

Overview of Complex Systems

Principles of Complex Systems | @pocsvox

CSYS/MATH 300, Fall, 2017

Prof. Peter Dodds | @peterdodds

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

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What's the John
Dory?

Sealie & Lambie
Productions



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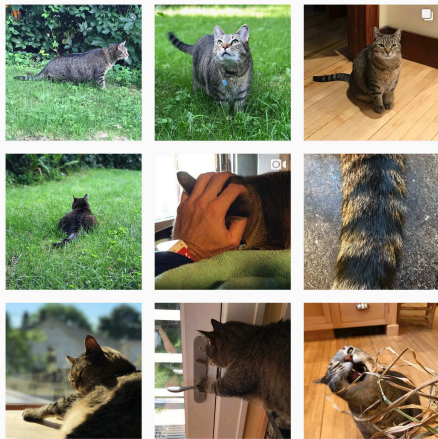


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What's the John
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Special Guest Executive Producer: Pratchett



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 On Instagram at [pratchett_the_cat](https://www.instagram.com/pratchett_the_cat) 



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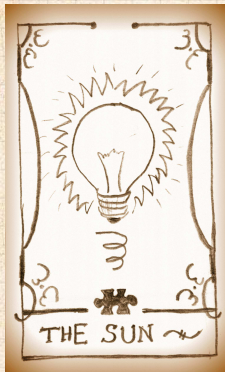
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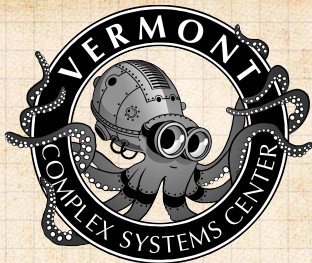


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Describe | Explain | Create | Share | Ethos: Play



vermontcomplexsystems.org



Vermont Complex Systems Center (2006-):

-  Diverse research and teaching portfolio (> 400 papers in 2010-2015).
-  Funding from many sources: NSF, NIH, DARPA, MITRE, Microsoft, foundations. In 2010-2015, \$70M tagged as Complex Systems.
-  Regular global press coverage: NYT, BBC, NatGeo, ...
-  Conferences: "Big Data, Big Stories", "Big Scale, Big Fail", "Prediction: the Next Big Thing" and Flash Mob Research events.
-  Well developed Educational platform in Complex Systems and Data Science.
-  Faculty hires of true Complex Systems scholars (+4 now).
-  Numerous NSF CAREER awards (including PECASE).
-  Connecting Graduate and Undergraduate Students across campus (SCRAPS) leading to real research output.

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Vermont Complex Systems Center—Misfit toys:

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What's the John Dory?



Peter Dodds,
Math/Stats



Josh Bongard,
CS



Chris
Danforth,
Math/Stats



Maggie
Eppstein, CS



Hugh
Garavan, Neu-
ro/Psychiatry



Yves Dubief,
ME



Jim Bagrow,
Math/Stats



Mads
Almassalkhi,
EE



Paul Hines, EE



Brian Tivnan,
MITRE



Laurent
Hébert-
Dufresne,
CS



Puck
Rombach,
Math/Stats

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We're interested in many things:

Sociotechnical
systems
Social
Contagion and
Influence
Happiness and
Well-being
Language and
Stories
Social unrest
Conflict
Robotics
Artificial
Intelligence

Data Science
Complex
Networks
Climate
Biology
Ecology
Geomorphology
Space
Complex Fluids
(Smart) Power
Grids
Critical
infrastructure

Defense
Policy
Health systems
Food systems
Epidemiology
Pandemics
Organizations
Economics
Wealth
inequality
Financial
Systems

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UVM Complex Systems

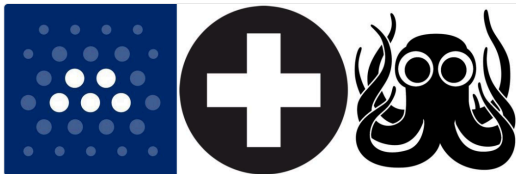
@uvmcomplexity

Following



Very happy to announce our awesome new partnership with Mass Mutual to support Complex Systems/Data Science:

uvm.edu/rss/news/?Page...



