

From the lead author of the international
bestseller *Limits to Growth*

Thinking in Systems

A Primer



Donella H.
Meadows

edited by Diana Wright



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— *A Primer* —

Donella H. Meadows

*Edited by Diana Wright,
Sustainability Institute*



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For a full list of publications please contact:

Earthscan
Dunstan House
14a St Cross St
London, EC1N 8XA, UK
Tel: +44 (0)20 7841 1930
Fax: +44 (0)20 7242 1474
Email: earthinfo@earthscan.co.uk
Web: www.earthscan.co.uk

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Thinking in Systems

OTHER BOOKS BY DONELLA H. MEADOWS:

*Harvesting One Hundredfold: Key Concepts and Case Studies in
Environmental Education* (1989).
The Global Citizen (1991).

WITH DENNIS MEADOWS:
Toward Global Equilibrium (1973).

WITH DENNIS MEADOWS AND JØRGEN RANDERS:
Beyond the Limits (1992).
Limits to Growth: The 30-Year Update (2004).

WITH DENNIS MEADOWS, JØRGEN RANDERS, AND WILLIAM W. BEHRENS III:
The Limits to Growth (1972).

WITH DENNIS MEADOWS, ET AL.:
The Dynamics of Growth in a Finite World (1974).

WITH J. RICHARDSON AND G. BRUCKMANN:
Groping in the Dark: The First Decade of Global Modeling (1982).

WITH J. ROBINSON:
The Electronic Oracle: Computer Models and Social Decisions (1985).

FOR DANA
(1941–2001)

and for all those who would learn from her

A NOTE FROM THE AUTHOR

This book has been distilled out of the wisdom of thirty years of systems modeling and teaching carried out by dozens of creative people, most of them originally based at or influenced by the MIT System Dynamics group. Foremost among them is Jay Forrester, the founder of the group. My particular teachers (and students who have become my teachers) have been, in addition to Jay: Ed Roberts, Jack Pugh, Dennis Meadows, Hartmut Bossel, Barry Richmond, Peter Senge, John Sterman, and Peter Allen, but I have drawn here from the language, ideas, examples, quotes, books, and lore of a large intellectual community. I express my admiration and gratitude to all its members.

I also have drawn from thinkers in a variety of disciplines, who, as far as I know, never used a computer to simulate a system, but who are natural systems thinkers. They include Gregory Bateson, Kenneth Boulding, Herman Daly, Albert Einstein, Garrett Hardin, Václav Havel, Lewis Mumford, Gunnar Myrdal, E.F. Schumacher, a number of modern corporate executives, and many anonymous sources of ancient wisdom, from Native Americans to the Sufis of the Middle East. Strange bedfellows, but systems thinking transcends disciplines and cultures and, when it is done right, it overarches history as well.

Having spoken of transcendence, I need to acknowledge factionalism as well. Systems analysts use overarching concepts, but they have entirely human personalities, which means that they have formed many fractious schools of systems thought. I have used the language and symbols of system dynamics here, the school in which I was taught. And I present only the core of systems theory here, not the leading edge. I don't deal with the most abstract theories and am interested in analysis only when I can see how it helps solve real problems. When the abstract end of systems theory does that, which I believe it will some day, another book will have to be written.

Therefore, you should be warned that this book, like all books, is biased and incomplete. There is much, much more to systems thinking than is

presented here, for you to discover if you are interested. One of my purposes is to make you interested. Another of my purposes, the main one, is to give you a basic ability to understand and to deal with complex systems, even if your formal systems training begins and ends with this book.

—DONELLA MEADOWS, 1993

A NOTE FROM THE EDITOR

In 1993, Donella (Dana) Meadows completed a draft of the book you now hold. The manuscript was not published at the time, but circulated informally for years. Dana died quite unexpectedly in 2001—before she completed this book. In the years since her death, it became clear that her writings have continued to be useful to a wide range of readers. Dana was a scientist and writer, and one of the best communicators in the world of systems modeling.

In 1972, Dana was lead author of *The Limits to Growth*—a best-selling and widely translated book. The cautions she and her fellow authors issued then are recognized today as the most accurate warnings of how unsustainable patterns could, if unchecked, wreak havoc across the globe. That book made headlines around the world for its observations that continual growth in population and consumption could severely damage the ecosystems and social systems that support life on earth, and that a drive for limitless economic growth could eventually disrupt many local, regional, and global systems. The findings in that book and its updates are, once again, making front-page news as we reach peak oil, face the realities of climate change, and watch a world of 6.6 billion people deal with the devastating consequences of physical growth.

