

**Systems Behavior and Chaos:**

**A non-mathematical introduction and analysis**

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**Abstract**

Describes the behavior of several small laboratory or “toy” systems in order to identify basic behaviors –including chaotic oscillation- that may apply to ecological, climatic, political, economic and other large systems of general concern, with the goal of helping us better cope with or manage them. Identifies eight basic systems behaviors including self-assembly. Describes forces holding systems together and why systems oscillate. Emphasizes role of energy showing how it can concentrate and cause dramatic events like rogue waves, and perhaps stock market crashes. Uses a simulation model to conduct possibly the most extensive exploration of the double pendulum to date. Suggests a possible way to find the root cause of chaos. Gives examples of real-world systems that appear to oscillate chaotically and suggests how toy systems behavior may help explain their behavior. Includes many links to videos and other source materials. Contains no mathematics. Suitable for any analytically minded person who knows high school physics and seeks to better understand how the world works, but also offers new data that experts in chaos theory should find useful. Ideal as general introduction to chaos theory for serious students before they delve into the math.

**Preface**

We live in a world of systems. We’re in some. We are ones. And we contain them. They range from galaxies and solar systems to atoms and molecules. They include things like: the nervous and digestive systems, the transport system, political systems like national and local government, plant and animal ecosystems, individual corporations, the economic system, atmospheric and oceanic systems, the financial system, the health care system, the judicial system, etc. It would be surprising if at a very fundamental level they had nothing in common: formed for entirely different reasons, or behaved in entirely different ways.

Nothing lives in a vacuum unaffected by things in the larger environment. Everything is linked to everything else. What happens to one part sends out ripples of change that affect everything else to a greater or lesser extent.

Systems are usually invisible and therefore not recognized as such, nor given the attention they deserve. Yes, the parts are visible, but not the forces linking them together. One goal I have is to give the reader a new lens through which to view reality; a lens which sees the invisible systems behind everything, including the evening news.

I first became interested in systems in grad school, where I studied for a PhD in Urban Systems Planning back in the early 70”s. My emphasis was urban transportation. Much more recently –after a career in strategic and business planning in telecom and aerospace- I got involved with urban transportation again; advocating as an ordinary citizen against a rail system on the basis that bus rapid transit would save billions. I testified at county council meetings, wrote an op-ed, and did extensive analyses. I came to realize in very visceral and hard-earned way that the ordinary citizen isn’t just fighting to change the opinions of ten council members. Instead he or she is fighting an entire system, which includes consultants, contractors, county staff, newspapers, and various interest groups. They were all linked in various ways and had all reached a compromise decision on what they wanted to do. This system strongly resisted any attempt to change things.

I began to think we needed to see these invisible systems, to understand how they form and function in order to better manage them in the public interest. This, strange as it might seem, was my primary motive for trying to write a science based book on the subject of systems self-assembly and behavior. It would span from the big bang to todays societal systems. This isn’t that still unwritten book. Instead this e-book documents research I did in preparation for writing it. Most systems seem to oscillate in a chaotic manner. I wanted to understand chaos, but its exceedingly complex and became more of a challenge than I expected. It became a black hole for time and consumed almost three years. Now I want to share what I learned, so I can get back to the book I’ve been wanting to write.

This is a semi-technical book in the sense it deals with physics but avoids any math. It deals with physics because all natural systems follow the laws of physics. Arguably the behavior of large societal systems like the economy is fundamentally driven more by physics than by man’s conscious decisions. Thus I am essentially looking for the basic “laws of systems” that apply across a very broad range of systems.

My general approach in this book is to begin by explaining what a system is, what forces hold them together, and what generic forms of behaviors they exhibit. This is hard science, not opinion. I’ve done some real honest research, and felt the joy scientists have when they get insights. I inject opinion when I suggest how these behaviors may be occurring in large real-world systems like the climate or the economy. History is about what things changed. Behavior is about how things change. I hope to address WHY things change. Ideally, I would provide some insight as to why history happens. Again that’s the ultimate goal. This book is just an initial step, but I want you to understand which way I’m heading.

I think I have discovered, probably rediscovered, some basic laws of systems. I’ve not had time to prove they apply to the real-world systems we care about most. But I’ve speculated a bit.

Among other things I hope specialists in all fields will try to see if there are basic laws of systems -like those I propose- and cooperate in writing a cross disciplinary book that summarizes how they apply in their fields of expertise. It would be a unifying framework for explaining how the world works. And hopefully decision makers at all levels will think more holistically in terms of systems, rather than on narrow issues.

I’m no expert in each of the various fields I span, especially not chaos theory. Hopefully any errors are innocuous. Finally, this isn’t a polished document. I’ve not time to make it so.

**Authors Background**

BS Electrical Engineering, Duke University

PhD Urban Systems Planning, University of Washington (Dissertation title: Telecommunications Substitutes for Transportation)

Worked generally as a strategic and business planner. Employment:

US Navy, officer

Ocean Science and Engineering

Boeing Aerospace Co.

Stanford Research Institute (Now SRI International)

Satellite Business Systems (IBM, Comsat and Aetna partnership)

Compression Labs (mfr. of video-teleconferencing equipment)

Boeing Computer Services

Now retired and living in Santa Rosa, Ca. where I am an occasional citizens advocate for more fact-based and fiscally responsible local government, especially relative to local transportation and greenhouse gas reduction projects.