12:16 PM - 7 Aug 2017

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Educational mission:

 Data Science Undergrad.

 Graduate Certificate in Complex Systems.

 Latest: MS in **Complex Systems and Data Science.**

 Next: PhD in **The Study of Interesting Things.**



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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).

 To be required: Prof. Jim Bagrow's "Data Science I" (STAT 287)

 The Sequel to PoCS: "Complex Networks" (CSYS/MATH 303).

Leveling up:

 MS in Complex Systems and Data Science (Fall 2015) 

 Next: PhD in Complex Systems and Data Science in the Fall of 2018

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What's the John Dory?



Peter Dodds



Tyler Gray



Aaron Schwartz



Eric Clark



Ben Emery



John Ring



David Dewhurst



Colin Van Dort



Chris Danforth

Andy Reagan
Data Scientist
MassMutualAbby Ross
Northfield Mount
Hermon SchoolChris Fusting
Data Science
ConsultantRyan Callagher
Northwestern
PhD student

compstorylab.org

Nick Allgaier
Psychiatry
Portland, UVMDylan Kivry
Chobanian GroupTom McAndrew
Cardiovascular
Research FoundationEmilia Cody
Data Scientist
AcobeMorgan Frank
MIT Media Lab
PhD StudentCathy Bliss
UVM LecturerMark Ibrahim
Data Scientist
InsightRoss Lieb-Lapgen
Dartmouth PhD
Cold Regions Research
& Engineering Laboratory

Litan Pechenick

Lewis Mitchell
Adeleide FacultyJake Williams
Drexel FacultyIsabel Kloumann
Cornell PhD
Facebook
Data ScientistFletcher
HazlehurstSharon Alajajian
Research Scientist
University of PennsylvaniaKameron Harris
Washington
PhD StudentPaul Lessard
Colorado
PhD StudentSuma Desu
Apple
Data ScientistMike Foley
Northeastern
PhD studentDarcy Glenn
Climate Science
UC London, MS student

+ Brian Tivnan's MITRE team;
Funding: NSF, NASA, MITRE, DARPA; [YOUR WONDERFUL
FUNDING AGENCY HERE]

Adjacent: Strava Story Lab team

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Courses:

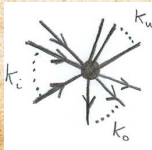
-  CSYS/MATH 300: Principles of Complex Systems (@pocsvox )
-  CSYS/MATH 303: Complex Networks (@networksvox )
-  MATH 124/122: Matrixology (Linear Algebra) (@matrixologyvox and @svdthematrices )
-  MATH 237: Numerical Analysis (@MachEps237 )
-  MATH 266: Chaos, fractals & dynamical systems (@NonperiodicFlow )
-  MATH 330: Ordinary Differential Equations (@dallthethingsdt )

 Courses act as research incubators and have helped generate many papers  (35+)

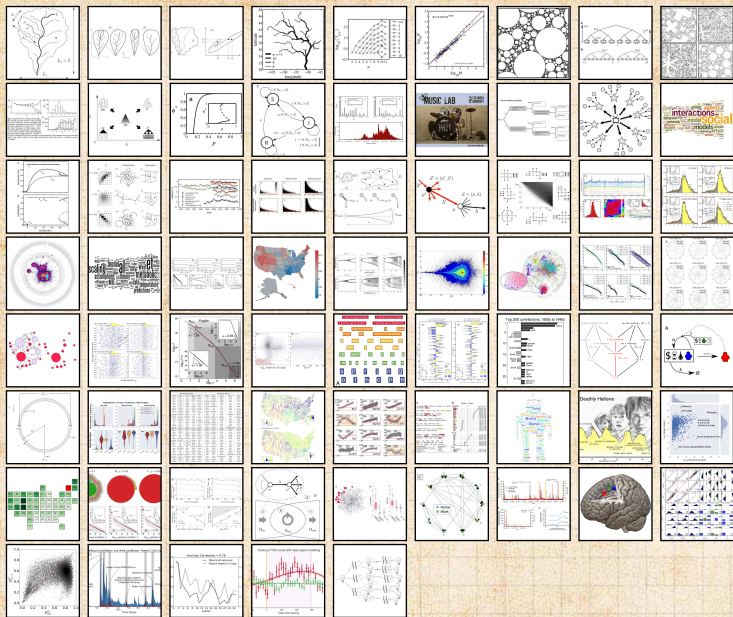
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Basics:



