

Overview of Complex Systems

Principles of Complex Systems | @pocsvox CSYS/MATH 300, Fall, 2015 | #FallPoCS2015

Prof. Peter Dodds | @peterdodds

Dept. of Mathematics & Statistics | Vermont Complex Systems Center
Vermont Advanced Computing Core | University of Vermont



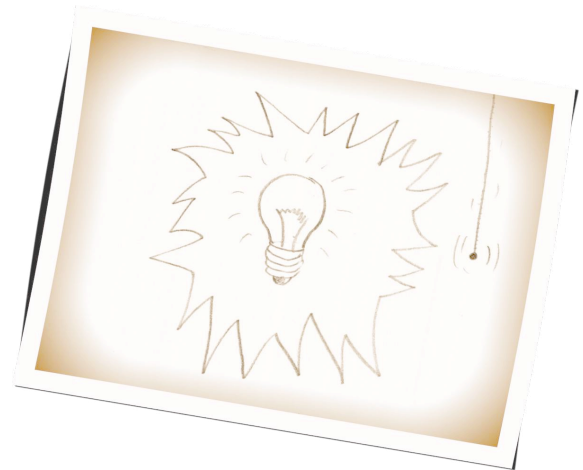
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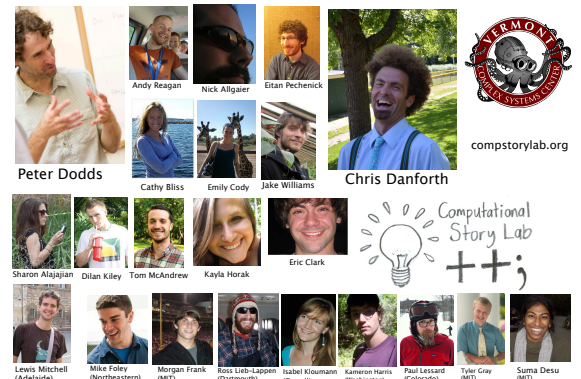


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Funding: NSF, NASA, MITRE.

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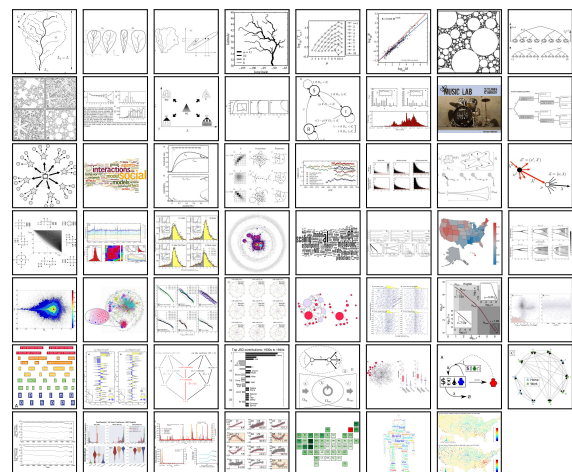
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Basics:

- Instructor: Prof. Peter Dodds
- Lecture room and meeting times:
403 Lafayette, Tuesday and Thursday, 1:15 pm to 2:30 pm
- Office: Farrell Hall, second floor, Trinity Campus
- email: peter.dodds@uvm.edu
- Course Website:
<http://www.uvm.edu/~pdodds/teaching/courses/2015-08UVM-300>
- Course Twitter handle: @pocsvox
- Course hashtag: #FallPoCS2015

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Exciting details regarding these slides:

- Three versions (all in pdf):
 1. Presentation,
 2. Flat Presentation,
 3. Handout (3x2 slides per page).
- Presentation versions are **hyperly navigable**:
⌕⌕⌕ back + search + forward.
- Web links look like [this](#).
- References in slides link to full citation at end.^[1]
- Citations contain links to pdfs for papers (if available).
- Some books will be linked to on Amazon.
- Brought to you by a frightening melange of [XyTeX](#), [Beamer](#), [perl](#), [PerlTeX](#), [fevered command-line madness](#), and an almost [fanatical devotion](#) to the indomitable [emacs](#).
#evilsuperpowers

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More super exciting details:

- We use Open Sans and make math look good:

```
\setmainfont[Ligatures=TeX]{Open Sans}  
\setsansfont[Ligatures=TeX]{Open Sans}  
\usefonttheme[onlymath]{serif}
```
- Working towards putting the course on Github.

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Potential paper products:

- The [Syllabus](#) and a [Poster](#).

