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From Complex Regions to Complex Worlds

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Articles

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INTRODUCTION

For me, 2001 was a pivotal year. First came the submission of our book, *Panarchy,* to the publisher.[1] *Panarchy* presents theory and examples to explain why complex living systems create and also benefit from crisis. Then on September 11 came the terrorist attacks on the two World Trade Center buildings, the Pentagon, and unsuccessfully, on the Congress or White House. Those September 11 events represented a huge financial, military, and governmental attack that has since spawned both conflicting and supportive responses from governments. It launched the world on a journey whose path is unpredictable and unknown. It turned the United States government from an inward reaction of political ideology to an outward reaction of governmental, industrial, and military power. It took me a year and a half to begin to understand how *Panarchy*, which has an essentially regional focus, can perhaps explain and offer actions for what is a global, geopolitical phenomenon. This paper is the result.

"Panarchy." That is an odd name, but one that is meant to capture the way living systems persist and yet innovate. It shows how fast and slow, small and big events and processes can transform ecosystems and organisms through evolution, or can transform humans and their societies through learning or the chance for learning. The central question is what allows

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1. PANARCHY: UNDERSTANDING TRANSFORMATIONS IN HUMAN AND NATURAL SYSTEMS (Lance H. Gunderson & C.S. Holling eds., 2002) [hereinafter PANARCHY].

rare transformation, not simply change.

The multi-authored book describing the integrative nature of *Panarchy* is in part a culmination of fifty years of my own research work, together with that of a fine group of friends and colleagues in the Resilience Project. During that project, my ideas expanded and grew as they interacted with the ideas of others—ecologists, economists, social scientists, and mathematicians—all coauthors of *Panarchy*. It was a process of mutual, creative discovery that then turned personal for each of us.

For me, over those fifty years the old notion of stable ecological systems embedded in the equilibrium images of Lotka-Volterra equations moved to that of resilience and multi-stable states;[2] then to cycles of adaptive change in which persistence and novelty entwined;[3] then to nested sets of such cycles in hierarchies of diversity covering centimeters to hundreds of kilometers, days to millennia;[4] and then to the transformations that can cascade up the scales, with small, fast events affecting big, slow ones.[5] Self-organization and natural selection jointly flourish and interact as a new way to view evolution. In the sciences of biological evolution, that combination can often be viewed as either an obscure or an excessive representation. But it is suggestive and provocative, and that has particular value at times of deep change.

Jargon? Yeah. So we decided to go "whole hog" and invent the term "panarchy" for the ideas, drawing on the mischievous Greek God Pan, the paradoxical spirit of nature. Join Pan, then, to the dynamic reality of hierarchies across scales, in which nature self-organizes lumps of living stuff on a more continuous, physical template described by power laws. Physics defines the attributes of the power laws. Biology self-organizes concentrations of opportunity and of species along

2. *See* S.R. Carpenter, *Alternate States of Ecosystems: Evidence and Its Implications for Environmental Decisions*, *in* ECOLOGY: ACHIEVEMENT AND CHALLENGE 357 (Malcolm C. Press, Nancy J. Huntly & Simon Levin eds., 2000); C.S. Holling, *Resilience and Stability of Ecological Systems*, 4 ANN. REV. ECOLOGY & SYS. 1, 5-6 (1973).

3. *See* C.S. Holling, *The Resilience of Terrestrial Ecosystems; Local Surprise and Global Change*, *in* SUSTAINABLE DEVELOPMENT OF THE BIOSPHERE 292, 308-14 (William C. Clark & R.E. Munn eds., 1986).

4. *See* C.S. Holling, *Cross-Scale Morphology, Geometry and Dynamics of Ecosystems*, 62 ECOLOGICAL MONOGRAPHS 447, 483-85 (1992).

5. *See* C.S. Holling, Lance H. Gunderson & Garry D. Peterson, *Sustainability and Panarchies*, *in* PANARCHY, *supra* note 1, at 63.

the power law relation. Part of that organization is maintained by diversity within and across scales,[6] a uniquely panarchical representation of the role of diversity in maintaining a sustainable system. For ecosystems and landscapes, all of this is arranged over an interactive scale from centimeters and days to hundreds of kilometers and millennia. Nothing static—all components flipping from quiet to noise, from collapse to renewal. Transformation is not easy and gradual. It is tough and abrupt.

The technical puzzles that I had accumulated over the years became resolved. And the fewer, but deeper and more intriguing paradoxes that I had experienced turned out to provide the foundation for a new understanding of sustainability. Those paradoxes did not emerge in my science, but did appear in the organizations of which I became a part. Not science, therefore, but human experience. Each organization had been created to capitalize on recent understanding, scales of perception, and integrative methods. They were creations of history made by politically sensitive individuals who saw value in combining integrative scholarship within a context of current politics. Each made large advances to understanding critical attributes of complex systems. Each triggered extensions of collaboration among scholars of different disciplines and nations. But, as time passed, each became less responsive to new opportunities.

