Speaking Nature's Language: Principles for Sustainability

Fritjof Capra

If anyone has learned to speak nature's language, it is Fritjof Capra. A founding director of the Center for Ecoliteracy and currently chair of its board, he has distinguished himself over the past forty years as a scientist, systems theorist, and explorer of the philosophical and social ramifications of contemporary science.

Introducing him to an overflow audience at a Bioneers Conference plenary, Kenny Ausubel said, "One of Fritjof Capra's greatest gifts is his ability to digest enormous amounts of information from highly complex, wide-ranging fields of inquiry. Not only does he explain them elegantly and clearly, but he distills their essence and sees their implications. Because he's a credentialed scientist who did his time with particle accelerators all over Europe and the United States, Fritjof never overstates his case or lapses into wishful thinking."

After receiving his Ph.D. in theoretical physics from the University of Vienna in 1966, Capra did research in particle physics at the University of Paris, the University of California at Santa Cruz, the Stanford Linear Accelerator Center, Imperial College of the University of London, and the Lawrence Berkeley Laboratory at the University of California. He also taught at UC Santa Cruz, UC Berkeley, and San Francisco State University.

He is the author of five international bestsellers: The Tao of Physics *(1975),* The Turning Point *(1982),* Uncommon Wisdom *(1988),* The Web of Life *(1996), and* The Hidden Connections *(2002). He coauthored* Green Politics *(1984),* Belonging to the Universe *(1991), and* EcoManagement *(1993), and coedited* Steering Business Toward Sustainability *(1995).*

He is on the faculty of Schumacher College, an international center for ecolog-

ical studies in England, frequently gives management seminars for top executives, and lectures widely to lay and professional audiences in Europe, Asia, and North and South America. He is an enormously popular speaker, addressing audiences of thousands, switching easily between German, French, English, Italian, and Spanish. The Center for Ecoliteracy's single greatest source of inquiries is people from as far away as Brazil and India who find the CEL website by linking from Capra's.

This essay distills thinking that has inspired the Center for Ecoliteracy and served as its intellectual touchstone for a decade.

AS I DISCUSSED IN THE PREFACE to this book, we can design sustainable societies by modeling them after nature's ecosystems. To understand ecosystems' principles of organization, which have evolved over billions of years, we need to learn the basic principles of ecology—the language of nature, if you will. The most useful framework for understanding ecology today is the theory of living systems, which is still emerging and whose roots include organismic biology, gestalt psychology, general system theory, and complexity theory (or nonlinear dynamics). For more discussion of the theory of living systems and its implications, please see my book *The Hidden Connections.*

What is a living system? When we walk out into nature, living systems are what we see. First, *every living organism*, from the smallest bacterium to all the varieties of plants and animals, including humans, is a living system. Second, *the parts of living systems* are themselves living systems. A leaf is a living system. A muscle is a living system. Every cell in our bodies is a living system. Third, *communities of organisms*, including both ecosystems and human social systems such as families, schools, and other human communities, are living systems.

Thinking in terms of complex systems is now at the very forefront of science. It is also very like the ancient thinking that enabled traditional peoples to sustain themselves for thousands of years. But although the modern version of this intellectual tradition is almost a hundred years old, it has still not taken hold in our mainstream culture. I've thought quite a lot about why people find systems thinking so difficult and have concluded that there are two main reasons. One is that living systems are nonlinear—they're networks—while our whole scientific tradition is based on linear thinking—chains of cause and effect.

In linear thinking, when something works, more of the same will always be better. For instance, a "healthy" economy will show strong, indefinite economic growth. But successful living systems are highly nonlinear. They don't maximize their variables; they optimize them. When something is good, more of the same will not necessarily be better, because things go in cycles, not along straight lines. The point is not to be efficient, but to be sustainable. Quality, not quantity, counts.

We also find systems thinking difficult because we live in a culture that is materialist in both its values and its fundamental worldview. For example, most biologists will tell you that the essence of life lies in the macromolecules—the DNA, proteins, enzymes, and other material structures in living cells. Systems theory tells us that knowledge of these molecules is, of course, very important, but the essence of life does not lie in the molecules. It lies in the patterns and processes through which those molecules interact. You can't take a photograph of the web of life because it is nonmaterial—a network of relationships.