Office hours:

- Maybe: 2:45 pm to 3:15 pm on Tuesdays near class room, 1:30 to 3:30 pm Wednesdays at Farrell Hall, Farrell Hall, second floor, Trinity Campus

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Graduate Certificate in Complex Systems (and Data Science):

- Principles of Complex Systems is one of two core requirements for UVM's five course teaching-learning/certificate-of-study-in-complex-systems/[Certificate of Graduate Study in Complex Systems](#).
- Other required course: Prof. Maggie Eppstein's "Modelling Complex Systems" (CSYS/CS 302).
- The Sequel to PoCS: "Complex Networks" (CSYS/MATH 303).

New [movie voice]:

- MS in Complex Systems and Data Science (Fall 2015)
- PhD in Complex Systems (Fall 2016)

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Yet more super exciting details:

- This is Season 9 of Principles of Complex Systems.
- Lectures will be called Episodes.
- All lectures are [bottle episodes](#).
- [Other tropes](#) will be involved.
- Last season's Episodes are [here](#).

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Wonderful foundational support for PoCS and CoNKS has come from the NSF:

- ▶ “CAREER: Explorations of Complex Social and Psychological Phenomena through Multiscale Online Sociological Experiments, Empirical Studies, and Theoretical Models.” 2009–2015.
- ▶ SES Division of Social and Economic Sciences SBE Directorate for Social, Behavioral & Economic Sciences
- ▶ Abstract is [here](#).
- ▶ People have [said nice things about PoCS](#).

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How grading works:

Questions are worth 3 points according to the following scale:

- ▶ 3 = correct or very nearly so.
- ▶ 2 = acceptable but needs some revisions.
- ▶ 1 = needs major revisions.
- ▶ 0 = way off.

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Team PoCS

We'll be trying out Slack:

- ▶ Place for discussions about all things PoCS including assignments and projects.
- ▶ Once invited, please sign up here: <http://teampocs.slack.com>
- ▶ Very good: Install Slack app on laptops, tablets, phone.
- ▶ Everyone will behave wonderfully.

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Important things:

1. Classes run from Tuesday, September 1 to Tuesday, December 8.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 14.
3. Last day to withdraw—Monday, November 2 (Sadness!).
4. Reading and Exam period—Thursday, December 10 to Friday, December 18.

Do check the course Twitter account, @pocsvox, for updates regarding the course (part of the course site).

Academic assistance: Anyone who requires assistance in any way (as per the ACCESS program or due to athletic endeavors), please see or contact me as soon as possible.

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Grading breakdown:

- ▶ **Projects/talks (36%)**—Students will work on semester-long projects. Students will develop a proposal in the first few weeks of the course which will be discussed with the instructor for approval. Details: 12% for the first talk, 12% for the final talk, and 12% for the written project.
- ▶ **Assignments (60%)**—All assignments will be of equal weight and there will be 10 ± 1 of them.
- ▶ **General attendance/Class participation (4%)**

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The nature of PoCS:

- ▶ Transitional from standard coursework to research-focused work. **#alittle scary**

Major themes:

- ▶ [The Complexity Manifesto](#);
- ▶ Complex Systems \equiv Modern, Normal Science;
- ▶ Roles and limits of Data, Theory, and Experiment;
- ▶ Emergence;
- ▶ Universality and Accidents of History;
- ▶ Structure and Stories: Micro-to-macro Mechanisms;
- ▶ Elements: Scaling, Surprise, Networks, Robustness, Failure, and Spreading.
- ▶ The Theory of Anything: Why Complexify?
- ▶ **It's all about stories.**

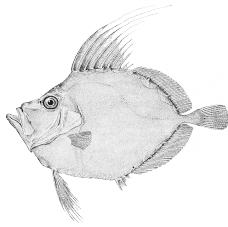
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Cryptolect: Course mascot:



- ▶ What's the Story?
- ▶ What's the John Dory?
- ▶ What's the John Dory for Rhyming Slang?
- ▶ Hemiteleia: beers \Rightarrow Edward Lear \Rightarrow Edwards.
- ▶ Also: Taxis \Rightarrow Boris Spasskies \Rightarrow Borises

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Topics:

Scaling phenomena:

- ▶ Allometry
- ▶ Scaling of social phenomena: crime, creativity, and consumption.
- ▶ Power law size distributions and non-Gaussian statistics
- ▶ Zipf's law
- ▶ Key mechanisms for generating power law size distributions
- ▶ Scaling in biology (elephants and platypuses).
- ▶ Law and Order—Theoricide Unit.
- ▶ Dimensional Analysis and Renormalization.

