Historical Ecology:
Integrated Thinking at Multiple Temporal and Spatial Scales

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That man is, in fact, only a member of a biotic team is shown by an ecological interpretation of history. Many historical events, hitherto explained solely in terms of human enterprise, were actually biotic interactions between people and land. The characteristics of the land determined the facts quite as potently as the characteristics of the men who lived on it. A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self_renewal. Conservation is our effort to understand and preserve this capacity.

Aldo Leopold, <u>A Sand County Almanac</u> (1949)

The current alarming state of our planet necessitates that we respond both to global changes that make local differences and to local practices that influence global change. We are thoughtful primates, proud of our intellectual and technical accomplishments. But the truth is that we are only part of a complex network of elements and relations that make up planet Earth. Within this enormous ecosystem we live our lives influenced by events and conditions that began long ago and far away.

My aim is to bridge the gulf dividing the "Two Cultures"–C. P. Snow's term for the division between physical and biological sciences on the one side and the social sciences and humanities on the other (Snow 1959). To explain this focus I should offer some personal background. I read Snow's essay in high school, and was horrified to realize that I would soon have to choose "between camps." I avoided having to make that choice due to an early and abiding interest in archaeology, a discipline whose practice unequivocally requires both the sciences and the humanities. This meant, however, that my professional life would be spent trying to master very different areas of study and engaging in shuttle diplomacy among them. So I am trained in paleoclimatology, geomorphology, archaeology, anthropology, ethnohistory, and classics; I have some familiarity with complex systems theory, ecology, history, and geography. For thirty years I have been studying the historical ecology of Burgundy, France. We have been able to trace environmental worldviews–what Aldo Leopold terms a 'land ethic'–over some 2800 years' time and to connect local Burgundian practices with environmental, economic, and social changes at the global scale (Crumley 2000; Crumley and Marquardt 1987). It is with these tools that I pursue the practice and implications of historical ecology, hoping to help construct a theoretical and practical framework that will bridge the Two Cultures gulf. Other historical ecologists have different tools in their toolbox and diverse interests.

Historical ecology traces the complex relationships between our species and the planet we live upon, charted over the long term (Crumley 1987a, 1994, 1998, 2001; Balée 1998; Egan and Howell 2001; Kirsch and Hunt 1997). A term new to both ecology and to history[1], practitioners take the term *ecology* to include humans as a component of all ecosystems, and the term *history* to include that of the earth system as well as the social and physical past of our species. Historical ecologists take a holistic, practical, and dialectical perspective on environmental change and on the practice of interdisciplinary research. Historical ecologists draw on a broad spectrum of evidence from the biological and physical

sciences, ecology, and the social sciences and humanities.   Together, this information forms a picture of human-environment relations over time in a particular geographic location.   The goal of historical ecologists is to use scientific knowledge in conjunction with local knowledge to make effective and equitable management decisions.

Development of an interdisciplinary grammar and   the identification of shared concepts and understandings is fundamental to the practice of historical ecology.   A good example is the term *landscape,* a unit of analysis in many academic disciplines (archaeology, geography, geomorphology, ecology, architecture, art, regional planning) and also a concept recognized by the general public.   Such concepts, along with widely held understandings about the way the world works–what anthropologists call cultural models–provide the basis for decisions about which practices are maintained or modified and which ideas are given substance.   Landscapes retain the physical evidence of these understandings.   They record both intentional and unintentional acts and reveal *both* humans' role in the modification of the global ecosystem *and* the importance of past natural events in shaping human choice and action.   In short, landscapes are read and interpreted by everyone, as likely to promote lively discussion in a gathering of citizens as in a group of scholars from various disciplines.

A working definition of landscape is the spatial manifestation of the human-environment relation (Marquardt and Crumley 1987:1).   Landscape is thus a convenient idea that serves as an initial (but never the only) *spatial scale* of analysis.   This is for two reasons.   First, landscapes do not have an intrinsic spatial or temporal or cognitive scale (e.g., one can speak of the medieval landscape of Europe or New York's Central Park landscape or the Internet landscape), but what all landscapes have in common is that they allow us to follow changes in the interaction of humans with their environment over some specified amount of time.   Thus 'the medieval landscape of Europe' assumes that different elements and relations pertained in Roman or Renaissance or contemporary times and that 'Europe' itself was a different size and shape.   Second, all landscapes are in both real and cognitive 'flux' as they are physically modified and imagined in myriad ways.

The landscape 'scale' is thus powerfully integrative, enabling the simultaneous study of both the physical environment and human activity, and leading the investigation of factors that helped form a landscape–such as its geology, or an historical event, or an invasive species–to data aggregated at other scales.   As with spatial scales, multiple *temporal scales* are necessarily part of the analysis as data sets with different temporal ranges are collated. Together, spatial and temporal scales are only limited by available data and the research question, and can include a spatial range from microscopic to global and a temporal range from very recent events to deep geological time.

By integrating evidence from many different disciplines, the history of human-environment interactions may be sketched for a particular locale.   The unique characteristics of every place challenge researchers to integrate a congeries of empirical environmental and cultural information.   This necessarily requires the abandonment of notions of 'nested' variables–often collectively termed hierarchies–common in biology and appropriated by other disciplines.   In the real world, both environments and societies present themselves as mosaics, the temporal and spatial boundaries of which are fluid and crisscross one another (deVries 2001, 2002; Marquardt and Crumley 1987; Nicholas 2001; Pickett and White 1985; Wiens 1976; Winterhalder 1984).   Complex systems theory offers a means by which this non-hierarchical, nonlinear organization may be conceived in the term *heterarchy* (Crumley 1987b, 1995, 2001, 2003; Ehrenreich et al 1995; Hoffstadter 1987; Marquardt and Crumley 1987; McCulloch 1945; Minsky and Papert 1972).   The fundamental utility of this term for re-thinking human-environment relations will be explored below.