Perceptual Shifts

Because living systems are nonlinear and rooted in patterns of relationships, understanding the principles of ecology requires a new way of seeing the world and of thinking—in terms of *relationships, connectedness, and context*—that goes against the grain of traditional Western science and education. Such "contextual" or "systemic" thinking involves several shifts of perception:

From the parts to the whole. Living systems are integrated wholes whose properties cannot be reduced to those of their smaller parts. Their "systemic" properties are properties of the whole that none of the parts has.

From objects to relationships. An ecosystem is not just a collection of species, but is a community. Communities, whether ecosystems or human systems, are characterized by sets, or networks, of relationships. In the systems view, the "objects" of study are networks of relationships, embedded in larger networks. In practice, organizations designed according to this ecological principle are more likely than other organizations to feature relationship-based processes such as cooperation and decision-making by consensus.

From objective knowledge to contextual knowledge. The shift of focus from the parts to the whole implies a shift from analytical thinking to contextual thinking. The properties of the parts are not intrinsic, but can be understood only within the context of the whole. Since explaining things in terms of their contexts means explaining them in terms of their environments, all systems thinking is environmental thinking.

From quantity to quality. Understanding relationships is not easy, especially for those of us educated within a scientific framework, because Western science has always maintained that only the things that can be measured and quantified can be expressed in scientific models. It's often been implied that phenomena that can be measured and quantified are more important—and maybe even that what cannot be measured and quantified doesn't exist at all. Relationships and context, however, cannot be put on a scale or measured with a ruler.

From structure to process. Systems develop and evolve. Thus the understanding of living structures is inextricably linked to understanding renewal, change, and transformation.

From contents to patterns. When we draw maps of relationships, we discover certain configurations of relationships that appear again and again. We call these configurations "patterns." Instead of focusing on what a living system is made of, we study its patterns.

Here we discover a tension between two approaches to the study of nature that has characterized Western science and philosophy throughout the ages. One approach begins with the question: What is it made of? Traditionally, this has been called the study of matter. The other approach begins with the question: What is the pattern? And this, since Greek times, has been called the study of form.

In the West, most of the time, the study of matter has dominated in science. But late in the twentieth century, the study of form came to the fore again, with the emergence of systems thinking. Chaos and complexity theory are essentially theories of patterns. The so-called strange attractors of chaos theory are visual patterns that represent the dynamics of a certain chaotic system. The fractals of fractal geometry are visual patterns. In fact, the whole new mathematics of complexity is essentially the mathematics of patterns.

Some Implications for Education

Because the study of patterns requires visualizing and mapping, every time that the study of pattern has been in the forefront, artists have contributed significantly to the advancement of science. In Western science the two most famous examples are Leonardo da Vinci, whose whole scientific work during the Renaissance could be seen as a study of patterns, and the eighteenth-century German poet Goethe, who made significant contributions to biology through his study of patterns.

This opens the door for educators' integrating the arts into the curriculum. Whether we talk about literature and poetry, the visual arts, music, or the performing arts, there's hardly anything more effective than art for developing and refining a child's natural ability to recognize and express patterns.

Because all living systems share sets of common properties and principles of organization, systems thinking can be applied to integrate heretofore fragmented academic disciplines. Biologists, psychologists, economists, anthropologists, and other specialists all deal with living systems. Because they share a set of common principles, these disciplines can share a common framework.

We can also apply the shifts to human communities, where these principles could be called principles of community. Of course there are many differences between ecosystems and human communities. Not everything we need to teach can be learned from ecosystems. Ecosystems do not manifest the level of human consciousness and culture that emerged with language among primates and then came to flourish in evolution with the human species.

Sustainability in the Language of Nature

By applying systems thinking to the multiple relationships interlinking the members of the earth household, we can identify core concepts that describe

the patterns and processes by which nature sustains life. These concepts, the starting point for designing sustainable communities, may be called principles of ecology, principles of sustainability, principles of community, or even the basic facts of life. We need curricula that teach our children these fundamental facts of life.

These closely related concepts are different aspects of a single fundamental pattern of organization: nature sustains life by creating and nurturing communities. Among the most important of these concepts, recognized from observing hundreds of ecosystems, are "networks," "nested systems," "interdependence," "diversity," "cycles," "flows," "development," and "dynamic balance."

Networks

Because members of an ecological community derive their essential properties, and in fact their very existence, from their relationships, sustainability is not an individual property, but a property of an entire network.

