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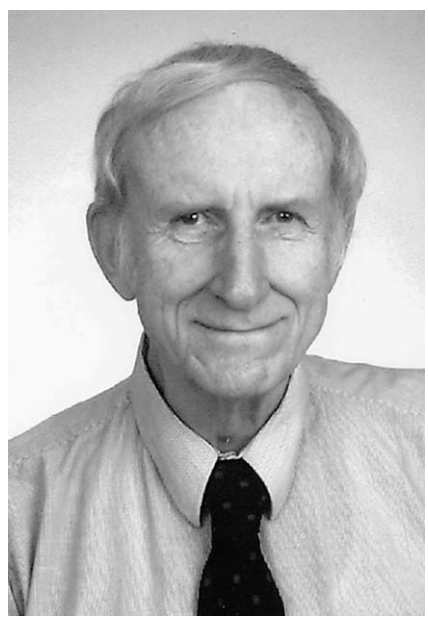
Prof. Howard T. Odum
1924 - 2002



> "Truth" is a state of mind in which there is no contradiction. A person perceives his idea as true because he has heard no contradiction. The less one knows, the easier it is to be dogmatic and to be sure that what one knows is true. We tend to defend dogmatically as true the things we are taught, whereas the things we learn from experience and experiments tend to be properly couched in some-times-contradictory reality. (Odum, 1995)

One of the most creative minds in the fields of ecology, environmental science, systems ecology, environmental policy, and energy studies died September 11, 2002. H.T. Odum was Graduate Research Professor Emeritus at the University of Florida's Department of Environmental Engineering Sciences and a member of the editorial board of ENERGY. The fact that it is difficult to pin down his field is testimony to his creative genius. He had hundreds of publications in scores of different journals. Subjects run the gamut from global strontium cycles to energetics of food

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webs in Silver Springs, Florida, to net energy analysis of fossil fuels, power plants, and renewable energies including OTEC systems for electrical energy generation.

HT, as his close friends and associates called him, began his teaching career in 1950 as an assistant professor at the University of Florida, teaching biology after completing his Ph.D. under G. Evelyn Hutchinson at Yale, where he studied the global strontium cycle (Odum, 1951). Prior to his studies at Yale, he served in the Air Force as a tropical meteorologist. He often said that it was the time spent as meteorologist in the tropics that initiated his intense interest in the energetics of systems of all scales. Watching the tropical weather patterns with their constant impulses and changing conditions, he began to form concepts of energetic causality.

At Florida with NSF funding, he undertook his seminal research on Silver Springs in which he evaluated the energetics of the spring's food web, publishing the results in Ecological Monographs (Odum, 1957). At about this same time, HT and his brother EP Odum published another study of a complete food web, the Eniwetok Atoll, in the Marshall Islands (Odum and Odum, 1955) demonstrating the important energetic subsidy provided by ocean currents and tides to overall productivity. The Silver Springs study is a "standard" in most texts on ecology used to illustrate energy and material flows in ecosystems.

Also while at Florida in the early 1950's, HT wrote one of his most important papers "Time's speed regulator: the optimum efficiency for maximum power output in physical and biological systems" with R.C. Pinkerton (Odum and Pinkerton, 1955, see also Odum, 1983b). This paper was modest in size but drew much attention and was often quoted. Following on the ideas of A.J. Lotka, a mathematical biologist, Odum and Pinkerton suggested that the optimum production of useful energy was in principle at 50% power loading and that real systems perform even lower than that. Odum continued from that first publication to suggest that the "Maximum Power Principle" should be the fourth law of thermodynamics (as did Lotka…see Lotka, 1922a, 1922b, and 1925).

Leaving Florida after 4 years, he spent two years at Duke and then became director of the University of Texas' Institute of Marine Science at Port Aransas, and then Chief Scientist at the Puerto Rico Nuclear Center at the University of Puerto Rico. During these 11 years Odum published an impressive quantity of research on whole ecosystem studies of the marine ecosystems of the Texas Gulf coast and the effects of radiation on tropical rainforests. Both collections of papers are widely quoted and considered some of the most important contributions to understanding the measurement of fundamental processes in marine and tropical ecosystems (see for instance Odum and Hoskin, 1958 and Odum and Pigeon, 1970). It was during this time that HT developed his energy circuit language and wrote extensively about the use of systems languages and simulation in education.

