ECOLOGY IS A BRANCH OF BIOLOGY. "The creation of the new science of ecosystem ecology is, without doubt, the most important single event that has occurred in the twentieth century." So declared Dr. S. Dillon Ripley, the Secretary of the Smithsonian Institution. As the reading public has recently become aware, an ecosystem is a natural unit including living and dead organisms and the chemico-physical environment. A lake and its life furnish a well-delimited example.

Although the unitary, ecosystem viewpoint was clarified and accepted by scientists only toward the end of the first half of our century, a few natural philosophers saw glimmerings of it long before. Two such men, Charles Darwin and George Perkins Marsh, whose best work was done before 1867 when the word "ecology" was coined, are now recognized as profound pioneer ecologists.

Still earlier hints of this holistic way of looking at Nature are found in writings of George Catlin, who in 1832 first proposed federal parks to preserve very extensive wilderness tracts, to include the plains Indian "galloping his wild horse . . . amid the fleeting herds of elk and buffaloe." Catlin, a professional painter and amateur Indian, lobbied in Washington for "a nation's Park . . ." Yellowstone National Park, the first National Park, was established 50 years later.

Henry David Thoreau described natural succession in forests, but approached the unitary idea most closely in studying small lakes — the type of habitat to be used most dramatically a century later in the first modern ecosystem research. Several scholars have reported recently, from a family letter by Thoreau, what they considered evidence that he was the first to use the word "ecology." What looked like this word in Thoreau's execrable handwriting has been firmly proved to be "geology" instead. The disproof saddened many Thoreauvians who felt he deserved to have invented a term so in tune with his philosophy.

In 1864, three years before biologist Ernst Haeckel named "ecology," the statesman-scholar-linguist George Perkins

The Ecological Way

ALTON A. LINDSEY*
Marsh published the ecological book *Man and Nature*, modestly subtitled *Physical Geography as Modified by Human Action*. In this extraordinary work, last reprinted 110 years later by Harvard University Press, Marsh gave to the most inclusive ecological unit we yet know the appropriate term “terraqueous machine.” This carries the connotation of an energy component. Today we call it the “planetary ecosystem.”

Marsh perceived smaller systems also, in principle and vaguely by modern standards but uniquely for his time:

We must remember that a wood is not an arbitrary assemblage of trees... without bond of union... it is, on the contrary, a whole, the different parts of which are interdependent upon each other, and it constitutes, so to speak, a true individuality. Every forest has a special character, determined by the form of the surface it grows upon and other factors.

The young Theodore Roosevelt revealed in his 1888 book *Ranch Life and the Hunting Trail* an understanding of the short-grass system in the high plains country that may well surprise even those aware that he majored in biology at Harvard with the intention of making field natural history his life work. He was the president of his local stockmen’s association in Dakotah Territory, and worried about overgrazing of the open range. The following quotation shows that he clearly recognized the principle of human ecology and land-use.

“At present we ranchers are far more afraid of each other. There are always plenty of men who for the sake of the chance of gain they themselves run are willing to
jeopardize the interests of their neighbors by putting on more cattle than the range will support — for the loss, of course, falls as heavily on the man who has put on too many; and it is against these individuals that we have to guard so far as we are able. To protect ourselves completely is impossible, but the very identity of interest that renders all of us liable to suffer for the fault of a few also renders us as a whole able to take some rough measures to guard against the wrong-doing of a portion of our number; for the fact that the cattle wander intermixed over the ranges forces all the ranchmen of a locality to combine... The best days of ranching are over. In its present (open range) form, stock-raising on the plains is doomed, and can hardly outlast the century."

Although a few natural philosophers and amateur naturalists (Darwin himself was an amateur) had the general idea, more specialized scientists named and systematized the ecosystem concept. Just before the turn of the century, two Wisconsin authorities on lakes, Birge and Juday, applied the holistic term “microcosm” to a lake and studied it as an ecological unit.

Compared with other life sciences, ecology had a delayed birth and in adolescence suffered reluctant acceptance by
other scientists and the public. Its start was given by Warmer and Schimper in Germany. American interest in ecology began about 1900 when Chicago botanist Henry Cowles was working out the course of vegetational change in the dune-
lands along the south shore of Lake Michigan. The chief site of his pioneer study is now a special nature preserve within the Indiana Dunes State Park; the latter is adjacent to the new and much larger national lakeshore. A young naturalist who lived at the edge of the dunes, James B. Watson, was to find in the special dunes biota the impetus for a biological career that led to his discovery with Crick of the double helix configuration of the hereditary material DNA.

In the generation following Cowles, most American ecologists were in the midwestern states. Many of them were botanists, few were zoologists. The field was long dominated by Fredrick E. Clements and J. E. Weaver of Nebraska. Both Clements and Weaver taught at the University of Minnesota briefly. Clements was greatly influenced by the thought of philosopher-statesman-general Jan Smuts in South Africa; Clements applied “holism” to biology. He concluded that the major unit in ecology should be the community, not cells or individuals.

His claim that living communities could be considered “super-organisms” met resistance in the general scientific community, but it helped pave the way for the modern ecosystem concept. A better term than any yet advanced was clearly needed.