I at last understood why the International Institute of Applied Systems Analysis in Austria ultimately could only grudgingly and partially change as the world transformed with the fall of the Soviet Union; it had to reduce and stabilize in a changing political world. Why the Institute of Resource Ecology at the University of British Columbia unhappily closed after great successes and despite huge opportunities. Why the University of Florida could only form a partial "horizontal" College of Natural Resources to integrate across a wide spectrum, a College that became isolated despite original dominant faculty support and trivial costs. Why Everglades restoration has such an extraordinary cost, distorted history,

6. *See* Garry Peterson, Craig R. Allen & C.S. Holling, *Ecological Resilience, Biodiversity, and Scale*, 1 ECOSYSTEMS 6, 12-13 (1998); Brian Walker, Ann Kinzig & Jenny Langridge, *Plant Attribute Diversity, Resilience, and Ecosystem Function: The Nature and Significance of Dominant and Minor Species*, 2 ECOSYSTEMS 95, 108-09 (1999).

but momentarily happy present. Each was, at stages, a frustrating, fun, and challenging place for change and transformation embedded in panarchies that both encouraged novelty at some scales and fought it at others. The Santa Fe Institute is another such place where a group of physicists, biologists, and computer specialists created both a new organization and a new field of inquiry in complex systems. Novelty, persistence, and evolution were all grists for the mill. It now is trying to restructure in an effort to recapture some of the original magic that has become partially lost in its own traditions. They are and were all rare and wonderful places for learning and experimentation whose benefits then moved elsewhere.

That is a big lesson. Major learned benefits need not, and generally do not, stay in the place where they were created. But they flourish elsewhere. Can we facilitate that spread? Can they return? That is a kind of globalization that we want to encourage.

It seemed to become clear why and how persistence and extinction, growth and constancy, evolution and collapse entwined to form a panarchy of adaptive cycles across scales. Hierarchy and adaptive cycles can combine to make healthy systems over scales from the individual to the planet, over days to centuries.

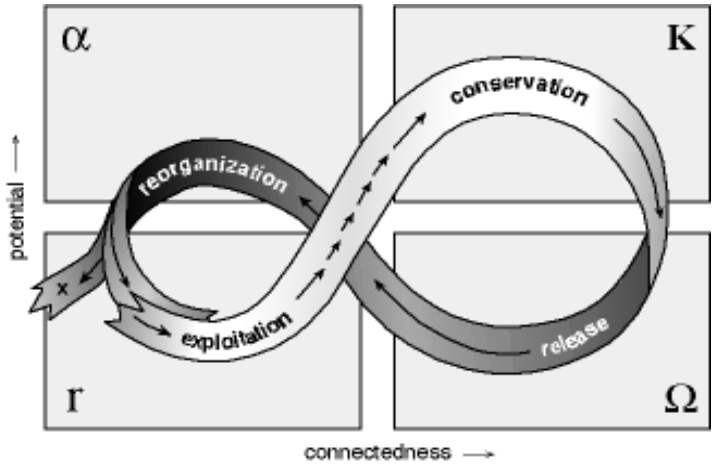
The panarchy shows that we benefit from local inventions that create larger opportunity while being kept safe from those that destabilize because of their nature or excessive exuberance. When innovation occurs, we can sense its fate. When collapse looms, we can judge its likelihood. And the timing and kind of responses to this swinging, turbulent process can be designed as an act of strategic decision. Sustainability both conserves and creates. So does biological evolution.

A BRIEF SUMMARY OF DISCOVERIES

The book *Panarchy* describes our effort to integrate theory and example from ecology, economics, and social systems. It started with the results of decades of examination of ecosystems and the effects of management on the ecological and social components. That led to an image of change that recognized, across all examples in living systems, the existence, at some scale or scales, from cell to biome, of four principal

phases that elements of a system can cycle through, that is, entrepreneurial exploitation (r), organizational consolidation (K), creative destruction (Ω) and re- or de-structuring (α). A stylized example is shown in Figure 1.

