

Growth and Development

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Ecosystems Phenomenology

With 54 Figures



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To Marijka

*omnibus formosior,
semper in te glorior!*

Preface

“What in the ever-loving blue-eyed world do these [Ulano-wicz’s] innocuous comments on thermodynamics have to do with ecology!”

Anonymous manuscript reviewer
The American Naturalist, 1979

“The germ of the idea grows very slowly into something recognizable. It may all start with the mere desire to have an idea in the first place.”

Walt Kelly
Ten Ever-Lovin’ Blue-Eyed Years with Pogo, 1959

“It all seems extremely interesting, but for the life of me it sounds as if you pulled it out of the air,” my good friend Ray Lassiter exclaimed to me after enduring about 20 minutes of my enthusiasm for the newly formulated concept of “ascendency” in ecosystems. “It wasn’t,” I replied, “but it would take a book to show you where it came from.”

If such was the reaction of someone usually sympathetic to my manner of thinking, what could I expect from those who viewed biological development in the traditional way? After all, I was suggesting that it is possible to quantify the growth and development of an entire ecosystem. Furthermore, I was maintaining that this development was not entirely determined by events and entities at smaller scales, and yet could influence these component processes and structures.

To be sure, mine was only the latest of many challenges to straight reductionism, but, like everyone else with a new idea, I thought mine was special. It was formulated in terms that evolved quite naturally from widely accepted phenomenological principles. Practically every other opposition to strict reductionism had generated heated controversy, so I was anxious for reaction to my synthesis—be it laudatory or vituperative! But response was slow in coming.

From some, it was a bemused “too transcendental” or “dream-like.” From a very few, there came the expected fulminations. But largely, I was met with indifference. I spent innumerable hours in imaginary confrontations with critics to prepare myself for entering reputed strongholds of neo-Darwinism. With few exceptions, those preparations proved unnecessary, as question periods were generally short, and most potential critics simply filed out of the seminar room without having uttered a word. Despite my obvious enthusiasm, it became clear that I was not communicating the thrust of my initiative.

The source of much of the indifference to my thoughts is apparent to me now. My formal education was in chemical engineering *science*. During

the years I was in graduate school, my institution was deemphasizing the strictly vocational aspects of engineering and stressing instead those elements of science that supported the profession. Much time, therefore, was devoted to evaluating the motivations and perspectives of those who significantly advanced these underlying disciplines. Thermodynamics was a particularly fertile domain for discussion, and I believe that most of us left the department with a high regard for pragmatic quantitative methods, phenomenological inquiry, and the macroscopic approach to quantifying whole systems.

By contrast, most of my audiences in biology departments had spent their formative years in growing admiration for the analytical process—dissecting that which is whole, probing that which is small, and looking for causes in component parts. Not only was there substantial disparity in the subjects we had studied, but factual matter had been assimilated under divergent perspectives. Perhaps what I was proposing was too foreign even to excite my colleagues' ire. Clearly, if I wanted to be taken seriously, I needed to write the book I had first mentioned to Ray.

Thus, it is with my coworkers in biology foremost in mind that I have written this text. My aim is to introduce everyone to the conceptual elements that gave rise to my theory without unduly burdening the reader with higher mathematics, technical details, or esoteric jargon. Whereas the reader may begin the introduction feeling that it is nonsense to talk about the growth and development of an ecosystem, I hope that by the sixth chapter the notion will no longer seem arbitrary or strange. True, to accommodate the phenomenological perspective will require many biologists to adjust some of their popularly held attitudes, but the ideas used in this synthesis are not so new or radical as to require the reader to renounce the entire framework upon which his career is built!

I would encourage potential readers who are not biologists to take heart. The subject of growth and development is broad enough never to allow this exposition to degenerate to where it has little interest to those outside biology. Scattered copiously throughout the chapters are implications and ramifications certain to pique the interest of those in fields such as economics, thermodynamics, cybernetics, cognitive science, network analysis, operations research, fluid mechanics, sociology, and possibly even philosophy.

Having emphasized the disparity between the backgrounds of the engineer and the biologist as a barrier to communication, I should confess that some other impediments to useful exchange were of my own unintentional doing. As I look back at my early publications on network development, they now appear to me rather inchoate and cryptic. Given that they were probably more coherent than my verbal presentations, it is little wonder that many readers and listeners seemed mystified, or at least judged my approach to be unduly transcendental. Having to distill all the conceptual background into reasonably concise and intelligible prose was

a tremendous learning experience, as well as a trial of my capacity for self-discipline.

