Sahlins and Service argue that narrow adaptation to a specialized niche would militate against change that might allow the exploitation of a new resource base, while the generalized ability to exploit a variety of resources might permit creative new economic techniques to be developed and adopted. This essentially Darwinian argument emphasizes relative "adaptive fit" to environmental conditions as the most important factor contributing to evolutionary success. While this adaptive scenario may indeed emerge as an important consideration in particular cases of culture change, we will argue here that the distinction between specialized and generalized adaptive strategies may not be the single most critical marker denoting potential for quantum transformation.

B. THE PUNCTUALIST MODEL OF CULTURAL EVOLUTION

[The] underlying "rules" which seem to govern the behavior of entities so diverse as a digital computer, living organism, or a sociocultural system are more than simple analogies. Delineating the similarities among these different kinds of systems is . . . a form of generalizing or of abstracting basic realities.

[Watson et al., 1971, p. 65]

Important parallels between evolutionary processes in biology and cultures have long been noted (Huxley, 1956; Sahlins & Service, 1960). Some writers suggest that these similarities may actually be homologies (Roosevelt, 1910). Culture is, after all, a biobehavioral extension of the earth's dominant life form and thus may be subject to the influence of certain basic developmental laws that affect all life as we know it. Indeed, general systems theorists examine behavior and structure at all levels of complexity for underlying systemic principles. The ubiquitous application of certain mathematically isomorphic models (such as the second-order differential equation system) across a wide range of disciplines (from physics to physiology and ecology) attests to the existence of underlying unities (Rappaport, 1972). Although the existence of isomorphisms in biological and cultural phenomena have been noted (Weinberg & Weinberg, 1974), the early age of general systems theory as an analytic tool suggests that it may be more productive to explore both the positive and negative aspects of such analogies (Bunge, 1981) rather than attempt to force phenomena into the same mold.

Within the restrictions that must govern application of all analogue models, the concept of punctuated equilibria may serve as a framework for developing a new paradigm of sociocultural evolution. This paradigm draws not upon gradualism and "adaptive fit" but utilizes concepts derived primarily from population genetics and from systems theory to explain homeostasis and its functioning in groups of varying size and structure. These concepts may provide a more robust analytic tool in the explanation and prediction of modern social change. The major features of a new punctualist paradigm of cultural evolution are described in the remainder of this section.

Formation of Peripheral Isolates. The cutting edge of cultural evolution may be forged through the action of social subsets, or small organizational forms, which have been "peripheralized" through the "push" of forces within a larger, more dominant organizational system. Peripheral isolates in human cultures may be formed as economic, social, and political pressures within the optimal environment generate sufficient motive force to trigger "out-migration" and exploration of "marginal environments." Such "environments" are not simply spatially defined but may include exploration in the worlds of new ideas, technologies, and sociocultural lifestyles. The most important consideration here is that the isolate group should exist in an environment at the boundary of the dominant group's sphere of influence that is less favorable than that of the dominant group. For human societies isolation may, therefore, be geographic (e.g., colonization of a frontier), economic (e.g., developing nations in the world market system), or philosophic (e.g., sectarian religious or political ideologies).

The initiation of human peripheralization probably involves forces of "motivational pull" as well as "push." Indeed, a most interesting exploration would center upon the common characteristics of cultural innovators that form the leadership of such isolates. For example, it has long been noted that frontier-opening human populations frequently contain a disproportionate number of "super-fit" individuals (i.e., individuals with greater-than-average physical stamina or intellectual capabilities) (Tanner, 1978). A partial cause of this nonrepresentative sample may be that the frontier experience attracts individuals with certain physical and mental characteristics. In the optimal environment, these individuals may not have received adequate challenge or stimulus or they may have experienced sociopsychological stress from actions associated with the display of their physical and/or mental prowess.

It is clear that the individuals who form the core of peripheral isolates manage somehow to escape the norms of canalization which restrict the behavior of their less-adventurous colleagues. The "sociological deviance" of such individuals must, therefore, be considered in a new light; from a punctualist perspective, such deviants may be an indispensable ingredient in the innovation formula and attempts to normalize their behavior probably reflect the force of social inertia.

Size and Variability of Peripheral Isolates. From a punctualist perspective, innovating peripheral groups in human populations are expected to fall within a certain size range—large enough to provide the "critical mass" of knowledge and resources necessary to maneuver in the suboptimal region, but small enough to permit the many advantages associated with flexibility (i.e., rapid rearrangement and/or increase of advantageous components or activities). The innovating human isolate should derive from its parent group most of the basic knowledge, concepts, skills, and resources requisite for major new forms of organization or technology. The isolate group—because of small size, random factors, and hostile environmental pressure — will then recombine these concepts and resources in totally new ways, triggering quantum social change.

Isolation of the Peripheral Population. In human societies, the model predicts that it will be necessary for isolate groups to maintain a separate identity from the parental population until major innovation is well consolidated and has proved successful (i.e., the isolate group has proved capable of self-maintenance and is more productive and efficient than the ancestral form). The punctualist model predicts that too close an interaction between the isolate form and its ancestor before quantum change has been stabilized will lead to resorption and a dampening of innovative action.