The social and environmental history of each region of the world may be investigated using archaeology, archival materials, oral tradition and history, and proxy measures drawn

from the Earth sciences for studying the area's previous and current environmental characteristics.   Of obvious importance are rules for analyzing and combining diverse categories of evidence.   For each category, the customary disciplinary techniques and protocols are respected (e.g., in the analysis of pollen or soil or the excavation of an archaeological site), but the structure of the inquiry as a whole is synergetic: collectively researchers exchange information and construct the overall design of the research, then continue to communicate as the work advances, together modifying the research design and working out problems as necessity arises (see Appendix A).

Inasmuch as historical ecology begins with the presumption that contemporary landscapes are the result of multiple factors that have interacted in complex ways throughout history, independent data sets provide an important cross-check in building consensus among collaborators.   For example, oxygen-isotope dating of Kenyan geomorphological samples places a flood event sometime during a 10-year period in a the mid-nineteenth century; oral tradition associates the flood with the initiation of an age-grade in 1856 or 1857.   If the evidence from the two sources is contradictory (oral tradition places the flooding in 1888), specialists then return to their data with new queries (How accurate is the chronological control?   Could there have been more than one flood event?).   Thus the advantages of both multi-disciplinary research (specialists work alone using appropriate techniques) and of interdisciplinary research (specialists cooperate and discover new aspects of their data) are combined.

While this working arrangement between the Two Cultures may sound ideal, everyone knows that very real battles are being fought.   Rather than following Snow into a dualistic world where warring camps send emissaries who more often than not meet a bad end, I suggest a means by which the perception of great dissimilarity between the two may be erased and a third great river of knowledge–older than either–be joined with them.   This latter is the empiricism which carried our most distant human ancestors into the present (Mithen 1996).   How was its value lost to us?   Three influential and interrelated movements in Western intellectual history--the Enlightenment, the formation of the first nation-states, and positivism–have led the majority of intellectual elites and a considerable portion of the general public to abjure traditional knowledge, an empirical tool with which humans have always made their way in the world.   In its place is an almost religious belief in our ultimate redemption by a sophisticated technology; somehow we will be saved from the outcome of our reckless use of chemicals, bioengineering, nuclear physics, and fossil fuels.

Do not mistake the arguments among the Two Cultures combatants as simply academic; they are profoundly political.   Everywhere their discourse advocates the dismissal of empirically derived qualitative information in favor of quantifiable data; the ridicule of indigenous knowledge in favor of technological superiority; the adoption of a definition of complexity that favors hierarchical power over democratic principles.   These premises, argued in scholarly articles innocently housed in dusty libraries, nonetheless underwrite global agendas that threaten the planet and impoverish humanity.

Historical ecologists regard history and politics as inseparable.   For example, changes in a landscape can be viewed as a history of shifting social power (Crumley 1987a; Mann 1986).   Viewed from the present day, landscape history is invariably tied to contemporary politics of compliance, often contrasting scientific and   institutional goals with traditional societies' practices and public awareness and participation (Brosius 2001; Johnston 1994, 1997, 1998, 2001).   One only need think of contested cities such as Jerusalem or contested monuments such as Devil's Tower in Wyoming, where Native American religious traditions are pitted against the very different interests of ranchers, sport climbers and the Park Service.   The study of collaborative schemes for solving such community and institutional differences of opinion on environmental issues has made

surprising headway in recent years.   Some of these schema–collective bargaining, stakeholder participation, role playing, and the European Union's term *concertation* (meaning cooperative dialogue)–produce solutions that are widely acceptable.   The study of such schemes underscores the fundamental role of values and perceptions in forming worldview.   Stakeholders challenge, debate, and come to understand one anothers' positions, and underlying values are examined in a new way (Poncelet 2001).   This does not mean that organic gardeners are converted to the use of pesticide but that the focus of the discussion becomes the stewardship of the Earth and not confrontation.   The collective value, then, is environmental well being and not the ironclad correctness of one's own position.   These democratic schemes for consensus move away from the inviolate authority of Science while still valuing its insights, and concede the necessity of democracy in assuring compliance. Historical ecology can shepherd these new ways of encouraging agreement: rather than policymakers assuming that their management strategies are superior to indigenous ones, historical ecologists can demonstrate that indigenous and popular strategies are also empirically derived and potentially useful (see Appendix B).

In many non-western societies, ecological knowledge, resource management systems, and worldviews are inseparable; a large literature in anthropology documents creative indigenous solutions to environmental problems (Balée 1998; Bates and Lees 1996; Brosius 2001; Berkes 1999; Berkes and Folke 2002; Crumley 1994, 2000, 2001, 2003; Lansing 1987,1991, 1994; Kempton 1995, 2001; Netting 1981, 1993; Rappaport 1968; Swezy and Heizer 1977; Trawick 2002).   In cognitive anthropology, the analysis of worldviews has come to be known as the study of cultural models (Holland and Quinn 1987).   These models make connections among different types of information and enable prediction and explanation.   They are cultural because they are shared and reproduced within a society, thus becoming traditional.   Diverse cultural models of nature underpin every society's thinking about the environment (Kempton et al. 1995) and the politics of these differences fuels environmental justice movements (Johnston 1994, 1997, 1998, 2001).

Science-based modeling is quite different.   Modelers rarely begin with actual data, but theorize about relations among elements.   A good example is that of climate modeling, which begins with a set of assumptions about how 'drivers' of climate (e.g. insolation, greenhouse gases) interact.   Modelers then change the parameters of the model to see how they affect the system.   This approach necessarily means that the models need to be kept simple; even then it takes a phalanx of parallel processors a considerable amount of time to run the models.   There is little room to include empirical behavior of the system in the form of historic climate and other proxy data.

I recall the open derision of any scientific link between climate and human history from NOAA atmospheric scientists (mostly modelers) as late as a 1992 conference organized by archaeologist Ervan Garrison and applied anthropologist Shirley Fiske.   Circumstances have changed in the interim and atmospheric scientists are now more interested in climate history, thanks to the work of some modelers (e.g., Reid Bryson and John Kutzbach) but much of the burden has rested on historians, geographers, archaeologists, and palynologists to demonstrate the utility of historical analogues (e.g., Hughes 1975, 1994, 2001; Pfister et al. 1992, 1999; Gunn 2000; Crumley 1994; Redman 1999; PAGES Newsletter 2000).