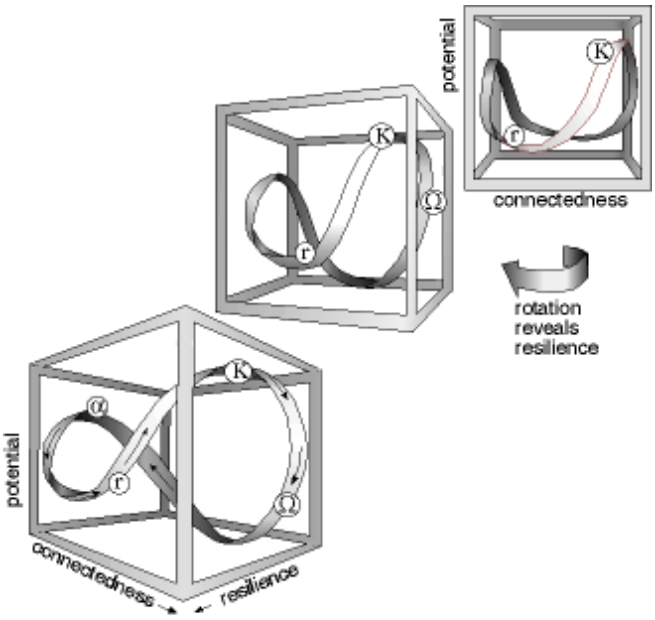
FIGURE 1: A STYLIZED REPRESENTATION OF THE FOUR SYSTEMS FUNCTIONS AND THE FLOW OF EVENTS AMONG THEM.[7]



When the final, third axis of resilience is added, the diagram appears as in Figure 2.

7. C.S. Holling & Lance H. Gunderson, *Resilience and Adaptive Cycles, in* PANARCHY, *supra* note 1, at 25, 34.

FIGURE 2: RESILIENCE IS ANOTHER DIMENSION OF THE ADAPTIVE CYCLE, AND, WHEN ADDED, SHOWS THAT THE FIGURE 8 OF FIGURE 1 IS SEEN AS THE CONSEQUENCE OF A TWO-DIMENSIONAL PROJECTION OF A THREE-DIMENSIONAL OBJECT.[8]



For an ecosystem like a forest, think of the centuries-long cycle of succession and growth from pioneer species, r, to "climax" species, K, followed by major disturbance like fire, storm or pest, Ω. Such disturbances occur as wealth accumulates and the system gradually becomes less resilient, that is, more vulnerable. As a consequence, a disturbance is created that releases accumulated nutrients and biomass that then allows their reorganization into the start of a new cycle, α. That reorganization can then exploit the novelty that accumulates but which is resisted or lies latent during the forward loop. Or for a wetland, like the Everglades, think of a fifteen-year succession from open pond to floating and suspended vegetation, to accumulating peat to sawgrass, again followed by major disturbance and a reorganization of the cycle.

Each phase of those cycles creates the condition for the next phase. A pattern of two phases of *growth* is generated,

8. *Id.* at 41.

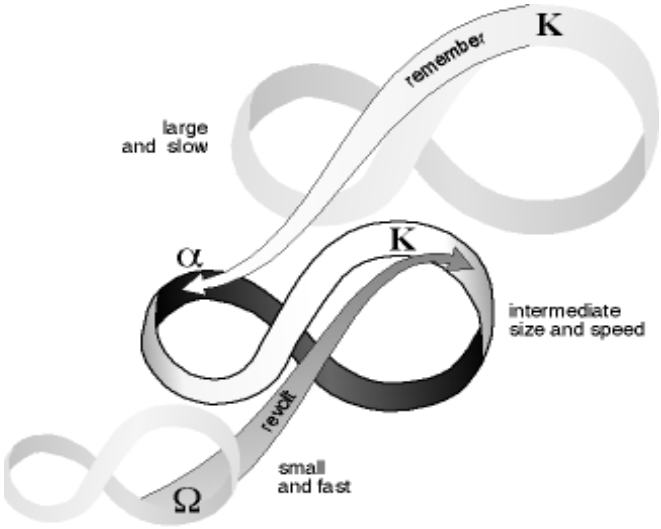
followed by two phases of *reorganization*. These two form a familiar slow, fairly predictable "forward-loop" pattern of growth and a less familiar, unpredictable and, in ecosystems, a more rapid "back-loop" pattern of reorganization.

It is the two together that make the cycle adaptive. Novel elements can accumulate, largely unexpressed, during the forward loop. Then, in the back loop, they can become the seeds for novel combinations that launch the next cycle. But the ecosystem cycle is embedded among a set of such cycles that cross scales in space and time from leaves, to trees, to patches, to stands, to forests, to biomes.

Finally, an important aspect of the adaptive cycle concept lies in the "pan" part of the panarchy—the cross-scale effects.[9] Adaptive cycles in ecosystems occur in scales ranging from leaves to biomes in a panarchy of increasing scale from centimeters and days to hundreds of kilometers and millennia. And the structures along that hierarchy affect one another by opening up the possibility for small scale novelty appearing during a back loop, to cascade to larger scales. At the same time, persistence is encouraged by the memory of large scale properties such as seed stores, biotic legacies, and institutional structures that influence renewal of a smaller scale cycle as suggested in Figure 3.

