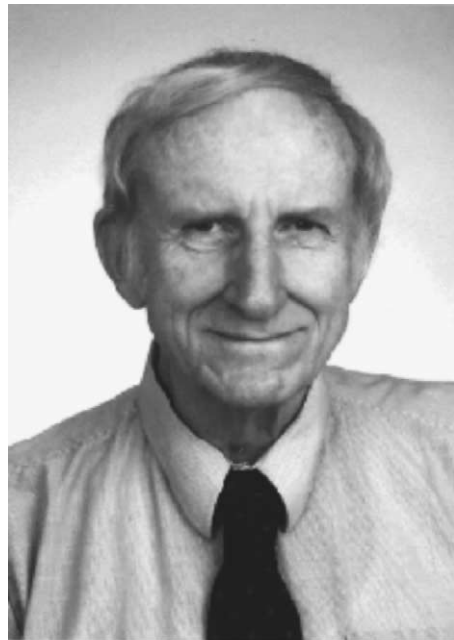


## Editorial Eulogy

With this special issue we hope, in some way, to pay tribute to and recognize an individual who had a larger than life presence and impact on so many of us. Howard T. Odum (or HT as he wished to be called) was a very special scientist and teacher who often walked alone but with several hundred of us following along behind as best we could. He was an individual who left an incredible legacy; a massive set of ideas, theories, and teachings, as well as a suite of accomplishments that few can begin to approach in volume, let alone originality. His approach to science and teaching and his more than ethical conduct (which was probably the result of his upbringing and southern roots) provides us a standard to which we can aspire, even if they are most difficult to emulate.

Following his Doctorate from Yale in 1951, H.T. Odum's 52-year academic career was punctuated by six moves that carried him from Yale to Florida, to North Carolina, to Texas, to Puerto Rico, back to North Carolina and finally back to Florida where in 1971 he settled down for good as Graduate Research Professor. At each step, with each move from one academic institution to another the opportunities for research and teaching that presented themselves shaped his life's work and provided a rich and fertile ground for development of his theories and philosophies. He encountered new ecosystems and new environmental issues, at each new institution, to which he seemed infinitely adaptable. Even though the systems and issues were very different, his "top-down, systems approach" and his focus on the similarities of adaptation of ecosystems and components reduced their complexity to manageable dimensions. Through his energetics approach he found similar components and similar processes in all systems at all levels of organization.



**Howard T. Odum**  
1924 - 2002

H.T. Odum was the recipient of numerous awards, among them:

Phi Beta Kappa

George Mercer Award, Ecological Society of America

Prize Institute de la Vie, Paris 1976

Distinguished Service, University of North Carolina, Chapel Hill

Distinguished Service, American Institute of Biological Sciences

The Crafoord Prize, Royal Swedish Academy of Sciences, 1987

University of Florida Presidential Medal, 1976  
 Distinguished Service, University of Puerto Rico  
 Honorary Doctor of Science, Ohio State University,  
 1995.  
 Elected Member Swedish Royal Academy of Science  
 Honorary Doctor of Science, University of Florida,  
 2003

H.T. Odum was an extraordinary individual. His love of teaching, his creative and imaginative way of viewing the biosphere, his grasp of so many different fields of science, and his drive and unbounded energy have left many students, colleagues, and associates awestruck. His unique way of understanding the biosphere and human's place within it, his gift to us all, will endure and expand as it is more fully understood by this and succeeding generations. He has left us a legacy of many hundreds of books and scientific publications, over 100 masters and Ph.D. students, and even a movie or two, but far beyond these tangible remnants of his scientific inquiry is the devotion to his students, close associates, family and to human kind. In his own words (in the *Prosperous Way Down Odum and Odum, 2001*, his most recent book with his wife Betty), "As sometimes attributed to past cultures, people may again find glory in being an agent of the earth." H.T. Odum was an agent of the earth, striving always to teach good stewardship and a profound understanding and respect for the cycles, hierarchies and especially energetics of the biosphere.

