

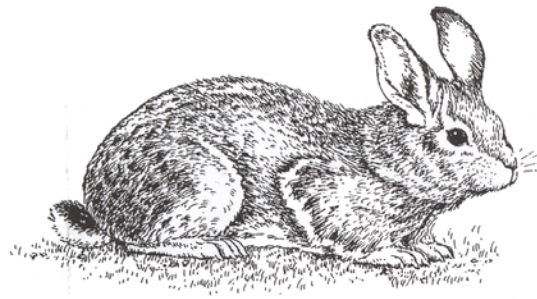
# EVERYTHING TIED TOGETHER

*The inescapable quality of all living species is their interrelatedness.*

No living thing exists by itself. Each plant or animal or human being exists as part of a living community, some members of which live inside other species and some of which are external to each other. Each is also part of an ecosystem that includes not just living species but the nonliving environment on which each depends. Each animal must continue to breathe air, changing it as it respire, giving off a different mixture of gases than it took in. Each must take on water, passing it through the body, modifying it, storing some temporarily, giving it off again in perspiration or urine. Each depends for its existence on external temperature that must remain within a tolerable range. Each must take in food that ties it in turn to a whole range of other living species each feeding on or being fed on by other species. There is no time when any person, or animal, or plant is not in a process of interacting and interchange with all the different factors and processes of the ecosystem in which he or she is operating. I don't know how many kinds of bacteria, protozoans, or other microorganisms live normally inside a human body, but there are many. We depend on them; they depend on us. You can't be alone and stay alive.

A biotic community is the complex of living species that occupy a particular area and interact with one another. It can be large or small. The rainforests of the Amazon form a vast complicated biotic community; the lawn in front of a suburban house is another, small and relatively simple. Each community in turn is the living part of an ecosystem, which can be defined as a biotic community and the physical environment with which it interacts.

You cannot protect or manage just one species, since what you do to it, or for it, will affect all other species it interacts with. This is the dilemma facing wildlife biologists and managers, and the full extent of it is only recently being recognized. Since all living communities and ecosystems are complex, we must learn to understand and deal with complexity. There are many simple examples that illustrate this. The cutting of trees in a forest does not just remove trees, it changes the conditions of life for all other forest species. Some increase, others disappear, and the interactions among all of them are modified. If insects, mice, rabbits, or deer become too numerous, they can slow down or even prevent forest trees from growing back in the area, at least until they find conditions unfavorable to their own abundance and begin to decline in numbers. The destruction of "weed" species with herbicidal sprays or of insect "pests" with insecticides affects not only the target species but the entire community – from the abundant life that exists within the soil, to all the species that dwell above the ground, or those that move through the area. Often the consequences from such spraying far exceed any that were intended by the sprayer.



## FUNCTIONING OF ECOSYSTEMS

---

The relationships within an ecological system are never static. Growth and death, change and replacement, go on continuously. Energy pours down from sunlight and is captured by green plants and transformed. Chemicals from soil, air, or water flow through the system along complicated pathways. Water moves through the system in an intricate cycle, starting from the ocean and atmosphere and returning to them again.

### *Energy Flow*

The functioning of an ecosystem depends on an inflow of energy. This is provided by sunlight, (for the most part), the energy which are captured by green plants and used in growth or metabolism, or are perhaps stored in chemical bonds in the plant starches, proteins, and other components. Thus, animals obtain their energy from sunlight indirectly, in its transformed state, stored in chemical compounds within the plants that herbivores eat. Carnivores in turn obtain their energy, third hand, from the plant eaters. The host of parasites, bacteria or fungi, and other microorganisms that derive their energy from living or dead animals may be several steps farther removed from the original sunlight source.

