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The Two Ecologies: Population and Com- munity Perspectives on Organizational Evolution

W. Graham Astley

This paper distinguishes between two ecological perspectives on organizational evolution: population ecology and community ecology. The perspectives adopt different levels of analysis and produce contrasting views of the characteristic mode and tempo of organizational evolution. Population ecology limits investigation to evolutionary change unfolding within established populations, emphasizing factors that homogenize organizational forms and maintain population stability. Population ecology thus fails to explain how populations originate in the first place or how evolutionary change occurs through the proliferation of heterogeneous organizational types. Community ecology overcomes these limitations: it focuses on the rise and fall of populations as basic units of evolutionary change, simultaneously explaining forces that produce homogeneity and stability within populations and heterogeneity between them.[•]

In adopting an analytical focus on events within already-established populations, population ecology has failed to explain how new organizational forms originate. Hannan and Freeman (1977: 936), for example, began their analysis of population ecology with the question: "Why are there so many kinds of organizations?" This question focuses inquiry on organizational diversity, the differentiation of organizations into varying population types, but as a point of departure for population ecology is misleading. Population ecology emphasizes forces that make organizations more uniform rather than more diverse. The theory of natural selection does not explain how new populations multiply to increase organizational variety; instead, it begins with existing populations and explains how differential survival progressively refines and homogenizes organizational forms as it perfects their adaptation to environments. By filtering out unfit members of the population and favoring only that subset of organizations optimally adapted to a given configuration of niche constraints, natural selection reduces rather than increases organizational diversity.

By limiting investigation to factors underlying the differential success of individual organizations within populations, population ecology does not account for the differential success of populations themselves as units of change. In order to account for this differential success, a "community ecology" framework of analysis is adopted in this paper that focuses inquiry on relationships between multiple, diverse populations in organizational "communities."¹ Populations multiply and survive only as constituent elements of a broader system of community evolution, and investigating this source of change calls for a higher level of analysis than that used by population ecologists (Carroll, 1984). Community ecology encompasses and complements the population ecology perspective: populations can only be regarded as basic units of analysis within a larger community if they persist as stable, internally uniform entities. The community ecology approach thus explains organizational evolution as the joint product of forces that simultaneously produce homogeneity and stability within populations and diversity between them.

The evolutionary development of organizational communities as sets of diverse, internally homogeneous, populations depends crucially on the nature of the technologies on which

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This distinction between population ecology and community ecology parallels the division of bioecology into "autecology," the study of individual organisms within single populations, and "synecology," the study of multiple, interdependent populations within communities and ecosystems (Whittaker, 1975: 4-5).

those populations are based. Population ecologists (McKelvey, 1978, 1982; McKelvey and Aldrich, 1983) have argued that technological factors are important in shaping population forms: organizations within populations become more homogeneous as they converge on a common set of techniques and know-how, while differences in technologies that result from the difficulty of transferring technologies across population boundaries differentiate populations from each other. What population ecologists have failed to address, however, is the role of technology in linking together multiple populations in larger complexes. Interdependencies between the technologies of different populations fuse those populations together into functionally integrated systems, or organizational communities. Only those populations able to function as constituent members of such communities survive.

To account for the rise and fall of populations as units of change, this paper focuses on technological innovation as a central force underlying evolution within organizational communities. The effects of technological change ramify throughout organizational communities as populations centered around sets of conventional technologies are replaced by clusters of new populations based on symbiotically related innovations. Instead of conceiving of population forms in terms of common structural, or morphological, characteristics — the approach adopted by population ecologists (e.g., Hannan and Freeman, 1984) and recently criticized by Betton and Dess (1985) — the community ecology approach thus conceptualizes population forms in terms of their functional roles vis à vis other populations within technologically interdependent communities. The latter conception focuses on what populations actually do in order to survive and corresponds to functionally based conceptualizations of niches (and, hence, population forms) currently favored in ecological theory (Whittaker, Levin, and Boot, 1973). The value of this approach can be seen by contrasting it with and showing how it overcomes limitations inherent in the population ecology perspective.

POPULATION ECOLOGY

Phyletic Gradualism

Population ecology focuses on how populations of organizations are transformed from within by the differential success of their constituent members. Some organizations fail and are selected out, while others survive. At the same time, new organizations are created and enter the population. As these units replace their failed predecessors, the population as a whole gradually changes composition. As Aldrich and Auster (1986) put it: "selective retention and creation at the organizational level of analysis creates metamorphosis at the population level." The analysis typically begins with a given type of population and investigates how natural selection progressively transforms that population over time (Carroll and Delacroix, 1982; Delacroix and Carroll, 1983; Freeman and Hannan, 1983; Tucker, Singh, and House, 1984; Tucker et al., 1985). Ecologists refer to such change as "phyletic gradualism," the gradual one-by-one selection of population members within single lines of descent, or lineages (Eldredge and Gould, 1972).