### 1. Through the MACROSCOPE: the legacy of H.T. Odum

In the world of science that we live in there are two kinds of people: Odumites and others. This is not simply an observation by us or the others who are contributing to this book, and whom we believe would universally agree, but also a statement often made by many other ecologists and scientists with only an indirect connection to Odum. We might add, even our own students would agree with the observation. It is usually followed with the explanatory statement that "... almost everyone who has been touched by the ideas and especially the presence of H.T. Odum was never quite the same again". His classes were often

so intellectually exciting that we could think of almost nothing else. Where even his simplest statements would ripple through our intellect causing waves of excitement and discussions that would carry us well into the night. Many of us felt that we were standing next to some huge dynamo, with our hair standing on end from the induced currents. Somehow, after being immersed in HT's ideas, theories, and philosophies we felt like we stood on a taller hill, looking farther with a broader overview of the surrounding landscape. Most of us still feel that way. So we often used the term "Odumite" to describe those of us who had been touched by what we saw as the genius of H.T. Odum.

On the other hand, those who have expressed almost open hostility to the ideas and theories of HT often used the term, "Odumite" in a derogatory manner. In fact, HT disliked the term, because it made *him*, instead of his ideas, the center. As he stated on numerous occasions, ideas are bigger than an individual and when they are identified with an individual they can easily be dismissed... not because the ideas are wrong, but because the individual is not well liked. When people focus on the individual instead of the idea, it becomes an issue of personalities and egos, instead of discussion and collegial discourse. So it was often easy to brand those of us who were "followers" of H.T. Odum as Odumites, and the belief in Odum's ideas as "Odumania" (see for example [Månsson and McGlade, 1993](#)). In somewhat of a reverse sting, some ecologists have identified "systems ecology" as the culprit that has moved ecology away from an organismal orientation and therefore its underpinnings in the dual realities of natural history and community ecology. Since H.T. Odum was one of the main proponents of systems ecology, his ideas were blasphemous to them and those of us that believed them were Odumites, not to be trusted in a world where reductionism and small scale biology held rein.

To most of us however, systems ecology was not the problem, but the solution. In the words of HT...

"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." (Odum, 1994)

Ecology should be, at least in our view, not just about species and populations but about systems and about synthesis, about how systems of different scales operate along common principles and are constrained by common energetics, and about how plant and animal populations are largely determined over space and time by environmental factors. It is through ecology and an understanding of the systems, hierarchies, and dynamic behavior of the natural world that we might gain an understanding of our place within it. Nature is about all levels of organization and to us it is problematic that ecology is often taught within biology departments, where species- or population- oriented biologists represent the highest level of complexity.

Odum was a systems ecologist, no doubt. He worked tirelessly throughout his career to firmly establish it as a science, but more than that, to expand and advance the science. Believing that diversity begets innovation, he embraced the approaches of others (more so in his later life) suggesting that the field was stronger as a result of the diversity of approaches and systems languages of others. Peculiarly, some ecologists said that he was not a believer in Darwin's theories. In fact Odum believed in natural selection operating at every level all the time and relentlessly. He was perhaps the strongest Darwinian we knew. His Darwinian perspective even extended to his own ideas, for he said on more than one occasion "let the future sort out my good ideas from those that are not so good". He, more than most, worked throughout his career orchestrating several interests into a complex symphony of field ecology, experimental measurement, theory, and policy. Over the span of 50 plus years, this symphony resulted in hundreds of publications that did not always fit neatly into academic departments or disciplines. Beginning with ecological studies of Silver Springs and the coral reefs of Eniwetok Atoll in the Pacific, and continuing with the Bays of Texas' Gulf coast, the Luquillo Forest of Puerto Rico, the saltmarshes of North Carolina's coast and finally the cypress wetlands of Florida, Odum's ecology was always big scale, experimental, and measurement oriented. These studies yielded however, theory, and a macroscopic, systems approach oriented toward understanding the "whole" and placing humanity smack in the middle. There was no question in his mind that humans were part of these systems or that humans ultimately controlled them... the only ques-

tion was, could Odum convince the rest of humanity (especially ecologists) that this was so.