Buffering of Subpopulations versus Exposure of Peripheral Groups. Large, dominant organizations will possess a varied array of strategic resources that will tend to shelter all of the subgroups operating within the primary system. Frontier-opening isolates, however, will be cut off from such protection and will have to stand or fall on the basis of their inherent abilities. The direct exposure of peripheral groups to harsh external conditions without benefit of extensive buffering mechanisms means that most human peripherals will not be able to withstand isolation for periods long enough to consolidate real change. Most human peripheral groups will fail to survive in the suboptimal zone and will either disintegrate, be resorbed into the main population, or continue to struggle along at very low densities.

Stochastic Nature of Success. Dominant sociocultural systems will inadvertently generate a continual flow of isolate-forming subgroups. Each isolate will constitute a unique "social experiment" and most of these will ultimately fail to achieve lasting change. Success may not be predicted on the basis of forecasting models which consider only a few variables. The future success of such groups will depend upon an extremely complex interplay of individual attributes (especially the knowledge-related characteristics of the participants), external forces, and random factors. While the mode and locus of change may be predictable, the future of any particular isolate certainly cannot be predicted given the current state of knowledge in the social sciences.

Rapid Change in Suboptimal Areas. The model predicts that quantum cultural shifts will occur in very short periods of time, somewhat akin to the "qualitative leaps" predicted by Hegelian dialetics or the "socialist revolution" yearned for by Marxist–Leninists. Once stasis has been disrupted and a new homeostatic balance has been achieved by the isolate, it will be impossible to stuff the quantum change back into its cultural womb. A successful innovation will assert itself and, where human culture is concerned, the true innovation is very likely to change the rest of the world as well. The ability of human innovation to permeate and transform older systems is one of the most important distinctions between social change and genetic change associated with speciation.

V. Examples of Punctuated Equilibria in Techno-economic Change

An important tradition in evolutionary anthropology has been a theoretical and empirical emphasis upon techno-economic components of cultural systems. Such components were viewed by Leslie White (1949) and Julian

Steward (1955) as critical subsystems linking human populations to their environments through energy and resource flow and serving as the "base" for other system components that organize and rationalize the techno-economic mode of production. Too frequently, perhaps, the evolutionary school has concentrated exclusively upon the role of techno-economic subsystems as the motive force driving change throughout cultural systems without paying proper attention to the positive feedback cycles that may originate within socio-organizational or ideological subsystems and serve as an "initial kick" to major systemic change. For example, the emergence of state-level societies does indeed require a minimal food production base, but the forces that stimulate state formation may be closely tied to acts of mutual aggression and the establishment of political alliances between groups in circumscribed environmental regions (Carneiro, 1970). A new form of techno-economic base is not necessarily required for the support of state-level civilizations, although the formation of states often has a profound impact on food production systems.

The systems approach to cultural anthropology provides a framework that demonstrates the importance of relationships between cultural components, permitting escape from the sterile notion of material determinism and enabling researchers to analyze dynamic interactions of techno-economics, social structure, and value subsystems, all of which must participate in quantum change to new grades of organization. Within the framework of a systems approach, techno-economic subsystems may continue to serve as a useful focus of investigation. While such subsystems are not the sole determinants or markers of new organizational grades, change within the techno-economic base has set the stage for major cultural advance throughout the history of humanity, and certain forms of social organization are quite impossible without an adequate energetic foundation (e.g., industrial capitalism could not arise de novo in a hunting and gathering society).

Two cases of techno-economic change that illustrate some of the primary features of a punctuated equilibria paradigm will be presented in the next section. This discussion is not meant to serve as a test of the model. Rather, the purpose of presenting these examples is to demonstrate the potential applicability of the punctualist paradigm.

A. ORIGIN OF FOOD PRODUCTION IN THE NEAR EAST

The transition from hunting and gathering to food production was a profound techno-economic transformation in the development of human culture. This revolutionary change, which occurred independently in the

Old and New Worlds around 10,000 B.C. and 4000 B.C., respectively, provided the foundation for stable, sedentary communities, for substantial increases in population density, and for complex forms of sociocultural organization.

Archaeologists have concentrated an enormous wealth of physical and intellectual resources on discovering the processes by which agriculture emerged. A prominent hypothesis advanced by Kent V. Flannery (1969) to explain plant production shares many features with the punctuated equilibria model. Although the archaeological evidence is not entirely conclusive, Flannery's hypothesis is consistent with the majority of archaeological data now available.