9. *See* Holling, Gunderson & Peterson, *supra* note 5, at 74-76.

FIGURE 3: KEY CONNECTIONS BETWEEN THREE LEVELS OF A PANARCHY, SHOWING WHEN SMALL AND FAST CYCLES CAN AFFECT LARGER AND SLOWER ONES (REVOLT), OR WHEN LARGE AND SLOW ONES CAN CONTROL RENEWAL OF SMALLER AND FASTER ONES (MEMORY).[10]



Specifically, back-loop reorganization at one smaller scale can trigger changes at larger, slower scales above. That is when novelty can be generated and sustained. Organizational consolidation of higher level scales can provide a "memory" that influences the recovery of system dynamics at finer scales below. That is what sustains repetition of adaptive cycles.

Those adaptive cycles and their relationships are not unique to the dynamics of ecosystems. I even see them in my own life. I happen to have had a pattern of seven to ten year cycles of unplanned intellectual growth, frustration and renewal that has been both great fun and has provided a great sense of discovery and passing frustration. Frances Westley describes her interview of an outstanding resource manager in Wisconsin, showing how his successes and failures were very much part of the phases of cycles of change—his own personal one—involving interorganizational groups, and formal and

10. *Id.* at 75.

political organizations.[11] His plans and interventions both paced the vulnerability in each cycle of that hierarchy of cycles and, in some instances, created the vulnerability needed for change.

Adaptive cycles and their intricate relationships also occur in societies where slow and fast, big and small structures interact. For institutions, Elinor Ostrom calls them operational rules, collective choice rules, and constitutional rules, each having different speeds of function, scale, and generality of relevance.[12] For J.K. Whitaker, those three structures in economies are fast individual preferences, slower and larger markets, and still more conservative and extensive social institutions.[13] Frances Westley sees decision in human societies working through processes of allocation within social norms and cultural myths.[14] Again these three occur at distinct scales, and the interaction among them involves the same processes of revolt and memory that can paradoxically both sustain and innovate. And old resilience colleagues—Fikret Berkes in northern Canada, Carl Folke in Sweden, and Madhav Gadgil in India—see knowledge systems persisting and adapting in endemic societies within structures of local knowledge, potentially modified by management practice, within a larger world view.[15] Each of those sets of triplets, together with ecosystem ones, could be represented as specific system labels in Figure 3.

Now all of that is well-structured, but it appears static. Where are the dynamics? Where does the transformation and persistence arise? Those are the elements that challenge every part of our lives—from the individual to all nations. That evokes questions of growth as well as questions of collapse.

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11. *See* Frances Westley, *The Devil in the Dynamics: Adaptive Management on the Front Lines*, *in* PANARCHY, *supra* note 1, at 333-60.

12. *See* ELINOR OSTROM, GOVERNING THE COMMONS: THE EVOLUTION OF INSTITUTIONS FOR COLLECTIVE ACTION 50-55 (1993).

13. *See* J.K. Whitaker, *Alfred Marshall*, *in* 3 THE NEW PALGRAVE: A DICTIONARY OF ECONOMICS 350, 352-353 (John Eatwell, Murray Milgate & Peter Newman eds., 1987).

14. *See* Frances Westley et al., *Why Systems of People and Nature Are Not Just Social and Ecological Systems*, *in* PANARCHY, *supra* note 1, at 103, 107-19.

15. *See* Fikret Berkes, Carl Folke & Madhav Gadgil, *Traditional Ecological Knowledge, Biodiversity, Resilience and Sustainability*, *in* BIODIVERSITY CONSERVATION 269 (C.A. Perrings et al. eds., 1994).

Growth is important, but even more so are the forces in a healthy system that dominate during episodes when growth is halted or reversed, when deep uncertainty explodes, when several alternative futures become suddenly perceived. The resulting unpredictability stifles informed action or triggers ignorant reaction. It is a time of back-loop crisis, but also of opportunity. During a back loop, unexpected interactions can occur among previously separate properties that can then nucleate an inherently novel and unexpected focus for future good or ill in the next cycle.

At such times, the future can also be suddenly shaped by external events such as those we now anticipate globally from slowly changing climate, from entrants of invasive species, from surprising diseases like AIDS and SARS, from human immigrants driven by geopolitical changes, or from unexpected terrorist events. Such apparently external events can launch future development along an unpredictable course. During such times, uncertainty is high, control is weakened and confused, and unpredictability is great. But space is also created for reorganization and innovation. It is therefore also a time when individual cells, individual organisms, or individual people have the greatest chance of influencing events. In societies, there is opportunity for exploratory experiment if the experiments are designed to have low costs of failure. The future can then be mapped by experiments that fail and succeed, rather than by long-term plans. It is the time when a Gandhi or a Hitler can use events of the past to transform the future for great good or great ill.