This series of papers follows in somewhat of a chronosequence, H.T. Odum's output and his effect on those of us who studied and worked with him. Sometimes personal, always with a sense of awe, the 30 plus articles collected here are the work primarily of former students, who volunteered to review some aspect of HT's work. We asked them to write in a way that is accessible and synthetic... with both a sense of how important these ideas have become and on occasion, where it was felt they might have missed the boat, or might be incomplete. Although Mark Brown and Charlie Hall originally perceived this as something we would do ourselves, the magnitude of the task soon became apparent and so we enlisted the help of many others who have been associated with Odum and who have volunteered to help. Nevertheless we have attempted to maintain some overall editorial control and synthesis, and remain responsible for any problems.

### *1.1. What we know about the young Howard Odum*

Howard Odum was born in 1923 to Howard Washington and Anna Louise Odum in Chapel Hill North Carolina. He was the third child of the elder Odums following his Brother Eugene (B. 1913) and sister Mary Francis (b. 1919). Their father was a forward thinking and creative sociologist who in many ways defined and redefined the science of sociology in the South. Their mother was a very intelligent and cultured woman. Their house was often full of the intense conversation of other intellectuals visiting the Odums, and it is clear that the intellectual environment for the young Odums must have been extremely interesting. Without detracting from the accomplishments of Gene Odum, perhaps the more well known of the two remarkable brothers, Mary Frances, their sister, often referred to HT as "the gifted one", but went on to say "his habit of very rapid speech sometimes meant that his ideas were lost on others". HT commented, on occasion, that his most important early influences were "The boy electrician" a love of birds inherited from his brother Gene, and the influence of the University of North Carolina biologist Robert Coker. A warm and wonderful rendering of Gene and HT's early years can be found in Betty Jean Craige's "Eugene Odum, Ecosystem Ecologist and Environmentalist" (Univer-

sity of Georgia Press, 2002) A number of personal perspectives on HT from former students, his wife, Betty, and colleagues can be found in the last section of “Maximum Power” (Hall, 1996).

Howard Odum was essentially an academician throughout his life. He graduated from the University of North Carolina in 1946 majoring in biology, served in the Air Force during World War II as a tropical meteorologist, where undoubtedly he gained his basic interest in large systems and the energetics behind them, received his Ph.D. from Yale University under the distinguished ecologist G. Evelyn Hutchinson in 1951 (and where he was also influenced by Gordon Riley), and taught at the University of Florida (1950–1954), Duke (1954–1956), University of Texas (where he directed the Marine Station from 1956 to 1963), was Chief Scientist at the Puerto Rico Nuclear Center (1963–1966), returned to teaching at the University of North Carolina (1966–1970) and finally at the University of Florida (1970–2002).

The memorial service for HT in the beautiful Knapaha gardens in Gainesville in October 2002, where this book was born, revealed a different side of Odum. Most of the eulogies were not by intellectuals about his incredible mind or accomplishments, although of course, there were some of those. Instead there was universal respect for his kindness, for his ability to bring out the best in everyone, his mentoring, and his care for the “underdog”. Former University of Florida Provost, Robert Bryan told how much easier his job of hiring prospective chairs and deans had been because of HT, for when a candidate came along for the inevitable interview the first question was often “Can I meet Howard Odum”? According to Bryan, these candidates, all from very different academic backgrounds, had one thing in common, they had heard of or read something of Odum’s that related to their field of interest. One of the eulogies was given by singer and song writer Dale Crider, who spoke for so many of us when he said “I never look at a tree, meet a new person, or read the newspaper without thinking about things I learned from Howard Odum”. In our own inadequate ways we and our colleagues will try here to share some of that knowledge and excitement with you.

In many respects the division of H.T. Odum’s life work into several sections having different subject content is artificial at best, and in fact might be the antitheses of what he would have wished. Throughout

his life, there was a continuum of thought, research, scientific inquiry, and generation of theory along several threads that were never abandoned or left behind. His life’s work was a tapestry of projects, both large and small, woven together into a collective whole that was far greater than the sum of its individual parts. At times Odum worked with whole ecosystems taking measurements and developing new techniques for measuring production, respiration and the transfer of energy through trophic networks. Even so, as Scott Nixon has noted, his knowledge of the taxonomy of individual species was often profound. At other times he worked with microcosms and simulation models, trying to emulate the larger world in aggregate. He was an engineer, when necessary, devising his own instruments when need arose. At times he was an artist, conjuring up diagrams and pictures to get his points across when words were not enough. In all cases, Odum was striving for clarity out of the “the bewildering complexity of human knowledge developed in the twentieth century. . .,” trying to ‘see’ the essence of nature and man-nature interactions, the pervasiveness of energy relations, and to develop understanding.

