PART ONE

CHAPTER ONE

the ecological model

The first law of ecology is that everything is related to everything.
—Barry Commoner

Many books and articles suggest that nature will inspire design to provide for a sustainable future. These sources provide lessons that tend to lead to patterns or forms that copy nature's solutions in form only. The deeper lesson of ecology is that nature's form is a direct response to capturing the flow of energies and materials that reside within that bioregion. The huge diversity in natural forms teaches us that there are many ways, many forms, to capture and use available energy. The form itself, made up of biological processes, maximizes the use and storage of energy and materials for its needs and functions within its ecological and energy location.

Ecology is the study of the *relationship* of plants and animals to their environment. The flow of material and energy between things within their environment is their spatial context—their community. It is the study of that spatial connectivity between organism and environment that makes ecology an excellent model for sustainable design. Conceptually, sustainable design expands the role of the design program, moving the design goal from object to community, and then designs the connections, illustrating the relationship between available energy and the natural place. The flow of renewable energy, which powers all the essential processes needed for life, dwarfs the power and use of nonrenewable energy sources. These energies power functions at no cost and without pollution-loading the environment. The removal of natural systems not only increases costs, but it reduces the functioning of natural systems—as nature is reduced, the cost of life and to life increases.

The physical environment includes the sun, water, wind, oxygen, carbon dioxide, soil, atmosphere, and many other elements and processes. The diversity and complexity of all the components in an ecological study require studying organisms within their environments. Ecological study connects many fields and areas of expertise, and in so doing illustrates holistic aspects of components and their relationships to one another within their spatial community.

Planning and architecture must work together to be sustainable. Sustainable design challenges the designer to design connections to the site and to the site's resident energy—to design holistically and connectedly and address the needs of the building and the environment and community of which it is a part. Sustainable design and planning make use of the regional climate and local resources. To design *sustainably* is to integrate the design into the ecology of the place—the flows of materials and energy residing in the community.

Ecology

German biologist Ernst Heinrich Haeckel introduced the term *ecology* in 1866. The term, derived from the Greek *oikos*, means "household," which is the root word for economy as well. Charles Darwin developed his theory of evolution by making the connection between organisms and their environments. Earth contains huge numbers of complex ecosystems that collectively contain all of the living organisms that exist. An organism's household includes the complex flow of materials within and outside of the system, and it is all powered by sustainable energies. Systems powered by sustainable energy tend to grow to a mature state called a *climax state* and then slow their growth and develop hardy species and environmental connections (e.g., redwood forests). Systems powered by nonrenewables grow rapidly to a point where growth and their structure can no longer be sustained, and then—at the point of growing past the resource base and structural abilities—die back (e.g., weed-filled lots). Nonrenewables, such as fossil fuel, due to their high net energy (usable energy), accelerate growth beyond what renewable energy can do, but then when nonrenewables become scarce or are used up, the growth decelerates to disorder and the system toward failure.

The biosphere is composed of the Earth plus the sliver of thin air extending out six miles from the Earth's surface. All life in this zone relies on the sun's energy. The biosphere has specific bioclimatic zones called *biomes*, which are tailored to their climate, soil, physical features, and plant and animal life. These components uniquely support their ecosystems, and they provide a working balance for the *basics,* as ecologist Ben Breedlove called them—feeding, breeding, resting, and nesting.

Ecology makes use of what is there. Since ecology is the study of organisms and their environment, it includes the study of the relationships and interactions between living organisms—including humans and their natural and built habitats.

Ecology as a Model

Architects are well aware of the value of a *model,* a scalar but accurate representation of a designed solution to a specific program. The ecological model is somewhat different. It still illustrates an accurate representation, but it does so by showing pathways between energy and material flows. An ecological model shows the processes that drive the ecological system under study, as well as the cycles associated with the flow of energy and materials essential to its existence.