Even there, of course, there have been enormous difficulties.   The first crude attempts to link human activity and the environment placed humans in an unequal relation with their surroundings (Huntington 19xx).   Led by social scientists and humanists, the rightful critique of this determinist effort remains a vivid part of their disciplinary socialization, spilling over into tensions between sociocultural anthropologists on the one hand and archaeologists and physical anthropologicst on the other.   One example: I once shared a taxicab from the airport to the annual American Anthropological Association

meetings with a cultural anthropologist; I responded to her question about my interests by saying that I study relationships between long term climate change and human societies. She looked horrified, physically moved away from me on the taxicab's back seat, and said "but that's Environmental Determinism, isn't it?" She said not another word to me for the rest of the ride.

How might these two very different notions of models be combined? Although one approach is primarily inductive (cultural models) and the other deductive (computer models), both are empirical, require creativity and learning, and their utility can be judged. Why not invite interested modelers of both kinds to a conference where the keynote speech addresses brain function and other points of similarity in the two approaches rather than differences?

In the current climate of hostility, perhaps the most important characteristic of historical ecology is that it celebrates the open-minded quest of scientific inquiry, the phenomenological intensity of the human experience of *place*, and the empirical basis for both. Moreover, the study of changes in the temporal and spatial configurations of landscapes, in conjunction with work in cognition, offers practical means of integrating the natural and social sciences and the humanities. The historical ecology of any part of the world is always an unfinished manuscript, passed from hand to hand, critiqued, debated, amended, revised. The approach values insights from the past as well as the present, employs the knowledge of science and society, stimulates creative thinking about the mitigation of contemporary problems, and encourages locally- and regionally-developed answers to global situations in which sensitive cultural issues play an important part.

Intellectual Architecture for the Global Scale

Three concepts that draw on intellectual traditions already familiar to many of us could leverage the next stage of integration. They are a revival and expansion of *multi-scale ecology*, the exploration of *complexity theory*, and incorporation of the alternative form of social order termed *heterarchy*.

Revitalizing Multi-scale Ecology. First used by natural scientists in the late nineteenth century, the term ecology (from the Greek *oikos*, dwelling) emphasizes the reciprocal relationships among living and nonliving elements of our world. Growing in concert with systems theory, ecology emerged as a discipline in its own right by the 1960s. The generation that came of age at about the same time our species first set foot off-planet (1969) could hardly help but note the contrast between American postwar materialism and the growing human, economic, and environmental toll in Viet Nam. They were the first eager students of the new academic discipline of ecology, which became for them a shorthand for the relation of our species to all facets of its *oikos*. For many, the first view of our blue planet and the compelling spirituality of the Gaia hypothesis inspired a definition of ecology that included all scales (local to global) of relations among living and nonliving elements and explicitly included humans.

The discipline of ecology has since bifurcated and its emphasis has undergone a scalar shift. Today micro ecology, with ties through cell and molecular biology and genomics to schools of medicine and public health, dominates the field; macro ecology (e.g., wildlife ecology, landscape ecology, Earth systems ecology) trains fewer practitioners and garners fewer research dollars than its larger and better-connected twin. Although Russian scientists pioneered the concept (Budyko 1980), only recently has the West perceived the need for a global-scale ecology. Broader scale ecologies (e.g., landscape ecology) are increasingly important, but even there lessons from the social sciences and humanities have been incorporated slowly. For example many ecologists conceive ecosystems as "natural" and human presence there as invariably negative, including the scholarly presence of the research scientists themselves (e.g., Naveh and Lieberman 1990; Forman and Godron 1986).

This quest for "pristine" ecosystems to study (that is, ones ostensibly "without human impact") and the tendency to leave time out of their considerations of systemic function and structure has caused North American ecologists in particular to stumble over definitions of 'wilderness' and its management. Criticisms from within and outside ecology have resulted in the search for a framework that draws on the strengths of systems theory, relates myriad anthropogenic and exogenous factors, and integrates all temporal scales and every spatial scale from microscopic to global.

The editor of a journal that publishes papers in both ecology and history analyzed manuscript reviewers' comments and found that scientists consider historians' (mostly qualitative) approaches imprecise and their styles of argumentation histrionic; historians perceive scientific (mostly quantitative) methods to be mechanistic and their findings trivial (Ingerson 1994). Historians concentrate on both intended and unintended consequences of human action and offer convincing examples of the plastic role of history and culture, but they usually have less command of the biophysical systems that also condition human activity. For their part, many scientists remain naive about how "natural" systems are shaped by politics, belief, and history. Journals such as *Landscape Ecology*, *Ecological Restoration* and *Ecological Applications* offer a forum for integrated approaches.

The Two Cultures divide between science and the humanities cost twentieth century ecology not only the insight of multiple spatial scales but also those of time. But it was not just ecology that forgot history and structure in the rush to model process; so too did geography, much of anthropology (including even archaeology for a time), physics, and climatology (with the exceptions of Gordon Manley and H. H. Lamb). Ecology could learn much from geology by working at multiple temporal as well as spatial scales and embracing the interpretive dialectic between structure and process.

Adapting Complexity Theory to Human Societies. Systems theory was a major influence on ecology from the outset and complex systems have been a focus of research since the 1930s (Bateson 1972; Ellen 1982). The benefits of environmental systems thinking are considerable, but there have also been significant criticisms. Chief among several issues is the charge that systems thinking is inherently reductionist and leads to the study and modeling of simpler and simpler systems at more and more minute scales. Just the reverse is required if we are to study our planet, where conjoined human and physical systems make it the most complex dissipative system known.

Researchers at the Santa Fe Institute and elsewhere concentrate on understanding the dynamics of complex systems in new ways[2]. They and investigators elsewhere have developed a new candidate idea: self-organization. The governing assumption in self-organization research is holism, the idea that an organism is more than just the sum of its parts. Self-organization researchers are critical of reductionist scientific endeavor, where the basic assumption has been that if the entity (living or not) can be broken down into its constituent parts, its behavior can be understood.