Sir Arthur Tansley of Cambridge University supplied this in 1935. An ecosystem, he said, is the community of plants and animals together with the environmental influences on which they depend. By combining life with the non-living environment, a new level of organization was added at the top. Tansley himself did not follow up the potentially great implications his concept contained.

At this point, ecology was still in swaddling clothes, for more familiar and formalized sciences had progressed beyond the chiefly observational stage. The grain of validity in the bushel of criticism was not that observation and description lack scientific value, since all science is “merely descriptive,” but, without the guidance of hypotheses illuminated by general principles, the results may be trivial. Aside from the evolutionary theory it shared with all of biology, ecology in 1940 lacked a validated conceptual framework with agreed-upon generality and consequence. The main
reason for this was that ecologists more often studied structure, at the higher levels of integration where ecology uniquely operates, than function at those same levels.

A young man was to change all this during what became, at his personal level, an agonizing race against the Grim Reaper. Raymond L. Lindeman was born on July 24, 1915 in Redwood County, Minnesota. As a boy he became interested in natural history. After graduating from Park College in Missouri, Ray began graduate work in 1936 as a teaching assistant at the University of Minnesota, majoring in zoology and minoring in botany. At an ecology seminar he gave there two years later, he started with this definition: “Ecology is concerned with the populations of communities and with the factors which control these communities.”

Shortly before Lindeman’s arrival at the university, botany professor William S. Cooper spotted from the air a small lake in a late stage of succession, surrounded by much wild land. Lindeman became the first of many scientists to do important work at this Cedar Bog Lake. His first paper, coming out when he was twenty-four, dealt with variations in a rotifer species of the lake plankton. Next he studied the bottom-deposits, puzzling out the stages the lake had passed through since the thawing continental ice sheet laid bare the area nearly 12,000 years before. In 1938 he laid out a study transect through the lake and surrounding bog and woods. He marked the northern end by driving a railroad spike into a red oak tree; the spike is still visible today. Lindeman drilled for core samples at intervals along the strip, and later workers used the same transect for several other kinds of studies.

Limnology involves a multitude of sciences. Lindeman had the breadth of interests that characterized the early ecologists. He was a field biologist.

In failing health but with unflagging courage, he concentrated on this small, shallow bog lake. During his long days on the water collecting his data and mulling over what they meant, he saw that by combining the stage-setting with the biotic community it supported, and treating it as an integrated unit through which energy from the sun is utilized and dissipated in gradual steps, he could reduce all the biological happenings to energy terms. The same sunlight that tanned his pallor caused by the long winter and hospital ordeals supplied the vital energy which he traced and measured through photosynthesis and animal food-chains and finally to reduction by decay organisms. This cycling of materials, and degradation of the energy through stepwise use, knit together the life forms and their intimate surroundings into a single logical, ecological unit, a lake ecosystem.

Because Lindeman was blind in his right eye he could not study air-photos stereoscopically, a disadvantage to an ecologist. The power of his mind was not matched by his physical capability, for his health had so declined that his wife Eleanor helped him regularly in the field work. The research necessitated rowing, dredging, towing, and dipping. It called for weighing, measuring, counting, identifying, and, above all, thinking. When he would begin vomiting blood again, it was time to spend several weeks in the hospital on a special diet. He never drank anything but milk. When he felt up to it, he and his wife would go back to intensive field work at Cedar Bog Lake. He became unusually serious and industrious, concentrating solely on work when it was possible. Mr. Lindeman’s professors recognized his brilliance and gave him a loose rein, but did not really understand what he was about. He alone was aware of the basic importance of his insight and he feared he might not have the physical stamina for finishing it. Although many graduate students have difficulties, his work was done, very literally, through the shedding of much sweat, blood and eventually tears.

The doctorate was granted in March of 1941. That fall he went to Yale University on a post-doctoral fellowship, to work with the great limnologist, G. Evelyn Hutchinson, who had begun thinking along similar holistic, energetic lines.
The Lindeman legacy, beyond the inspiration of his commitment to science, is in the form of six papers. In the last one is what Edward Kormondy called “The most significant formulation in the development of modern ecology.”

This paper was at first rejected by the editors of the major American ecological journal, Ecology. The reviewers, two leading limnologists, felt that it made too many assumptions for publication. But any assumptions Lindeman made have been amply vindicated by time. Through the urgings of two University of Minnesota botanists, his advisor, Dr. S. Eddy, and Dr. Hutchinson, the paper was published in the same journal in 1942 as “The Trophic-Dynamic Concept in Ecology.” It synthesized much of Lindeman’s work and thought. As an addendum to the paper, there appeared an obituary of the author.

Lindeman reminded readers that “All function and indeed all life within an ecosystem depends upon the utilization of an external source of energy, solar radiation.” He recognized different groups of organisms, considered trophically, as producers, nearly always green plants; consumers, including animals and non-green plants; decomposers which reduce organic substance into forms no longer alive. (Trophic simply refers to food and nutritive processes.) Through an ecosystem, materials cycle and recycle, but energy always follows the downward gradient, in accord with the second law of thermodynamics. Productivity is the rate of production in a given group, usually that at a particular trophic level.