In a biological evolutionary setting, it is a time when mammals can replace dinosaurs as the dominant life form. The back loop is the time of the "Long Now,"[16] during which we each must become aware that we are participants.

That is what the editors of another book of the Resilience Project present.[17] In the specific social and ecological systems they describe, the essence of sustainability is defined by processes that evolved on the back loop, processes that respond to novelty, memory, and instability.[18] They reverse existing

16. *See* STEWART BRAND, THE CLOCK OF THE LONG NOW: TIME AND RESPONSIBILITY 27-31 (1999).

17. *See* NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS: BUILDING RESILIENCE FOR COMPLEXITY AND CHANGE (Fikret Berkes, Johan Colding & Carl Folke eds., 2003) [hereinafter NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS].

18. *See* Carl Folke, Johann Colding & Fikret Berkes, *Synthesis: Building*

traditions of exploration and analysis by focusing on the back loop of collapse and reorganization, rather than on the front loop of growth and predictability.[19] They therefore focus on foundations for change. They focus on forces of evolution from biology, ecology, society, and culture.

I came to these conclusions in a process involving alternating periods of working on theory with more applied work. Each period persisted on its own for a time and generated ideas that were resolved by the other for a time. Carl Walters was my partner, friend, and engaging provocateur for the fundamental applied work. The work led to constructive ways to engage colleagues and stakeholders in novel analysis and synthesis of systems and issues.[20] That has led to deep programs of specific discovery[21] and has launched a broad collaborative study and design of regional systems by the Resilience Alliance.[22] Those dips into application, too, covered a fairly long period of about thirty-five years and were launched by the invention of Adaptive Management that in many ways has become important in regional scale management internationally. That progress in application and its connections with developments in theory and method has been summarized in a sequence of books.[23]

But all of these studies were regional in character. That is, all emerged from places where people, government, and ecosystems related tightly together. Forest management in New Brunswick, fisheries management and recreational development in British Columbia, alpine village progression in

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Resilience and Adaptive Capacity in Social-Ecological Systems, *in* NAVIGATING SOCIAL-ECOLOGICAL SYSTEMS, *supra* note 17, at 352.

19. *See id.*

20. *See, e.g.*, C.S. Holling & A.D. Chambers, *Resource Science: The Nurture of an Infant*, 23 BIOSCIENCE 13-20 (1973).

21. *See, e.g.*, Brian H. Walker & Marco A. Janssen, *Rangelands, Pastoralists and Governments: Interlinked Systems of People and Nature*, 357 PHIL. TRANSACTIONS ROYAL SOC'Y LONDON B 719 (2002) (describing a study of rangelands, livestock, and their human managers as an example of complex adaptive systems).

22. *See* Brian Walker et al., *Resilience Management in Social-Ecological Systems: A Working Hypothesis for a Participatory Approach*, 6 CONSERVATION ECOLOGY 14 (2002), *available at* http://www.consecol.org/vol6/iss1/art14. For more information on the Resilience Alliance, see http://www.resalliance.org (last visited Oct. 2, 2005).

23. *See* ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (C.S. Holling ed., 1978); KAI N. LEE, COMPASS AND THE GYROSCOPE: INTEGRATING SCIENCE AND POLITICS FOR THE ENVIRONMENT (1993); CARL WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES (1986).

Austria, rangeland development in Zimbabwe, wetlands, city, and agricultural development for the Everglades of Florida—all of these, plus others, were chosen for study simply because they were there. Not because these areas covered a spectrum of politics, or of environments, or of economic developmental stages—though they did—but only because they were places facing or imbedded in a back loop of change, open to fresh exploration and imagination. They were, therefore, places where individuals could discover deep insights collaboratively.

But is panarchy a framework for thought and then action in a potential phase of geopolitical transformation after September 11, 2001? Not just regional, but global and international? Are we in another period of change as we experienced in the 1930s and 40s? Are we in a "deep back loop" that opens the same opportunities and crises as the regional back loop studies that we have described?

FROM THE SCIENCE OF CHANGE TO THE POLITICS OF CHANGE IN A COMPLEX WORLD

Some of the events we experience in society are small and incremental, but are accumulative. They slowly accumulate experience and wealth; that is when we are becoming progressively more economically efficient. But if we look widely at that economic, spinning process of incremental change, we occasionally, like now, encounter the paradox that accumulated increases in wealth and efficiency also combine with an increased narrowness of view, and a rigidity, to make it difficult to achieve agreement on how to respond differently to new challenges. We become separate from the poor, the distant, and the different. But they can act, and that can generate instability and surprise. Witness now the turbulence released by protest in the Middle East and the responses of the United States and Europe that interact with it and each other.