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Topics:

Complex networks:

- ▶ Structure and Dynamics
- ▶ Statistical Mechanics
- ▶ Phase transitions
- ▶ Random Networks
- ▶ Scale-free Networks
- ▶ Small-world Networks
- ▶ Multilayer networks
- ▶ Much more in Complex Networks next semester

Multiscale complex systems:

- ▶ Hierarchies and Scaling
- ▶ Modularity

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Topics:

Integrity of complex systems:

- ▶ Generic failure mechanisms
- ▶ Network robustness
- ▶ Highly Optimized Tolerance (HOT): Robustness and fragility
- ▶ Predictability

Information and Language:

- ▶ Search in networked systems (e.g., the web, social systems)
- ▶ Search on scale-free networks
- ▶ Knowledge trees, metadata and tagging
- ▶ Evolution and structure of natural languages

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Topics:

Sociotechnical Systems:

- ▶ Biological and social spreading models
- ▶ Schelling's model of segregation^[12]
- ▶ Granovetter's model of imitation^[7]
- ▶ Collective behavior and Synchrony
- ▶ Global cooperation from bad actors
- ▶ Global conflicts from good actors
- ▶ Stories (Homo Narrativus)
- ▶ The Sociotechnocene

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Topics:

Large-scale social patterns:

- ▶ Movement of individuals
- ▶ Cities
- ▶ Happiness
- ▶ Twitter

Collective decision making:

- ▶ Wisdom and madness of crowds
- ▶ Systems of voting
- ▶ The role of randomness and chance
- ▶ Success inequality: superstardom

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Season's Narrative Arc (or Places We Will Go):

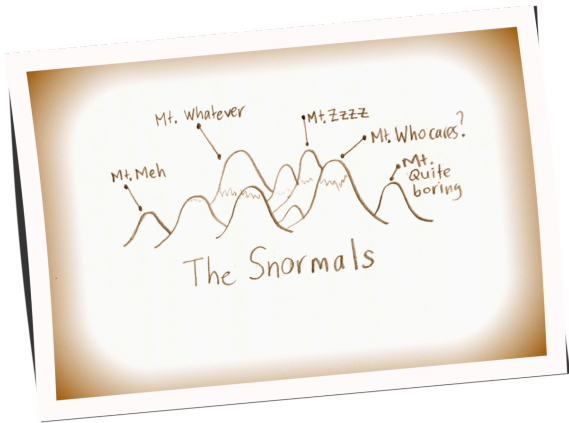
- ▶ Overview of Complex Systems with bonus Manifesto
- ▶ Thread of Understanding Sociotechnical Systems.
- ▶ Allometric scaling in complex systems.
- ▶ Size distributions of system elements:
 - ▶ Power-law size distributions.
 - ▶ Description and Mechanisms of Becoming.
- ▶ Robustness of Complex Systems.
- ▶ Complex networks—how system elements are connected:
 - ▶ Structure, Growth Mechanisms, Processes on Networks.
 - ▶ Social Contagion, Voting, Fame and Fate, Stories.
- ▶ Complexification: The Theory of Anything.

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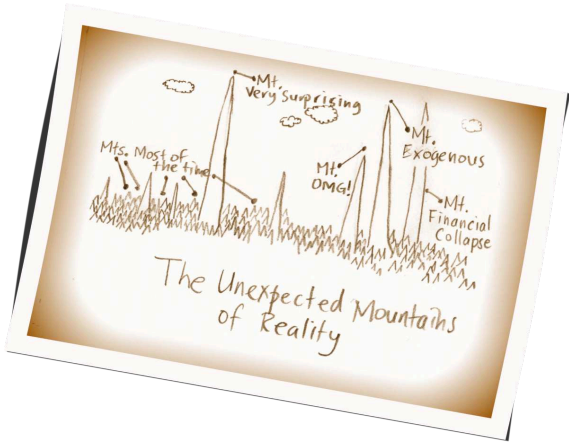


Schedule in detail:

Week # (dates)	Tuesday	Thursday
1 (9/01 and 9/03)	Overview; Fundamentals: The Complexity Manifesto	Scaling
2 (9/08 and 9/10)	Power-law size distributions	Zipf's law; Fundamentals: Data, Emergence, Limits to Understanding
3 (9/15 and 9/17)	Projects; Power-law mechanisms: Randomness	Power-law mechanisms: Variable Transformation
4 (9/22 and 9/24)	Power-law mechanisms: The Rich-Get-Richer	Power-law mechanisms: Optimization
5 (9/29 and 10/01)	Robustness and Fragility	Fundamentals: Statistical Mechanics Language evolution
6 (10/06 and 10/08)	Robustness vs. SOC	Complex networks: Introduction Basics and Examples networks Small-world networks
7 (10/13 and 10/15)	Complex networks: Key Properties Generalized random	Complex networks: Small-world networks Project presentations†
8 (10/20 and 10/22)	Complex networks: Scale-free networks	Project presentations†
9 (10/27 and 10/29)	Project presentations†	Complex networks: Scale-free networks Contagion: Introduction
10 (11/03 and 11/05)	Complex networks: Scale-free networks	Contagion: Introduction
11 (11/10 and 11/12)	Biological Contagion	Social Contagion
12 (11/17 and 11/19)	Interesting Scaling	Interesting Scaling
13 (11/24 and 11/26)	Thanksgiving	Thanksgiving
14 (12/01 and 12/03)	Voting and Success	The Sociotechnocene
15 (12/08)	The Big Story	—

†: 3-4 minutes each + 1 or 2 questions;

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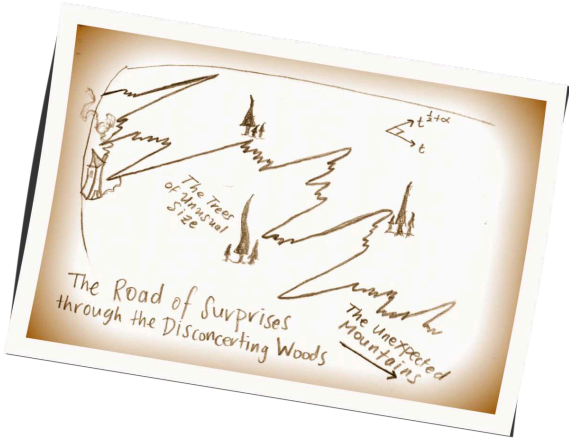


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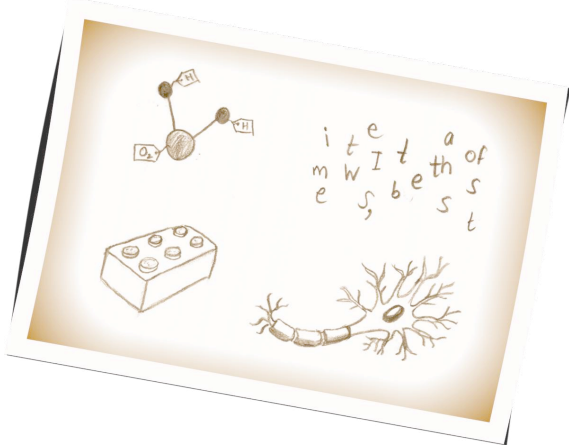


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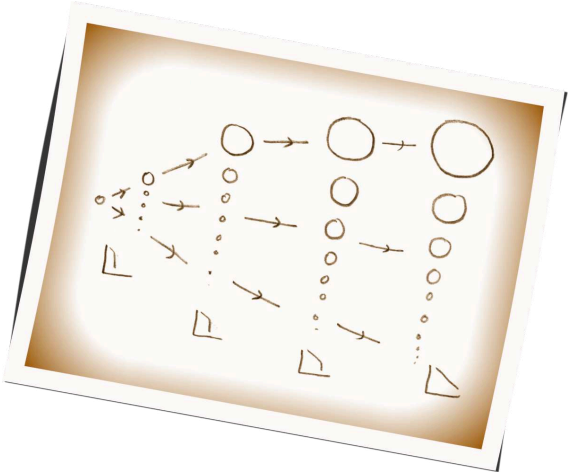


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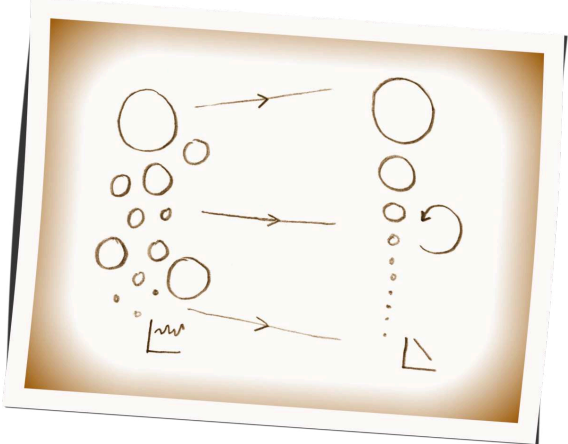


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Projects

- ▶ Semester-long projects, individual or in pairs.
- ▶ Develop proposal in first few weeks.
- ▶ May range from novel research to investigation of an established area of complex systems.
- ▶ Two talks + written piece.
- ▶ Usage of [the VACC](#) is encouraged (ability to code well = super powers).
- ▶ Massive data sets available, including Twitter.
- ▶ Academic output (journal papers) resulting from Principles of Complex Systems and Complex Networks can be found [here](#). Add more!
- ▶ We'll go through a list of possible projects soon.