Flannery was influenced by the work of Lewis Binford (1968), who argued that causes cited earlier as the impetus for agricultural innovation (e.g., Childe's use of climatic change, 1937/1951) were inadequate and unsupported. Binford was particularly unimpressed with Braidwood's notion (1975) that domestication began in the Hilly Flanks region of the Fertile Crescent where potential domesticates already existed. Although there is evidence that hunting and gathering groups did exploit the rich environments in which future domesticates grew wild (and indeed these people gathered wild cereal grains and probably understood seed germination), Binford asserted that populations would not be likely to adopt a new economic system in the absence of severe pressure to do so. Rather, the hunters and gatherers in optimal ecological zones would maintain their population densities at carrying capacity, thus relieving the pressure to adopt new economic modes, by "budding off" daughter populations to surrounding areas. Binford suggested that the origins of agriculture might be found in the marginal environments invaded by the daughter groups that were pushed out of the optimal zone.

Flannery (1969) built upon Binford's arguments, noting that extant hunting and gathering populations can easily extract sufficient calories from wild foods "without even working very hard." Even the !Kung of the Kalahari Desert may be able to obtain an average of 2100 calories per person per day through the efforts of an average 3-day workweek (Lee, 1968). Flannery cited the field experiment performed by Harlan and Zohary (1966) in which Harlan, equipped with only a flint-blade sickle, was able in 1 hour to gather 1 kg of edible wheat from wild stands in the Hilly Flanks. Flannery judged that during the 3-week period in which wheat must be harvested in the Hilly Flanks a family of experienced gatherers could collect an entire year's supply of cereal. Such abundance, argued Flannery, would generate tremendous inertial forces that would preclude agricultural innovation in this rich and diverse environment.

On the other hand, the Flanks are bordered by less favorable environments that could receive overflow population from the optimal zone. Flannery contended that it was in the surrounding marginal areas, lacking wild forms of grain, that human populations first began the regular cultivation of plants and domestication of animals.

According to Flannery, population pressure and varying resource availability in the preferred environment would propel groups of hunters and gatherers into the marginal regions. When climatic conditions were less favorable, population pressure would be strong and continuous, causing bands to flow from the optimal core area into peripheral zones. Increasing population density in the marginal environment would be a strong incentive to experiment with new production techniques. Groups existing under such conditions and possessing knowledge of wild cereals and their domesticable properties would have attempted to recreate the lush stands of wheat growing wild on the Hilly Flanks by sowing seeds obtained from the ancestral population (Flannery, 1965).

Once such experiments proved successful, selection would favor groups that expanded cultivation and concentrated energy on sowing, tending, and reaping cereal grain crops. Flannery (1969, 1973) suggests that, during this period of increasing cultivation, humans themselves became selective agents for rapid genetic changes in the cereals (e.g., by selecting grains with tough rachises and brittle husks, both necessary characteristics of high-yield domesticated cereal crops). Removal of these plants from their native environment also subjected them to new selective pressures and resulted in genetic changes such as polyploidy, thereby producing the domesticated cereal types of modern times. These genetic changes increased the yield of grain crops, establishing agriculture as a superior techno-economic system and contributing to its rapid adoption by other groups and diffusion to contiguous regions.

The parallels between Flannery's hypothesis and the punctuated equilibria model are striking. These parallels include:

1. Systemic inertia of ancestral populations;
2. Population "push" leading to the spin-off of peripheral isolates into marginal zones;
3. Quantum change originating in the marginal area;
4. Peripheral group carrying all basic components necessary for development of a new economic system; and
5. Very rapid change and re-establishment of homeostasis at a new level of organization.

This example of techno-economic transformation, which developed under the influence of Flannery's system-thinking, demonstrates the value of evolutionary vision that reaches beyond phyletic gradualism. Innovation was not bound within the confines of a slow, adaptive response to environmental change (see Childe, 1937/1951) nor did change occur in the region of surplus resources where Braidwood (1975) logically expected it. While population pressure in the central zone was an important environmental stimulus to innovation, the unexpected genetic changes which humans wrought in the cereal grains were probably an equally important, if not the critical, trigger to a massive positive feedback cycle that continually rewarded increasing investments in agricultural activity. Thus a complex interplay of population dynamics, environmental conditions, human creative vision, and random factors combined to generate a qualitative economic shift that changed the history of life on earth.

There are some important differences between this example of human innovation and the events which trigger speciation, but even these differences only serve to highlight other parallels. For example, genetic change is conditioned by the new, unique combination of genes in subgroups invading marginal zones, while quantum change in culture will depend upon the availability and utilization of knowledge-related attributes. Yet, as in the case of speciation, the hunter–gatherer bands invading suboptimal zones were "preadapted" to innovation. The assumption of preadaptation is derived from data available on extant hunter–gatherer populations; such groups typically understand that seeds generate plants, and they may even sow some seeds in order to make stands more accessible to human collection (Flannery, 1965). In fact, there is evidence (Hole & Flannery, 1967; Solecki, 1964) that preagricultural people already possessed some of the technology requisite for cereal grain consumption (e.g., grinding stones and storage pits).

The idea that wild plants grow from seeds which can be sown to produce more plants was a discovery whose precise origin among hunting and gathering people will probably never be determined. Like genetic mutations, such ideas probably arose repeatedly and in many different places. The ultimate utility of such an idea was conditioned by the existence of environmental "pull," just as a new mutation will only confer selective advantage under special environmental conditions.