Can that instability be part of a process of creative destruction? Is it part of the larger, more spasmodic cycle of transformation that can lead to a new phase of opportunity? If so, how can we help or even understand? How do we turn the destructive events into a process of creative renewal? That process is a phase in a slower and larger part of a cycle of change that includes incremental growth in efficiency and wealth as only one different, faster phase.

It creates an opportunity for fundamental transformation of rules guiding the relations between nations and cultures,

rather than simply a change of national structure or of events.

Since the Berlin Wall fell, the world has been on an internationally expanding sequence of national and international exploration, some collapses and some hesitant, partial recoveries. Think of the collapse of the U.S.S.R., of the recovery efforts in Eastern and Central Europe, of collapse and partial economic recovery in Southeast Asia, of economic instability in Latin America, of economic, ecological, and social disaster in Africa. Of September 11.

The world seems to be currently moving towards a major transformation. Part, but not all of that transformation is the same as that seen in the inherent rhythms of natural systems. Complex natural systems work in rhythms—with a front-loop phase of slow, incremental growth and accumulation, and a back-loop stage of rapid reorganization leading to renewal, or, rarely, to collapse.

The front-loop phase is more predictable with higher degrees of certainty. In both the natural and social worlds, it maximizes production and accumulation. We have been in that mode since World War II. The consequence is an accumulation and concentration of wealth, but also an emergence of greater vulnerability due to the increasing number of interconnections that link that wealth, and those who possess it, in efforts to sustain it. Little time and few resources are available for alternatives that explore different visions or opportunities. Emergence and novelty is inhibited. This growing connectedness leads to increasing rigidity in its goal to retain control, and the system becomes ever more tightly bound together. This reduces resilience and the capacity of the system to absorb change, thus increasing the threat of abrupt change. We can recognize the need for change but become politically stifled in our capacity to act effectively.

Should abrupt change occur, there is a move to the back-loop stage. I argue this started in our international world of nations with the fall of the Berlin Wall and the collapse of communism following the earlier defeat of fascism. Both the communism and fascism of the last seventy years fell to the slow evolution of modern democratic systems of governance. Wealth and broadening wealth accumulated to lead to our present vulnerability on a world stage. We are entering the back loop of reorganization that entails the collapse of accumulated connections, the release of bound up knowledge and capital. But it also opens a creative potential and the

opportunity for "creative destruction," as described by Joseph Schumpeter.[24]

The creative aspect of this destruction is bound up with the release of knowledge and the appearance of new or latent elements which can re-associate in novel and unexpected ways to trigger re-growth or reorganization into fundamentally new front-end learning loops. That has already occurred through the major opportunities created by easy universal use of computers and telecommunication. Terrorists can use the Internet as well as the "dot-coms," scientists, and citizens. This back-loop phase is inventive, inherently unpredictable, and uncertain. One can observe this process of birth, growth, and change in front-loop/back-loop cycles in all systems—from a cell in the body, to an individual in his or her phases of life, to the operations of management agencies, to society itself.

Natural ecological and individual cycles inevitably open brief opportunities to flip to new organizations between slow periods of growth. But social systems incorporate an additional factor. Clever human beings have learned to look forward and create the future before it happens. But these innovations are often local. Others have identified ways to persist within existing structures, avoiding the need for change—witness the brilliance of some leaders in preserving existing institutions when change and transformation is needed. However, the longer the system is "locked in," the greater the vulnerability and the bigger and more dramatic its collapse will be.

That has been the pattern we saw earlier in examining resource agencies, ecosystems, and society and the way they interrelate. For resource management agencies that operate outside the discipline of a market, this results in pathology—industries that become dependent, ecosystems that lose their resilience, and management that becomes myopic and defensive. That encourages a loss of trust in governance that can provide the crisis needed for organizational change as part of a democratic process. There are good examples of crises triggering new approaches to forest fire management, flood management, and control of lake eutrophication and pests. Typically, management becomes somewhat more complex, more open, and more integrative across scales of variables.[25]

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24. *See* JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM, AND DEMOCRACY 81-86 (2d ed. 1942).

25. *See generally* BARRIERS AND BRIDGES TO THE RENEWAL OF ECOSYSTEMS AND INSTITUTIONS (Lance H. Gunderson, C.S. Holling & Stephen

For whole societies that lack a democratic process of periodic evaluation and revision, we have seen, historically, examples of the full extreme—periods of social or economic collapse so profound that only the family remains as social support to the individual. It can result in a poverty trap, where, in the generation of deep collapses and cycles, the emergence and renewal that will take place usually shifts elsewhere. The novelty develops in one place and then typically shifts elsewhere, expanding, extending, testing, and deepening the work as it moves. The intellectual area or topic becomes the evolving entity, not the organization or society that nurtured its early phases.