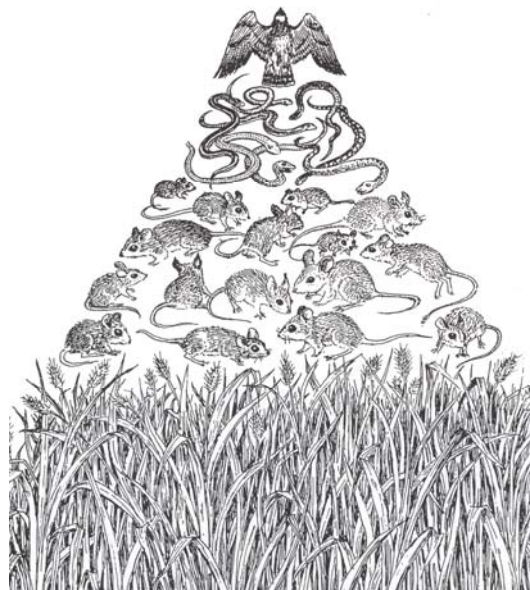
The amount of energy available in sunlight is large in relation to the amount actually captured and used by a biotic community. Most of it is lost to the ecosystem; it is reflected back from vegetation, water, or ground surface, or radiated back as heat waves. The efficiency with which green plants transform and store the energy available to them is relatively low, often around 1% ends up stored in plant tissues. But efficient or not, plants are the most effective converters of solar energy into forms useful to animals and humans.

In each energy transfer, from plants, to herbivores, to carnivores, some energy is lost. No energy transfer can be 100% efficient. Hence, the quantity of green plant material, with its stored energy, must be large in relation to the quantity of herbivorous animals that feed on it. All the energy stored in plant carbohydrates, oils, or proteins cannot be transformed into an equal quantity of energy stored in animal tissues. Most is lost, in the form of heat, during the chemical conversions of digestion and metabolism. Similarly, the quantity of herbivore energy must be larger than the quantity of energy that ends up stored in the body of a carnivore.

One pound of deer meat cannot produce one pound of mountain lion. Much is lost in the process of conversion.

Because of the energy relationships, it is sometimes useful to portray the distribution of living organisms within an ecosystem in the form of a biotic pyramid, broad at the base and tapering toward the top. At the base are all the green plants, in the middle the herbivores, on top the carnivores – with their numbers, or total weight (biomass), tending to decrease upward from layer to layer.

However, pyramids suggest something static and permanent, and it is not the number or weight of organisms present at any one time that is important, but how much they increase in a given period through reproduction and growth. In a marine ecosystem one may find at a particular time a relatively small quantity of the floating green plants, the phytoplankton, on which most of the animal species depend. However, over a growing season that phytoplankton has the capacity to produce an enormous quantity of plant material that supports the fish and invertebrate animal population.



In considering wildlife populations, it is sometimes true that predators may determine the level of prey populations, but the converse is always true. It may be, in a particular area, that the numbers of hawks, owls, weasels, and bobcats are controlling the number of quail; yet it is always the abundance and productivity of quail and other prey species that determines the level of predators that can be supported.



### ***Nutrient Cycling***

Energy flows through an ecosystem in one direction, fueling the physiological systems it passes through along the way, stored for short or long periods, but eventually ending up as heat or reflected light, too dispersed to be useful to the system. Other pathways in an ecosystem, however, tend to be circular. Soil minerals, for example, enter green plants via the roots to be stored in roots, stems, leaves, fruits, or seeds. Here they may be eaten by animals and stored for a time in their tissues. When the plants or animals die, microorganisms work on their bodies to restore the minerals to the soil. Thus, the same molecule of a nitrate or a phosphate may be used again and again in an ecosystem, moving from soil to plant, to animal, back to soil, and up again over a different pathway. Viewed over a long period of time such chemicals are in constant motion, and at any one time a high percentage of nutrients may be tied up in plant or animal life. In some tropical forests, for example, the soils, if considered alone, are relatively infertile. Their chemical nutrients are tied up in the trees and animal life and are returned only briefly to the surface before being captured once more by root systems and used by other organisms. These forest areas may seem remarkably fertile and productive, but if the forest is destroyed or removed, the soils that once supported it can rapidly lose their fertility and are incapable of supporting agricultural crops for very long.

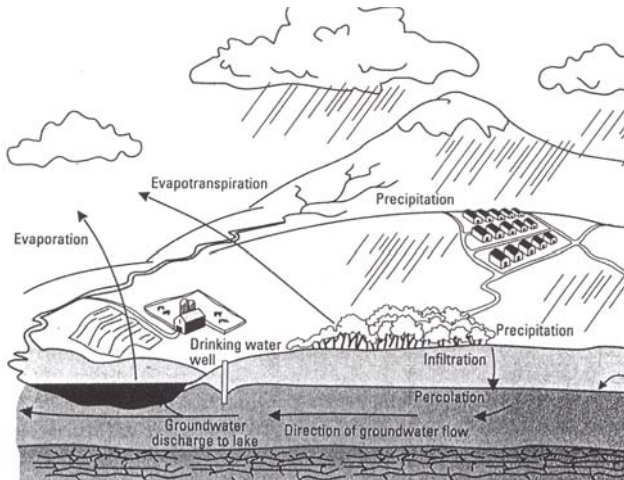
Without the constant turnover of minerals from the natural community, those nutrients present in the soil proper can be quickly leached away by rain, or exhausted by being removed in the production and harvesting of a few years of farm crops.