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+pocs@uvm.edu



Course Website:

<http://www.uvm.edu/pdodds/teaching/courses/2017-08UVM-300> 



Course Twitter handle: @pocsvox



Course hashtag: #FallPoCS2017

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Potential paper products:

 The Syllabus  and a Poster .

Office hours:

 1:15 pm to 2:30 pm on Tuesday, 1:15 pm to 4:45 pm Thursday.
Farrell Hall, second floor, Trinity Campus

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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).

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⚙ 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 Xe_LTeX , Beamer , perl , PerTeX , fevered command-line madness , and an almost fanatical devotion to the indomitable emacs . #evilsuperpowers



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[#evilstupidpowers](#)

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



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More super exciting details:

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 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.







Yet more super exciting details:

PoCS | @pocsvox

What's the John
Dory?

 This is Season 11 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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What's the John Dory?

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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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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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 29 to Friday, December 8.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 11.
3. Last day to withdraw—Monday, October 30 (Sadness!).
4. Reading and Exam period—Saturday, December 9 to Friday, December 15.

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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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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
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-  **It's all about stories.**

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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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 *It's all about games.*

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- The Theory of Anything: Why Complexify?
- It's all about stories.**

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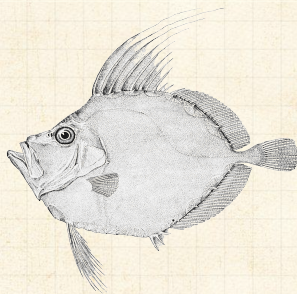
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Cryptolect:

Course mascot:



 What's the Story?

 What's the John Dory?

 What's the John Dory for Rhyming Slang?

 Hemiteleia: beers \Rightarrow Edward Lears \Rightarrow Edwards.

 Also: Taxis \Rightarrow Boris Spasskies \Rightarrow Borises

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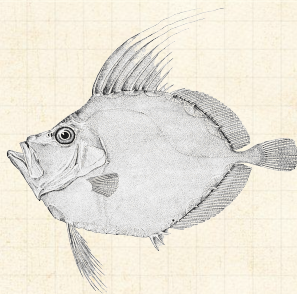
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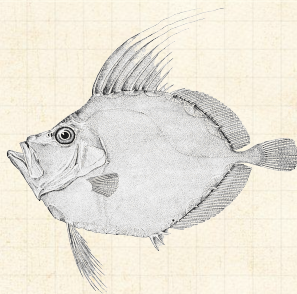
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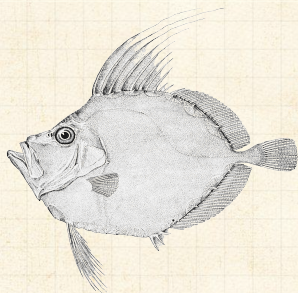
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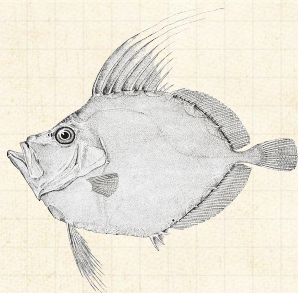
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



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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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Sociotechnical Systems:

-  Biological and social spreading models
-  Schelling's model of segregation ^[13]
-  Granovetter's model of imitation ^[8]
-  Collective behavior and Synchrony
-  Global cooperation from bad actors
-  Global conflicts from good actors
-  Stories (Homo Narrativus)
-  The Sociotechnocene

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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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The Secret of Success will be revealed:

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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 measurement of scaling



Robustness of Complex Systems.