Future archaeological research in the Near East might test the validity of a number of predictions generated from the punctualist framework. For example, the punctualist perspective predicts:

1. The initially smaller size of marginal bands invading peripheral zones compared to typical hunting and gathering bands in the Hilly Flanks;
2. Weaker links (e.g., trade) between peripheral bands and the ancestral group than between bands within the ancestral population; and
3. An array of alternative futures for spin-off populations, including resorption, or continuing marginal survival in the suboptimal zone with a hunter–gatherer economy.

Archaeologists themselves can formulate stronger and more appropriate hypotheses for testing on the basis of the punctualist paradigm. Transformation in human societies is dependent upon knowledge generation and knowledge reproduction subsystems (i.e., the creation of new ideas, the original synthesis of knowledge, new applications of knowledge, dissemination of information). Although such subsystems do deposit remains in the fossil record (technologies, settlement patterns, population densities), it is evident that the fullest appreciation of knowledge-related processes involved in quantum change will only be gained by field observation of extant human societies. Therefore, the next example focuses upon contemporary techno-economic change.

B. TECHNOLOGICAL INNOVATION IN MODERN INDUSTRY

I believe quite simply that the small company of the future will be as much a research organization as it is a manufacturing company, and that this new kind of company is the frontier for the next generation.

[Edwin Land, founder of Polaroid, 1946; see Jacobs, 1982, p. 35]

Technological innovation is a primary motive force driving modern industrial economies (Kelly & Krantzberg, 1978). Industrial innovation— including the generation of new ideas, the development of prototype models, and the commercialization of new products and processes—is the force that generates productivity improvement, holds down costs, and stimulates market demand. All of these effects contribute to economic growth and the creation of new jobs.

In the United States, technological innovation is both a serious economic problem and an exciting socioeconomic phenomenon. On the one hand, sluggish productivity growth in several basic manufacturing industries (e.g., steel, motor vehicles, textiles) has riveted the attention of federal policymakers on the failure of these industries to adopt existing technological innovations and develop new technology-based products. These basic industries are virtually stagnant, creating very few new jobs and frequently failing to record a profit. On the other hand, many observers of modern American life have proclaimed that the nation has entered an era of technological revolution (Boulding, 1964; Drucker, 1970; Toffler, 1970). This claim is based upon burgeoning technological change in the areas of telecommunications, information processing, artificial intelligence, and genetic engineering. The so-called high technology industries operating in these fields display strong growth profiles; such industries are vigorous competitors in the international market, they show impressive performance in the areas of employment and return on investment, and they are aggressively developing and commercializing ingenious products that are already altering the nature of our entire society (Joint Economic Committee, 1982).

While technological change has always been an essential component in the process of industrial development, it appears that the current technological revolution may be driven by a new type of company. These new advanced technology firms are *science-based.* Science-based firms are distinct from firms in more traditional industries in a number of ways. First, they place a high priority upon research and development (R&D) and invest a disproportionately large percentage of their revenue in such activities relative to other areas such as marketing and production (Jacobs, 1982). Science-based companies employ large numbers of Ph.D.s and skilled technicians; in fact, scientists and inventors are frequently founders and owners of such firms. Secondly, recent investigations (Freeman, 1974; Tornatzky et al., 1982) suggest that such firms display higher research productivity than non-science-based firms with large in-house research and development operations (e.g., they generate a larger number of patents per dollar of research and development expenditure). Such firms also have been found to contribute a disproportionately large share of seminal inventions (Hamberg, 1964; Jewkes, Sawers, & Stillerman, 1958; U.S. Dept. of Commerce, 1967).

Science-based firms also differ from traditional industries in their use of a business strategy that uniquely combines "technology push" and "market pull" considerations. Naturally, the scientific entrepreneurs owning and managing these companies are motivated to maximize return on investment, but they are usually seeking something more than profit alone. Frequently, they have been personally involved in the development of a radically new product concept and their marketing strategy is a means of realizing their vision that this new concept will succeed and may even "change the face of the earth" (Jacobs, 1982). Partly as a result of this vision and drive, small science-based companies often take risks that other businesses will not dare. In many cases, these risks have paid off and small, scientifically oriented firms have been responsible for major contributions in the establishment of whole new industries in fields ranging from radio and chemicals to office copiers to semiconductors and amorphous materials (Freeman, 1971; Jacobs, 1982; Shimshoni, 1966, 1970).

The emergence of a new type of industrial organization and the important impact of these firms on modern socioeconomic structure and the quality of life may indeed warrant the view that science-based firms constitute a significant cultural innovation. Although we stand only upon the threshold of the "technological revolution" and cannot foresee the ultimate effects of computer technology, artificial intelligence, and gene-splicing upon future generations of humanity, it is conceivable that in retrospect the science-based industrial organization will be judged a critical agent of quantum transformation in the economy, social structure, and value systems of modern culture. Such speculation is even more fascinating when the emergence of science-based firms is viewed from the perspective of a punctuated equilibria model of culture change. We will now describe the major features of a punctualist view of technological innovation.