Nutrients required by plants and animals are in part derived from soil minerals obtained from the breakdown and decomposition of rocks. Some come primarily from the atmosphere, either in rainwater, or through the action of microorganisms. Nitrogen is in this category, with the atmosphere serving as its primary reservoir. Some nitrogen is converted to nitrates by the action of lightning and enters the soil through precipitation. Much of it is captured by nitrogen-fixing bacterial or algae, and may either enter the soil or be transferred to plants or animals directly from the organisms that convert it into nitrates.



## Hydrologic Cycles

Water moves through an ecosystem in a different way from soil minerals. Its principal reservoir is the ocean from which it enters the atmosphere by evaporation.



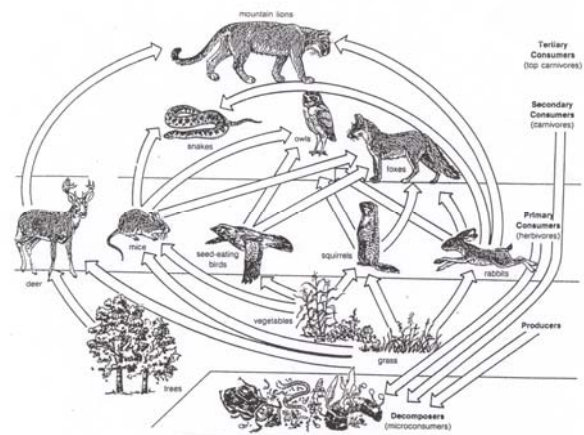
Moving with the atmosphere, it enters ecosystems in the form of precipitation. This may land on trees or soil and in part be evaporated directly back to the air. What reaches the soil may sink on through and leave the ecosystem via springs, streams, or underground channels, or be stored for a time in porous rock structures. The water remaining in the soil is taken up by plant roots and may either join in chemical bonds to form plant tissues or be lost from the leaves in transpiration. Water tied up in plants is used by animals, and some desert species, for example, may get all their water in this way. Most animals will use water directly from raindrops, dew, springs, ponds, or streams. All water tied up in plant or animal tissue is in time returned to the soil or evaporated back to the atmosphere, eventually to make its way back to the oceans once again. The various pathways followed by water in the circular travels from ocean to atmosphere to land and back to ocean are termed the hydrologic cycle.

Thus, there is a constant flow of energy through an ecosystem, whereas water and chemical nutrients flow or cycle within an ecosystem. So long as input balances loss, the system remains stable.

If, however, losses come to exceed input, as so often occurs through human interference, the system is modified. One community may be replaced by another, or if the loss continues for too long the ecosystem can lose its living components and break down.

## Food Chains and Webs

The pathways over which energy and chemicals move through an ecosystem are called food chains. Normally these pathways are lined together in intricate food webs. In a simple food chain, for example, sun energy enters grass that is eaten by a meadow mouse who is eaten by a hawk. The chain has three links, each representing an energy level, or trophic level. However, such a simple chain is an abstraction or useful simplification. In nature the hawk would support various internal and external parasites, and on its death would provide food for all the organisms involved in the breakdown and decay of its tissues. Furthermore, it would be unlikely to feed only on mice, but on other species as well. The meadow mice, in turn, would be fed on also by other predators: owls, weasels, coyotes; the grass would support a variety of herbivores: leaf-sucking and leaf-mining insects, for example, which could provide food for wasps and spiders, which in turn feed flycatchers, thrushes, or other birds. Food chains always become tied into complicated webs, and actual energy pathways can be difficult to trace.



## ECOSYSTEM DEVELOPMENT

---

A stable ecosystem does not suddenly come into existence. It may take centuries, or even thousands of years, to develop. The process by which it forms, originally, from an area that did not support life, is known as primary biotic succession. This, along with the slower process of organic evolution, has allowed organisms to spread over and occupy most of the surface of the earth.