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By concentrating attention on phyletic change within single, continuous lineages, population ecology fails to capture the evolutionary change associated either with the formation of entirely new populations or with the extinction of old ones. First, as McKelvey (1982: 438) noted, population ecology focuses not on the origin of populations but on their regulation and growth once they have been recognized as existing. This perspective, consequently, cannot account for increases in the number or diversity of different population types. If new organizational forms emerge only through gradual transformations in which they replace older forms, no additional populations are introduced. Similarly, population ecology cannot account for population extinction, the death of all organizations within a population. For selection to operate through differential survival, some organizations must prevail as the successful competitors — they can't all disappear.

Population Stability

Population ecology not only fails to explain the emergence of diverse organizational forms through the birth of new populations, it emphasizes the production of homogeneity and stability within existing populations. The very utility of the population perspective is based on the assumption of relative permanence in population forms (Aldrich, McKelvey, and Ulrich, 1984). Though population ecologists contend that evolutionary transformations unfold gradually within populations, they note that such transformations occur only within the context of overall population stability. The perspective, consequently, seems to concentrate more on how populations withstand change than adapt to change.

McKelvey (1982: ch. 7) thus argued that while populations change incrementally over time, they persist as stable "organizational species." Organizational species can be distinguished in terms of their dominant competencies, or "comps," that is, in terms of their characteristic technical and managerial know-how. Comps play the same role as genes in population gene pools. Organizations of the same species share in the same "intercommunicating compool" and thereby transmit technical and managerial know-how from one generation of employees to another. Just as biologists have found that interbreeding and gene flow stabilize biological species (Mayr, 1963: 178), so information flow stabilizes organizational species. Intercommunication establishes a common reservoir of ideas that binds organizations together into a unified entity (a species) that persists over time. Moreover, just as the high flow of comps within populations unifies species, the restricted flow of comps between different populations isolates species from each other. Populations retain their distinctive character over time because dominant competencies are not easily learned or transmitted across population boundaries.

Work on the diffusion of innovations provides support for the idea that populations function as intercommunicating compools. Mansfield (1968: 126) reported on one study of decisions organizations made to adopt new techniques. Only about half of the information on which decisions were made was generated within the adopting firms; the other half was technical information transferred into the firm from other firms in the industry. Moreover, he found that within an industry,

information transfer about a new technique diffuses exponentially once the technique is introduced. The probability that a firm will introduce a new technique is an increasing function of the proportion of firms already using it (Mansfield, 1968: 133). This "bandwagon effect" is good evidence of how communication between the members of organizational populations stabilizes population identities over time. It is one example of what DiMaggio and Powell (1983) have called "mimetic processes" that encourage organizations within a population to mimic each other as a way of dealing with uncertainty.

Further, Sahal (1981:57) has provided empirical evidence for the idea that isolating processes differentiate populations from each other. In support of what he calls the "principle of technological insularity," he found an observed lack of inter-industry transmission of technical know-how. Know-how seems to be, in large part, product- and industry-specific. The development of technology takes place through a process of learning that is context dependent, bottled up in the industry of its origin. Technical progress in an industry generally depends on the gradual acquisition of skills through participation in the production process on which the industry is based. Since learning takes place through direct experience, industries face significant costs not only in the search for technologies developed elsewhere, but in adapting those technologies to the new conditions in which they are to be used. Such costs drastically reduce the influx of new techniques into an industry, limit organizational variability within the population, and, consequently, stabilize its form over time.

The Limits of Phyletic Evolution

The contention that populations exhibit overall stability as distinct entities must be reconciled with the idea that phyletic evolution gradually modifies population forms over time. What, in fact, occurs is that phyletic evolution transforms populations, but within the limits set by the overall propensity of those populations to adapt. This is because selection can only transform a population if the population exhibits sufficient internal variability as raw material from which the environment can select. But, as intercommunicating compools, organizational populations homogenize themselves through an inbreeding of technical know-how and are largely cut off from sources of environmental variation.

The limitations on change produced by an inbreeding of technical know-how are described by Sahal (1981: 32), who noted that once a branch of industry is established, the core technology on which it was founded remains largely unchanged. Modifications that are made tend to be, from a design standpoint, only incremental, even if they are highly significant improvements from a cost standpoint. This is because the basic design of a technology acts as a "guidepost"; it embodies a set of ground assumptions and starting premises that constrain the course of subsequent improvements in that technology's form and govern the extent to which further innovation is possible. Sahal cites as examples the farm tractor, airplane, and electric motor industries, all of which rely on core technologies introduced over half a century ago. These technologies have undergone a great deal of cost improvements since then, but such progress has occurred only

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through a gradual refinement of essentially invariant patterns of design. Moreover, as Kuznets (1930) and others have noted, gradual modifications and improvements in a given basic form of technology can only go so far. The marginal returns of further innovative advances inevitably decrease as their marginal costs increase. The development of a technology eventually reaches certain dead ends, with little prospect for further advances in its capability.