Briefly they contend that current understandings of evolution force us to see a universe in which randomness alone explains the infinitesimal chance that life could be created out of a chemical soup. In other words, in the evolutionary process the introduction of transmission errors through mutation and the operation of selection do not alone explain the complexity that may be seen in myriad living systems, from fireflies to fiddle players. They argue that a second, more fundamental source of order exists, called *self-organization*. This means that there is a synergy that comes from communication, and that two (or more) communicating entities have different properties than each alone (Jantsch 1982; Kauffman 1993, 1995; Langton 1992; Mithen 1996). The development of communication is important for both the emergence of cognition in human history and the formation of community. The self-renewing, autonomous, reproductive aspect of self-organization (termed autopoiesis)

may be related to two varieties of human communication, language and social organization, that persist in collective memory and material culture and are stored and passed on from generation to generation (Climo and Cattell 2003; Connerton 19xx; Crumley 2000; Gunn 1994; Maffi 1995; McIntosh et al 2000; Nora 19xx).   This is, of course, an essential definition of culture and a valuable entry point for social scientists.

The complexity thinkers do not advocate the abandonment of Darwinian evolution as a central paradigm, but rather the *addition* of self-organization.   They argue that selection and self-organization form the structure of the universe; neither alone suffices.   Together, Darwinian evolution and self-organization bring order from chaos: self-organization creates new forms and evolution judges their goodness of fit.   Each new stage of organization has the potential for further change, emphasizing the transformative nature of all communication.

In summary, key universal features of complex systems thinking are: *integration* (holism), *communication* (self-organization) and *history/initial conditions* (chaos).   These correspond with key features of *social* systems: integration (culture), communication (language, society), and history/initial conditions (traditions, structures and materials, strategies, habits of mind). This new systems thinking has opened an important door between the social and biophysical sciences, in that it can accommodate the results of human cognition (religion, politics, systems of formal knowledge such as science).   Many of us are already familiar with "old" systems thinking and its critique, can find refreshing potential in complex systems research, which offers a means by which human history and culture can be accomodated in a biophysical framework.

Hierarchy and Heterarchy: Re-Visioning Social Organization.   From earliest human societies to the present day, coupled individual creativity and collective flexibility have met with success.   Thus biological diversity has a correlate in human societies: the toleration of difference in individuals and groups and of variety in circumstances increases societal choice and offers a reserve of alternative solutions to problems.   Similarly, organizational flexibility--economic, social and political--enables societies to adjust to changed circumstances.

Although there exist several useful vocabularies for discussing the organizational characteristics of society, twentieth century American archaeology has been dominated by one: the framework of band, tribe, chiefdom and state (Service 1971).   Using this framework, considerable flexibility was attributed to bands and tribes, but much less to stratified society (chiefdoms and states).   The difference was seen primarily in terms of increasing "complexity,"–defined not as the more richly networked systems of complexity theory but as more nested, hierarchically organized systems–that are manifest in hierarchies of power and their attendant systems of communication.   Yet while hierarchical organization characterizes many aspects of state power, hierarchy alone does not capture the full range of state organizational relations.   Alternative forms of social order and state power--coalitions, federations, leagues, unions, communities--are just as important to state operation as they are in more egalitarian groups (bands and tribes).

Terming such groupings associations, Service noted their importance.   Unfortunately, subsequent archaeological theory disregarded this avenue and concentrated instead on how power pyramids are constructed by elites.   Yet as the September 11, 2001 events demonstrate, power flows in many channels (Samford 2000) and can manifest entirely outside the framework of state hierarchies and beyond their control.   In self-organization terminology, this is termed *chaos* or surprise (Crumley 2001), and is related to systemic negligence in engaging other dimensions of power.

Hierarchy (the classic, pyramidal organizational form) is a structure composed of elements that on the basis of certain factors are subordinate to others and may be ranked (Crumley 1979:44, 1987b:158).   In a control hierarchy each higher level exerts control over

the next lower level; the US court system and the army are control hierarchies.   By contrast, disturbances at any level in a scalar hierarchy (referring only to the size of the conceptual field) can affect any other scales (Crumley 1995b:2).   This is because in control hierarchies, individuals and groups with authority and those with responsibility are isomorphic; information and the means of communicating it becomes a commodity to be hoarded (e.g., literacy).   In scalar hierarchies, for better or worse, elements at all scales are in communication with elements at all other scales (see Appendix C).

Another way of conceiving of this meshwork of dimensions and levels is as a heterarchy, a term that describes the relation of elements to one another when they are unranked, or when they possess the potential for being ranked in a number of different ways depending on conditions (Crumley 1987b:158; see note 2).   Understood from a heterarchical perspective, sources of power are counterpoised and linked to values, which are fluid and respond to changing situations.   This definition of heterarchy and its application to social systems is congruent with Warren McCulloch's research into how the brain works (McCulloch 1988)[3].   A strong influence on the self-organizing systems theorist Kauffman (1993, 1995:xx), McCulloch first employed heterarchy in a contemporary context (1945) in the examination of independent cognitive structures in the brain, the collective organization of which he terms heterarchy.   He demonstrates that the human brain is not organized hierarchically but adjusts to the re-ranking of values as circumstances change.   McCulloch's heterarchical "nervous nets," source of the brain's flexibility, is a fractal (same structure at a different scale) of the adaptability of fluidly organized, highly communicative groups.

For example, an individual may highly value human life in general, but be against abortion rights and for the death penalty (or vice versa).   The context of the inquiry and changing (and frequently conflicting) values (Cancian 1965, 1976; Bailey 1971; Crumley 1987b) mitigates this logical inconsistency and is related to what Bateson (1972) terms a "double bind."   Priorities are re-ranked relative to conditions and can result in major structural adjustment (Crumley and Marquardt 1987:615-617).

McCulloch's insight about the autonomous nature of information stored in the brain and how parts of the brain communicate revolutionized the neural study of the brain.   It also solved major organizational problems in the fields of artificial intelligence and computer design (Minsky and Papert 1972).   What McCulloch realized was that information stored in bundles as values in one part of the brain may or may not be correlated with information stored elsewhere, depending on the context; in computer terminology, subroutine A can subsume ("call") subroutine B and vice versa, depending on the requirements of the program. Rather than the "tree" hierarchy of the first computers, those today use an addressing (information locating) RAM (Random Access Memory) system that is heterarchical, more like a network or matrix (deLanda 19xx).