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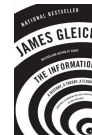
Popular Science Books:



"Simply Complexity: A Clear Guide to Complexity Theory" by Neil F. Johnson (2009).^[8]



"Complexity: A Guided Tour" by Melanie Mitchell (2009).^[11]



"The Information: A History, A Theory, A Flood" by James Gleick (2011).^[5]

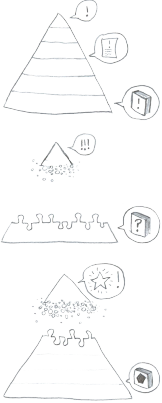
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The narrative hierarchy—Stories and Storytelling on all Scales:



- ▶ 1 to 3 word encapsulation = a soundbite = a buzzframe,
- ▶ 1 sentence, title,
- ▶ few sentences, a haiku,
- ▶ a paragraph, abstract,
- ▶ short paper, essay,
- ▶ long paper,
- ▶ chapter,
- ▶ book,
- ▶ ...

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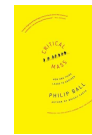
On complex sociotechnical systems:



"Human Behaviour and the Principle of Least-Effort" by G. K. Zipf (1949).^[16]



"Micromotives and Macrobehavior" by Thomas C. Schelling (1978).^[13]



"Critical Mass: How One Thing Leads to Another" by Philip Ball (2004).^[2]

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Popular Science Books:

Historical artifact:



"Complexity: The Emerging Science at the Edge of Order and Chaos" by M. Mitchell Waldrop (1993).^[15]

Shout-out: Dr. Andrew P. Morokoff, MBBS PhD FRACS D.Thau (Bug)



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It's all about algorithms (stories):



"The Engine of Complexity: Evolution as Computation" by John E. Mayfield (2013).^[9]



"On the Origin of Stories: Evolution, Cognition, and Fiction" by Brian Boyd (2010).^[4]



"The Storytelling Animal: How Stories Make Us Human" by Jonathan Gottschall (2013).^[6]

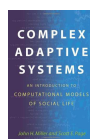
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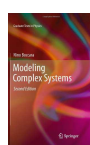
A few textbooky books:



"Complex Adaptive Systems: An introduction to computational models of social life" [↗](#)
by John H. Miller and Scott E. Page and John H. Miller and Scott E. Page (2007). ^[10]



"Critical Phenomena in Natural Sciences" [↗](#)
by Didier Sornette (2003). ^[14]



"Modeling Complex Systems" [↗](#)
by Nino Boccara (2004). ^[3]

Eventually: "Principles of Complex Systems"

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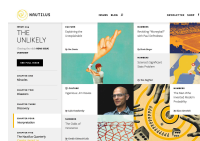
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Other inputs:

► Complexity Digest:
<http://www.comdig.org> [↗](#)
<https://twitter.com/cxdig> [↗](#)



► Nautilus Magazine:
<http://nautil.us/> [↗](#)

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Relevant online courses:

- Melanie Mitchell (Santa Fe Institute): [Introduction to Complexity](#) [↗](#)
- Lada Adamic (Facebook): [Social Network Analysis](#) [↗](#)
- Principles of Complex Systems and Complex Networks [↗](#)

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References I

- [1] P. W. Anderson.
More is different.
[Science](#), 177(4047):393–396, 1972. [pdf](#) [↗](#)
- [2] P. Ball.
[Critical Mass: How One Thing Leads to Another](#).
Farra, Straus, and Giroux, New York, 2004.
- [3] N. Boccara.
[Modeling Complex Systems](#).
Springer-Verlag, New York, 2nd edition, 2004.
- [4] B. Boyd.
[On the Origin of Stories: Evolution, Cognition, and Fiction](#).
Belknap Press, 2010.

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Centers:

- Santa Fe Institute (SFI)
- New England Complex Systems Institute (NECSI)
- Michigan's Center for the Study of Complex Systems ([CSCS](#)) [↗](#)
- Northwestern Institute on Complex Systems ([NICO](#)) [↗](#)
- Also: Indiana, Davis, Brandeis, University of Illinois, Duke, Warsaw, Melbourne, ...,
- [Vermont Complex Systems Center](#) [↗](#)



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