Although much of the earth is now covered with vegetation, there are places where various stages of primary succession can be seen. A volcano in Italy erupts and pours molten lava down its slopes; a glacier in Alaska retreats and leaves pulverized earth and rocks in its wake; an earthquake in Chile brings to the surface bare rock from layers beneath the ground; or a lake fills in with soil and debris eroded from the surrounding lands. Each of these newly formed sites becomes an area where succession occurs. Each is eventually invaded by plant seeds or spores carried by wind, water, gravity, or animals moving from other places. Those species of plants that are hardy and able to adapt to the rigorous new environment can invade and colonize the new land. They then can provide a home or food for a few kinds of animals and microorganisms. Together these will, through growth and decay, begin to break down and modify the rocky or lifeless substrate beneath them. In time they form a simple, developmental soil. Weather, sunlight, and water further modify the physical environment. As the substrate changes, as rocks break down through weathering and minerals become oxidized, other plants and animals, more exacting in their requirements, can invade and in turn bring more changes. Plant roots reach deeper and more organic debris is incorporated with the minerals of the soil. Hardy lichens may be replaced by mosses, and these in time by grasses, shrubs, or trees. Eventually a relatively stable grouping of species will occupy the area. The soils will come into balance with the climate and vegetation, become mature, and subject to only slow future change. The vegetation in turn reaches the most complex level that the combination of soil and climate can support.

Animal life becomes adapted to the prevailing vegetation and in turn affects and maintains it. This end product of succession can be termed a climax ecosystem. However, it is an “end product” and stable only in a relative sense in that the process of change ceases to be obvious in terms of human lifetimes. Change continues, even if at a slow evolutionary pace. However, climax communities, barring major disturbance, tend to hold the ground, with the species of the climax replacing themselves through reproduction.

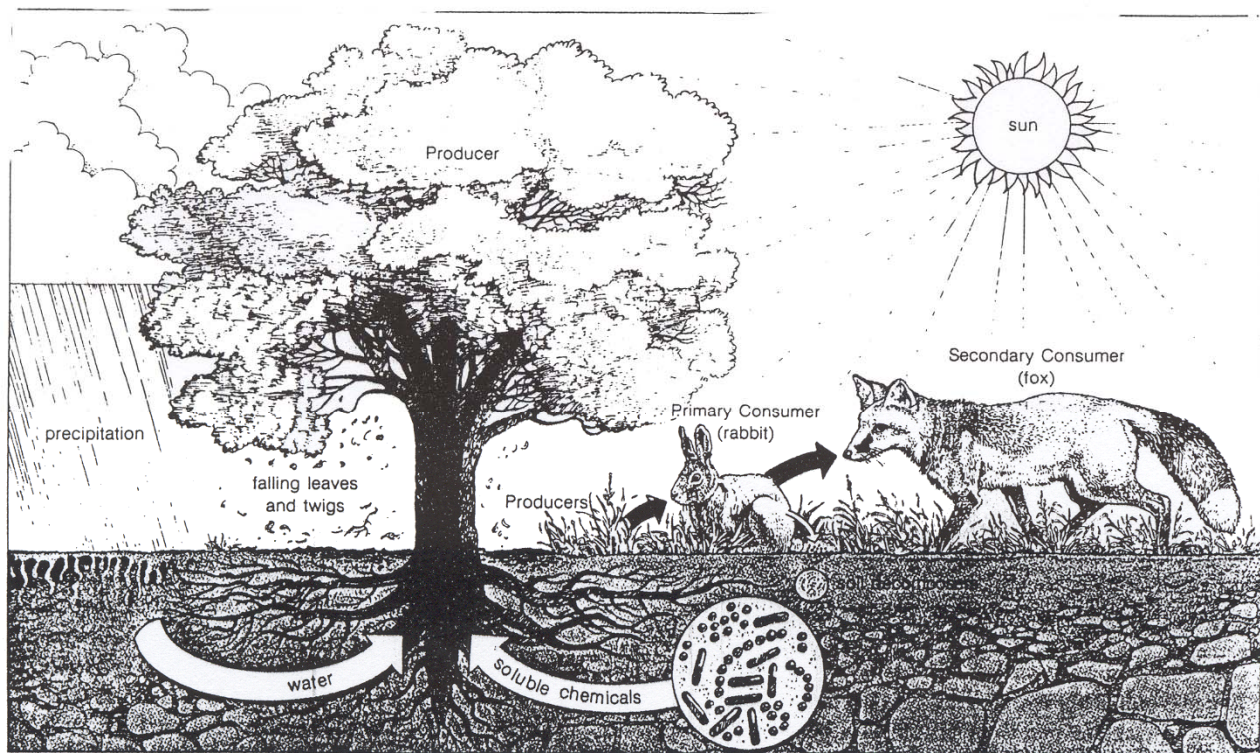
If fire, windstorm, or other disturbance should destroy a mature climax community, the process of ecosystem development that then takes place is known as secondary biotic succession. A burned-over forest regenerates itself at a much more rapid rate than that at which it was first formed through primary succession. Soils are still in place and need not be formed from a lifeless substrate. Plant seeds are usually available from nearby unburned communities, or they may survive the fire. Usually broad-leaved herbs and some grasses are the first species to become obvious; the purple fireweeds of northern forest are an example. In time these herbaceous plants will be overtopped and replaced by shrubs. Still further down the line are those trees that do best in open situations (alders or aspens) or there may be pines that take over and shade out the shrubs to form a subclimax forest. Eventually, trees with seedlings that thrive in forest shade will grow up to replace the more light-demanding species. These (spruce, hemlock, beech, or maple for example) may close in to form the climax forest. Commonly – but not always – these will form a community generally similar in composition to the one that was present before the fire.