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12.7 Eco systems

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12.9 Cosmos

**General references**

# I read and much benefitted from the following books, even though I ignored the math. They fully showcase the complexity of chaos theory. For brevity I use “Ca” numbers when referring to them in this book.

# Ca 1 Chaos: Making a New Science, 2008 by [James Gleick](https://www.amazon.com/James-Gleick/e/B000AQ3M1I/ref=dp_byline_cont_book_1)

# Ca 2 Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering (Studies in Nonlinearity) by [Steven H. Strogatz](https://www.amazon.com/Steven-H.-Strogatz/e/B001KHB290/ref=dp_byline_cont_book_1)

# Ca 3 Newton's Clock: Chaos in the Solar System, 1993, by [Ivars Peterson](https://www.amazon.com/Ivars-Peterson/e/B001IXPZ08/ref=dp_byline_cont_book_1)

# Ca 4 Chaotic Dynamics: An Introduction, 1990, by [Gregory L. Baker](https://www.amazon.com/Gregory-L.-Baker/e/B001HCW20Q/ref=dp_byline_cont_book_1) and, [Jerry P. Gollub](https://www.amazon.com/s/ref=dp_byline_sr_book_2?ie=UTF8&text=Jerry+P.+Gollub&search-alias=books&field-author=Jerry+P.+Gollub&sort=relevancerank)

# Ca 5 Chaos: From Simple Models to Complex Systems (Series on Advances in Statistical Mechanics) by [Massimo Cencini](https://www.amazon.com/Massimo-Cencini/e/B003VMZD1A/ref=dp_byline_cont_book_1) , [Fabio Cecconi](https://www.amazon.com/s/ref=dp_byline_sr_book_2?ie=UTF8&text=Fabio+Cecconi&search-alias=books&field-author=Fabio+Cecconi&sort=relevancerank) and [Angelo Vulpiani](https://www.amazon.com/s/ref=dp_byline_sr_book_3?ie=UTF8&text=Angelo+Vulpiani&search-alias=books&field-author=Angelo+Vulpiani&sort=relevancerank)

# Ca 6 Chaos and Fractals: New Frontiers of Science, 1992 by [Heinz-Otto Peitgen](https://www.amazon.com/Heinz-Otto-Peitgen/e/B000AQ78AO/ref=dp_byline_cont_book_1) , [Hartmut Jürgens](https://www.amazon.com/s/ref=dp_byline_sr_book_2?ie=UTF8&text=Hartmut+J%C3%BCrgens&search-alias=books&field-author=Hartmut+J%C3%BCrgens&sort=relevancerank) and [Dietmar Saupe](https://www.amazon.com/Dietmar-Saupe/e/B00DPAW8S4/ref=dp_byline_cont_book_3)

# Ca 7 From Calculus to Chaos: An Introduction to Dynamics, 1997 by [David Acheson](https://www.amazon.com/David-Acheson/e/B004MLEZFY/ref=dp_byline_cont_book_1)

# Ca 8 An Introduction to Chaotic Dynamical Systems, 1989 by [Robert Devaney](https://www.amazon.com/s/ref=dp_byline_sr_book_1?ie=UTF8&text=Robert+Devaney&search-alias=books&field-author=Robert+Devaney&sort=relevancerank)

# Ca 9 COMPLEXITY: THE EMERGING SCIENCE AT THE EDGE OF ORDER AND CHAOS, 1992 by [M. Mitchell Waldrop](https://www.amazon.com/M.-Mitchell-Waldrop/e/B000APDNB8/ref=dp_byline_cont_book_1)

# Ca 10 Coping with Chaos (Wiley Series in Nonlinear Science), 1994 by [Edward Ott](https://www.amazon.com/s/ref=dp_byline_sr_book_1?ie=UTF8&text=Edward+Ott&search-alias=books&field-author=Edward+Ott&sort=relevancerank) (Editor), [Tim Sauer](https://www.amazon.com/Tim-Sauer/e/B001IQUMEE/ref=dp_byline_cont_book_2) (Editor), [James A. Yorke](https://www.amazon.com/s/ref=dp_byline_sr_book_3?ie=UTF8&text=James+A.+Yorke&search-alias=books&field-author=James+A.+Yorke&sort=relevancerank)

# Ca 11 Sync: How Order Emerges From Chaos In the Universe, Nature, and Daily Life by [Steven H. Strogatz](https://www.amazon.com/Steven-H.-Strogatz/e/B001KHB290/ref=dp_byline_cont_book_1)

# Ca 12 Mathematics and the Unexpected, 1998 by [Ivar Ekeland](https://www.amazon.com/s/ref=dp_byline_sr_book_1?ie=UTF8&text=Ivar+Ekeland&search-alias=books&field-author=Ivar+Ekeland&sort=relevancerank)

# Ca 13 Fractals and Chaos: An illustrated course, 1997 by [Paul S. Addison](https://www.amazon.com/Paul-S.-Addison/e/B001H6WNVK/ref=dp_byline_cont_book_1)

# Ca 14 Chaos Theory Tamed Hardcover, 1997 by [Garnett P. Williams](https://www.amazon.com/Garnett-P.-Williams/e/B001IR1JJ0/ref=dp_byline_cont_book_1)

# Ca 15 Chaos: A Very Short Introduction, 2007 by [Leonard Smith](https://www.amazon.com/s/ref=dp_byline_sr_book_2?ie=UTF8&text=Leonard+Smith&search-alias=books&field-author=Leonard+Smith&sort=relevancerank)