Another example of the utility of self_organizing systems theory (chaos, heterarchy, system history) is in the critique of ecologists' theories of ecosystem structure and process (Winterhalder 1984). While a shared goal is to define change over time, the difference is in how it is seen as occurring__in an 'orderly' (linear, hierarchical) fashion or in a more dynamic manner.   Frederic Clements' influential paradigm of succession involved the idea of orderly, linear, and predictable stages__early succession, mid_succession, climax–in which there was no room for human activity except as "disturbance" of "natural" processes.   An ecohistory informed by complexity theory would trace a geographically specific, dynamic human-environment relationship that is not bound by the old laws of equilibrium and stasis.

In summary, heterarchies are self-organizing systems in which the elements stand counterpoised to one another.   In social systems, the power of various elements may fluctuate relative to conditions, one of the most important of which is the degree of systemic communication. Hierarchies and heterarchies of power coexist in all human societies,

including states. Societal dilemmas in which values are in conflict are resolved by achieving a novel, transcendent state that either ranks competing values relative to one another (hierarchy) or does not allow them to be definitively ranked (heterarchy).   At each successive level of integration and over time, new ordering principles come into play.   Thus, conflict or inutility leads to suspension of old forms but ensure the   preservation of useful elements through communication to provide creative new solutions to challenges (transcendence of older forms).   In these novel forms societies retain near-term flexibility, although there is of course no guarantee that the new form is more stable than the old or that tensions will not re-appear in another guise (surprise).   For example, revitalization movements such as the Native American Ghost Dance or Christianity seek transcendence through individual and collective rededication based on both new information and the retention of selected old values; an example is the "born again" phenomenon, also termed mazeway reformulation (Wallace 1970).

The addition of the term heterarchy as a descriptor of power relations in so-called complex societies (Crumley 1979, 1987b, 1995b) is a reminder that there exist in every society forms of order that are not hierarchical, and that interactive elements in complex systems need not be permanently ranked relative to one another.   Although a heterarchical ("egalitarian") form of order has long been recognized in smaller ("simpler") societies, it has been rejected as an appropriate organizational form for states.   It is both impractical and inaccurate to exclude such a fundamental adjustment mechanism from the characterization of more populous political forms.   The more successfully a society consolidates power and melds distinct hierarchies (e.g. religious, political, economic) into hyperhierarchy or hypercoherence, the less flexibility there is in dealing with surprise (Crumley 2001, 2003) (Appendix D).   The current theoretical paradigm in archaeology and elsewhere, which falsely assumes that the only form of order is hierarchy, no longer explains data collected in many parts of the world (Ehrenreich et al 1995).   Complexity theory and the concept of heterarchy can reinvigorate the interpretation of social systems and shed new light on the relationship between environmental change and societal collapse (see Appendix E).

An Interdisciplinary Effort

Clearly, humans must respond *both* to global changes that make local differences *and* to local practices that drive global change, employing every means at our disposal.   We must search for common ground, in relatively new terrain and on relatively neutral terms. The term *environment* must encompass the built environment, the cultural landscape, and nature wild and tame. The definition of *ecology* must include humans as a component of all ecosystems.   The term *history* must include that of the earth system as well as the social and physical past of our species.

Construction of an integrated framework has proven difficult, in large part due to the scalar incompatibility of human activity with planetary-scale atmospheric phenomena. Patterns of settlement and land use, emissions, and extractive procedures must be investigated at regional and local scales.   On the other hand, aggregated human behavior as regards global-scale changes (e.g., climate) must be verified at the macro scale through methods involving parallel change events in widely dispersed regions.   Growing scientific understanding of the interconnectivity of the atmosphere, hydrosphere, biosphere, and geosphere in the global system provides reasonable background cause-and-effect linkages and cyclicity, but wide-ranging social science theory and methods must be articulated to meet global science and and attribute broader systemic causation.   Without environmental and cultural information at local and regional scales, there exists no opportunity to test and refine global models; without planetary-scale confirmation of the long-term effects of human activity, arguments over values (embedded in property rights, social justice, environmental

policy, and other issues) will not abate.

Policy makers everywhere are ad hoc students of causation. They address myriad issues in which human and environmental conditions are inextricable. Situations they must anticipate and to which they must respond require enormous knowledge at multiple scales of time and space. After all, there is no reform without compliance; history and society, messy as they are to integrate into scientific research, are of fundamental importance (Johnston 1994, 1997, 1998, 2001).

The arrow of causation in the evolution of all systems–including human societies–points in two directions. For humankind, this means that we are not inevitably on a rising stair of accomplishment but may find ourselves in the blink of an eye in a condition much more dire and hopeless than at any time in that part of human history red in tooth and claw. In that there is no guarantee of progress, we are a species like any other. We must review a description of the world that is solely mechanistic and denies spirituality as an essential characteristic of the human species. We have allowed pragmatic arguments to triumph in almost every quarter, and to relegate emotions to a small, closely moderated compartment of our psyche. While they were not the earnest ecologists some have imagined, our human forebearers did at least see that the sun, the heavens, the earth, the waters, their fellow creatures and themselves were all a single system, and held all sacred. While they too made management mistakes, they never lost sight, as have we, of the integrated nature of the Universe.

Historical ecology marshals a powerful array of conceptual and practical tools, permitting the integrated investigation of change driven by conditions at global, regional, and local scales. It honors the values, knowledge and sensibilities of people at all times and places. It is also a practical guide for research, encouraging interdisciplinary discoveries, aiding conservation, and amplifying creative and integrative explanation. In it we have a means by which we can study ourselves as a conscious species in conjunction with the history of our planet. Historical ecology can show us how our world works, how we are not bystanders but instigators of change in the world, and how we must now act on its behalf.