Complex networks—how system elements are connected:



Stochastic Growth Mechanisms: Processes on Networks



Social Contagion, voting, Fame and Folk Stories



Complexification: The Theory of Anything and the Rise of Algorithms

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-  Complex networks—how system elements are connected:
 -  Statistical Growth Mechanisms: Processes on Networks
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-  Complexification: The Theory of Anything and the Rise of Algorithms

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Schedule in detail:

Week # (dates)	Tuesday	Thursday
1 (8/29 and 8/31)	Overview; Fundamentals: The Complexity Manifesto	Scaling
2 (9/05 and 9/07)	Power-law size distributions	Zipf's law; Fundamentals: Data, Emergence, Limits to Understanding
3 (9/12 and 9/14)	Projects; Power-law mechanisms: Randomness	Power-law mechanisms: Variable Transformation
4 (9/19 and 9/21)	Power-law mechanisms: The Rich-Get-Richer	Power-law mechanisms: Optimization
5 (9/26 and 9/28)	Robustness and Fragility	Fundamentals: Statistical Mechanics Language evolution
6 (10/03 and 10/05)	Robustness vs. SOC	Complex networks: Introduction Basics and Examples networks Small-world networks
7 (10/10 and 10/12)	Complex networks: Key Properties Generalized random	Complex networks: Small-world networks
8 (10/17 and 10/19)	Complex networks: Scale-free networks	Project presentations [†]
9 (10/24 and 10/26)	Project presentations [†]	Complex networks: Scale-free networks
10 (10/31 and 11/02)	Complex networks: Scale-free networks	Contagion: Introduction
11 (11/07 and 11/09)	Contagion	Biological Contagion
12 (11/14 and 11/16)	Social Contagion	Social Contagion
13 (11/21 and 11/23)	Thanksgiving	Thanksgiving
14 (11/28 and 11/30)	Voting and Success	(Away: Quarterology)
15 (12/05 and 12/07)	Stories	The Big Story