We are a part of nature; all changes in nature and to our habitat affect us. It is important to understand what is being affected and how. This knowledge is basic to defining the sustainable design problem. *Odum's model,* devised by systems ecologist and holistic thinker Dr. Howard T. Odum, illustrates the relationship between flows of energy and materials, between system components, and between producers and consumers. All of life functions this way. We can change the relationship between the components by changing the connections and flows between the components: for example, increasing agriculture's gross output with the use of fertilizers and pesticides and converting natural landscape into agricultural or urban *land use*. This land-use change results in the gain of a community but also the loss of the valuable contributions from nature—clean air and water. The sun powers photosynthesis (creating an energy storage, carbohydrates), and powers the cycling of materials (water, nutrients, and organic material—weather and hydrologic cycles) distributed by gravitational forces. The ecological model illustrates the flows of energy and materials, the distribution of which is powered by sustainable energies, including the sun, gravity, and natural cycles.

Odum's model is helpful because it illustrates the simple, essential relationships and connections between natural energies and renewable resources. Since sustainability is achieved by using local renewable resources, the model illustrates the places of opportunity and connections needed for designing interfaces.

> "There is as yet no ethic dealing with man's relation to land and to the plants which grow upon it. Land . . . is still property. The land-relation is still strictly economic, entailing privileges but not obligations. Individual thinkers since the days of Ezekiel and Isaiah have asserted that the despoliation of the land is not only inexpedient but also wrong. Society, however, has not yet affirmed their belief."
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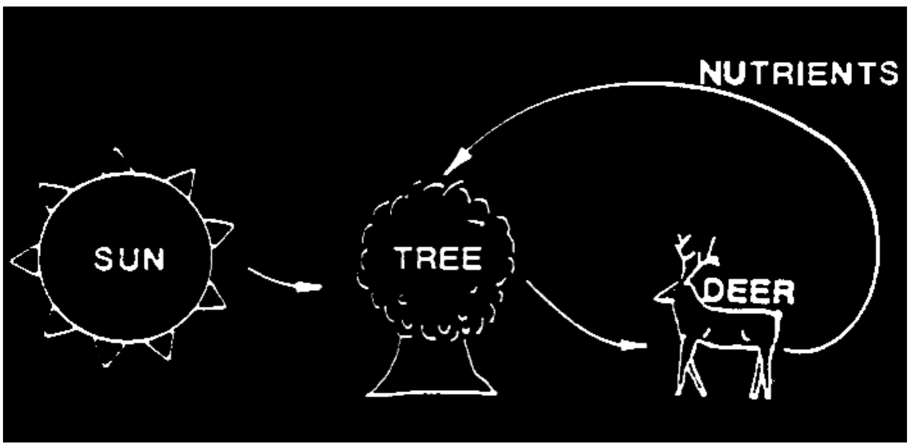
> ALDO LEOPOLD, 1949



Odum's model is simple—sustainability is cycling, storing, and connecting to sustainable energies.

> "We have a remarkable ability to define the world in terms of human needs and perceptions. Thus, although we draw the borders to demarcate countries, provinces, or counties, these lines exist only on maps that humans print. There are other boundaries of far greater significance that we have to learn to recognize . . . Natural barriers and perimeters of mountains and hills, rivers and shores, valleys and watersheds, regulate the makeup and distribution of all other organisms on the planet . . . We, in urban industrialized societies, have disconnected ourselves from these physical and biological constraints . . . Our human-created boundaries have become so real that we think that air, water, land, and different organisms can be administered within the limits of our designated jurisdictions. But nature conforms to other rules."
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> DAVID SUZUKI, *TIME TO CHANGE* (TORONTO, ONTARIO: STODDART, 1994), 34–35.

Recognizing the need, understanding the importance, and designing the connections within natural-system laws will provide a framework that will produce sustainable results. In part, this is a shift in basic thinking about what is design but also what is land. For most of the history of land use and associated zoning regulations, the emphasis has been on the so-called *highest and best use* of the owner's property—now called more simply *property rights*. In the recent past, land-use issues have primarily had to do with designing solutions to solely satisfy the owner and dismiss community's rights for the greater good.

Due in part to misplaced and poorly conceived urban sprawl, considerations have shifted from only serving property owners' rights to including community interests. Today we must think about the highest and best use for the *region's health and needs* and of the *common good*, while protecting the public and private good. Property rights law is about the *rights of the property* as much as it is about the rights of its owner, focusing such laws on what Thomas Jefferson referred to as obligations. There is an important distinction between *growing*—such as weeds—and *developing*—such as redwoods—property or land. Sustainable design is about development and stewardship.