The sequence that has been described is a depiction of the dominants at each stage of secondary succession. Often trees, shrubs, forbs, and grasses will all start growing in the first year following the fire. The herbaceous plants grow faster and dominate for a time; the shrubs then grow taller and shade them out; the trees continue to grow to overtop the smaller shrubs.

The stages are not everywhere the same and they vary with substrate and the availability of seeds, or the ability of the burned-over vegetation to sprout from stumps or root crowns. They modify it by feeding on plants that develop in each successional stage. Usually, however, there is the sequence from pioneer community, through middle successional stages, to subclimax and climax communities. If disturbance is particularly severe and seed sources not readily available, a burned-over forest may remain for many decades or longer in some mid-successional stage such as chaparral or sagebrush in the western United States.

A knowledge of succession is important to the wildlife biologist or manager, since animals are as much a part of succession as plants and some species are best adapted to each stage in succession. Quail may thrive in the weeds and brush that comes in after a fire; deer and ruffed grouse will do best in middle successional stages. Few large mammals prefer a forest climax, but a variety of insectivorous birds, some seed-eating birds, shrews, and moles may do best in such vegetation.

There are animal “weeds” that belong to the pioneer stages of development: white-footed mice, kangaroo rats, ground squirrels. There are climax species that seem to tolerate little disturbance; the woodland caribou may be an example. Some animal populations can arrest a biotic succession as surely as it can be arrested by frequent fire. Bison, on the Great Plains of the West, maintained the short-grass prairie, where, in their absence, taller grasses would have taken over. Many types of vegetation depend on fire for their continuance, and in the absence of frequent fires become replaced by other forms; chaparral and pine savanna are examples of fire-dependent types. But fire is a normal component of their environments, as predictable as weather and climate. In order to manage wildlife, it is essential to know the relation of species to the various stages of ecosystem development, and then to maintain those stages if we wish to maintain the species. This may involve setting back succession through fire or other means: for climax species it may involve protection from disturbance.



Major components of an ecosystem that supports the food web.

## CHANGE AND DEGRADATION

---

All ecosystems are subject to slow changes, but rapid change can have undesirable consequences. Degradation of an ecosystem is a change from a more productive to a less productive condition, and unless there are reasons for preferring the latter, it is undesirable.