From the population ecology perspective, these observations suggest that while natural selection may, to some extent, modify populations over time, the populations ultimately stabilize in form. Phyletic change is governed by limiting parameters that entail an eventual exhaustion of evolutionary development within populations founded on a given technology. The gradual transformation of a population through natural selection only refines the basic organizational form established at the population's inception. Chandler (1977: 48–51) thus described how "technological limits to institutional change" preserved, virtually unchanged, the "traditional" form of single-unit business enterprise for several centuries, despite constantly changing economic conditions in the U.S. economy throughout that period. When modern multiunit business enterprises did eventually replace traditional forms, moreover, they emerged quite suddenly, rather than through a gradual transformation of traditional forms. Before 1870, very few modern business enterprises existed, but by 1920 they dominated the U.S. economy. The coming of such enterprises marked a "revolution" in American business. The modern organizational form did not descend phyletically from the traditional form; it appeared only with the emergence of new populations in new sectors of industry founded on new technologies. This source of change, the proliferation of new organizational forms through the differentiation of new population types, has dominated the course of institutional evolution in U.S. business history. Population ecology's focus on phyletic descent within relatively stable populations fails to address this revolutionary source of change and is, therefore, severely limited as a theory of evolution.

Environmental Isomorphism

The stability that organizational populations exhibit over time calls into question a central assumption of the population ecology perspective: the notion that natural selection transforms populations by making them isomorphic with their environments. According to population ecologists, environments select only "optimal" forms as they perfect organizational adaptation to the environment (Hannan and Freeman, 1977: 939). Organizational forms that do not exactly "fit" a predefined configuration of niche constraints are selected out, as if filtered through an environmental sieve of definite mesh. To survive, organizations must conform to intractable "selection criteria" that offer little recourse to organizations maladapted for a given environment. This results in what Hannan and Freeman (1977: 957) refer to as the "principle of isomorphism," according to which a "one-to-one correspondence" between organizational forms and environmental selection criteria is established.

The apparent stability that populations exhibit over time does not, however, support the contention that organizational populations inevitably become more isomorphic with their environments. For example, Stinchcombe (1965) found that different organizational types originated at different points in history, and, once formed, tended to persist relatively unchanged. Organizational forms established in older industries reflected the "social technologies" available at the time of their founding, and these older industries did not significantly modify their characteristic forms as new industries, based on new organizational forms, arose alongside them. Given that environments presumably changed rather constantly over these time periods, Stinchcombe's (1965) analysis suggests that organizational populations do not closely track changes in their environments. They persist, instead, because of "internal traditionalizing processes" (Stinchcombe, 1965: 168), not because of their adaptive superiority in current environmental conditions. Contrary to the population ecology view, forces external to populations do not inevitably move organizations toward a better fit with their environments. Instead, homeostatic forces within populations predominate over environmental selection to retard evolutionary change and preserve what are, in effect, nonadaptive forms (Gould, 1980). Well-established populations typically survive over their life-spans without evolving very noticeably and without maintaining a tightly adjusted relationship to their surroundings (Stanley, 1979).

Competitive Saturation

Paradoxically, even where environmental selection does shape population forms, it effectively inhibits rather than promotes the emergence of organizational diversity and change. The conditions under which environmental selection has its greatest impact are those conditions that encourage homogeneity and uniformity within organizational populations. This follows from the idea that selection operates under conditions of resource scarcity (Aldrich, 1979: 27–28). When the "environment optimizes," as Hannan and Freeman (1977: 939) put it, it does so by selecting that subset of organizations that compete best for limited resources. This implies that environments are always more or less saturated with competitors — a key premise of natural selection arguments (Stanley, 1981: 52). The assumption of competitive saturation is important in this sense: for the environment to optimize, that is, to choose between competitors, the joint demand of those competitors must exceed the available supply of environmental resources, so that only a limited range of the most fit organizations are selected. The rigors of competition place organizational mutations at a survival disadvantage, as they stray from the population's "modal form" (McKelvey, 1982: 100). Homogenization is thus inevitable in competitively saturated environments of finite resources (Hawley, 1950: 202). Population ecology's focus on selection through competition, therefore, points to factors that reduce rather than increase organizational variety and that effectively slow down the rate of evolutionary change.