As students and colleagues of H.T. Odum’s, we have witnessed his single-minded drive for understanding. It is impossible to recall a time when he was at a loss for a “systems” observation as to why something was as it was nor a time when he could not find something positive to say to a junior colleague or caught without an encouraging word for one of his students. These are the things that most shaped our image of H.T. Odum, as scientist and teacher. These represent the legacy that he left us.

In the sections that follow we hope to capture some of the brilliance that was H.T. Odum, and to show the diversity and yet single mindedness that occupied his life. To begin, with we present the last paper Odum worked on prior to his death. Titled “Energy Hierarchy and Transformity in the Universe” this paper was presented at the 2nd Biennial Energy Research Conference held in Gainesville Florida in September 2001.

## 2. Early and continuing interests: biogeochemistry

H.T. Odum’s Ph.D. dissertation under G.Evelyn Hutchensen at Yale University dealt with the global strontium cycle. In letters home to his parents and

brother Gene (unpublished) he at first showed tremendous excitement about the research possibilities and the fact that his work was related to important “happenings” of the time. Later under the drudgery of analysis after analysis of samples, he wrote that it had lost some of its excitement, but that once the measurements were finished, he was sure it would once again stimulate his interests. In the end, it is obvious that HT never lost his interest for global cycles. These early measurements and the insights they provided seemed to incubate over the years and surfaced again with his interests in lead cycles in the environment and in his most interesting work in the late 1990’s and early part of this century, relating biogeochemical cycles to energy hierarchies and economic cycles.

In the following section, Limberg describes Odum’s early work with the strontium cycle and his belief that the elemental geocycles are inextricably connected with biotic cycles. Delfino describes the book *Heavy Metals in the Environment: Using Wetlands for Their Removal*, Odum et al., 2000 a book edited by Odum that resulted from research in Florida and Poland on wetlands affected by lead. In classic Odum style, he “assumed the task of blending many different writing styles into a reasonable coherent book” (see also Lugo’s review of the rainforest book in Section 2 ). Boggess reviews his theoretical work relating material cycles to the energy hierarchy and to the cycles of human economic system.

The papers of Section 1

1	The Biogeochemistry of Strontium: a review	Limburg, Karin E.
1	Revisiting Heavy Metals In the Environment: Using Wetlands For Their Removal	Delfino, Joseph J.
1	Biogoeconomics—Energy Hierarchy, Biogeochemical Cycles and Money	Boggess, Carolyn Fonyo

**3. Ecosystems and metabolism**

Throughout Odum’s career he returned again and again to ecosystem level studies. His first ecosystem studies were conducted on the Silver Springs in the

early 1950s. Kemp and Boynton describe how he devised a means of measuring total ecosystem primary production and respiration and quantitatively evaluate energy flow through the ecosystem. Following closely on the heels of the Silver Springs study, Odum teamed up with his brother Gene to measure productivity and estimate trophic structure of a coral reef community in the Pacific. Barile provides an interesting review of the their methods and the controversies that inevitably followed publication of their very new and different research. From the coral reefs of the Pacific, HT descended on the Texas Coast where he was director of the University of Texas’ Institute of Marine Sciences at Port Aransas (1956–1964). Here, as Swaney and Hall describe, he undertook the daunting task of measuring the Texas Bay ecosystems to determine whole ecosystem metabolism while administering and supporting a faculty that was undertaking many traditional studies in biology and fisheries. While it is hard to pinpoint exactly when Odum struck on ideas (for they often crop up in very early writings as almost random musings), it was during his years at Texas that several threads of his career appeared, including: Ecological Economics (Kangas), Ecological Engineering ( Armstrong) and the use of microcosms for ecosystem emulation (Browder). In addition, his use of the symbolic systems language he sometimes called “energetics” blossomed with the “invention” of the “storage tank” that Robert Byers attributed to the water storage tanks that rural Texas communities had for public water supply.