> "The earth belongs to the living. No man may by natural right oblige the lands he owns or occupies, or those that succeed him in that occupation, to debts greater than those that may be paid during his own lifetime. Because if he could, then the world would belong to the dead and not to the living."
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> THOMAS JEFFERSON, ARCHITECT

The *ecological model* illustrates the relationship between needs and things that are provided. Some examples include the heat from the sun, from the Earth, from biological processes; cooling from evaporation, from plant transpiration, from the Earth; water and waste distribution powered by gravity, precipitation, air movement, microclimates; soils and food; and the interaction between these parts.

Sun-generated power and all cycles driven by it are sustainable engines. The more connected to these sustainable engines a process or product is, the greater the potential is for it to be sustainable, as well as affordable and profitable. Humans, biota, water, wind, crops, and so on are all powered by solar energy. The more these sustainable energies are integrated into the built environment, the closer that environment will be to being sustainable.

> " 'To grow' means to increase in size by the accretion or assimilation of material. *Growth* therefore means a quantitative increase in the scale of the physical dimensions of the economy. 'To develop' means to expand or realize the potentials of; to bring gradually to a fuller, greater or better state. *Development* therefore means the qualitative improvement in the structure, design and composition of the physical stocks of wealth that result from greater knowledge, both of technique and of purpose. A growing economy is getting bigger; a developing economy is getting better. An economy can therefore develop without growing or grow without developing."
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> "BOUNDLESS BULL," *GANNETT CENTER JOURNAL* (SUMMER 1990): 116–117.

Ecologies are adapted to the bioclimate of a region—the solar energy, soil, water supply, humidity, wind, topography, altitude, and natural events such as hurricanes, fires, floods, and droughts. Some of these energies and resources occur within the site, while some are from outside the site:

Outside energies: actions from outside the site happening to the site

- Solar (heat, light)
- Wind
- Climate

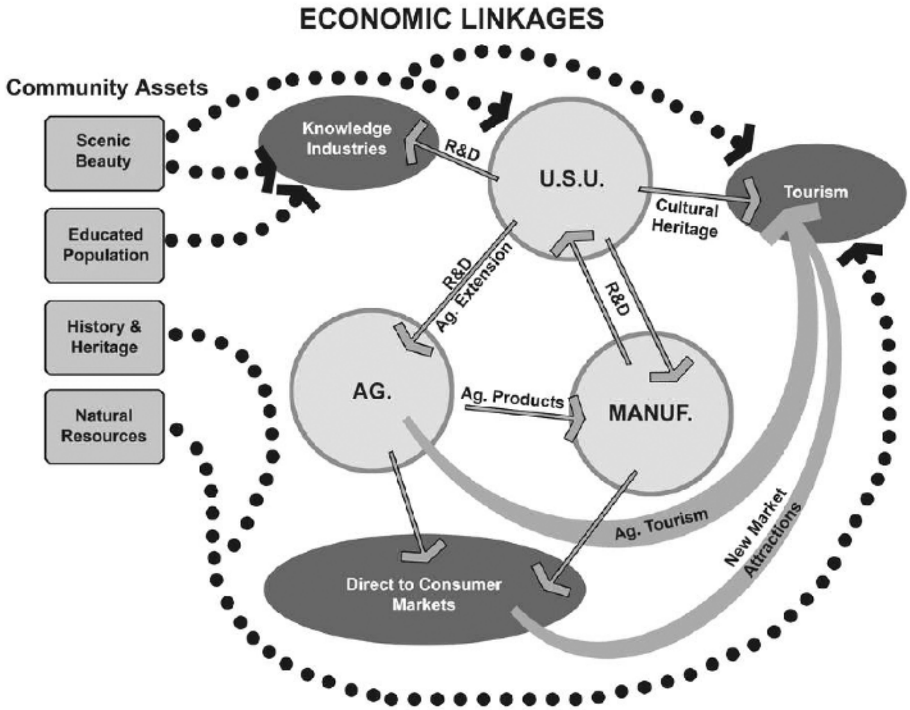
Inside energies:

- Gravity
- Soils and geology
- Microclimate
- Productivity and learning

Waste Debts

All ecologies have *wastes,* but those wastes are actually part of a cycle. They are part of the flows of energy and material within the ecology of the biome, and they are essential to the health and sustainability of the biome. Because these wastes are essential to and connected to the development and health of the system, they supply and power the system's development.