A stable ecosystem is characterized by a constant turnover of materials, and a rough balance between losses of materials from the system and their replacement from atmosphere or substrate. Thus, in the virgin prairie, soil minerals moved upward through grass roots to leaves and stems that were fed upon by buffalo. When the buffalo died, the minerals were once more returned to the prairie soil to nourish a new generation of grass plants and buffalo. In drought years some soil would be lost to the system through wind erosion, and in other years some minerals would be leached and washed away in rainwater. But in an undisturbed prairie these losses would not be large and would be balanced in part by materials blown in by winds or carried by water from outside the system, and in part by new minerals added through the breakdown of rock fragments in the lower layers of the soil. Nitrates lost by leaching would be balanced by those fixed from the atmosphere by bacterial or algae, or by those carried in with rainwater. The prairie system was complex, with hundreds of plant species using various layers and portions of the soil, and a variety of animals feeding in turn on the various species and parts of plants or on each other. Food webs were complicated.

When Europeans first reached the prairie and attempted to live there, they found most of its components were not of direct use, and the indirect benefits were not apparent. The prairie produced buffalo, prairie chickens, and other game the settlers could eat, and there were a variety of foods that could have been used if the settlers had taken time to learn about them. But when the grasslands were plowed and planted to corn or wheat, soil nutrients, water, and sun energy were channeled directly into food production.

A sparse human population, supported by the native biota, was replaced by a dense population supported by farm produce. The prairie in time became a supplier of cereal grains to the world. In the process, however, the original ecosystem was simplified, and the living components of it were largely replaced, with hundreds of species giving way to a few dominants (corn, wheat, or soybeans) and those that could live with these in the new agroecosystem.

Unfortunately, such tinkering with ecosystems is risky. The earth is covered with ruins of past civilizations that failed to recognize these risks in time. Soils that have developed with, and as a part of, natural vegetation may not be able to hold up when planted with one or a few species of agricultural crop plants. Corn or wheat is harvested and taken away, and not allowed to return to the soil. Livestock fed on grain are shipped away to markets in distant cities and do not decay on the prairie. The new human masters of the land seldom allow their own remains to return to the soil. The original dense cover of prairie grasses shielded the soils from the impact of rainwater and the force of wind. Cereal grains fail to provide an adequate shielding. Thus, in the prairie region erosion began to occur, fertility began to decline, and the physical structure of the soil – formed by a dense network of plant roots – did not hold up under continual plowing and planting to cereal grains. A low point was reached in the 1930s when the Dust Bowl developed as a result of drought and continued misuse of the land. Many farmers went out of business. Those that remained began to practice a new and more expensive form of agriculture that involved adding chemical fertilizers – phosphates, potassium, and nitrates – taking up soil conservation techniques and using a variety of pesticides and herbicides to control insect pests and weeds attracted to the new kind of ecosystem created by commercial agriculture.

Elsewhere in the world things are worse. In modifying ecosystems and in replacing natural vegetation, we must remain aware of the necessity for replacing the soil-forming, soil-holding qualities of that vegetation. Additional problems also arise from the simplification of ecosystems. When the original variety of vegetation and animal life is replaced by a few cultivated species, an ideal, uniform habitat is created for those species that feed on cultivated plants. Lacking natural predators or other enemies, such species can increase to great numbers. The use of pesticides can bring temporary relief, but most commercial organic pesticides now in use are nonselective, killing friend and foe alike, and further reduce populations of natural predators. Furthermore, through killing off individuals most vulnerable to the particular poison, these tend to select for insecticide-resistant forms of the crop-destroying insect, causing a continued search for new or stronger pesticides. These in turn have serious side effects, which often are their principal effects, that destroy wild animal life.

In most instances, lands that are damaged by unwise attempts to make them grow unsuitable crops or by attempts to produce or support too many domestic animals can be repaired.

Sometimes simple rest is all that is needed, allowing natural processes of biotic succession to put things back together again. Sometimes more drastic measures are called for: erosion control devices, fertilization, replanting with species that can restore structure and fertility to the soil. Some lands have been pushed too far. A point of no return is reached when the rate of erosion or extent of soil destruction is too far advanced to allow recovery within a calculable period of time. Some of the Western ranges, grazed too heavily for too long, have reached this point. Mountain slopes are particularly vulnerable because once the soil has washed downhill, it cannot ordinarily be put back in place; the bare bones of the mountains begin to show – scenic perhaps, but not productive.

Most severe wildlife problems are associated with lands that have in one way or another been misused. Although some species occasionally increase to spectacular levels in relatively undisturbed ecosystems, such increases of previously benign species of wildlife to levels at which they become serious pests are a symptom of land misuse.

Reference: Wildlife Biology, R.F. Dasmann, 1981, Wiley & Sons, Inc.