Following Texas, Odum turned his attention to the rainforests of Puerto Rico’s Luquillo Experimental Forest. As Chief Scientist at the University of Puerto Rico’s Puerto Rican Nuclear Center, he conducted experimental irradiation of the rain forest and once again engaged in the massive undertaking of measuring whole ecosystem metabolism. In this case Odum constructed an enclosure out of plastic sheets to enclose and thus measure CO<sub>2</sub> concentrations in inflow and outflow air streams to calculate production and respiration. Lugo, describes Odum’s work there, which was far more than mere metabolism measurements, as it was manifested in his edited volume “A Tropical Rainforest”, a gigantic book of 1667 pages that is chock full of data, pictures, diagrams and Odum insights.

Next Odum turned his attention to the cypress swamps of the Florida flatwoods. With a million

dollars from Rockefeller Foundation and National Science Foundation, he assembled more than a dozen scientists and even more graduate students to study the use of cypress wetlands for waste water recycle. Every aspect of the ecosystems was studied from soil micro biota to insects, to birds and mammals. Measurements were made of whole ecosystem primary production, evapotranspiration and respiration, as well as complete nutrient and hydrological budgets. The book that resulted, "Cypress Swamps", edited by Kathy Ewel and Odum, is described by Goforth in this section. While the book gives details of "... technical aspects of nutrient cycling mechanisms, productivity rates, producer and consumer diversity patterns and distribution of microorganisms...", *Cypress Swamps* also describes the role of cypress wetlands within the larger landscape and underscores the usefulness of wetlands as an interface ecosystem."

Browder concludes this section with a review of "Ecological Microcosms", by Beyers and Odum. As Browder puts it, "... a big book about small worlds." Beyers was one of Odum's first graduate students. Both Odum and Beyers worked with microcosms through out their careers. The last microcosm work of Odum was his involvement with the Biosphere 2 program just prior to Columbia University taking over management. Browder suggests that "Ecological Microcosms", "... encapsulates in an unselfconscious way the entire spectrum of H.T. Odum's dynamic and diverse professional life, from its roots in basic ecology to the application of emery to world-scale social and environmental problems."

#### The papers of Section 2

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|---|---|---|
| 2 | Productivity, Trophic Structure, and Energy Flow in the Steady-State Ecosystems of Silver Springs, Florida                        | Kemp, W.M. and Boynton, W.R.            |
| 2 | On the significance of: Odum, H.T. and Odum, E.P., 1955. Trophic structure and productivity of a windward coral reef community on | Barile, Peter J.                        |
| 2 | Odum in Texas: A Brief Review of H.T. Odum's Texas Bays studies   | Swaney, Dennis P. and Charles A.S. Hall |
| 2 | H.T. Odum and the Luquillo Experimental Forest  | Lugo, Ariel E.                          |

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|---|---|---------------|
| 2 | Cypress Swamps: Demonstrating the Utility of Swamps | Goforth, Gary |
| 2 | Review of Ecological Microcosms                     | Browder, Joan |

#### 4. General systems, ecological modeling and symbols

To say Odum was a systems scientist is an understatement. Viewing his life's work as a body of information, theory and application, it is easy to see that his passion was systems ... any scale, any size, any type. Odum's book, *Systems Ecology* (Odum, 1983) and later renamed *Ecological and General Systems* (1994) was a tour-de-force of 644 pages describing the physical, kinetic, energetic, cybernetic, and mathematical underpinnings of his approach and drawing comparisons with over 50 other systems languages.

Odum felt strongly that the broadest spectrum of the population as possible needed to understand systems ... not only their organization, but more importantly how they behaved. People needed to understand how systems changed. ... how they grew, died, reacted to impulses, or reorganized to accommodate new conditions if they were to transform policy making driven by qualitative guesses about outcomes, to quantitative predictions based on system energetics. Odum worked through out his career to develop a systems language that would make the abstract equations of the mathematical modelers concrete. A symbol language that would allow comparison between systems so that commonalties were evident. While President of the International Society for Systems Sciences, he called for a project to translate models of all scales into systems diagrams so that everyone could better understand them. Odum's symbol language was also a simulation tool. Diagrams drawn with the symbols were directly translated into mathematical equations, programmed in one of several programming languages and simulated. There exists today a plethora of papers and books that describe the language and the hundreds (probably thousands) of models that were developed. In this section Brown describes the evolution of Odum's symbol language tying that evolution to the changes in technology that were available over the years. and Kangas describes the early simulation mod-

eling of Odum when he first used passive analogs to represent energy flow in systems. Comar describes the influences of Odum’s language and its ability to organize perceptions on his work in developing countries.