Most economies are based on the premise that their debts can be paid later—deficit spending is a critical element in a growing economy. As with all debts, waste debts must be paid, usually at a higher expense than is affordable. Nuclear power is an example of a net-energy producer (although it is not as good as fossil fuel), but it is also a producer of toxic waste that has a lethal half-life of 250,000 years. This cost is not part of the economic balance sheet. Consequently, the measured growth during the use of nuclear power is not real growth, as toxic material storage is not



An ecologic/economic model. As in most places, in Cache Valley, Utah, the economy is directly connected to its ecological health and scenic beauty.

accounted for in the debt column, a debt that must be paid for over a 250,000-year period.

There are more than 1,500 Superfund sites in the United States, and the estimated cost of cleanup is in the trillions of dollars. As of 2006, storage and cleanup of nuclear waste, just one of the superfund challenges, has no permanent solution, only a temporary storage solution. The best temporary solution is to store the waste in special glass containers guaranteed to work for 10,000 years, just a fraction of the 250,000-year half-life, in which the waste will remain toxic to humans. The containers are guaranteed by a company that most likely will be bankrupt or no longer in existence long before the guaranteed and stipulated working time.

Since its inception in 1980, 1,551 contaminated sites have been put on the National Superfund Priority List; 257 sites have been cleaned up and 552 have been partially or mostly decontaminated through 2001.

ENVIRONMENTAL DEFENSE FUND, JULY 8, 2002

Toxic brownfields and other contaminated sites remain a significant hidden cost to the economy. The use and abuse of such land by a previous owner creates a debt to the common owners—the public, the surrounding neighborhoods, the nation, and the economy. Such abuses were allowed in part because the economic value of the polluter to the community, both local and national, was considered critical. Now the real costs are in, the profit has been spent, and the public is charged the debt. According to the NRDC, groundwater contamination in the United States is estimated to be over 40 percent.

Thomas Jefferson, in addition to being a nation-shaper, farmer, writer, and president of the United States, was an architect. He was also father of land use and urban and regional design in this country. The beauty he saw in this new, developing country was integrated into the Jeffersonian grid, which was based, in large part, on ideals grounded in the greater good for the community, as well as for private good. Common space, agriculture, and a carrying capacity based on the land's natural resources were central to his vision. Inspired by the principles of freedom and community, he designed and helped to implement a community grid to be managed by the people. His plan, which was designed to express the needs and desires of the whole community, also preserved individual needs and desires. The framework of his plan, which put the community first and understood individuals as *part of the whole,* showed his ecological thinking.

Philosophically, Native Americans lived within the ecological model: There was a continuous stewardship of, tribute to, and respect for the land. Beginning with an understanding of the land's relevance to the culture of people and of place, the decisions made by the tribe were connected to the land and its inextricable connection to the long-term sustainability of the tribal community—respecting tribal history and stewarding the tribal future.

The Value of Land

As human populations expanded into the natural landscape, the relationship between the land and ownership of it became a source of conflict. Questions of

> The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons (the public areas). Such an arrangement may work reasonably satisfactorily for centuries, because tribal wars, poaching, and disease keep the numbers of both humans and beasts well below the land's carrying capacity. Finally, however, comes the day of reckoning—that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.
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> As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.
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> 1. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.
> 2. The negative component is a function of the additional overgrazing created by one more animal. Since, however, all herdsmen share the effects of overgrazing, the negative utility for any particular decision-making herdsman is only a fraction of −1.

> Adding together the component partial utilities, the rational herdsman concludes that the only sensible course to pursue is to add another animal to his herd. And another . . . and another . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each herdsman is locked into a system that compels him to increase his herd without limit—in a world that is limited.
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> GARRETT HARDIN, "THE TRAGEDY OF THE COMMONS," *SCIENCE, 162* (DECEMBER 1968), 1243–1248.

stewardship soon became central to the issues of freedom and ownership. For example, in the early 1900s, zoning laws started with one neighbor's land use resulting in the interruption, pollution, or denial of access to clean water and sunlight to another neighbor. At the beginning of the 2000s, there is an intriguing design problem on a regional, perhaps continental scale: the problem of designing for all conditions and needs simultaneously—maximum system value. There are no political solutions to this. The solutions lie in a design and planning that assures that the rights of the commons and the individual are both supported. Property lines do not recognize critical and contingent natural systems, and those natural systems provide an economic and environmental value to all.

