

# Overview of Complex Systems

## Principles of Complex Systems | @pocsvox

### CSYS/MATH 300, Fall, 2016 | #FallPoCS2016

Prof. Peter Dodds | @peterdodds

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



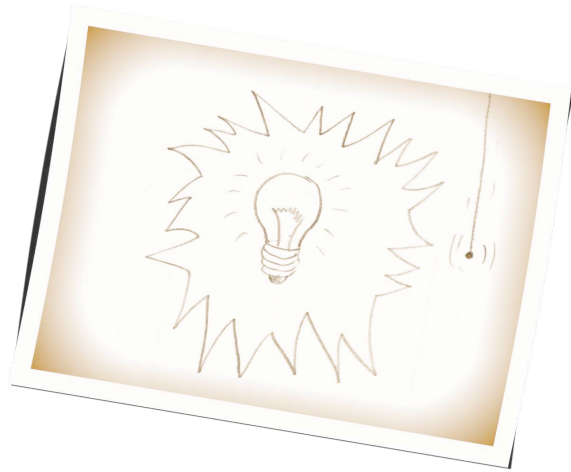
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- Course Information
- Topics
- Narrative Arc
- Course Map
- Projects
- Centers, Books, Resources
- References



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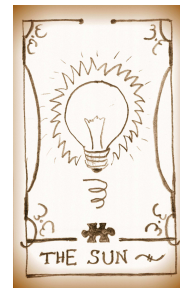


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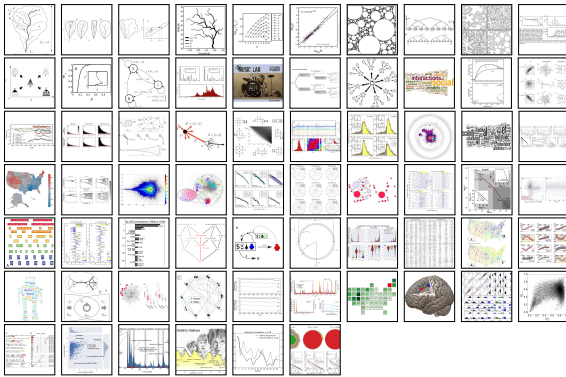
Funding: NSF, NASA, MITRE.

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## Potential paper products:

The Syllabus and a Poster

## Office hours:

10:00 am to 11:55 am on Wednesdays,  
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).

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## New [movie voice]:

MS in Complex Systems and Data Science (Fall 2015)

PhD in Complex Systems (Eventually ...)

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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.

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 X<sub>Y</sub>TeX, Beamer, perl, PerlTeX, fevered command-line madness, and an almost fanatical devotion to the indomitable emacs. #evilsuperpowers

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## Basics:

- Instructor: Prof. Peter Dodds
- Lecture room and meeting times: 102 Perkins, Tuesday and Thursday, 11:40 am to 12:55 pm
- Office: Farrell Hall, second floor, Trinity Campus
- email: peter.dodds@uvm.edu
- Course Website: <http://www.uvm.edu/pdodds/teaching/courses/2016-08UVM-300>
- Course Twitter handle: @pocsvox
- Course hashtag: #FallPoCS2016

## 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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## Team PoCS

We'll continue to try 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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## Yet more super exciting details:

- ☞ This is Season 10 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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## 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  $10 \pm 1$  of them.
- ☞ **General attendance/Class participation (4%)**

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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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## Important things:

1. Classes run from Tuesday, August 30 to Tuesday, December 6.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 12.
3. Last day to withdraw—Monday, October 31 (Sadness!).
4. Reading and Exam period—Saturday, December 10 to Friday, December 16.

**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.

## The nature of PoCS:

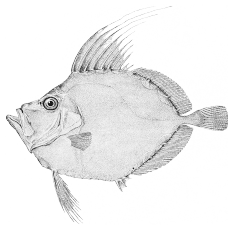
- Transitional from standard coursework to research-focused work. [#alittlescary](#)

## 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.**

## 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's  $\Rightarrow$  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 <sup>[12]</sup>
- 🔗 Granovetter's model of imitation <sup>[7]</sup>
- 🔗 Collective behavior and Synchrony
- 🔗 Global cooperation from bad actors
- 🔗 Global conflicts from good actors
- 🔗 Stories (Homo Narrativus)
- 🔗 The Sociotechnocene

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## Schedule in detail:

Week # (dates)	Tuesday	Thursday
1 (8/30 and 9/01)	Overview; Fundamentals: The Complexity Manifesto	Scaling
2 (9/06 and 9/08)	Power-law size distributions	Zipf's law; Fundamentals: Data, Emergence, Limits to Understanding
3 (9/13 and 9/15)	Projects; Power-law mechanisms: Randomness	Power-law mechanisms: Variable Transformation
4 (9/20 and 9/22)	Power-law mechanisms: The Rich-Get-Richer	Power-law mechanisms: Optimization
5 (9/27 and 9/29)	Robustness and Fragility	Fundamentals: Statistical Mechanics Language evolution
6 (10/04 and 10/06)	Robustness vs. SOC	Complex networks: Introduction Basics and Examples networks Small-world networks
7 (10/11 and 10/13)	Complex networks: Key Properties Generalized random	Complex networks: Small-world networks
8 (10/18 and 10/20)	Complex networks: Scale-free networks	Project presentations†
9 (10/25 and 10/27)	Project presentations†	Complex networks: Scale-free networks
10 (11/01 and 11/03)	Complex networks: Scale-free networks	Contagion: Introduction
11 (11/08 and 11/10)	Contagion	Biological Contagion
12 (11/15 and 11/17)	Social Contagion	Social Contagion
13 (11/22 and 11/24)	Thanksgiving	Thanksgiving
14 (11/29 and 12/01)	Voting and Success	The Sociotechnocene
15 (12/06)	The Big Story	—

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

## 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.

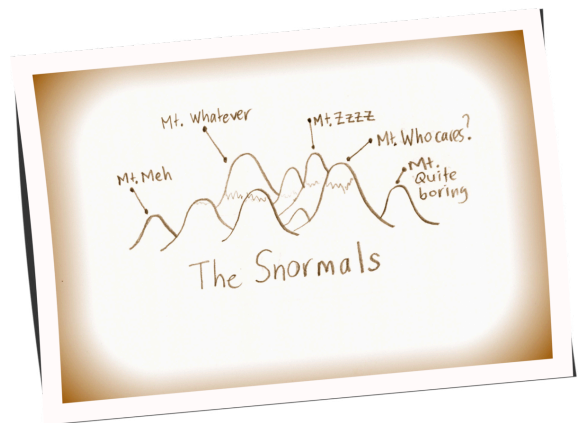
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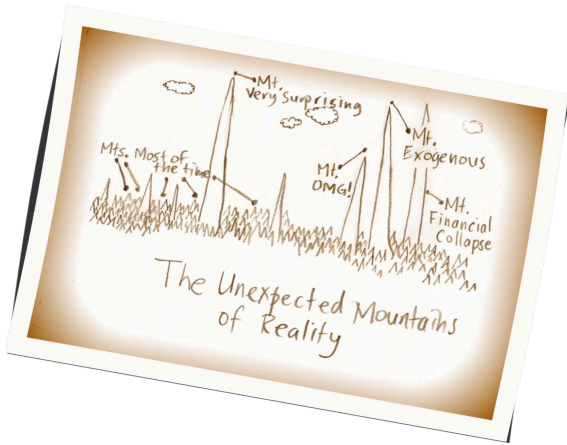
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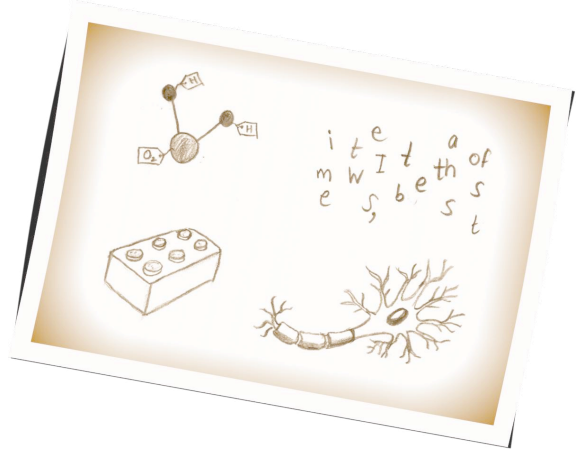
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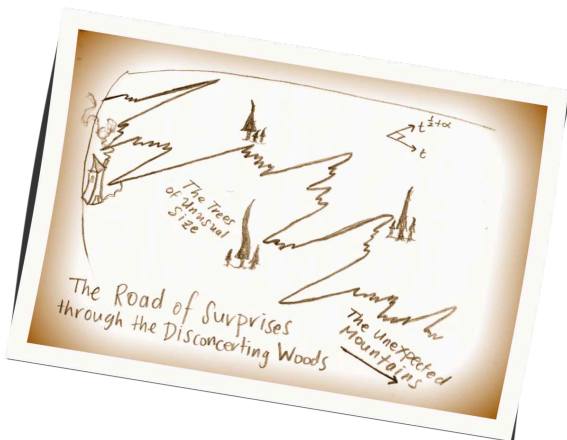
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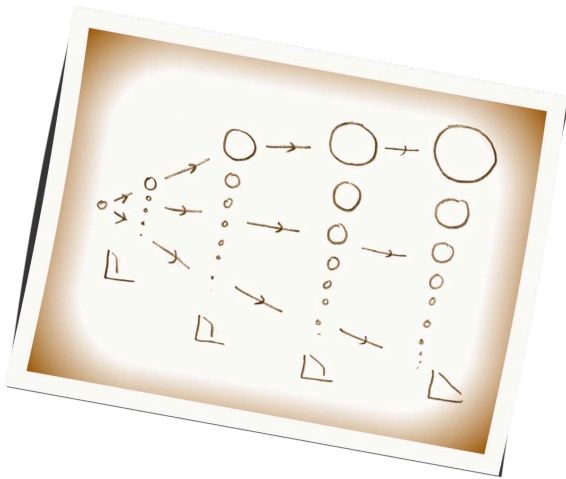
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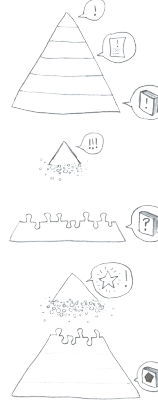
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## The narrative hierarchy—Stories and Storytelling on all Scales:



- 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,
- ...