Note 1.   For an overview of historical ecology see Crumley 1994 and Balee 1998.   Don S. Rice attributes first use of the term to the archaeological palynologist Edward S. Deevey, who directed the Historical Ecology Project at the University of Florida in the early 1970s. Historian J. Donald Hughes uses the term environmental history in his 1975 book, but with a human ecologist, an economist, anthropologists, and other historians contributed to *Historical Ecology: Essays on Environment and Social Change* (1981) edited by historian Lester J. Bilsky.   Anthropologist Alice Ingerson organized a session on historical ecology at the 1984 American Anthropological Association annual meeting.   She sought to address the chasm between cultural (e.g., nature as metaphor) and environmental (energy cycles) studies in anthropology, and to explore political economy and social history approaches.   I first used the term as the title of a chapter in *Regional Dynamics: Burgundian Landscapes in Historical Perspective* (1987) edited with William H. Marquardt, and subsequently edited a School of American Research volume entitled *Historical Ecology: Cultural Knowledge and Changing Landscapes* (1994).   Since the early 1990s ethnographer and cultural ecologist William Balee has been fostering historical ecology; together we edit the *Historical Ecology Series* for Columbia University Press (Balee 1998; McIntosh et al. 2000).   Restoration ecologists Dave Egan and Evelyn A. Howell edit *The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems* (2001).   A recent search of websites employing the term found dozens of references representing a variety of projects.   Most--although not all--of these sites explicitly address the relation between the environment and human activity.

Note 2. If you are interested in reading more broadly on complexity, self-organization and related concepts, here are some introductory references: Goodwin 1994; Jantsch 1982; Kauffman 1993, 1995; Kiel and Elliott 1996; Langton 1992; Lewin 1999; Mingers 1995; Williams 1997.   For applications in the social sciences, see: Adams 1988; Kontopoulos 1993; Schieve and Allen 1982; Scott 1991.

Note 3.   If you would like to read more about heterarchy and its connection to brain research, computer design, artificial intelligence, and social organization, here are some references: Bateson 1972; Crumley 1979, 1987b, 2001, 2003a, 2003b; Crumley and Marquardt 1987; Ehrenreich et al 1995; Kontopoulos 1993; McCulloch 1945, 1988; Minsky and Papert 1972; Mithen 1996.

Appendix A: Forming a Research Group in Historical Ecology
What characterizes an integrated Research Design?

Establish a common vision for the outcome of the research (for example, "to understand how Region X has changed since Time Y"). Establish a flexible common grammar (for example terms need not have to have precisely the same meaning for everyone; the goal is to collectively explore different understandings). Choose the time period and area to be intensively examined (but leave fluid the temporal and spatial limits of the project). Determine broad initial characteristics of the region (its physical characteristics such as climate, soil, etc and its social and economic characteristics). What events and conditions, environmental and anthropogenic, have transformed the landscape over time and space?). Form interdisciplinary teams to address components of these transformative events and conditions (e.g., the history of water and its production, distribution, consumption, discard; regional demographic history; regional land use history). Determine major categories of available data (e.g., list means by which the passage of time may be measured; list data that reflect current conditions). Determine stakeholders and develop means of including them (can citizens help with the research? can businesses donate equipment?). Collect this empirical data and do a preliminary analysis of major regional characteristics before beginning to model the regional system.

What are the politics of integrated research in historical ecology?

Contemporary political issues might include societal inequities, cultural differences, diverse agendas, power relations as they relate to resource use. Explore policy as field(s) of play: interpretations of causation, choices for mitigation, etc. Foster transparence in decision making (e.g., what GIS parameters were used when choosing a highway's path?).

In what ways can researchers (and others) be encouraged to work effectively together?

Develop broad mutual goals through visioning exercises (e.g., improve quality of life for the region). Come to value all kinds of research for their unique contributions (use diverse examples). Understand the intellectual and practical importance of a holistic perspective (e.g., more coherent research design, increased public support, broader fiscal base). Distinguish between multi_disciplinary and inter_disciplinary research and discuss the benefits and shortcomings of each. Eliminate confusion about scalar hierarchies (a tool of research) and control hierarchies (the latter implies greater importance of one scale over another). Introduce the idea of heterarchy (avoids reductionist thinking, moves the focus to complex relations among scales). Introduce non_linear systems thinking including the ideas of chaos and its relation to system history and emergence (these ideas that are critical for understanding all complex systems, particularly those in which humans are a part). Plan regular seminars for investigators to discuss their work and ideas with one another. Plan 'research exhibitions' at which researchers and citizens mingle. Provide regular social opportunities for the investigators. Determine the timing of the research (construct a flow chart that allows empirical data to feed into modeling and involves modelers in the planning of field work).

Form a Research Procedures Committee to address data compatibility problems, (e.g., scalar differences of time and space, formal and interpretive differences such as statistical vs. narrative). Determine how Project modelers will accommodate diverse data sets. Study multi_causality (cause_effect, simultaneous causation, proximal/distal causation, affect (influence) and effect (result), etc.

Form a Research Coordination Committee to ensure ongoing Project congruity. Establish schedule for exchange of research summaries among groups and regularly review the groups (are new ones needed? do old ones still serve?)

Form an Outreach Committee to coordinate contacts with universities, governmental agencies, etc. and promote research findings as guides to policy. Foster community

alliances, including community participation in the research.   Explore funding opportunities, take the lead in proposal submission.

Form an Ethics Committee to handle sensitive issues and serve Project researchers as a grievance committee.   Explore how the research could be used (pro/con).   Will all interested parties have access to all data?

Appendix B: Who Uses Historical Ecology?

Several national and international professional organizations have found utility in historical ecology.   For example, the Society for Ecological Restoration (SER) has published an historical ecology handbook for their many members who are drawn from diverse disciplines (Egan and Howell 2001).   This provides those engaged in ecological restoration with tools and concepts that prepares them to integrate biotic and social communities at multiple temporal and spatial scales.   Ecological restorationists must understand the origins of the changes they observe and decide what portions of the ecosystem to restore based on the reference model they develop from the data, the anticipated effects of the restoration project and its political, social, and economic implications.   One of the most successful applications of historical ecology to restoration projects has been undertaken by the San Francisco Estuary Institute <http://www.sfei.org/>   (Grossinger 2001). Using the resources, energy, and expertise of professionals, governments, residents, and activists, their Historical Ecology Project has documented change in San Francisco Bay over hundreds of years, identified remnants of earlier conditions, and developed a scheme for the Bay's thoughtful conservation and restoration.