Technological Inertia in the Large Company. Homeostatic forces in large, mature firms, even those with substantial in-house R&D operations, may prevent such organizations from developing and exploiting radical new product concepts (Tornatzky et al., 1982). Recent investigations show that large firms typically will not commercialize a product if it has only a narrow, specialized market (Freeman, 1974; Jacobs, 1982). Such companies require the lure of large markets to justify R&D expenditures, so that a radical new technology with profound potential but a small initial market niche will not meet quarterly "bottom line" objectives and will be ignored by company decision makers. In fact, large companies may actually suppress their own R&D results or buy and sequester the rights to new products developed elsewhere in order to ensure that the product does not reach the marketplace (Freeman, 1974).

These considerations suggest that in large companies, even those that are technology-based, decision making is concentrated in the hands of individuals whose focus of concern is return on investment rather than technological innovation per se. Such organizations have enormous capital investments in existing product lines and more attention is probably paid to the profitability of these lines with an avoidance of new, high risk ventures (Freeman, 1974; Jacobs, 1982). While such companies typically employ scientists and possess sophisticated R&D facilities, the objective of such operations is more likely to be improvement of existing products rather than development of entirely new product concepts.

Formation of the Small Science-based Firm. Major technological advance may be forged by small groups of scientists who are both "pushed" and "pulled" out of large research organizations to enter unstable, high risk market niches. A substantial body of literature shows that many new advanced technology companies emerge as a result of spin-off from existing firms (Joint Economic Committee, 1982). In fact, entire new industries frequently begin in this way (Jacobs, 1982). Typically, scientists, engineers, and technicians working in a large industrial laboratory or in a number of different research establishments (e.g., a government laboratory or university) will develop an idea for a product which they are unable to commercialize within their employing organizations. Financial policy in their home operation or regulations governing entrepreneurial behavior of employees may "push" these inventors out of the place in which their idea was developed. "Motivational pull" is another factor contributing to the formation of such companies. The founding group of inventors often have "a solution in search of a problem" (i.e., they have developed an exciting new technology which as yet has no market). The inventors decide to leave their home company, lured by the personal profit that will accrue to discovery of an appropriate "problem" (i.e., market) for their product concept. Significantly, such individuals frequently have personality attributes that motivate them to achieve success through the development of unique ideas (Jacobs, 1982; Tornatzky et al., 1982).

In keeping with the punctualist paradigm, the founders of small science-based firms generally carry with them most of the basic technical knowledge and concepts needed to develop new products. It is also important to note that the "microenvironments" entered by these groups of entrepreneurs are generally hostile, being characterized by lack of critical resources (capital availability), predator stress (threat of acquisition by a large company), and strong competition from other groups of entrepreneurs.

Size and Variability of the Small Firm. Although the small science-based company must possess a "critical mass" of variable skills and resources (ideas, technical expertise, marketing skill, and venture capital), it must also remain small enough to realize a number of important advantages associated with small, "organically" (vs. mechanistically) functioning organizations (Kelly & Krantzberg, 1978; Tornatzky et al., 1982). Clearly, the number of owners and workers in small research-oriented companies is less than the number of such individuals in large firms and gives a nonrepresentative sample of employees in large manufacturing establishments. The high concentration of Ph.D.s, technicians, inventors, and entrepreneurs in science-based firms has been noted previously. Yet in spite of, or perhaps because of, the concentration of a few unique skills in a small number of highly motivated individuals, these companies display several significant advantages over traditional manufacturing establishments.

Recent investigations have shown that small firms are able to maneuver more quickly in markets in which technology is rapidly changing; they can make decisions, reorganize priorities, and change strategies more rapidly than large bureaucratized companies. Such advantages are likely to derive from the close and informal association of owners, scientists, and marketing experts that facilitates communication and permits the close coordination and rapid trial of new strategies necessary for tight maneuvering in turbulent markets. In fact, the physical proximity and personal relationships of scientists, inventors, and business people in the small firm effectively "couples" the typically diffuse stages of the innovation process (i.e., invention, prototype development, and marketing) and may significantly reduce the time normally required to move an idea from the formative stage to the marketplace.

Isolation, Exposure, and Success. The spin-off of inventors and entrepreneurs from industrial R&D departments, government laboratories, and universities causes a loss of protective buffering and more direct exposure and trial of the new group's capabilities. In large organizations, research groups are at least partially supported by general corporate funds that flow from revenue-generating operations. Short- or intermediate-range periods of low productivity for such groups do not usually result in their dissolution or in the firing of individuals. Large corporations are able to continue support for such research groups from the massive financial resources that are available. When a group of individuals leaves the corporate nest, however, they lose the protective financial buffering of a large financial empire and must survive or fail on the strength of their own skills in the marketplace. Immediate and direct exposure to the market effectively eliminates most small companies in a very short period of time—90% of all small firms declare bankruptcy within their first four years of operation (Dun & Bradstreet, 1980).