Odum’s systems theory was grounded in thermodynamics. Yet he was quick to point out where thermodynamics got off the track because of its lack of recognition that all energy is NOT the same form and utility and thus not all forms can be compared directly. Odum was convinced that open systems thermodynamics required a concept of energy quality that took into account the differences in energy form. A major aspect of Odum’s open systems thermodynamics was the Maximum Power principle (later renamed the Maximum Empower Principle). As he stated in his 1994 book, *Ecological and General Systems*. . . “Maximization of useful power may be the most general design principle of self-organizing systems.” Odum proposed the maximum empower principle as a fourth law of thermodynamics and later, two other systems properties as the 5th and 6th laws. In this section, Cai, Olsen and Campbell describe Odum’s Maximum EmPower Principle as a foundation for understanding the link between humans and nature. Tilley reviews Odum’s quest for understanding of systems organization that lead him to propose 4th, 5th and 6th Laws of Thermodynamics.

The papers of Section 3

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|---|---|--|
| 3 | A Picture is Worth a Thousand Words: Energy Systems Language and Simulation | Brown, MT                                  |
| 3 | The Role of Passive Electrical Analogs in H.T. Odum’s Systems Thinking      | Kangas, Patrick                            |
| 3 | Maximum (Em)Power: A Foundational Principle Linking Man and Nature          | Cai, T.T., Olsen, T.W., and Campbell, D.E. |
| 3 | Howard T. Odum’s Contribution to the Laws of Energy                         | Tilley, David R.                           |

**5. Ecological engineering**

Engineering is generally perceived and presented as a “hard” field. The term hard has several meanings in

this context. Most engineering, is in fact “hard” in that it uses concrete, steel and energy intensive procedures to solve problems. Some say engineering is hard because it uses mathematics and physics that are often difficult to comprehend. But the real sense of engineering is not that it is about concrete or about mathematics but instead about problem solving. Since the 1950s, and even today, one of the largest single engineering problem has been waste treatment. The engineering solution to waste treatment has typically been “hard” . . . concrete, steel and energy intensive technology. Yet there was, and is, a softer approach. From the early 1950s Odum envisioned a partnership of humanity and nature and since he was keenly aware that nature had no wastes, but instead recycled everything, he was quick to propose a new engineering paradigm “Ecological Engineering” that capitalized on the recycle potential of natural ecosystems. In this section Armstrong traces the beginnings of Odum’s life long interest in ecological engineering to his work on the Texas Gulf Coast Bays while Director of the Marine Institute. Then Mitsch and Day describe Odum’s influences on their proposal for restoration of the Mississippi River floodplain wetlands.

The papers of Section 4

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|---|---|---------------------------|
| 5 | The Beginnings Of Ecological Engineering  | Armstrong, Neal E.        |
| 5 | Thinking Big with Whole Ecosystem Studies and Ecosystem Restoration—A Legacy of H.T. Odum | Mitsch, Bill and John Day |

**6. Environment and society**

One of the most important insights that H.T. Odum had was simply to consider humans as a legitimate object of ecological inquiry. This caused him to run into two academic bramble patches simultaneously. Many ecologists, focused on the sanctity of their beloved nature, were used to (and still do) view humans as something outside of nature, rather than as a legitimate part of a new, evolving nature. On the other hand the study of humanity, in the view of many, is properly done only under the aegis of social scientists, who trumpet “free-will” and thus no causality and especially no determinism. In contradiction to both of these world

views Odum believed. . . “Much of the earth is occupied by humanity, either as part of ecosystems or interfacing as users and controllers. Where humans comprise a major part, new kinds of systems evolve with human culture at the hierarchical center. Information processing, social structure, symbolism, money, political power, and war become important components along with the vegetation, consumer organisms, and the inanimate work of the biosphere.” . . .