In museology, an impressive example may be found at the Florida Museum of Natural History in Gainesville.   Using the framework of historical ecology, the new SW Florida Hall <http://www.flmnh.ufl.edu/sflahall/> contrasts the economy of archaeologically and historically known peoples with that of contemporary residents, carefully documenting changes over six millennia in natural resources on land, along the shoreline, and in the Gulf of Mexico.   Multiple drivers of change–technology, population, climate, pollution–are embedded in a contemporary landscape and ecology familiar to many visitors.   Seeing examples of both positive and negative human activities in one's own region is a powerful lesson for the visitor, and working together for a decade on this complex and profoundly integrated project has been an exhilarating experience for the museum staff.

Government agencies have also embraced the bio-cultural premise of historical ecology.   Both Parks Canada and the United States Park Service have mission statements that pledge an integrated approach to conservation, restoration, and development of national environmental and cultural treasures.   At the global level, international institutions such as World Heritage can find promise in historical ecology in helping to mitigate disastrous effects on cultural treasures (Crumley 2003c).   The International Geosphere-Biosphere Programme (IGBP) use integrated "case studies" in specific regions and locales to link global-scale changes to local- and regional-scale activity (Oldfield 1993, l996).   My project's work in Burgundy (France) is one of these case studies; we examine historic and contempoary regional management strategies against a shifting backdrop of trade, transport, and governmental policies.   We demonstrate that even in technologically sophisticated countries such as France, the regional environment (especially climate, soils, and terrain) plays an enduring and pivotal role in shaping successful adaptation (Crumley 2000).

Appendix C: Characteristics of Authority Structures: Hierarchies and Heterarchies

White (1995:118) provides a useful scheme for understanding continua in the various organizational dimensions of complex societies.   For both hyperhierarchical states and those more heterarchically organized, White characterizes individual rules for behavior, gender

relations, economy, social status, conflict resolution, social ideology, the political relation between leaders and followers, and temporal dynamics. To this I wish to add an examination of the contrasting conditions of decision making (Crumley 2001) and clarify a single link: the relation between administrative structure and environmental stability and change.

Hierarchical polities. Administrators in strong hierarchies (hypercoherent authoritarian states termed hyperhierarchies) have the following advantages. Due to a clear decision making chain, they respond well to fast-developing crises (e.g., military attack, insurrection). Because the rules and responsibilities are known to all, political interactions among decision makers are few and formalized, and political maintenance of the system is low. Administrative hierarchies are equipped with powerful security forces that can successfully defend the state perimeter and suppress internal dissent.

Hierarchical polities are at a disadvantage because data-gathering techniques, tied to the pyramidal decision-making framework, slow the arrival of some kinds of information (especially subversive activity) at the apex of the pyramid and necessitate the formalization and elaboration of internal security forces. Decisions are rapid and expedient but they are not necessarily popular; popular dissatisfaction is high and there must be considerable investment in coercion and/or chicanery. In any event, security costs are high.

Heterarchical polities. Administrators in heterarchically organized polities are treated to good quality information from many sources within and outside of the decision-making lattice. For the most part, decisions are fair and reflect popular consensus. Decision makers hear of a variety of solutions to problems. Because heterarchies are more likely to value the contributions of disparate segments of the community (women, ethnic groups, etc.), the society as a whole is better integrated and the workforce is proud and energized.

Heterarchical polities are at a disadvantage because consensus is slow to achieve, increasing the time it takes to make a decision (but see below). Decision makers must engage in interpersonal dialogue with constituents, which requires considerable time and energy investment and constant maintenance. The cacophonous voices and choices a decision maker hears complicate the search for workable solutions.

Tradeoffs. The greater a group's involvement, the greater the range of response choice and the more inclusive the consensus, but the response time is slower and long-range planning is more difficult. Spontaneity, polyvalent individuality linked to achieved status, inclusive or counterpoised definition of state power, and flexibility are valued in heterarchies; hierarchies value rule-based authority, rigid class lines linked to ascribed as well as achieved status and rank, a control definition of state power, and the status quo. Of course, state democracies exhibit characteristics of both, which explains in part why they are more stable than authoritarian states.

Appendix D: Complexity in State Societies
Theories of self-organization and chaos give us a new, nonlinear, dialectical way to think about human biological and cultural evolution, and especially the formation and function of the state (Gumerman and Kohler 1994; Haken 1983; Harvey and Reed 1996; Kiel and Elliott 1996; Schieve and Allen 1982; Scott 1991). At each successive level of integration, new ordering principles come into play (**suspension of old forms**) (Jantsch 1982:348), drawing upon a store of knowledge (**preservation**) and providing creative solutions to new challenges (**transcendence of older forms**). In using an example from pre-Roman and Roman times that combines longue duree history with event- and actor-based chronicle and cyclic patterns in which knowledge loss and environmental change co-occur (conjuncture), I have argued that in uncertain times the sharing of information and flexible

authority structures reduce risk by increasing available information to decision makers and multiplying solutions (Crumley 1993, 1995x, 2001, 2003). In any event, the "crux of the problem therefore becomes the exploration of how the processes of decentralization and centralization fluctuated over time and space and...why these temporal-spatial oscillations occurred" (Iannone 2002:71; see also King and Shaw 2003).