At the Center for Ecoliteracy, we understand that solving problems in an enduring way requires bringing the people addressing parts of the problem together in networks of support and conversation. Our watershed restoration work, for example (see "'It Changed Everything We Thought We Could Do'" in Part III), began with one class of fourth-graders concerned about an endangered species of shrimp, but the work continues today because it evolved into a network that includes students, teachers, parents, funders, ranchers, design and construction professionals, NGOs, and government bodies. Each part of the network makes its own contribution to the project, the efforts of each are enhanced by the work of all, and the network has the resilience to keep the project alive even when individual members leave or move on.

Nested Systems

At all scales of nature, we find living systems nesting within other living systems—networks within networks. Although the same basic principles of organization operate at each scale, the different systems represent levels of differing complexity.

Students working on the Shrimp Project, for example, discovered that the shrimp inhabit pools that are part of a creek within a larger watershed. The creek flows into an estuary that is part of a national marine sanctuary, which is included in a larger bioregion. Events at one level of the system affect the sustainability of the systems embedded in the other levels.

Within social systems such as schools, the individual child's learning experiences are shaped by what happens in the classroom, which is nested within the school, which is embedded in the school district and then in the surrounding school systems, ecosystems, and political systems. At each level phenomena exhibit properties that do not exist at lower levels. Choosing strategies to affect those systems requires simultaneously addressing the multiple levels and recognizing which strategies are appropriate for different levels. For instance (see "Sustainability—A New Item on the Lunch Menu" in Part IV), the Center recognized that changing schools' food systems required moving from working with individual schools to working at the district level and then to the larger educational and economic systems in which districts are nested.

Interdependence

The sustainability of individual populations and the sustainability of the entire ecosystem are interdependent. No individual organism can exist in isolation. Animals depend on the photosynthesis of plants for their energy needs; plants depend on the carbon dioxide produced by animals and on the nitrogen fixed by bacteria at their roots. Together, plants, animals, and microorganisms regulate the entire biosphere and maintain the conditions conducive to life.

Sustainability always involves a whole community. This is the profound lesson we need to learn from nature. The exchanges of energy and resources in an ecosystem are sustained by pervasive cooperation. Life did not take over the planet by combat but by cooperation, partnership, and networking. The Center for Ecoliteracy has supported schools such as Mary E. Silveira (see

"Leadership and the Learning Community" in Part III) that recognize and celebrate interdependence.

Diversity

The role of diversity is closely connected with systems' network structures. A diverse ecosystem will be resilient because it contains many species with overlapping ecological functions that can partially replace one another. When a particular species is destroyed by a severe disturbance so that a link in the network is broken, a diverse community will be able to survive and reorganize itself because other links can at least partially fulfill the function of the destroyed species. The more complex the network's patterns of interconnections are, the more resilient it will be.

On the other hand, in communities lacking diversity, such as monocrop agriculture devoted to a single species of corn or wheat, a pest to which that species is vulnerable can threaten the entire ecosystem.

In human communities ethnic and cultural diversity may play the same role as does biodiversity in an ecosystem. Diversity means many different relationships, many different approaches to the same problem. At the Center for Ecoliteracy, we have discovered that there is no "one-size-fits-all" sustainability curriculum. We encourage and support multiple approaches to any issue, with different people in different places adapting the teaching of principles of ecology to differing and changing situations.

Cycles

Matter cycles continually through the web of life. Water, the oxygen in the air, and all the nutrients are continually recycled. Communities of organisms have evolved over billions of years, using and recycling the same molecules of minerals, water, and air. Mutual dependence is much more existential in ecosystems than in social systems because the members of an ecosystem actually eat one another. Ecologists recognized this from the very beginning of ecology. They focused on feeding relations and discovered the concept of the food chain that we still use today. But then they realized that those are not linear chains but cycles, because the bigger organisms are eaten eventually by the decomposer organisms, the insects and bacteria, and so matter cycles through an ecosystem. An ecosystem generates no waste. One species' waste becomes another species' food. As I noted in the preface, one reason for the Center's enthusiasm for school gardens is the opportunity that gardens afford for even very young children to experience nature's cycles.

The lesson for human communities is obvious. A conflict between economics and ecology arises because nature is cyclical, while industrial processes are linear. Businesses transform resources into products plus waste, and sell the products to consumers, who discard more waste after consuming the products. The ecological principle "waste equals food" means that—if an industrial system is to be sustainable—all manufactured products and materials, as well as the wastes generated in the manufacturing processes, must eventually provide nourishment for something new. In such a sustainable industrial system, the total outflow of each organization—its products *and* wastes—would be perceived and treated as resources cycling through the system.