Population ecology's emphasis on selection in competitively saturated environments is directly linked to its analytical focus

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on stable, well-established populations. Selection within a population begins to operate as available resources within a niche start to become exhausted. In industrial contexts, this occurs in the firm "shake-outs" characteristic of later stages of the product life cycle. At this stage of population growth, competition centers on the exploitation of economies associated with standardized products and technologies and is oriented toward price and cost reduction. Such "price competition" contrasts with the "competition through innovation" associated with earlier stages of the product life cycle (Kamien and Schwartz, 1982: 23). In the latter form of competition, rivals compete not by producing standardized goods and services more cheaply for saturated markets, but by discovering new, unsaturated, niches and offering innovative goods and services that no one else can supply. The existence of untapped demand at the incipient stage of population growth encourages experimentation and permits a variety of organizational forms to coexist before a dominant population form emerges in later stages of population growth (Moore and Tushman, 1982: 134). Most organizational change and diversity arises from this process through which new populations are initially established. This is why a community ecology approach, focusing on the origin of new lineages rather than just on selection within established lineages, is necessary.

COMMUNITY ECOLOGY

Punctuated Equilibrium

The one major point of convergence between population ecology and community ecology is the common assumption that various forces work to produce an overall stability in population forms. The community ecology approach goes beyond population ecology, however, in identifying the beginning and end points of such stability. According to this approach, because organizational populations are rather stable, most organizational change must occur in the process through which new populations are born and old ones die. Discrete origins and extinctions thus "punctuate" extended periods of negligible change, or "equilibrium," in population forms (Eldredge and Gould, 1972). Evolution consequently moves with an episodic, not gradual, tempo. An abrupt branching of new lineages produces a stepwise rather than a continuous pattern of change. Instead of replacing their ancestors through a steady process of transformation, new populations diverge to coexist alongside their ancestors until the latter are suddenly extinguished.

Mensch's (1979) work on technological innovation points to the relevance of the punctuated-equilibrium model in describing the evolution of industrial structure. He distinguishes between "improvement innovations," which cumulatively refine a given technology, and "basic innovations," which open up new realms of activity by creating new markets and new branches of industry. Significantly, he compares technological development to the growth of an "evolutionary tree" in which basic innovations produce new branches, and improvement innovations account for linear extensions of those branches. If we assume that different branches of industry must be occupied by significantly different population forms, we can treat the occurrence of basic innovations as the establishment of

new lineages and the occurrence of improvement innovations as phyletic evolution within lineages.

Mensch's (1979) data reveal that after a basic innovation is launched, it is followed by a series of improvement innovations that, at first, are introduced slowly but then with accelerating speed, before finally slowing down and leveling off. This leveling off occurs with the increasing perfection of the basic technology until the potential for additional improvements in form is exhausted. Further, because successive improvement innovations become increasingly costly, demand falls off and a lull in the industry's growth follows, as the market saturation characteristic of later stages of the product life cycle approaches. At this point, the industry finds itself in a "technological stalemate," which it can only surmount by switching to new lines of development founded on new basic innovations. The pattern of industrial evolution that emerges is characterized by "spurts of basic innovations and subsequent sequences of improvement innovations that eventually run out of steam" (Mensch, 1979: 41).

The Direction of Evolution

One centrally important point in Mensch's (1979: 48) argument is that "these two forms of innovation are explained by completely different theories." The technological guideposts that culminate in a dead-end street determine the direction in which improvement innovations go. But technological stalemates produce conditions that introduce random elements. The situation becomes "structurally ready for basic innovations that could go in several directions" (Mensch, 1979: 74). The eventual adoption of a particular innovation typically depends on a multitude of chance events. The random element in change is crucial here, because it brings into operation a set of factors different from those underlying phyletic evolution. While phyletic evolution is subject to certain limiting constraints, the birth of new organizational species opens up new avenues of development in what is inherently an unpredictable pattern of evolution.

Piore and Sabel (1984), for example, compared the course of industrial evolution to the growth of a "branching tree." Long periods of stability, they contended, are abruptly ended by innovative breakthroughs that move industrial evolution down entirely new paths. Stability results from the adoption of a given technology: once made, technological choices entail large investments in equipment and know-how and so discourage subsequent changes in the course of industrial development. But, eventually, the limits of existing arrangements are felt, and impending crisis fosters the branching of new industrial sectors. Most important, these branching points, or "industrial divides," divert change in unpredictable directions; fortuitous events punctuate history, switching the course of evolution onto new, divergent tracks. New technologies do not simply emerge as logical extensions of old technologies. Rather, the choice of new technologies is governed by "historical happenstance" and "blind decision," not by technical necessity. The triumph of a technological breakthrough over competing adaptations depends on its timing and the resources available to its champions rather than on its intrinsic superiority. In other words, history might have turned out

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differently: industrial evolution is filled with abandoned, though technically viable alternatives to what exists.