In this section, King reviews the first succinct writings of Odum’s regarding the relationships between humanity and nature that appeared in his book *Environment Power and Society* (Odum, 1953). Deister, provides some insight into how the theories of Odum were influential in her work with the public policy decision making arena. In two papers, Peterson discusses his and Odum’s thoughts on planning and how they evolved into decision-making in Oregon’s Governor’s Office in 1974.

#### The papers of Section 5

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|---|--|-----------------------|
| 5 | Creating a New Conceptual Framework: Environment Power and Society   | King,<br>Robert       |
| 5 | Using Energy Flows to Track and Influence Organizational Dynamics and Decision Making  | Deister,<br>Ane D.    |
| 5 | Comments on Relationship of Energy and Complexity and Planning. Architectural Design; Vol.10; 1972   | Peterson,<br>Larry L. |
| 5 | The Oregon Resource Interaction Model: An application of systems energetics principles to decision-making in state government State of Oregon—1974 | Peterson,<br>Larry L. |

## 7. Ecology and economics

Of all the social sciences, economics effects us the most, as all kinds of pronouncements routinely are brought forth and actually implemented that effect what we do and how we do it. Although Howard Odum did not dig into economics too deeply (some of his students did) he made some very explicit initial observations that are the essence, we believe, of two

real economies actually do work and that are missed by virtually all economists. These are that money is not a measure of value, but rather simply a means of exchange (hardly novel). But money DID have meaning because it enabled the possessor to have access to the energy services that would generate the goods and services he or she wanted. Just because these energy flows took place elsewhere (solar energy in Costa Rica produced our cup of coffee, petroleum from the middle East was used to make the steel in Korea that is the basis for an “American” built car and so on) does not mean that it is not critical. Another important insight from Odum is that he fully understood that the flow of energy in properly functioning ecosystems was critical to economic activity, and he did not believe that the ways that pollutants impacted nature were “externalities” but rather an erosion of the necessary capital machinery provided by nature that was necessary for all economic activity.

In this series of papers Kangas examines some of Odum’s early Texas work and finds many signs that Odum was thinking about humans and their economic systems as other examples of the ecosystems he was studying, subject to many of the same energetic laws and constraints. Pillet examines how Odum has thought about economic externalities from a very different perspective than is the case of conventional economics. Finally, Zucchetto, reviews Odum’s 1973 *Ambio* paper that may have been one of his more daring and thought-provoking.

#### The papers of Section 6

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|---|---|------------------------|
| 6 | Ecological Economics Began on the Texas Bays During the 1950s                             | Kangas,<br>Patrick     |
| 6 | Emternalities as an Odumite Counterpart to Economic Externalities. . . !                  | PILLET,<br>Gonzague    |
| 6 | Reflections on Howard T. Odum’s Paper: Energy, Ecology and Economics, <i>Ambio</i> , 1973 | Zucchetto,<br>James J. |

## 8. Emergy analysis

Emergy is probably the least understood and the most widely criticized of Odum’s theories and con-



cepts. The concept developed over a 30 odd year period of time beginning in the early 1970's and culminated in the publication of his book, Environmental Accounting. (Odum, 1996). Odum defined energy as the energy required to make something. Since it takes resources to make resources, it was not difficult to suggest that the true value of something was the resources required to make it, instead of the utility one might get from using it. Central to the concept of energy was the concept of energy quality...all energy is not the same. A joule of sunlight is not the same as a joule of oil. Thus a significant contribution of the energy theory is its revelation of the comparative qualities of energy.

Emergy evolved throughout the three decades of its development. For a brief period it was called embodied energy until it was realized that others in the field were using the term to describe a different concept. David Scienceman, a visiting Australian physicist, contributed the concept of energy memory and the word emergy was born in the late 1970s. Soon to follow was the word transformity which replaced "energy transformation ratio" and the concept of empower which was emergy per time. At first emergy was expressed as coal emergy but this soon gave way to solar emergy when it was noted that energies with lower qualities than coal had magnitudes less than one.