In 1966, Odum returned to North Carolina, with teaching appointments in the Departments of Environmental Science and Engineering, Botany, and Zoology at the University of North Carolina at Chapel Hill. It was here that HT began his first explorations into concepts of Ecological Engineering, building large mesocosms at UNC's Marine Lab at Moorehead City. Using treated effluent from the city's waste treatment plant, Odum and students studied the marine ponds as they self-organized under the influences of the fresh, nutrient rich, effluent waters (Odum, 1985).

While in Chapel Hill, HT published "Environment Power and Society" (Odum, 1971), a book that changed the lives of many who read it -- altering their world view and heading them off on a quantitative, systems oriented path, toward shaping the debate concerning the importance of

energy and environment to economic well being. Odum observed that all wealth stems from the environment and its myriad systems and processes and that the value of services and commodities should be based on the energy and resources required to produce them, rather than on what someone is willing to pay for them. This is counter to the view of neoclassical economists, who believe that willingness to pay is an appropriate method for pricing and thus valuing the environment.

HT returned to the University of Florida in 1971 initiating his program in Systems Ecology in the Department of Environmental Engineering Sciences. It was at Florida, during his 31-year tenure as Graduate Research Professor, that the ideas generated from the study of many systems began to mature into a generalized approach to energy systems. The concept of energy quality emerged (see Odum, 1973, 1974, 1976a) and was at first vigorously resisted by many but is now widely accepted. His concepts of valuing the environment had been enunciated many years earlier in Texas and North Carolina, but began to coalesce in his call for an "ecological economics," as he taught the first graduate level classes on the subject in the mid 1970's (Odum, 1973, see also Odum, 1994b). Ecological engineering, or the management of self-organization of systems for the benefit of both humanity and environment, began to take shape and resulted in nearly a decade of research into wetland systems for wastewater treatment (Ewel and Odum, 1978). In the early 1970's in response to the sharp rise in energy prices and increased interest in alternative energy supplies, Odum testified in Congress that alternative sources should be evaluated as net energy not just gross. This prompted Senator Mark Hatfield of Oregon to introduce a bill in 1975 for a federal law that made net energy analysis a requirement of proposed alternative energy systems. (See Odum, 1976b, and Odum et al., 1976)

The decade of the 1970's also saw investigations in regional science especially studies of the complex networks of humans and environment in southern Florida where major ecological crises were brewing. With funding from the US Department of Interior and the Florida Division of State Planning, HT and his graduate students embarked on studies of South Florida, the Everglades, and Lake Okeechobee that resulted in recommendations for fixing many of the problems, nearly a quarter century prior to Congress allocating billions for the same tasks.

In 1983, HT published "Systems Ecology" his textbook introduction to general systems based on his graduate courses given at UNC during 1966-1970 and at the University of Florida during 1970-1981 (Odum, 1983a). HT described the objective of the book as follows:

> "If the bewildering complexity of human knowledge developed in the twentieth century is to be retained and well used, unifying concepts are needed to consolidate the understanding of systems of many kinds and to simplify the teaching of general principles."

It is in this book that Odum's systems language, the energy circuit language, was fully explained and the kinetics and mathematical underpinnings given, as well as its interface with computer simulation. The second edition was titled "Ecological and General Systems" probably a more fitting title as the book was striving to teach general principles that applied to all systems (Odum, 1994a).