Unlike peripheral demes, however, successful small firms may face an increasing danger of resorption or premature splitting. Large corporations are constantly scouting for aggressive young firms to acquire and for successful inventors and entrepreneurs to hire. Young science-based firms also experience splits of their own as individual partners decide to take the ideas and run. The peripheral field for advanced technology companies is thus tremendously unstable, and only a very few of these business "experiments" survive to become truly innovative forces.

Rapidity of Uptake. The punctuated equilibria model predicts that those few successful experiments in technological innovation will experience rapid growth and diffusion. New technologies may totally replace older ones within a generation or, even more spectacularly, whole new industries can be spun off from ancestral organizations (Jacobs, 1982). The success and expansion of human innovations will differ significantly from that of newly evolved species, which are prevented from sharing their unique genetic "discoveries" with ancestral populations by the action of isolating mechanisms. Cultural innovations are distinct because they are capable of rapid uptake by organizations other than the one giving them birth, including uptake by parental groups which may be totally transformed in the diffusion process.

VI. Conclusion

> *One of the virtues of the evolutionary view is that, more than any other perspective, it makes the concerns of cultural anthropology directly relevant to modern life in the future. As Tylor once put it, it is the "knowledge of man's course of life, from the remote past to the present," the study of the* evolution *of culture, that will enable us to forecast the future. The modern social sciences, now that they are almost exclusively nontemporal, or functional, have not been able to help us to judge the future and thus guide our actions and deliberations in relation to modern political problems. The past-as-related-to-the-future has long since been left to dogmatic Marxists or to the more respectable but nevertheless equally non-scientific "universal" historians, such as Brooks Adams, Spengler, Huntington, and Toynbee.*
>
> [Sahlins & Service, 1960, p. 94]

Anthropologists and other social scientists have tended to view change as a diffuse phenomenon, occurring continuously and affecting all components of sociocultural systems. Cultures have been viewed as gradually evolving through internal adjustment to structural strain, through imperfect and incomplete enculturation processes, or as a result of adaptation to external pressures and cross-cultural diffusion. In this chapter, we have drawn a distinction between the gradual fluctuations required to maintain homeostasis and the change that disrupts an equilibrium state and leads to the emergence of new forms of socioeconomic organization. The punctuated equilibria model views the peripheral isolate as a primary vector of quantum culture change. This paradigm has the power to organize and rationalize what would otherwise appear to be disparate facts about prehistoric and contemporary technological innovation processes.

Many questions are raised by this analysis. To what extent can it be formalized in mathematical or computerized form? In a later chapter (see Chapter 10, this volume), Zeigler and Baba develop a rationale for systems modeling and simulation of sociocultural research hypotheses. Modeling and simulation of isolate formation may enable social scientists to test the futures of social experiments conducted under varying conditions and determine the markers of evolutionary potential.

What type of research program must be formulated to adequately test the validity of the punctualist paradigm? Perhaps more so than for any other field of social investigation, quantum change requires a unified, interdisciplinary approach to data gathering and analysis. Archaeology is well suited to the investigation of major changes that have taken place in the past. The punctuated equilibria model can be applied to analyses of several prehistoric transformations, including the shift from prehominid economies to the hominid hunting mode, the development of agriculture in the New World, and the emergence of the nation-state. Historians can also contribute to this investigation through exploration of quantum change in the recent past (e.g., the development of modern industrial economy). In the study of current social transformation, anthropologists, linguists, sociologists, and psychologists may determine whether the punctualist paradigm is applicable to processes of change beyond the techno-economic domain. How do language shifts occur? How and where are major new forms of social organization prototyped and pioneered? Is the inventor–entrepreneurial personality a constant factor in social change? What other personality types or individual roles are critical in the process of social innovation?

What are the policy implications of punctuated equilibria? If large dominant systems are heavily committed to an established homeostatic equilibrium, then there will probably be inherent systemic biases against radical innovation. As culture evolves and dominant ancestors become larger and more powerful, systematic inertia may actually inhibit or prevent successful splitting of isolate groups. The dominant organizational form will certainly maintain structural–functional relations which heavily favor the present equilibrium state, creating pervasive, diffuse, and unconscious prejudice against the isolate and rendering its viability all the more doubtful. Subtle biases against innovation may be found in exploring the socioeconomic environment in which small science-based firms operate. Small companies are disproportionately affected by federal regulations and corporate tax structure, and they face notorious difficulties in obtaining start-up capital from traditional financial institutions. Corporate co-optation strategies are also growing in strength as large companies seek new ways to attract and hold entrepreneurs and inventors within their organizational domains (Robert S. First Conference, 1982). Finally, and perhaps most significantly, small R&D firms developing radical new technologies (e.g., in amorphous material or solar technologies) may find their most lucrative markets within developing Third World nations or other non-Western economies. This raises a serious question regarding the ability of mature industrial economies in the West to adopt and implement such innovative technologies.