States are, relative to other social formations, relatively unstable. If states are considered complex dissipative systems in the new terminology, societal forces and environmental conditions would vary over time (and space) while state structure adjusts and endures. Interesting contemporary research on complex systems suggests the proposition that states have identifiable "basins of attraction," taking more hierarchical forms in environmentally stable periods, more heterarchical forms in periods of surprise. As Gunn (1994) notes, the more varied the history of acquired knowledge about a region's episodic climate, the more ably novel environmental conditions can be withstood. A long period of stability permits both the consolidation of power (hyperhierarchy) and the eventual loss of information and structure that enable less salubrious times to be endured (Hassan 1994). While marked environmental change is only one means by which surprise is introduced, it can be (given reduced flexibility) a powerful force in precipitating widespread systemic change. In theory, democracies (states with both hierarchical and heterarchical elements) would be the most stable form, except that even in them inequality of wealth, lack of cooperation, rigid ideology, and corruption introduce grave threats to stability (Midlarsky 1999). The real question about hierarchy and heterarchy is: under what conditions does one set of affiliations (or structures, or relations) take precedence over another?

The tension between order and chaos–or in this discussion, between democratic and authoritative power--is the source of systemic creativity (that is, the potential of the system to change its parameters completely and become more richly networked). However, systems near chaos are subject to surprise. The human species and even individual human lives are all examples. The particular "surprise" can be environmental change, but many other possibilities present themselves: invasion, disease, and the like.

In summary, while hierarchy undoubtedly characterizes power relations in some state societies, there are myriad coalitions, federations, democracies, and other examples of shared, counterpoised, heterarchical state power; all state systems have some heterarchical elements, just as all egalitarian societies have some relations that are hierarchical (e.g., age). Yet while the democratic principle is enshrined in many state constitutions (for example executive, legislative, and judicial "checks and balances" in the U.S. constitution), many other forces determine the degree to which democratic ideals are realized (e.g. the constitution of the USSR was modeled after that of the U.S.). As sources of societal power diversify, markets expand, and belief systems and ethnicities multiply, more rigid hierarchies are unable to control disparate forms of social communication and thus to contain chaotic systemic behavior. The result is systemic administrative collapse, whether through revolution or slow disintegration. Administrative hierarchies most often err in assuming the primacy of the uppermost scale of governance, declaring their hegemony over other realms and scales. Yet far-reaching change can be generated at any scale, and the true dialectic may be between history and surprise.

Appendix E: Weather System History and Culture: The Atlantic Basin

Already familiar with broad temporal scales, the increasing breadth of spatial scale in archaeology has made it possible to link long-term human history with long-term climate records at a scale that accords with the scale of continental- and global-scale climate (Markgraf 2001). As Willey (1983: 447) notes, this amplification of scales greatly improves our understanding of causality, and ultimately enables us to compare the history of human

activity at the planetary scale.

A comparison of societies inhabiting Northwest Europe and Central America over the past two millennia offers an intriguing example. The Azores high pressure system off the northwest coast of Africa brings precipitation to central and eastern North America (often in the form of huge, powerful storm systems) and also (both from the American continent and in a more direct path to the north) to Atlantic Europe. The history of this huge Atlantic Basin system allows us to follow the history of societies on both sides of the Atlantic as the power of the Azores high has waxed and waned in concert with global warming and cooling cycles (Crumley 2003; Gunn 1994). Although temperate northwest Europe and subtropical Mesoamerica are dissimilar in many environmental respects, they nonetheless share more than the same weather generating system. Seasonal variability in the weather results in considerable risk for both ecosystems. Historically, this has been offset by cultural knowledge about the parameters of variation in basic systemic elements (precipitation, temperature, soil quality, etc), but at times social and economic conditions have precluded application of that knowledge or previous knowledge has not been appropriate for conditions.

Away from the Atlantic margins in western continental Europe, the situation is even more complex. Not one but three powerful high pressure generators (the Azores, Greenland, and Siberian systems) meet in central France and cause huge annual, decadal, and centennial variation in seasonal rainfall, summer heat, number of frost-free days, and the like. The region's terrain and vegetation are extremely heterogenous, with considerable variation in elevation, topography, soils, and vegetation. For much of its history this natural mosaic generated wealth through diverse commercial production. Chief among these were stock breeding (horses, cattle, sheep, pigs), cereal cultivation, metal mining and fabrication, artisanal activities, and extensive import/export activities.

I have examined how environmental conditions (especially stability/instability) and variable success at transmitting environmental and cultural knowledge from generation to generation influences governmental forms (Crumley 1993, 1994, 1995, 2000, 2001, 2003). By studying the enduringly wealthy region of Burgundy, my colleagues and I have traced the role of global environmental change in politics and society over approximately 2000 years' time (Crumley and Marquardt 1987; Gunn et al 2003). Through the diversification of production and political, social, and spatial decentralization, the pre-Roman population of Europe was able to adjust to environmental uncertainty. The Roman victory over Iron Age Celtic society and subsequent suppression of indigenous knowledge (in the form of druidic teaching), combined with a long period of stable climate (the Roman Climate Optimum, Denton and Karlen 19xx), resulted in the loss of four thousand years of accumulated indigenous knowledge and plunged western Europe into the Dark Ages.

As in much of northwest Europe, environmental diversity in central America is heterogenous at many scales, with considerable sub-ecotonal variation in physiography, rainfall, soils, potable water and other resources. Annual temporal variation is important as well, in that the timing of the arrival of the rainy season and its intensity have profound effects for agriculture. In ancient Maya times (roughly 200 BC to about 800 AD) the *political* system was organized vertically, while the *economy* was shaped by environmental constraints and characterized by fluidly networked interregional exchange. Particularly intriguing are research results that document systemic change over time. In the Maya Preclassic, water and soil management strategies slowed environmental decline caused by changes in climate (e.g. rainfall, sea level) and human activity. Nonetheless, gradually diminishing water resources in bajos and elsewhere, deforestation, and the loss of soil fertility posed significant problems for upland and lowland settlements alike, leading in some areas to abandonment. Through time the management of food production underwent a centrifugal process, intensifying production in marginal areas. This was made possible through corporate

groups, which formed when environmental conditions deteriorated, or when an influx of people into the area required that marginal zones be rendered productive.   Despite the success of such community structures in the countryside, the huge centers of population were apparently ignorant of the corporate role in the conservation of environmental resources. Ultimately, the insensitivity of urban elites to the fragility of the environment and to the importance of the rural corporate infrastructure, combined with an uninformed attempt at hierarchical management of resources, may have crashed the system (Houk 2003).

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