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

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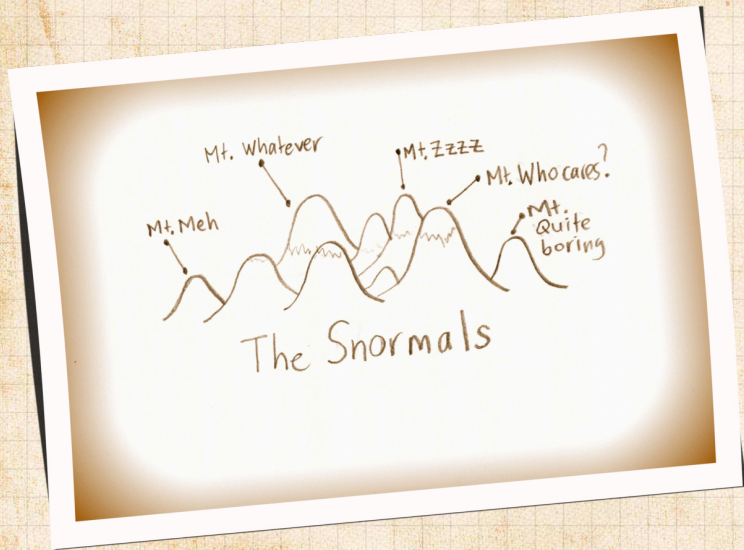
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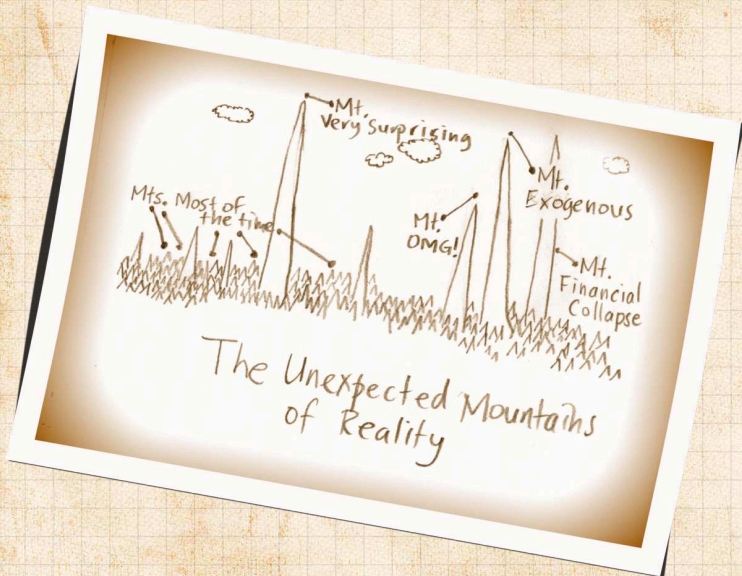
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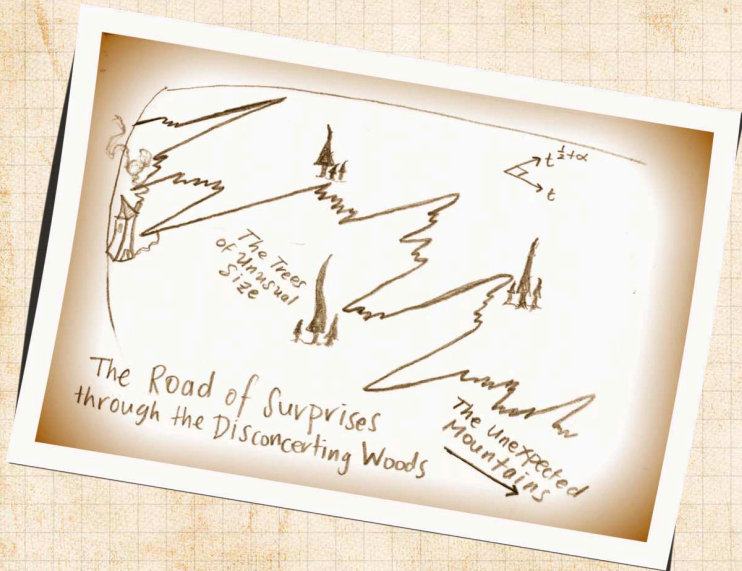
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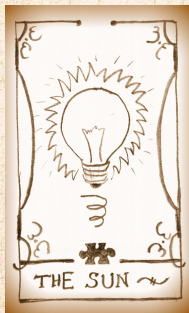
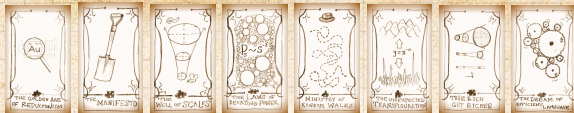
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- 📦 Develop proposal in first few weeks.
- 📦 May range from novel research to investigation of an established area of complex systems.
- 📦 Two talks + written piece.
- 📦 Usage of [the VACC](#) is encouraged (ability to code well = super powers).
- 📦 Massive data sets available, including Twitter.
- 📦 Possible: Work with Twitter data and Story Lab on socially meaningful problems.
- 📦 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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- 🧩 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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Projects

- 🧩 Semester-long projects, teams.
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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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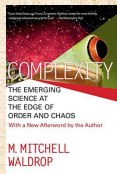


Popular Science Books:

PoCS | @pocsvox

What's the John Dory?

Historical artifact:



“Complexity: The Emerging Science at the Edge of Order and Chaos” [a](#) [↗](#)
by M. Mitchell Waldrop (1993). ^[16]

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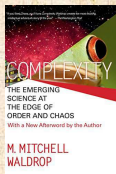


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Shout-out: Dr. Andrew P. Morokoff [🔗](#),
MBBS PhD FRACS D.Thau (Bug) [🔗](#)



Popular Science Books:

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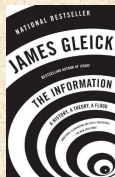
What's the John Dory?