In short, Dana helped usher in the notion that we have to make a major shift in the way we view the world and its systems in order to correct our course. Today, it is widely accepted that systems thinking is a critical tool in addressing the many environmental, political, social, and economic challenges we face around the world. Systems, big or small, can behave in similar ways, and understanding those ways is perhaps our best hope for making lasting change on many levels. Dana was writing this book to bring that concept to a wider audience, and that is why I and my colleagues at the Sustainability Institute decided it was time to publish her manuscript posthumously.

Will another book really help the world and help you, the reader? I think

so. Perhaps you are working in a company (or own a company) and are struggling to see how your business or organization can be part of a shift toward a better world. Or maybe you're a policy maker who is seeing others "push back" against your good ideas and good intentions. Perhaps you're a manager who has worked hard to fix some important problems in your company or community, only to see other challenges erupt in their wake. As one who advocates for changes in how a society (or a family) functions, what it values and protects, you may see years of progress easily undone in a few swift reactions. As a citizen of an increasingly global society, perhaps you are just plain frustrated with how hard it is to make a positive and lasting difference.

If so, I think that this book can help. Although one can find dozens of titles on "systems modeling" and "systems thinking," there remains a clear need for an approachable and inspiring book about systems and us—why we find them at times so baffling and how we can better learn to manage and redesign them.

At the time that Dana was writing *Thinking in Systems*, she had recently completed the twenty-year update to *Limits to Growth*, titled *Beyond the Limits*. She was a Pew Scholar in Conservation and the Environment, was serving on the Committee on Research and Exploration for the National Geographic Society, and she was teaching about systems, environment, and ethics at Dartmouth College. In all aspects of her work, she was immersed in the events of the day. She understood those events to be the outward behavior of often complex systems.

Although Dana's original manuscript has been edited and restructured, many of the examples you will find in this book are from her first draft in 1993. They may seem a bit dated to you, but in editing her work I chose to keep them because their teachings are as relevant now as they were then. The early 1990s were the time of the dissolution of the Soviet Union and great shifts in other socialist countries. The North American Free Trade Agreement was newly signed. Iraq's army invaded Kuwait and then retreated, burning oil fields on the way out. Nelson Mandela was freed from prison, and South Africa's apartheid laws were repealed. Labor leader Lech Walesa was elected president of Poland, and poet Václav Havel was elected president of Czechoslovakia. The International Panel on Climate Change issued its first assessment report, concluding that "emissions from human activities are substantially increasing the atmospheric concentra-

tions of greenhouse gases and that this will enhance the greenhouse effect and result in an additional warming of the Earth's surface." The UN held a conference in Rio de Janeiro on environment and development.

While traveling to meetings and conferences during this time, Dana read the *International Herald Tribune* and during a single week found many examples of systems in need of better management or complete redesign. She found them in the newspaper because they are all around us every day. Once you start to see the events of the day as parts of trends, and those trends as symptoms of underlying system structure, you will be able to consider new ways to manage and new ways to live in a world of complex systems. In publishing Dana's manuscript, I hope to increase the ability of readers to understand and talk about the systems around them and to act for positive change.

I hope this small approachable introduction to systems and how we think about them will be a useful tool in a world that rapidly needs to shift behaviors arising from very complex systems. This is a simple book for and about a complex world. It is a book for those who want to shape a better future.

—DIANA WRIGHT, 2008

If a factory is torn down but the rationality which produced it is left standing, then that rationality will simply produce another factory. If a revolution destroys a government, but the systematic patterns of thought that produced that government are left intact, then those patterns will repeat themselves. . . . There's so much talk about the system. And so little understanding.

—ROBERT PIRSIG, *Zen and the Art of Motorcycle Maintenance*

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Introduction: The System Lens

Managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other. I call such situations messes. . . . Managers do not solve problems, they manage messes.

—RUSSELL ACKOFF,¹ operations theorist

Early on in teaching about systems, I often bring out a Slinky. In case you grew up without one, a Slinky is a toy—a long, loose spring that can be made to bounce up and down, or pour back and forth from hand to hand, or walk itself downstairs.

I perch the Slinky on one upturned palm. With the fingers of the other hand, I grasp it from the top, partway down its coils. Then I pull the bottom hand away. The lower end of the Slinky drops, bounces back up again, yo-yos up and down, suspended from my fingers above.

“What made the Slinky bounce up and down like that?” I ask students.

“Your hand. You took away your hand,” they say.

So I pick up the box the Slinky came in and hold it the same way, poised on a flattened palm, held from above by the fingers of the other hand. With as much dramatic flourish as I can muster, I pull the lower hand away.

Nothing happens. The box just hangs there, of course.

“Now once again. What made the Slinky bounce up and down?”

The answer clearly lies within the Slinky itself. The hands that manipulate it suppress or release some behavior that is latent within the structure of the spring.

That is a central insight of systems theory.