Quantum Speciation

For bioecologists, the random part of the process through which new species branch off from old ones lies in the fortuitous set of conditions that promote the emergence of mutant forms. When such forms successfully take hold and survive, they do so through a process known as "quantum speciation" (Grant, 1963), in which certain factors suspend the forces that normally limit change to the gradualistic pattern produced by phyletic evolution. One such force, of paramount importance, is population gene flow, which retards evolutionary change by suppressing the emergence of radical mutations. Though genetic mutations occur all the time within species, they typically do not take hold, since they are outnumbered in the population gene pool and rapidly dissipate through the normal intermixing process. However, if by accident a geographic barrier happens to isolate physically a few mutant individuals, they may escape homogenizing pressures in their parent population, interbreed among themselves, and eventually become reproductively isolated to form a new and quite different species. A combination of two random events, mutation and isolation, is necessary for quantum speciation to occur.

Basic technological innovation can be thought of as the organizational counterpart to biological mutation. Basic innovations emerge through a process that is clearly parallel to quantum speciation in the biological world. The growth of the U.S. semiconductor industry is a prime example of an industry whose development comprised a long series of linked quantum speciations (Brittain and Freeman, 1980; Braun and MacDonald, 1982). The industry's growth has been dominated not by technological evolution within single lineages, but by a branching process in which each new branch emerged with the rise of a different genre of firms riding the wave of an ascendant technology. This has meant a continuing and dramatic turnover in the identity of the industry's market leaders, as early receiving-valve manufacturers were successively displaced by transistor firms, semiconductor companies producing various kinds of integrated circuits, and, most recently, businesses exploiting microprocessor technology.

The advent of each new innovation has underscored the importance of isolation in the speciation process. The critical factor fostering technical advance was not the invention of new devices but isolation of the development of those devices from the source of their invention. For example, established receiving-tube firms such as General Electric, RCA, and Raytheon played a dominant role in improving transistor design, performance, and manufacturing processes in the early fifties. But despite all the money and effort they put into research and development and the fine record of patent awards and innovation of these valve companies, the transistor market early and rapidly fell into the hands of new companies such as Texas Instruments, Transitron, and Hughes. The explanation for this is that the established firms looked upon the transistor simply as a replacement for the valve and were largely unaware of the impact it could have. Since the transistor was so radically

different from the valve in the way it worked and in the way it could be manufactured and sold, it could not be comfortably accommodated in the settled technological atmosphere of the existing industry without changes that the industry was then unwilling to make.

A similar pattern is evident in the case of integrated circuits and later the microprocessor. The key to the success of these new developments was not that they captured segments of existing markets but that they opened up a whole spectrum of new markets. As very small firms, Fairchild and Intel pioneered, respectively, the planar process and the microprocessor and so fostered the creation of new "compoos," as small offshoot populations expanded into entirely new niches. Spin-offs begun by personnel from Fairchild in particular were responsible for the creation of the "Silicon Valley" phenomenon in California. This quasi-isolation of a critical mass of personnel using the same knowledge base and operating in the same locale freed the valley firms from the institutional constraints of the earlier industry. Silicon Valley is a prime example of how the isolation of one intercommunicating compool from another has been the key factor in industrial evolution.

Open Environmental Space

The isolation of mutant forms from a parent population will only succeed in establishing a new population under certain conditions. "Ecological opportunity" (Stanley, 1981: 96) must be available for the mutant population to colonize its new environment successfully. This will exist where competitive saturation of the new environment is at a level low enough to relax selection pressures. The environment must approximate an "unfilled ecospace," unoccupied by other populations (Gould and Eldredge, 1977: 144). Otherwise, the mutant forms will be "crowded out," just as they would be in their parent population. Open environmental space is needed to foster a release of variability that would normally be held in check by the stabilizing selection characteristic of the competitively saturated environments that are highlighted by population ecologists.

The availability of open environmental space as a key factor in the evolution of the semiconductor industry is indicated by the following observations drawn from Brittain and Freeman (1980). First, each technological innovation opened up new environmental space as "first mover advantages" were exploited before "population densities" and competition were able to increase. Second, this resulted in "exponential" growth after the introduction of each innovation, indicating that growth was a function of accelerating organizational learning curves — those characteristic of early sigmoid population growth, before limitations of environmental carrying capacity are brought into play. Third, innovation created many and different avenues to success, often simultaneously in diverse niches and through diverse organizational forms, indicating that the environment was generally open and receptive to the many "random" variations that occurred.

These observations indicate that the growth of the industry was in large part driven by the internal potential of the semi-

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conductor firms for generating and developing technological opportunities and was not simply induced by external environmental forces. Economists call this the "technology-push," as opposed to the "demand-pull" explanation of innovation (Kamien and Schwartz, 1982: 33). In other words, when new population forms invade open environmental space, they need not be in any sense "optimally" fitted to the new environment. Instead, what happens is that the variant forms are permitted relatively unhampered expression; they impose their presence in a vacant environment where other variations might have survived equally well. New forms lay claim to an environment "simply by being first, not by being better in some Newtonian mechanical sense" (Gould and Eldredge, 1977: 144). The assumption of an isomorphic relationship between organizations and environments is, in this case, unwarranted.