If the punctuated equilibria model truly highlights a locus, mode, and tempo of change inherent in many life systems, then governmental policy modifications may not be able to significantly alter the pattern of inertia and spin-off described in the examples presented above. However, it is possible that ancestral systems will discover ways and means to infuse innovation and nudge inertial systems toward critical goals and objectives. Government can act to limit homeostatic mechanisms and to enhance countervailing tendencies toward innovation. Antimonopoly suits and affirmative action programs for small business may be examples of such tendencies toward disruption of homeostasis. Constitutionally guaranteed liberties also give license to sociocultural and ideological experimentation. Universal education enhances the potential of individuals to creatively exploit this license by increasing the likelihood that new ideas will be generated by the few and tolerated by the many.

At this point, we are surely not in a position to propose policies that will promote quantum advance based on validated models. However, even now the punctuated equilibria paradigm may sensitize social policymakers to issues and opportunities not perceived from the conventional Darwinian perspective. New species, once established, cannot be collapsed back into their ancestral population because of stringent genetic barriers. Cultures, however, have always been susceptible to penetration by new ideas, and we may yet learn to perform quantum leaps as humanity continues to make itself.

Acknowledgments

The authors wish to express their deepest appreciation to Linda Darga, at Children's Hospital in Detroit, Michigan, for her critical review and constructive commentary. Thanks are also due Patricia Schneider and Mary Mayberry for their expert assistance in the preparation of several manuscripts which culminated in this chapter.

References

Binford, L. R. Post-Pleistocene adaptations. In L. R. Binford & S. R. Binford (Eds.), *New perspectives in archeology.* Chicago: Aldine, 1968.
Braidwood, R. J. *Prehistoric men.* Glenview, Ill.: Scott, Foresman, 1975.
Boulding, K. E. *The meaning of the twenty-first century.* New York: Harper & Row, 1964.
Bunge, M. Analogy between systems. *International Journal of General Systems,* 1981, *7*(4), 221–224.
Carneiro, R. A theory of the origin of the state. *Science,* 1970, *169,* 733–738.
Childe, V. G. *Man makes himself.* New York: New American, 1951. (Originally published, 1937.)
Darwin, C. *On the origin of species by means of natural selection.* London: John Murray, 1959.
Drucker, P. K. *Technology, management and society.* New York: Harper & Row, 1970.
Dun & Bradstreet. *Quarterly Failure Report* (Dun's Statistical Review). First-Fourth Quarters, 1980.
Eldredge, N. Alternative approaches to evolutionary theory. *Bulletin of the Carnegie Museum of Natural History,* 1979, No. 13, 7–19.
Eldredge, N., & Gould, S. J. Punctuated equilibria: An alternative to phyletic gradualism. In T. M. Schopf (Ed.), *Models in paleobiology.* San Francisco: Freeman, Cooper, 1972.
Flannery, K. V. The ecology of early food production in Mesopotamia. *Science,* 1965, *147,* 1247–1256.

Flannery, K. V. Culture history vs. culture process: A debate in American archeology. *Scientific American,* 1967, *217*(2), 119–122.
Flannery, K. V. Origins and ecological effects of early domestication in Iran and the Near East. In P. J. Ucko & G. W. Dimbleby (Eds.), *The domestication and exploitation of plants and animals.* Chicago, Aldine, 1969.
Flannery, K. V. The origins of agriculture. *Annual Review of Anthropology,* 1973, *2,* 217–310.
Freeman, C. F. *The role of small firms in innovation in the United Kingdom since 1945.* (Report to the Bolton Committee of Inquiry on Small Firms, Research Report No. 6). London: HM Stationery Office, 1971.
Freeman, C. F. *The economics of industrial innovation.* Middlesex, England: Penguin, 1974.
Fried, M. Land tenure, geography and ecology in the contact of cultures. *American Journal of Economics and Sociology,* 1952, *11,* 391–412.
Fried, M. *The evolution of political society.* New York: Random House, 1967.
Gould, S. J., & Eldredge, N. Punctuated equilibria: The tempo and mode of evolution reconsidered. *Paleobiology,* 1977, *3*(2), 115–151.
Gould, S. J. Darwinism and the expansion of evolutionary theory. *Science,* 1982, *216,* 350–387.
Hamberg, D. Size of firm, oligopology and research: The evidence. *Canadian Journal of Economic and Political Science,* 1964, *30*(1), 62–75.
Harland, J., and Zohary, D. Distribution of wild wheats and barley. *Science,* 1966, *153,* 1004–1080.
Harris, M. *The rise of anthropological theory.* New York: Crowell, 1968.
Hole, F., & Flannery, K. V. The prehistory of southwestern Iran: A preliminary report. *Proceedings of the Prehistoric Society,* 1967, *33*(9), 147–206.
Huxley, J. S. *Evolution: The modern synthesis.* New York & London: Harper, 1943.
Huxley, J. S. Evolution, cultural and biological. In W. L. Thomas, Jr. (Ed.), *Current Anthropology.* Chicago: University of Chicago Press, 1956.
Jacobs, M. The physicist as entrepreneur. *Physics Today,* January, 1982, pp. 34–40.
Jewkes, J., Sawers, D., & Stillerman, R. *The sources of invention.* New York: Macmillan, 1958.
Joint Economic Committee of the United States Congress. *Location of high technology firms and regional economic development.* Washington, D.C.: U.S. Govt. Printing Office, 1982.
Kelly, P., & Krantzberg, M. *Technological innovation: A critical review of current knowledge.* San Francisco: San Francisco Press, 1978.
Lee, R. B. What hunters do for a living. In R. B. Lee & I. DeVore (Eds.), *Man the hunter.* Chicago: Aldine, 1968.
Lerner, I. M. *Genetic homeostasis.* Edinburgh: Oliver and Boyd, 1954.
Mayr, E. *Systematics and the origin of species.* New York: Columbia University Press, 1942.
Mayr, E. Isolation as an evolutionary factor. *Proceedings of the American philosophical society,* 1959, *103,* 221–230.
Mayr, E. *Animal species and evolution.* Cambridge, Mass.: Harvard University Press, 1963.
Mintz, S. Canamelar, the sub-culture of a rural sugar plantation proletariat. In J. Steward (Ed.), *The people of Puerto Rico.* Urbana: University of Illinois Press, 1956.
Murdock, G. P. Evolution in social organization. In *Evolution and anthropology: A centennial appraisal.* Washington, D.C.: The Anthropological Society of Washington, 1959.
Murphy, R., & Steward, J. Tappers and trappers: Parallel processes in acculturation. *Economic Development and Culture Change,* 1955, *4,* 335–355.
Rapoport, A. The uses of mathematical isomorphism in general systems theory. In G. J. Klir (Ed.), *Trends in general systems theory.* New York: Wiley, 1972.