Today's land-use patterns are much the same as this classic "tragedy"—using more land, more water, more soil, and more nonrenewable energy at rates that cannot be sustained. At the point where the use exceeds the supply, the standard of living is reduced and the quality of life goes down as well. Whenever nonrenewably generated electricity is used for lighting while the sun is shining, water is pumped to users while it falls (for free) from the clouds and is distributed by gravity, or materials are shipped thousands of miles to be used for a few years (or even less) and then discarded into the landfills, the tragedy expands.

Paradigm Shift

Public policy is influenced by the values and theories that are broadly held by the practitioners and researchers working in a given area of policy making. This underlying system of beliefs is referred to as a *paradigm*. A paradigm is a framework or foundation of understanding that is accepted by a professional community. Paradigms affect how professional questions are framed, research is conducted, and professional practice is changed. Paradigms are based on a *consensus* of what constitutes accepted facts and theories.

When an existing paradigm is replaced with a new one, a paradigm shift is underway. A paradigm shift occurs when the accumulation of a body of knowledge—for example, finding that design has negative impacts and can be done differently—emerges and illustrates deviations from the old paradigm. Sustainable design is a paradigm shift, where the solutions plug into natural resources, renewable energies, and place-based knowledge.

Thinking as a System: Connectivity, Not Fragmentation

In 1974, Howard Odum related the story of a project, the Crystal River Power Plant in central Florida, where he was hired to analyze environmental impacts. The challenge was to look at the comparative environmental costs of the thermal effluent, which was directly fed into an estuary, and compare the costs with an alternative approach, which incorporated cooling towers to disperse the waste heat. The Crystal River Power Plant needed a considerable number of cooling towers. These evaporative towers, constructed of wood, lowered the temperature of the thermal effluent through evaporative cooling and therefore reduced the thermal stress to the Crystal River—a crystal-clear, natural treasure. The environmentalists were convinced that the heat would degrade the estuary, and they strongly preferred treatment of the thermal effluent prior to it being introduced into the river.

Odum's analysis resulted in some counterintuitive conclusions. First, there would be considerable loss to the forest ecosystem every five to ten years to rebuild the wood cooling towers, and these huge towers would have a negative visual impact on the neighboring communities. More importantly, heat is a useful energy, and Odom was interested in employing that heat effluent as a usable energy.

Some ecosystems are perfectly adapted to heat stress; the saltwater estuary at Crystal River is one example. Oyster beds there populate the shallow waters and are capable of withstanding temperatures above 140°F. These organisms, in fact, had accelerated growth due to heat. The thermal effluent was gravity fed and distributed to the estuary, producing a prime productivity environment, with the waste heat as free energy. The analysis showed that the estuary was not only suited for the heat, but also benefited from it. In this case, the bias against the thermal effluent did not measure up.