The notion of open environmental space consequently has important implications for the environmental determinism-strategic choice debate. Population ecologists have tended to conceptualize the environment in terms of forces and constraints that impinge on organizations. The view of niches as intractable concentrations of resources that may or may not be occupied, depending on whether organizational forms "fit" a predefined configuration of resource constraints, is indicative of this (Freeman, 1982: 19; Aldrich, 1979: 112). The significance of the concept of open environmental space lies in the attention it draws to the receptiveness of the environment, not just to "optimally fit" organizational forms but to "tolerably fit" organizational forms. Within limits, a given environment may tolerate a variety of different forms, offering opportunity for variations to impose themselves on the environment. In this sense, niches do not pre-exist, waiting to be filled, they materialize as the product of organizational action (McKelvey, 1982: 109). Organizations do not, in other words, fortuitously fit into predefined sets of niche constraints; rather, they opportunistically enact their own operating domains.

In reality, debating whether organizational action is the product of opportunistic choice or environmental constraint is like debating whether a glass is half empty or half full. All environments have resource constraints, but then some have more than others. By the same token, therefore, some environments must have fewer resource constraints than others. The latter exhibit less stringent selection criteria and thus are more open to the emergence of new variations. Environmental constraint, seen from one point of view, is, consequently, open opportunity, from the other. As the opposite side of the coin from environmental selection, opportunistic choice is thus the central dynamic of organizational change whenever conditions of environmental openness prevail. Its importance diminishes to the extent that environments are competitively saturated.

Organizational Communities as Ecological Systems

Community closure. This leads us to a consideration of organizational communities as contexts governing the extent to which ecological opportunity, in the form of open environmental space, is available. Organizational communities are functionally integrated systems of interacting populations; they are emergent entities that, over time, gain a degree of autonomy from their environments. This occurs as populations

within communities begin to function mainly by exchanging resources with each other rather than directly with the environment. The more that communities elaborate this internal structure of functional interdependencies, the more they shut themselves off from outside influences. By locking their members into a given set of relationships, communities approximate closed systems containing a limited number of possible niches within their boundaries. As communities evolve toward such closure, niches are progressively filled, and competitive saturation gradually inhibits the emergence of new populations. Community closure is thus the major factor regulating the availability of open environmental space.

Community closure evolves through a characteristic pattern of development known in ecological theory as "succession" (Odum, 1969). During succession, change unfolds simultaneously in the structure of relationships within populations and in the structure of relationships between populations. Succession thus involves a development of community relationships along two axes, the competitive and the symbiotic (Hawley, 1950: 201–203; 1968).

Competition. Initially, the supply of environmental resources within a particular niche exceeds the joint demand of units having similar needs, so that competitive relationships are absent. When demand begins to exceed supply, competition ensues, which induces increasing homogeneity among rivals as they seek the most efficient means of competing. Then the pressure of congestion begins to operate selectively, eliminating the weakest competitors. Elimination continues until demand no longer exceeds supply and is renewed whenever an imbalance occurs. At this point, the limits of competitive saturation are reached, and equilibrium is maintained through the selection mechanism. The result is that the population stabilizes both in size and in characteristic form. This pattern of development, culminating in equilibrium, is represented in the familiar S-shaped or sigmoid growth curve.

The parallel with the product life cycle that typifies industrial evolution should be clear. Edwards (1979: 40) has outlined how, between 1870 and 1900, the U.S. steel industry evolved toward a stable state, through what he described as "natural" equilibrating forces of competition. Stabilization occurred as competition within the industry, by reducing prices and shrinking profit margins, drove all producers to seek new markets, expand production, and reduce costs in order to survive. But a consequent intensification of competition robbed entrepreneurs of their expected excess profits. Their only resource was then to reinvest in new and expanded production, in the hope that innovation or expansion would lower the entire cost curve and restore lost margins. But competitors soon adopted these innovations, and prices declined again. Inefficient producers were quickly eliminated and the stage was set for renewed competition between the remaining survivors. With producers seeking to recoup profits by expanding production, the industry also found itself overproducing for the market. This cycle of spiralling competition, among firms whose production capabilities expanded more rapidly than the market, continued until a stable industry emerged, dominated by a small, homogeneous set of producers competing on similar terms.