The developed world has been in a phase of extraordinary wealth accumulation. The proportion of people in the world labeled as poor has dramatically declined between 1980 and 2000.[26] But pockets of poverty deepen and extend in Africa.[27] Parts of South America teeter on economic collapse.[28] And in all situations, good and bad, there are implicit assumptions that the critical, hidden ecological processes that sustain economic development persist. Inevitably, it has made society blind to the many signals of vulnerability and resistant to possible solutions. There is growing instability: inequity between rich and poor, and new physical and global impacts stemming from society's actions lead to global vulnerabilities such as global economic instabilities, climate change, biodiversity loss, unexpected diseases, and geopolitical instability. These are large in scale and consequence. They are new enough in extent that we lack the institutions to manage the transitions. They suggest a stage of vulnerability that could trigger a rare and major pulse of social transformation.

The world of man has witnessed only three or four such major "pulses," or periods of transformation, in its evolution—agricultural settlement by the first hunter-gatherers, the industrial revolution, and now, the global interconnected communications-driven revolution. Society is now at a stage in

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S. Light eds., 1995).

26. *See* David Dollar, *Globalization, Poverty, and Inequality Since 1980* 16-19 (World Bank Policy Research, Working Paper No. 3333, 2004), *available at* http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2004/09/28/000112742_20040928090739/Rendered/PDF/wps3333.pdf.

27. *See id.*

28. *See, e.g.*, Jack Chang, *Argentina Recovers – Sort of*, PHILA. INQUIRER, Aug. 14, 2005, at E12.

history of this major pulse—the end of one pulse and the beginning of another. The immense destruction that a pulse signals is both frightening and creative. It raises fundamental questions about transformation. The only way to approach such a period—where uncertainty is very large and one cannot predict what the future holds—is not to predict, but to act inventively and exuberantly in diverse adventures in living and experimentation.

That leads, then, to a strategic sense of how to proceed. Not to plan the details, but to invent, experiment, and build. Sounds easy, but at such times existing centers of local power resist larger opportunity because of the threats that the unknown suggests. So a sequence of goals needs to be seen and encouraged:

- Encourage innovation: a rich variety of experiments and transformative approaches that probe possible directions. It is important to encourage experiments with a low cost of failure to individuals, to the environment, and to careers, as many of these experiments will fail.
- Reduce inhibitions to change, common when systems get so locked up.
- Protect and communicate the accumulated knowledge needed for change.
- Encourage discourse among the full range of parties to try to understand where we are going and how to achieve it.
- Encourage new foundations for renewal that build and sustain the capacity of people, economies, and nature for dealing with change, and ensure that these new foundations consolidate and expand understanding of change.
- Allow sufficient time. This pulse is a global phenomenon—the United Nations, war in Iraq, global economic vulnerabilities, etc.—and it could potentially affect all levels of hierarchy, all the way up the chain, from the individual and family to national and global systems.

The fall of the Berlin Wall was a catalyst for emerging, spreading deep transformative change which has continued with the events of September 11.

HOW TO RESPOND IN A "BIG BACK LOOP"

The present responses of the world community at large have been, at best, adequate or bad. The question is how to tip more toward adequately good and achieve a better balance in the world—improving the poverty-stricken populations, achieving a reduction in extremes of population growth and collapse, or nurturing inventive solutions. What I observe is that the good approaches are less in ascendance at the present, while narrow and powerful military and protectionist economic approaches take precedence. In the late economic bubble of the 1990s, business and government linked to dangerously usurp the balance provided by government. That threatens the breadth of influence needed in democracy. There is a tendency to greater extremism, ignoring the broad inequities within society, or to narrow approaches that preclude any concerns for addressing diversity. The scale of the issues is such that they are beyond the reach of any one company, sector of the economy, or government. There is a need for cooperative international effort—a major contribution to transformation by people of vision or groups of people thinking deeply about the nature of risk and finding novel ways to approach it.

That is why the Internet is such a positive force at this time. It is a place for inventing the creative experiments that cover scales and that can fail safely as new possibilities are created and tested. It can be inherently international.

We can act as nested sets of communities and then scale upward, trying to engage people functioning at all levels. Those are communities of citizens really, but ones with different roots in scholarship, business, government, and non-governmental enterprise. If Shell Oil can invent ways to open their visions of the future, and British Petroleum can begin strategic subsidy of untraditional energy supplies, surely small groups of scholars, governments, and citizen groups can invent experiments outside each of their own organizational constraints. We only need a mechanism that can encourage, evaluate, and communicate these visions, not just locally, but globally as well. Our Resilience Alliance[29] provides just one specific example.