> "In *The Culture of Nature*, landscape architect Alexander Wilson observes: 'My own sense is that the immediate work that lies ahead has to do with fixing landscape, repairing its ruptures, reconnecting its parts. Restoring landscape is not about preserving lands—*saving what's left*, as it's often put. Restoration recognizes that once lands have been *disturbed*—worked, lived on, meddled with, developed—they require human intervention and care. We must build landscapes that heal, connect, and empower, that make intelligible our relations with each other and with the natural world; places that welcome and enclose, whose breaks and edges are never without meaning.' "
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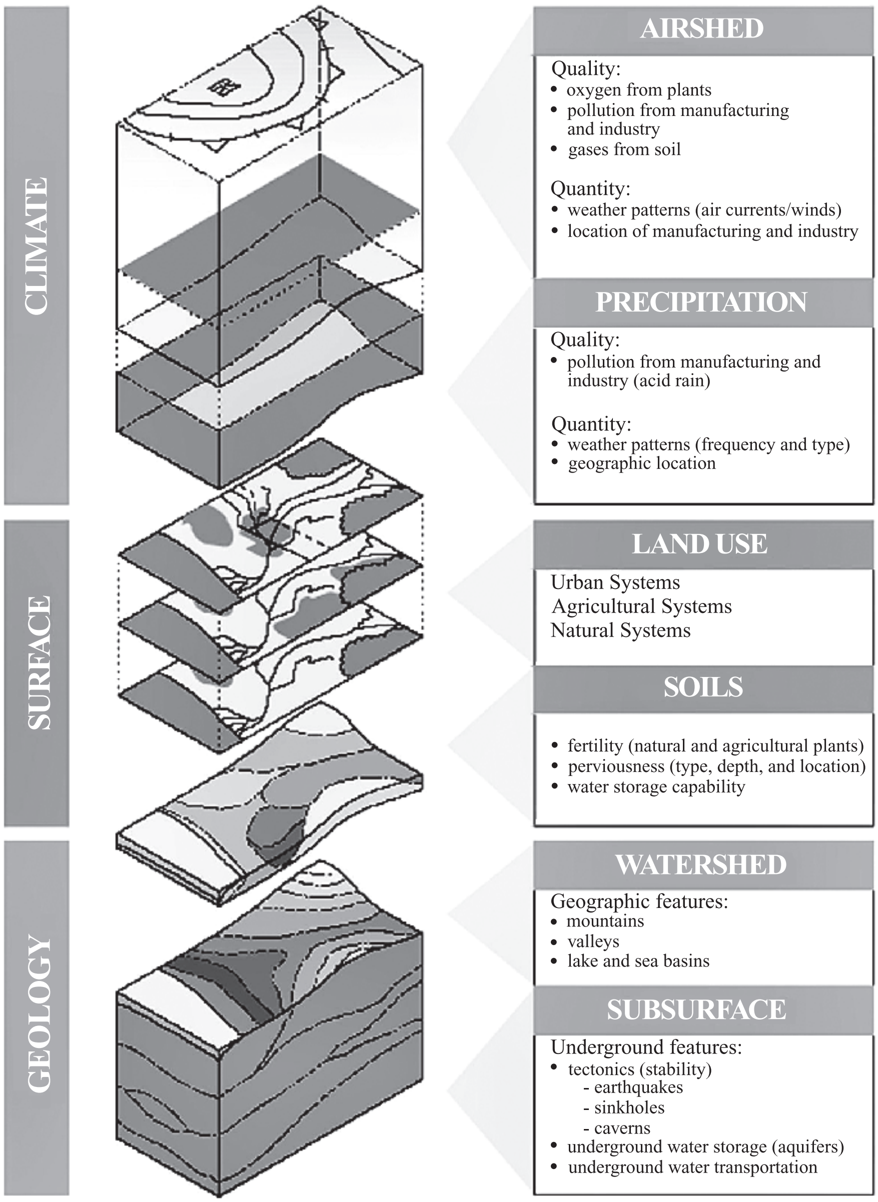
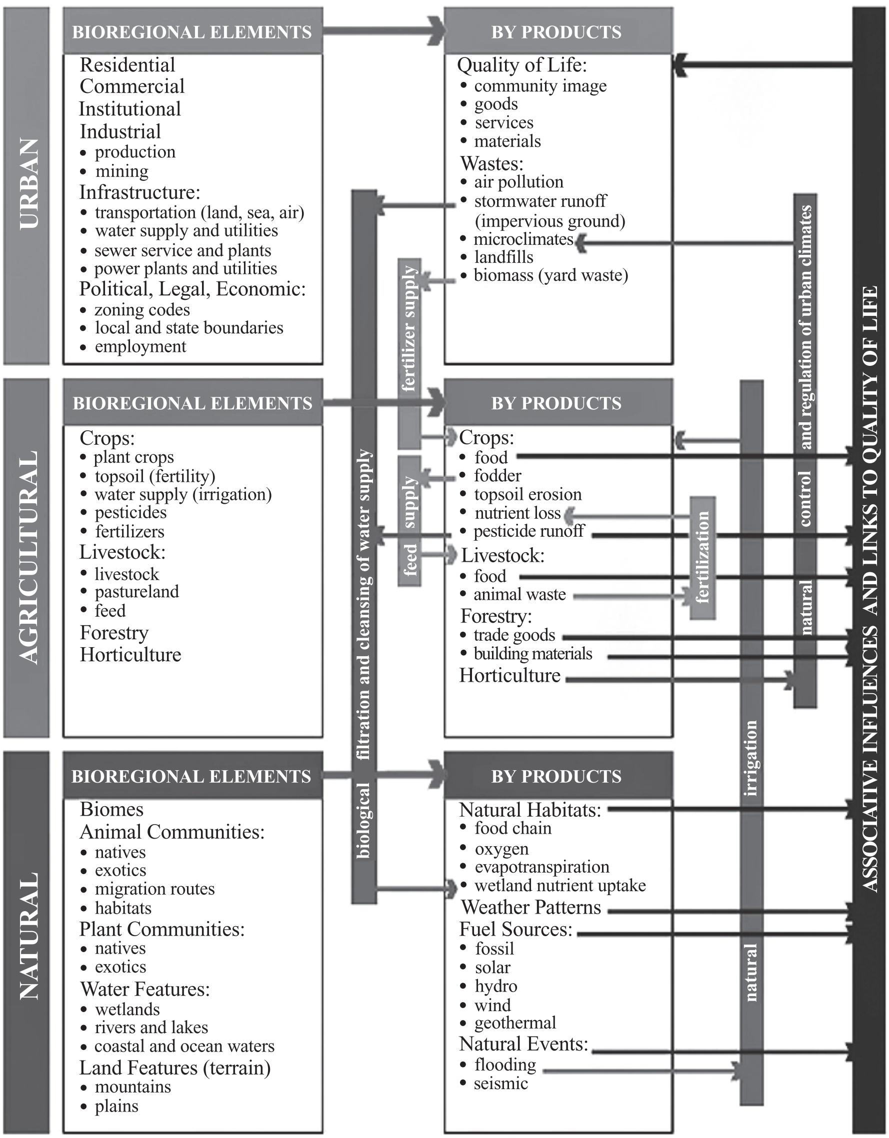
> ADELHEID FISCHER, "COMING FULL CIRCLE: THE RESTORATION OF THE URBAN LANDSCAPE," *ORION: PEOPLE AND NATURE* (AUTUMN 1994).