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Symbiosis. While competition runs its course within populations, symbiotic interdependencies emerge between those populations. This begins as new populations branch out from established ones to fulfill ancillary roles in which they become dependent on but noncompetitive with their ancestors (Hawley, 1950: 203). In the early stages of community development, branching occurs frequently, since many niches are available. Invasions of the community by populations from outside also occur. In this way, functional complementarities and interpopulation dependencies rapidly multiply as an integrated community develops (Daubenmire, 1968). This process continues until the community reaches a certain size, after which the complexity of its internal relationships can no longer increase without reducing the community's effectiveness as a functional unit (Hawley, 1950: 203). With the approach of this "climax" stage, the emergence of new populations progressively winds down (Whittaker, 1975; Pianka, 1978). The climax stage also coincides with competitive saturation within populations, since numbers in each population are balanced against the needs of other populations. Since the community as a whole is now "full," no new populations can be added without disturbing the functional integration of the system. At this point, the community is in equilibrium. It is a closed, self-contained, self-maintaining system, marked by stability in the form and numbers of each population (Gutierrez and Fey, 1980).

Though by no means verifying this model in its details, Chandler's (1977) description of how the railroads initiated a whole series of developments in the U.S. economy does suggest the central role that symbiotic interdependence plays in industrial evolution. The railroads were at the center of the intricately interrelated transportation and communications infrastructure, which provided the right-of-way for telegraph and telephone lines and also encouraged the formation of the modern postal system. In addition, the railroads came to operate nearly all domestic steamship lines in the U.S., and their stations acted as central points for the development of urban traction systems. Distribution and marketing enterprises arose that relied on the telegraph and postal services to transact business and on the railroads and steamships to deliver on a precise schedule. Later, department stores, mail-order houses, and chain retail stores were also able to capitalize on high-volume, high-turnover sales made possible by the transportation and distribution systems, which, in turn, opened up national markets for mass producers. Finally, within manufacturing, consumer-goods industries relied heavily on the growth of chemical and oil refining, metal-working machine and tool production, and other producer-goods industries. In short, the early development of the U.S. economy depended on a series of direct working relationships between industries that could only function on a large scale as symbiotic partners.

Community stability. The growth of internal complexity accompanying system closure fosters a stabilization of communities but also sets them up for eventual collapse. When stability develops within communities it is often only precariously maintained. May (1973: 173), for example, contended "that complex and stable natural systems are likely to be fragile, tending to crumple and simplify when confronted with disturbances beyond their normal experience." If com-

plex communities experience disturbance beyond a certain threshold level, they may disintegrate because of a domino effect (Curtis, 1956; Paine, 1966). Loucks (1970) has consequently observed that succession produces "periodic waves," with episodes of instability interjected into extended states of equilibrium. As Golley (1977: 326) put it: "Climax communities are defined as dynamic equilibrium states that are persistent through time. A severe disturbance upsets this equilibrium or destroys the community, and recovery of an equilibrium condition eventually occurs through ecological succession."

The succession model of community evolution is, thus, entirely consistent with a punctuational view of change. Community succession functions as the regulator determining the availability of open environmental space. Community closure progressively eliminates open space and inhibits the potential for new populations to emerge. The sudden disintegration of communities may therefore empty the environment and invite a flood of quantum speciations to take advantage of the new opportunity. In the organizational context, this would mean long periods of little change in industrial structure, followed by episodes in which numerous new branches of industry are established before activity again stabilizes.

Mensch's (1979) research on "basic innovations," in fact, revealed such a pattern. He found that basic innovations occurred in clusters. That is, multiple branches of new industry arose together as they replaced old, stagnating economic regimes, themselves comprised by multiple interdependent sectors. Specifically, he found that the crests of waves of basic innovations occurred in 1825, 1885, and 1935, right in the middle of major economic depressions. The first wave resulted from the technological growth driven by developments in electrical production, railroads, steel, cement, and pharmaceuticals and was fueled primarily by wood. The second wave was based on a group of technologies, including vulcanized rubber, photography, electric motors, electric lighting, the telephone, the steam turbine, and others, and was fueled primarily by coal. The technologies driving the third wave included the jet engine, plastics and polymers, automotive technology, and electronics, with oil being the important energy source.

Mensch (1979) contended that the transition from one set of dominant technologies to another is discontinuous, because there is no preparation for the new wave until the old one is spent. If reasonable prosperity exists, there is generally little incentive to go into anything new. Innovative possibilities are easily buried in this situation. Investment in current operations pays satisfactorily, without the risks and possible disruptions attending untried ventures. But economic stagnation is the inevitable result of this policy, and eventually crisis must ensue. At this point, all of the potential changes that were earlier delayed may now be unearthed, as traditional modes of production are called seriously into question. This is why basic innovations occur in periods of depression. Capital suddenly seeks new kinds of investments because the old ones are demonstrably in trouble.