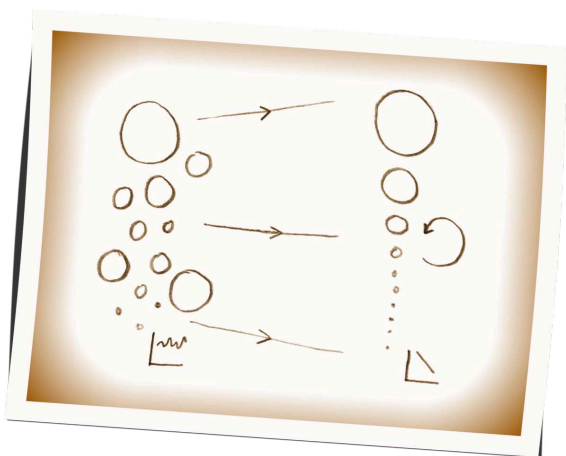
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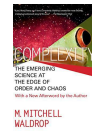
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## Popular Science Books:

### Historical artifact:



"Complexity: The Emerging Science at the Edge of Order and Chaos" [a](#) [g](#)  
by M. Mitchell Waldrop (1993).<sup>[15]</sup>

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



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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 [g](#) 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](#) [g](#). Add more!
- We'll go through a list of possible projects soon.

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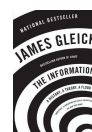
## Popular Science Books:



"Simply Complexity: A Clear Guide to Complexity Theory" [a](#) [g](#)  
by Neil F. Johnson (2009).<sup>[8]</sup>



"Complexity: A Guided Tour" [a](#) [g](#)  
by Melanie Mitchell (2009).<sup>[11]</sup>



"The Information: A History, A Theory, A Flood" [a](#) [g](#)  
by James Gleick (2011).<sup>[5]</sup>

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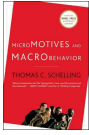


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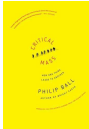
## On complex sociotechnical systems:



“Human Behaviour and the Principle of Least-Effort” [a](#) [🔗](#)  
by G. K. Zipf (1949).<sup>[16]</sup>



“Micromotives and Macrobehavior” [a](#) [🔗](#)  
by Thomas C. Schelling (1978).<sup>[13]</sup>



“Critical Mass: How One Thing Leads to Another” [a](#) [🔗](#)  
by Philip Ball (2004).<sup>[2]</sup>

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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](#) [🔗](#)

## It's all about algorithms (stories):



“The Engine of Complexity: Evolution as Computation” [a](#) [🔗](#)  
by John E. Mayfield (2013).<sup>[9]</sup>



“On the Origin of Stories: Evolution, Cognition, and Fiction” [a](#) [🔗](#)  
by Brian Boyd (2010).<sup>[4]</sup>



“The Storytelling Animal: How Stories Make Us Human” [a](#) [🔗](#)  
by Jonathan Gottschall (2013).<sup>[6]</sup>

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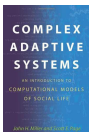
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## Centers:

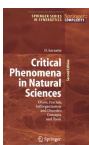
- [🔗 Santa Fe Institute \(SFI\)](#)
- [🔗 New England Complex Systems Institute \(NECSI\)](#)
- [🔗 Michigan's Center for the Study of Complex Systems \(CSCS\)](#) [🔗](#)
- [🔗 Northwestern Institute on Complex Systems \(NICO\)](#) [🔗](#)
- [🔗 Also: Indiana, Davis, Brandeis, University of Illinois, Duke,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



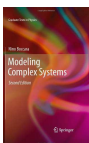
## A few textbook books:



“Complex Adaptive Systems: An Introduction to Computational Models of Social Life” [a](#) [🔗](#)  
by John H. Miller and Scott E. Page and John H. Miller and Scott E. Page (2007).<sup>[10]</sup>



“Critical Phenomena in Natural Sciences” [a](#) [🔗](#)  
by Didier Sornette (2003).<sup>[14]</sup>



“Modeling Complex Systems” [a](#) [🔗](#)  
by Nino Boccara (2004).<sup>[3]</sup>

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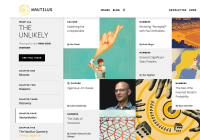
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## Other inputs:

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



- [🔗 Nautilus Magazine:](#)  
<http://nautil.us/> [🔗](#)

Eventually: “Principles of Complex Systems”



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