"Simply Complexity: A Clear Guide to Complexity Theory" [a](#) [📖](#)
by Neil F. Johnson (2009). ^[9]



"Complexity: A Guided Tour" [a](#) [📖](#)
by Melanie Mitchell (2009). ^[12]



"The Information: A History, A Theory, A Flood" [a](#) [📖](#)
by James Gleick (2011). ^[6]

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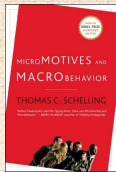
On complex sociotechnical systems:

PoCS | @pocsvox

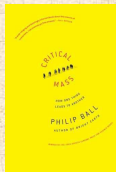
What's the John Dory?



“Human Behaviour and the Principle of Least-Effort” [a](#) [↗](#)
by G. K. Zipf (1949). ^[17]



“Micromotives and Macrobehavior” [a](#) [↗](#)
by Thomas C. Schelling (1978). ^[14]



“Critical Mass: How One Thing Leads to Another” [a](#) [↗](#)
by Philip Ball (2004). ^[2]

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It's all about algorithms (stories):

PoCS | @pocsvox

What's the John Dory?



"The Engine of Complexity: Evolution as Computation" [a](#) [↗](#)

by John E. Mayfield (2013). [10]



"On the Origin of Stories: Evolution, Cognition, and Fiction" [a](#) [↗](#)

by Brian Boyd (2010). [5]



"The Storytelling Animal: How Stories Make Us Human" [a](#) [↗](#)

by Jonathan Gottschall (2013). [7]

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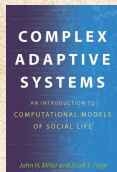
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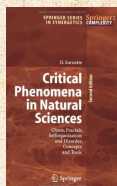


A few textbooky books:



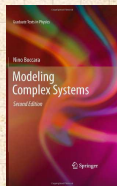
“Complex Adaptive Systems: An introduction to computational models of social life” [a](#) [↗](#)

by John H. Miller and Scott E. Page and John H. Miller and Scott E. Page (2007). ^[11]



“Critical Phenomena in Natural Sciences” [a](#) [↗](#)

by Didier Sornette (2003). ^[15]



“Modeling Complex Systems” [a](#) [↗](#)

by Nino Boccara (2004). ^[4]

Eventually: “Principles of Complex Systems”

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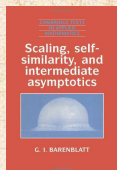
References



Books on scaling:

PoCS | @pocsvox

What's the John Dory?



“Scaling, self-similarity, and intermediate asymptotics” [a](#) [↗](#)

by G. I. Barenblatt (1996). ^[3]

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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**



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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Other inputs:

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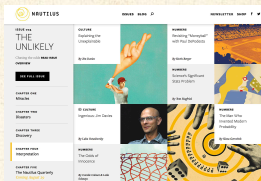
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Complexity Digest:

<http://www.comdig.org>

<https://twitter.com/@cxdig>



Nautilus Magazine:


<http://nautil.us/>



[Aeon: http://aeon.co/](http://aeon.co/)



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- [2] P. Ball.
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- [6] J. Gleick.
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Pantheon, 2011.
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The Storytelling Animal: How Stories Make Us Human.
Mariner Books, 2013.
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Oneworld Publications, London, UK, 2009. pdf 
- [10] J. E. Mayfield.
The Engine of Complexity: Evolution as Computation.
Columbia University Press, New York, 2013.
- [11] J. H. Miller and S. E. Page.
Complex Adaptive Systems: An introduction to computational models of social life.
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[14] T. C. Schelling.
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Simon & Schuster, New York, NY, 1993.

[17] G. K. Zipf.
Human Behaviour and the Principle of
Least-Effort.
Addison-Wesley, Cambridge, MA, 1949.