Rappaport, R. A. *Pigs for the ancestors: Ritual in the ecology of a New Guinea people.* New Haven: Yale University Press, 1968.
Robert, S. First Conference on Technology Transfer and Innovation, 1982. In M. Hooker (Chair), Roundtable Session on Industry–University Research, Washington, D.C., Sept. 13–14, 1982.
Roosevelt, T. *Biological analogies in history.* New York: Oxford University Press, 1910.
Sahlins, M. D., & Service, E. R. *Evolution and culture.* Ann Arbor: University of Michigan Press, 1960.
Schoch, R. M. Letters to the editor. *Science,* 1982, *220,* 360.
Service, E. Indian–European relations in colonial Latin America. *American Anthropologist,* 1955, *51,* 411–425.
Service, E. *Primitive social organization.* New York: Random House, 1962.
Shimshoni, D. *Aspects of scientific entrepreneurship.* Unpublished doctoral dissertation, Harvard University, 1966.
Shimshoni, D. The mobile scientist in the American instrument industry. *Minerva,* 1967, *8*(1), 59–89.
Solecki, R. S. Shanidan Cave, a later Pleistocene site in northern Iraq. *Report of the VIth International Congress on the Quaternary,* 1964, *4,* 413–423.
Steward, J. H. Cultural causality and law: A trial formulation of the development of early civilization. *American Anthropologist,* 1949, *51,* 1–27.
Steward, J. H. *Theory of culture change: The methodology of multilinear evolution.* Urbana: University of Illinois Press, 1955.
Tanner, T. M. *Focus into man: Physical growth from conception to maturity.* Cambridge, Mass.: Harvard University Press, 1978.
Toffler, A. *Future shock.* New York: Random House, 1970.
Tornatzky, L. G., Eveland, J. D., Boylan, M. G., Hetzner, W. A., Johnson, E. C., Roithman, D., & Schneider, J. *The process of innovation: Analyzing the literature.* Washington, D.C.: National Science Foundation, 1982.
Turnbull, C. *The Mountain People.* New York: Simon & Schuster, 1972.
U.S. Department of Commerce. *Technological innovation: Its environment and management.* Washington, D.C.: U.S. Government Printing Office, 1967.
Watson, P. J., LeBlanc, S. A., & Redman, C. L. *Explanation in archeology.* New York & London: Columbia University Press, 1971.
Weinberg, D., & Weinberg, G. M. Biological and cultural models of inheritance. *International Journal of General Systems,* 1974, *1*(2).
White, L. Energy and the evolution of culture. *American Anthropologist,* 1943, *45,* 355–356.
White, L. A. History, evolutionism and functionalism: Three types of interpretation of culture. *Southwestern Journal of Anthropology,* 1945, *1,* 221–248.
White, L. A. *The science of culture.* New York: Grove, 1949.
White, L. A. The concept of evolution in cultural anthropology. In *Evolution and anthropology: A centennial appraisal.* Washington, D.C.: The Anthropological Society of Washington, 1959.
Wissler, C. *An introduction to social anthropology.* New York: Holt, 1929.
Wolfe, E. Closed corporate peasant communities in Mesoamerica and central Java. *Southwestern Journal of Anthropology,* 1957, *13,* 1–18.
Wolfe, E. *Peasants.* Englewood Cliffs, N.J.: Prentice–Hall, 1966.