It was a natural to use emergy to evaluate all sorts of systems. When first developed, the concept was applied to energy systems, but soon Odum and colleagues were evaluating ecosystems agricultural systems, and human dominated systems. Transformities (ratio of emergy required to make something to the energy of the product) for products of every sort were calculated and tables of transformities compiled. By the turn of the century Odum and colleagues had begun producing a series of folios where emergy transformities were compiled and published for use by others.

In this section Hau and Bhavik review the concept of emergy providing a discussion of both its conceptual strengths and criticisms by others. Herendeen compares emergy analysis and energy analysis and Betty Odum provides a description of the application of emergy analysis to evaluation of shrimp mariculture in Ecuador.

The papers of Section 7

7	Emergy: An Engineering View	Hau, Jorge L. and Bhavik R. Bakshi
7	Energy Analysis And Emergy Analysis-A Comparison	Herendeen, Robert A.
7	Emergy Analysis of Shrimp Mariculture in Ecuador	Odum, Betty

**9. A prosperous way down**

If indeed the oil-gas world is a one shot deal, if humanity has built up far more infrastructure and human numbers than can be supported without the influx of this very special stuff petroleum, what kind of a future is in store for us? The response of most is to say "OK, we need to figure out some other energy source, solar panels, windmills, nuclear or whatever". Howard Odum thought that oil was special, that he was living through a one shot run of history when fuel would be cheap. (Charlie Hall believes that what this means is that the EROI or energy return on investment for oil is high). Odum always thought that if a full, comprehensive analysis was made of all the necessary inputs then there would be few if any other energy sources that could match petroleum, which after all is the net production of some ancient ecosystems. Some thirty years after the "energy crunches" of the 1970s, despite a great deal of effort there is no obvious competition for petroleum (or coal) on the horizon, at least at the scale required, and some alternatives, such as nuclear, look even less immediately promising. We do not know exactly when we will "run out of cheap oil" but it is almost certainly within a generation and maybe much sooner (Hall et al. 2003; Hall et al., in press). So the last best thing Odum left us was a plan for dealing with what he believed to be an inevitable future. In this section Ortega and Ulgiati provide two complimentary views of the book "A Prosperous Way Down"

The papers of Section 8

8	Prosperous Way Down, A Proposal For Action	Ortega, Enrique
8	H.T. Odum and E.C. Odum, The Prosperous Way Down	Ulgiati, Sergio

## 10. Philosophical overview of the contributions of H.T. Odum

It is certainly much too early to understand the full contribution of Howard Odum's science to the long haul, but this is a good place to start this effort. The following papers are a suite of very different papers examining the potential of Odum's legacy. We think that you, like us, will find this very interesting reading. Bastianoni examines how one of Odum's basic ideas, which have been thrown out by the dozen's each year, turned out to be extremely helpful for his own career in a rather different context than Odum had originally considered. Campbell examines the perspective of the need for, and the ways that might be used, to bring the basic ideas of Odum to a much broader audience. Giannantoni (who has published an extremely interesting mathematical and philosophical examination of emergy and maximum power principle just this year) examines Odum's concept of emergy within a broader philosophical perspective, McLachlan–Karr reviews Odum's paper on the ecosystem, energy and human values in *Zygon*, the journal of religion and science, suggesting "The most controversial contribution of the paper was that the systems view presented was contrary to the dominant religious and social science based interpretations of human faith and values in modern society". Finally, Maud asks whether Odum's systems overview, and especially his energy flow language, finally accomplishes the great philosopher Leibnitz's final goal, a near universal language.

The papers of Section 9

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|---|--|----------------------|
| 9 | Sitting on a giant's shoulders   | Bastianoni, Simone   |
| 9 | Prophet Where Art Thou?, Partnership with Nature and Other Prophecies of H.T. Odum | Campbell, Dan        |
| 9 | A harmonious dissonance  | Giannantoni, Corrado |

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| 9 | The Ecosystem, Energy and Human Values   | McLachlan-Karr, John       |
| 9 | Realizing The Enlightenment: H.T. Odum's Energy Systems Language Qua G.W.V Leibniz's Characteristica Universalis.* | Maud <sup>©</sup> , Sholto |

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