BIOREGIONALISM



Sustainable and renewable energy is best understood at the regional scale where the interactions are the spatial relationships between air (climate and essential gases), land use (water distribution, surface use, and ecology), and geology (soil characteristics and water storage potential.

B I O U R B A N I S M



These same relationships occur at the urban and community scale. Missing are the connections back into and between the components. The location of these components is a function of the natural system character.

> "We are now engaged in a great global debate about how we might lengthen our tenure on the earth. The discussion is mostly confined to options having to do with better technology, more accurate resources, prices, and smart public policies, all of which are eminently sensible, but hardly sufficient. The problem is simply how a species pleased to call itself *Homo sapiens* fits on a planet with a biosphere. This is a design problem and requires a design philosophy that takes time, velocity, scale, evolution, and ecology seriously."
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> DAVID W. ORR, *THE NATURE OF DESIGN* (NEW YORK: OXFORD UNIVERSITY PRESS, 2002), 50.

How many more opportunities are there where environmental stress and waste can be connected to the right biology and have a positive result rather than an expensive mitigation? Understanding these connections provides an opportunity for architects and designers to start developing schemes that both *fit* and *function* within the ecological system.

When ecologists study a particular system or biome, they start by defining the boundary as the next larger system. The sustainable design challenge starts similarly, studying the environmental context at the next larger scale, as a living pattern and interdependent system. In ecology the connections between systems are vital to life, whereas in conventional designing and planning only legal boundaries are used, and opportunities to integrate a site's resources and microclimate are typically left unexplored. Consequently, when designing sustainably if the project is architectural in scale, the neighborhood system must be included in the study; if the neighborhood is the project, then the city must be studied; and if the city, then the study starts with the regional scale. For this reason, the new challenge may well be to think globally, live locally, and *act regionally.* Designing regionally is the scale at which the most benefit toward sustainable living can be achieved. The need and the ability to design at this scale exist, but the will to do it does not.

Since ecology is the study of the *relationship* of plants and animals to their environment, designing ecologically requires the incorporation of sustainable relationships to power the design. The ecological model illustrates the foundation of the sustainable model and, consequently, a model for sustainable design. The resulting design will be planned to receive, store, and distribute sustainable energy and resources.