What Mensch failed to address specifically, though it was implied, is why economic stagnation would appear across

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multiple industrial sectors nearly simultaneously. Research by Clark, Freeman, and Soete (1981) suggested an answer. These authors provided additional data confirming Mensch's observations on innovation clustering but argued that his explanation for this clustering reveals only part of the whole story. They contended that the bunching of basic innovations is not just depression-induced, in the sense that new technologies are called upon to replace the old exhausted ones. Bunching, they suggested, may be related to fundamental breakthroughs in science and technology, as bursts of invention produce technically related families of innovations — what Schumpeter (1939) described as the "swarming" of innovations. Rosenberg (1979) offered a similar interpretation, arguing that the key to industrial growth lies in this interlocking of mutually reinforcing technologies. He suggested that innovation clustering underlay the early industrial revolution and also the clusterings around electrification beginning in the late nineteenth century, around the internal combustion engine in the early twentieth century, and around plastics, electronics, and computerization in more recent years.

These interpretations are not incompatible with Mensch's (1979) position. The argument that depression acts as a trigger for major innovations does not preclude a subsequent explosion of related innovations based on common technological synergies. Moreover, if new industrial complexes are set in place by interrelated clusterings of innovations, then we would only expect these technologies to stagnate in tandem and produce a coordinated demise of old industrial complexes. As Rosenberg (1979) suggested, technologies are linked not just in the sense that one innovation leads to the introduction of others but in the sense that their continued functioning is possible only by virtue of an ongoing symbiotic relationship.

Note, also, that the provision of open environmental space, not invention alone, is the key factor underlying innovation clustering. For example, for a number of decades the U.S. telecommunications industry has experienced steady development, measured growth, and relative stability. But, suddenly, the onset of deregulation has fostered an accelerating curve of new technologies and a consequent reshaping of industrial structure (Astley and Fombrun, 1983). The result is a rapid proliferation of new population forms, virtually all of which are symbiotically related in technologically interdependent webs. The point here is not that new technologies have just been invented; most of their potential has long been well known. Rather, the existence of the stable AT&T regime at the hub of the telecommunications community delayed the implementation of these inventions, in spite of a changing scientific and technical environment. Only the exogenous shock of government regulation finally destabilized the industry, providing open environmental space in niches formerly protected from competitive invasion.

CONCLUSION

The utility of the population perspective in organization theory is based on the dual assumption that organizations are neither "all unique" nor "all alike" (McKelvey and Aldrich, 1983). As a theory of evolution, however, population ecology explains only why the first of these assumptions holds; it draws attention to

homogenizing rather than to diversifying forces in change. Population ecology cannot account for the absolute proliferation or decline in the number of populations existing or account for the rise and fall over time of different population types. The approach does explain gradual transformations occurring within lineages, but this change occurs much too sluggishly to account for the large amount of organizational evolution that, in fact, takes place. Phyletic change, moreover, always eventually exhausts its potential for further development. The explanation of broad-scale, long-term evolution consequently requires the adoption of a community ecology approach in which populations themselves are basic units of change and communities are the relevant contexts of inquiry.

The two ecologies do not, however, differ simply with respect to levels of analysis; they imply that quite different principles govern the course of evolution. In the population ecology view, organizational change moves along environmental tracks. Selection operates as a rather efficient perfecting mechanism, keeping populations finely tuned to established niches. Evolution approximates a constrained optimization in which convergence on adaptively superior forms is attained. In the community ecology view, on the other hand, evolution may go in any direction; it is divergent rather than convergent, characterized by radiating growth rather than by limiting constraint. New populations typically succeed not because they more effectively duplicate functions performed by their predecessors but because they open up new niches and establish new avenues of development offering previously unforeseen growth potential. Instead of optimizing adaptive relationships to given environments, new populations create their own tracks in an emergent, inchoate, essentially random pattern of change.

The key difference between the two ecologies lies in their respective evaluations of the role that organizational variability plays in determining the course of evolution. Variation is an essential component of the population ecology model, but one that is always subjugated to forces of selection. The assumption is that when the environment dictates a change, appropriate variability is present within a population to provide an effective response to shifting selection criteria. Variation is, thus, simply the "raw material" (Aldrich, 1979: 31) on which selection operates. The community ecology view, in contrast, points to variation as an important evolutionary force in its own right. Chance, fortuity, opportunism, and choice are the dominant factors determining the direction in which evolution progresses. In the absence of selection pressures, organizational variability becomes, itself, the central dynamic of change.

Moreover, though variation and selection are, at different points in time, differentially salient as evolutionary forces, they should not be regarded simply as alternative sources of change. Strictly speaking, there is only one source of change, namely, organizational variation. Environmental selection only stabilizes population forms and, in effect, retards evolutionary change. To account for long-term changes in population forms by reference to shifting selection criteria (Aldrich and Mueller, 1982), for example, is to account for change indirectly by focusing on the consequences rather than on the direct causes of change. When selection criteria shift, it is only because organizational variations are successful in establishing new

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populations in which competition for scarce resources ensues. Selection is the regulator of evolutionary change; variation is its dynamo.

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