Flows

All living systems, from organisms through ecosystems, are open systems. Solar energy, transformed into chemical energy by the photosynthesis of green plants, drives most ecological cycles, but energy itself does not cycle. As it is converted from one form of energy to another (for instance, as the chemical energy stored in petroleum is converted into mechanical energy to drive the pistons of an automobile), some of it—often much of it—inevitably flows out and is dispersed as heat. We are therefore dependent on a constant inflow of energy.

A sustainable society would use only as much energy as it could capture from the sun—by reducing its energy demands, using energy more efficiently, and capturing the flow of solar energy more effectively through solar heating,

photovoltaic electricity, wind, hydropower, biomass, and other forms of energy that are renewable, efficient, and environmentally benign. Among the complex reasons that the Center for Ecoliteracy promotes farm-to-school food programs (see "Rethinking School Lunch" in Part IV) is that buying food grown close by reduces the unrenewable energy that is required to ship tons of food over thousands of miles to supply school lunches.

Development

All living systems develop, and all development invokes learning. During its development, an ecosystem passes through a series of successive stages, from a rapidly growing, changing, and expanding pioneer community to slower ecological cycles and a more stable fully exploited ecosystem. Each stage in this ecological succession represents a distinctive community in its own right.

At the species level, development and learning are manifested as the creative unfolding of life through evolution. In an ecosystem, evolution is not limited to the gradual adaptation of organisms to their environment, because the environment is itself a network of living organisms capable of adaptation and creativity.

Individuals and environment adapt to one another—they coevolve in an ongoing dance. Because development and coevolution are nonlinear, we can never fully predict or control how the processes that we start will turn out. Small changes can have profound effects. For instance, growing their own food in a school garden can open students to the delight of tasting fresh healthy food, which can create an opportunity to change school menus, which can create a systemwide market for fresh food, which can help sustain local family farms.

On the other hand, nonlinear processes can lead to unanticipated disasters, as occurred with DDT and the development of "superorganisms" resistant to antibiotics, and as some scientists fear could happen with genetic modification of organisms. A sustainable society will exercise caution about committing itself to practices with unknown outcomes. In "The Slow School" (in

Part I), Maurice Holt describes the unforeseen consequences of schools' wholesale commitment to standards-measurement techniques derived from manufacturing and industry.

Dynamic Balance

All ecological cycles act as feedback loops, so that the ecological community continually regulates and organizes itself. When one link in an ecological cycle is disturbed, the entire cycle brings the situation back into balance, and since environmental changes and disturbances happen all the time, ecological cycles continually fluctuate.

These ecological fluctuations take place between tolerance limits, so there is always the danger that the whole system will collapse when a fluctuation goes beyond those limits and the system can no longer compensate for it. The same is true of human communities. Lack of flexibility manifests itself as stress. Temporary stress is essential to life, but prolonged stress is harmful and destructive to the system. These considerations lead to the important realization that managing a social system—a company, a city, or an economy—means finding the *optimal* values for the system's variables. Trying to maximize any single variable instead of optimizing it will invariably lead to the destruction of the system as a whole.

Every living system also occasionally encounters points of instability (in human terms, points of crisis or of confusion), out of which new structures, forms, and patterns spontaneously emerge. This spontaneous emergence of order is one of life's hallmarks and is where we see that creativity is inherent in life at all levels.

One of the most valuable skills for utilizing ecological understanding is the ability to recognize when the time is right for the emergence of new forms and patterns. For example, out of frustration with the failure of piecemeal hunger intervention to have much long-term impact, "community food security" programs are emerging across the country. This movement addresses the overall systems—from energy and transportation to government commodities purchasing to the effect of media on children's food preferences—that permit communities to meet (or prevent them from meeting) their needs for nutritious, safe, acceptable food.

It is no exaggeration to say that the survival of humanity will depend on our ability in the coming decades to understand these principles of ecology and to live accordingly. Nature demonstrates that sustainable systems are possible. The best of modern science is teaching us to recognize the processes by which these systems maintain themselves. It is up to us to learn to apply these principles and to create systems of education through which coming generations can learn the principles and learn to design societies that honor and complement them.

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