People need to pay greater attention to the sustainability of the organization in which they operate: many organizations

29. For more information on the Resilience Alliance, see http://www.resalliance.org (last visited Oct. 2, 2005).

are driven by short timeframes, by the fast variables. Probably the greatest difficulty is to communicate the issue of time—the key feature of a sustainable, adaptive system is the need to recognize the sustaining properties of slow variables. As a system changes, it will trigger observable changes in the fast dynamic, but the slower ones often will not give any indication of observable change. People who are most effective and active often have great skills in dealing with faster variables, but not the slower ones. They tend to focus on short-term issues, such as return on investment. It is the rare person who, for a time, defends and transcends that and organizes the turbulence for a new transformation. For me, in the past, that has been a Churchill or a Roosevelt.

But both cultural attitudes and ecosystems change slowly. For example, the basic vegetation cycle in wetlands takes a few decades to develop, while its sustainability depends on the accretion of the peat that occurs over hundreds of years—a long-term, slow variable that is not as easily recognized. In societies, the fast variables are economic ones and the slow variables are educational and cultural. The questions are how to recognize and communicate the importance of investment in the slower variables, and how to combine the advantages of encouraging fast variables without threatening the slow variables.[30]

There are now some business leaders already thinking about longer-term issues and cooperation, thinking outside the business envelope. There are always some companies and industries that understand that long-term change can lead to short-term scarcities, which would create new profitable markets. There is tremendous power in facilitating the growth of this understanding.

But cells and societies also reproduce and reinvent in the process of cyclic transformations. That is when evolution and deep changes are created. The bewildering, entrancing, unpredictable character of nature and people, the richness, diversity, and changeability of life comes from that evolutionary dance generated by cycles of growth, collapse, reorganization, renewal, and reestablishment.

And what is the role for science in the midst of this back

30. *See* Stephen R. Carpenter, *Regime Shifts in Lake Ecosystems: Pattern and Variation*, *in* 15 EXCELLENCE IN ECOLOGY 143-62 (Otto Kinne ed., 2003), *available at* http://limnology.wisc.edu/regime.

loop of change? On substance, I would argue for novel integrative work on ecosystem scales, but very much integrating economic and social with the ecological, searching for the simple features of complex systems that occur in the interaction between fast and slow processes, small and big ones. These are fundamentally nonlinear in their dynamics and therefore generate occasional surprise that is the challenge for policy and for politics. We need an emphasis on a search for generality. This requires cooperative works with other experts in other fields, ones who share the curiosity and fun of mutual discovery. We need development and testing of a range of methods and a disbelief in any of them. And we need a wedding of theory, empirical examples, and application. That is the emphasis and the process that led to *Panarchy*.

A recent paper uses panarchy to suggest the significance of the three modes of learning and of discovery.[31] The first mode is the gradual accumulation of skills and techniques in the r to K phase[32] (see Figure 1). That is incremental, front-loop learning. The second mode is the mode of learning on the back loop from Ω to α.[33] This is more profound, but still only tests the existing system, opening it to novel combinations that have accumulated from r to K. Some of those combinations can nucleate a new cycle that is a variant, perhaps an appropriate variant, for the next cycle of change.[34] It is very much natural selection in the Darwinian sense, but it does not transform the system. Pursuing the Darwinian metaphor, it involves some novelty in the form of cross-overs and recombinations of existing options and ideas, but it does not involve real mutations—that belongs to the third mode.

The third mode of learning is transformational and does concern self-organization that can transform the system into truly novel strategies and processes. This is where transformative capacity lies. It represents true invention that can become reality in the kind of situation where the system is deeply responsive—vulnerable—to change or where change is desperately needed. The consequences are inherently uncertain and unpredictable. We see those new beginnings

31. *See* Brian Walker, C.S. Holling, Stephen R. Carpenter & Ann Kinzig, *Resilience, Adaptability and Transformability in Social-Ecological Systems*, 9 ECOLOGY & SOC'Y (2004), http://www.ecologyandsociety.org/vol9/iss2/art5.

32. *See id.*

33. *See id.*

34. *See id.*

now in the possible transformations created by the opportunities and fears opened by the Internet, by genetic engineering of crops, and by novel computer and communications technology. It is the transformative capacity of the world and how to nurture it that now comes most vividly to mind. It creates new panarchies.

I show my biases for our science and scholarship by arguing for a combination of the best of multiscale synthesis, complexity theory, evolutionary biology, and human history as the foundation to understand and manage our complex, transforming world. And I argue for a host of safe-fail experiments to test new ways of communicating, living, and sustaining our foundations.