The total amount of organic structure formed per year for any level (Lindeman wrote) . . . commonly expressed as the annual “yield,” actually represents a value uncorrected for
Raymond L. Lindeman
in 1939, at age of 23.

Photo by Donald B. Lawrence.

Editor’s Note: Harvey L. Gunderson and Donald B. Lawrence knew Lindeman well.

Both Gunderson and Donald B. Lawrence have served our Natural History Society well as Members of our Board of Directors.
dissipation of energy by (1) respiration, (2) predation, and (3) post-mortem decomposition... Food cycles rarely have more than five trophic levels... Productivity is a rate, while efficiency is a ratio... referred to the previous level's productivity. Progressive efficiencies of the various food-cycle levels indicate for each level the degree of utilization of its potential food supply or energy source... The consumers at progressively higher levels in the food cycle are progressively more efficient in the use of their food supply.

Thus, the food chain shown in the Catlin painting passes energy from sun to grass to bison to man. More food-energy is available to the bison than to his Indian predator, and the grazing animal uses what it gets less efficiently. At each step energy is degraded. Some is frittered away uselessly as heat. Energy flows gradually downgrade, doing useful work at each step, whereas a prairie fire would dissipate the energy rapidly and with destructive effect. An atomic-fission explosion is instantaneous, its energy downslope much steeper, and the effect still more catastrophic. Evolution has devised a slow trickle approach for getting maximum utility from the energy falling on our planet; there are many other and more complex food interrelationships in the plains ecosystem than the one I cited. Every organism present has its role as a producer or some type of consumer.

Most simply stated, ecology is the science of the structure and function of Nature. Its basic unit is not the molecule or cell. Ecology is unique among biological fields in that its basic unit is at the upper end of Nature's "organizational chart," the ecosystem. The latter term now has a wider meaning than in Lindeman's day, for now even one protozoan cell in a minute drop of water may be considered an ecosystem. At the other extreme is the most complex known ecosystem, the Earth's biosphere or "planetary ecosystem." The latter represents, in the present state of space science, the single all-encompassing concept in biology.

Lindeman did not have the refined tools and methods available to ecologists today — computers, mathematical modeling of energy flow, and radioactive tagging, to mention a few. His instrument was a perceptive and original mind skilled in both analyzing and synthesizing thought processes.

Almost within an heroic stone's-throw of Cedar Lake Bog there is now a fine research center and support buildings in a 5,500-acre research reserve used by the University of Minnesota biologists and visiting scientists. The diversified tract of land and water habitats has been designated a National Natural Landmark. The portrait of Lindeman I am including here is proudly displayed within the main building. Notable ecosystem studies followed Lindeman's work in the forests and marshes of this preserve. It is appropriate that much of the planning for the 1964-72 International Biological Program, on the biological basis of productivity worldwide, was done at this place where Lindeman had originated the principles.

While ecosystem ecology is currently very "productive", other approaches are being investigated and taught by professional ecologists in our day. Profound work continues in physiological ecology at the species level. Population biology has a strong ecological as well as genetic component; it is highly mathematical and theoretical. Applied ecology is increasingly important in a world environment which is managed far from adequately for long-term survival of our species.

Modes of ecological thought, so revealing of the natural world, have been adopted in the social sciences, human history, anthropology, international relations, philosophy, and religion. An outstanding instance is the revolutionary approach to economics which N. Georgescu-Roegen introduced in 1971 in his book The Entropy Law and the Economic Process. Little on our agenda for the future can be more important than a just and lasting peace between economics and ecology.

The Lindemans had no children. Mr. Lindeman passed away on June 29, 1942, from a rare and inadequately diagnosed form of hepatitis, leaving his body to the Yale Department of Anatomy. His papers are in the archives at the university library. Without quite reaching his twenty-seventh birthday, he did work that eventually brought about a synthesis which justifies and clarifies the comment by mystic Frederick Elder: "Life on Earth has many facets, but the important point is that all facets are part of the same diamond."

As young Lindeman determined the changes in a natural habitat from youth to its senescence, perhaps it was his failing physical powers that focused his attention on the energy factor in the diverse lives he was examining. An analogy to the cycling of life of Nature, the residue of his thought provided the nutriment to stimulate growth at a higher stage — the science to which he devoted his few productive years. It may well have been the deepening shadow on his own life which gave rise to his conviction that "The discrimination between living organisms as parts of the 'biotic community' and dead organisms as parts of the 'environment' seems arbitrary and unnatural."

Long ago a Roman philosopher, Emperor Marcus Aurelius, commented on the span of a man's life, as a play.

To look upon the world for a longer or a briefer period makes no difference. What then is there to fear if you are sent away by the same Nature that brought you, as if the magistrate who had chosen an actor were to dismiss him? "But I have not played the five acts, but only three." "You have played well, but in your life at any rate the three acts are the whole play." For he sets the limit who was at one time the cause of your creation, and is now the cause of your dissolution. You have no responsibility for either. So depart graciously, for he who dismisses you is also gracious.

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