Once we see the relationship between structure and behavior, we can begin to understand how systems work, what makes them produce poor results, and how to shift them into better behavior patterns. As our world

continues to change rapidly and become more complex, systems thinking will help us manage, adapt, and see the wide range of choices we have before us. It is a way of thinking that gives us the freedom to identify root causes of problems and see new opportunities.

So, what is a system? A system is a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time. The system may be buffeted, constricted, triggered, or driven by outside forces. But the system's response to these forces is characteristic of itself, and that response is seldom simple in the real world.

When it comes to Slinkies, this idea is easy enough to understand. When it comes to individuals, companies, cities, or economies, it can be heretical. The system, to a large extent, causes its own behavior! An outside event may unleash that behavior, but the same outside event applied to a different system is likely to produce a different result.

Think for a moment about the implications of that idea:

- Political leaders don't cause recessions or economic booms. Ups and downs are inherent in the structure of the market economy.
- Competitors rarely cause a company to lose market share. They may be there to scoop up the advantage, but the losing company creates its losses at least in part through its own business policies.
- The oil-exporting nations are not solely responsible for oil-price rises. Their actions alone could not trigger global price rises and economic chaos if the oil consumption, pricing, and investment policies of the oil-importing nations had not built economies that are vulnerable to supply interruptions.
- The flu virus does not attack you; you set up the conditions for it to flourish within you.
- Drug addiction is not the failing of an individual and no one person, no matter how tough, no matter how loving, can cure a drug addict—not even the addict. It is only through understanding addiction as part of a larger set of influences and societal issues that one can begin to address it.

Something about statements like these is deeply unsettling. Something else is purest common sense. I submit that those two somethings—a resistance to and a recognition of systems principles—come from two kinds of human experience, both of which are familiar to everyone.

On the one hand, we have been taught to analyze, to use our rational ability, to trace direct paths from cause to effect, to look at things in small and understandable pieces, to solve problems by acting on or controlling the world around us. That training, the source of much personal and societal power, leads us to see presidents and competitors, OPEC and the flu and drugs as the causes of our problems.

On the other hand, long before we were educated in rational analysis, we all dealt with complex systems. We are complex systems—our own bodies are magnificent examples of integrated, interconnected, self-maintaining complexity. Every person we encounter, every organization, every animal, garden, tree, and forest is a complex system. We have built up intuitively, without analysis, often without words, a practical understanding of how these systems work, and how to work with them.

Modern systems theory, bound up with computers and equations, hides the fact that it traffics in truths known at some level by everyone. It is often possible, therefore, to make a direct translation from systems jargon to traditional wisdom.

Because of feedback delays within complex systems, by the time a problem becomes apparent it may be unnecessarily difficult to solve.

— *A stitch in time saves nine.*

According to the competitive exclusion principle, if a reinforcing feedback loop rewards the winner of a competition with the means to win further competitions, the result will be the elimination of all but a few competitors.

— *For he that hath, to him shall be given; and he that hath not, from him shall be taken even that which he hath (Mark 4:25)*

or

— *The rich get richer and the poor get poorer.*

A diverse system with multiple pathways and redundancies is

more stable and less vulnerable to external shock than a uniform system with little diversity.

— *Don't put all your eggs in one basket.*

Ever since the Industrial Revolution, Western society has benefited from science, logic, and reductionism over intuition and holism. Psychologically and politically we would much rather assume that the cause of a problem is “out there,” rather than “in here.” It's almost irresistible to blame something or someone else, to shift responsibility away from ourselves, and to look for the control knob, the product, the pill, the technical fix that will make a problem go away.

Serious problems have been solved by focusing on external agents—preventing smallpox, increasing food production, moving large weights and many people rapidly over long distances. Because they are embedded in larger systems, however, some of our “solutions” have created further problems. And some problems, those most rooted in the internal structure of complex systems, the real messes, have refused to go away.

Hunger, poverty, environmental degradation, economic instability, unemployment, chronic disease, drug addiction, and war, for example, persist in spite of the analytical ability and technical brilliance that have been directed toward eradicating them. No one deliberately creates those problems, no one wants them to persist, but they persist nonetheless. That is because they are intrinsically systems problems—undesirable behaviors characteristic of the system structures that produce them. They will yield only as we reclaim our intuition, stop casting blame, see the system as the source of its own problems, and find the courage and wisdom to *restructure* it.

Obvious. Yet subversive. An old way of seeing. Yet somehow new. Comforting, in that the solutions are in our hands. Disturbing, because we must *do things*, or at least *see things* and *think about things*, in a different way.

This book is about that different way of seeing and thinking. It is intended for people who may be wary of the word “systems” and the field of systems analysis, even though they may have been doing systems thinking all their lives. I have kept the discussion nontechnical because I want to show what a long way you can go toward understanding systems without turning to mathematics or computers.

I have made liberal use of diagrams and time graphs in this book