I sincerely hope that several years from now, we will have made sufficient progress in articulating the process of development in natural systems so that this work will then appear rather primitive by comparison. For now, however, I think that this is my best effort at describing whole community development, and it should suffice to initiate dialogue with many who hold dissimilar opinions on the meanings of growth, development, and life.

Robert E. Ulanowicz

Acknowledgments

I am indebted to a number of friends and associates for their help in formulating this work. Perhaps the individual who most directly facilitated this thesis is my close friend and colleague, Trevor Platt. To my memory, Trevor was the only individual ever to respond to a precursory statement of these ideas, which I included at the end of a 1972 publication. Several years later, when I was struggling with numerous professional distractions, Trevor managed my appointment to SCOR Working Group No. 59 and encouraged me to use the new position both as justification to devote more time to the study of thermodynamics and development and as an international platform from which to make known my findings. It was while doing background research for the Working Group that my notions on growth and development took on their present, concrete mathematical form. Chairman Kenneth Mann and other members of the Working Group provided me welcome encouragement and criticism during those crucial early months.

Whereas growth may be quick, maturation is often a slow and agonizing process. During the course of writing this book, my chief source of counsel has been my very good friend and collaborator, Alan Goldman. Seldom have I encountered more penetrating insights, creative alternatives, or incisive criticisms than those which Alan has provided me. Citations of our common work are scarce, but that certainly should not be a gauge of our significant cooperation, from which I have greatly learned and richly benefitted.

Particular mention is also due several individuals at The Institute of Ecology at the University of Georgia. Bernard Patten was especially helpful to me during the revision of my first draft—not only through his own painstaking review of the work, but by the use of this text in his course on advanced systems ecology. Thomas Burns, Lee Graham, Masahiko Higashi, and Thomas James, students in that course, were kind enough to supply me with written critiques. I owe a special salute to a man whom I have never had the honor of meeting, Eugene Odum. It was reading his *Fundamentals of Ecology* which moved me to change careers and pursue

the study of ecology. In his only missive to me, he was exceedingly generous in his assessment of my attempts to synthesize his observations on ecosystem development, an act that gave me the needed confidence to continue on what, to many, seemed a radical course of thought.

Over the last few years, Simon Levin of Cornell University has guided several of my journal articles into print, and he was a most welcome catalyst to the publication of this work by Springer-Verlag.

A number of other colleagues read and commented on parts (and in many cases all) of the draft manuscript. Henri Atlan, Albert Cheung, Michael Conrad, Richard Emery, James Kay, Bruce Hannon, Robert May, Ian Morris, Robert O'Neill, Eric Schneider, Janusz Szyrmer, and Richard Wiegert gave most generously of their time and advice. Beyond reviewing my rough draft, these individuals have done much through our personal associations to influence my career and thinking. I should also add that I have not always followed the advice they offered, so that any shortcomings of this volume should be ascribed entirely to me.

My financial support while writing this text has come primarily from my own organization, the Chesapeake Biological Laboratory. I have been most fortunate to work for a series of administrators and with a host of colleagues who, for the most part, have been very indulgent about my pursuit of development theory at times when it was decidedly not in their own fiscal interests to do so. The Laboratory also provided me with the able secretarial services of Gail Canaday, who used her excellent skill on the word processor to produce a text that amounted to typewriter artistry. Frances Younger executed the illustrations with both proficiency and enthusiasm. Numerous ideas in the last two chapters were developed while I was partially supported by grant No. ECS-8110035 from the Systems Theory and Operations Research Program of the National Science Foundation.

On a personal note, the roots for this theory go back over a quarter century while I was still in school and living at home. My parents, Edward and Mary, provided me with an environment extraordinarily free from those concerns (and often responsibilities) that might have otherwise interfered with the freedom to indulge my every intellectual fancy. May they find in this work some small token of my appreciation for their labors and love.

Lastly, and most certainly not least, it is traditional for an author to thank spouse and family for their patience and support. These I have received in abundance. But my wife, Marijka, was far more than just supportive. She labored diligently with me in reworking the first draft—polishing the syntax, testing my explanation of ideas. Her influence is found on almost every page, and it is with affection and gratitude that I dedicate this work to her.

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