Often his new ideas and concepts were met with resistance. In some cases the resistance waned as more and more people gained understanding , but some still garner sharp criticism and resist-

ance today. Probably his most creative and least understood concept was that of energy quality termed Emergy Accounting and based on Transformity (see Odum, 1984; Odum, 1986; Odum, 1988a; Odum, 1994c). A powerful mixture of common sense, ecological energetics, and thermodynamics, the conceptual framework and principles of emergy were developed during the 1980's and early 1990's and led to publication of his book "Environmental Accounting"(Odum, 1996). It was at this time that Odum suggested the Maximum Power Principle should more correctly be the Maximum Empower Principle as he pointed out that systems did not tend to maximize power, but instead, empower (emergy per time). His rational was that power maximization would favor high power, low transformity processes, which in evolutionary terms would not prevail in competition with more complex systems of low power but high transformity. Thus systems that maximize empower are favored in the evolutionary context.

In 1987, HT and his brother EP were recognized with the Crafoord Prize for ecology, awarded by The Royal Swedish Academy of Sciences. The Crafoord prize is one of the largest scientific prizes in the world. It is awarded annually within one of the subject areas; mathematics, astronomy, geo-science or, bioscience . In his acceptance speech, HT stated …

> "The study of ecosystems suggests principles by which energy flows generate hierarchies in all systems. From these it was clear that energy laws controlling self-organization were principles of open systems quite beyond classical energetics, involving a generalization of concepts of evolution in energy terms. During the trials and errors of self-organization, species and relationships were being selectively reinforced by more energy becoming available to designs that feed products back into increased production." (Odum, 1988b)

While many see the concepts and principles of emergy as a means of evaluating energy systems, they are far more, for they provide a quantitative framework for a generalized model of system energetics that can be applied at all scales, from the nano-environment to the cosmos. The theory is deeply grounded in hierarchical organization, which HT proposed as a fifth law of thermodynamics. By proposing maximum empower and hierarchical organization as the fourth and fifth laws, Odum was suggesting "dynamic systems principles" that can be used to understand and explain the organization of complex system networks using higher order mathematical representations (simulation models) as a complement to and an extension of the simpler equations and models that are generally used to investigate and understand the 1st, 2nd, and 3rd laws.

In the 1990's and leading into the millennium HT increasingly focused on the concept of the pulsing dynamic behavior of systems and suggested that pulsing maximized empower. His pulsing paradigm paralleled the then fashionable landscape ecology concepts of patch disturbance and dynamic equilibrium that challenged classical theories of ecological succession. As a consequence of his belief in pulsing systems and as an outgrowth of his grounding in ecology and systems ecology, Odum recognized that all systems, including western capitalist economies cannot grow forever, and that dwindling energy supplies would eventually require western economies to contract. His book, written with his wife Elisabeth Odum, and titled "The Prosperous Way Down" (Odum and Odum, 2001) was aimed at helping humankind make the transition to a lower energy future in a prosperous way, essentially leading the way to the promised land on a "low energy cruise."

HT Odum always spoke of the "Systems Approach," a top down approach to understanding that required a systems language (other than words), a quantitative means of evaluating multiple scales at the same time (emergy), and principles of organization (maximum empower etc.) He took his examples and analogies from the ecological world, saying that since it had had millions of years of self-organization and "testing" we could learn a lot about systems from observing nature. The concept of steady state is an intrinsic property of ecological systems and was never far from Odum's lexicon of properties used to compare systems of widely different composition and functioning. He once stated,

> "With the use of the common system structure for energy systems networks that we find whenever we look, a different perspective on a steady-state universe is found. It is not one of explosion and contraction but is more of an ecosystem of hierarchical stars and galaxies, one where dispersed low-energy Kelvin radiation and distributed matter converges stepwise to the intense centers of highest transformity, energy and matter recycling to form a closed loop, as it does on a much smaller scale where there is a Maxwell-Boltzmann distribution in a gas at equilibrium." (Odum, 1995)

His last paper outlined in some detail this concept of a cosmos composed of a hierarchy of processes connected in ever increasing cycles of convergence of energy and matter yet held together by recycle pathways (Odum, 2003). His view of the cosmos was conceived with the creative energy he brought to everything he addressed.

There is no telling what might have been in store in the coming years. Those of us who were lucky enough to have spent time with him and studied his concepts in more than a cursory way understand his genius and wish to pay tribute. HT, your creative genius and vision of how systems work will be sorely missed.

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