

# Course Overview for PoCS

Last updated: 2022/08/29, 21:21:11 EDT

Principles of Complex Systems, Vols. 1, 2, & 3D  
 CSYS/MATH 300, 303, & 394, 2022-2023 | @pocsvox

Prof. Peter Sheridan Dodds | @peterdodds

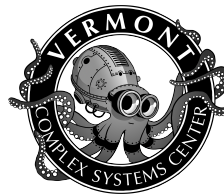
Computational Story Lab | Vermont Complex Systems Center  
 Santa Fe Institute | University of Vermont



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Describe | Explain | Create | Share | Ethos: Play



[vermontcomplexsystems.org](http://vermontcomplexsystems.org)

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## Vermont Complex Systems Center (2006-):

- Diverse research and teaching portfolio (> 400 papers in 2010-2015).
- Funding from many sources: NSF, NIH, DARPA, Microsoft, MITRE, Computer Associates, MassMutual, Google, foundations.
- Regular global press coverage: NYT, BBC, WaPo, NatGeo, ...
- Conferences: "Big Data, Big Stories", "Big Scale, Big Fail", "Prediction: the Next Big Thing", [NetSci 2019](#), [ALife 2020](#).
- Fully developed educational platform in Complex Systems and Data Science.
- [Complex Networks Winter Workshops in Quebec City \("Canoe"\)](#)
- Faculty hires of true Complex Systems scholars.
- Numerous NSF CAREER awards (including PECASE).
- Connecting Graduate and Undergraduate Students across campus (SCRaPS).
- Paper Shredder, Research Jam, and ComplexITea.
- [Talkbotopus](#)

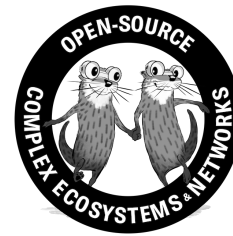
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## Major support:

- MassMutual Center for Excellence in Complex Systems and Data Science  
[vermontcomplexsystems.org/partner/MMCOE/](http://vermontcomplexsystems.org/partner/MMCOE/)
- University of Vermont-Google Open-Source Complex Ecosystems And Networks (OCEAN)  
[vermontcomplexsystems.org/partner/OCEAN/](http://vermontcomplexsystems.org/partner/OCEAN/)



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## We're interested in many things:

- Sociotechnical systems
- Complex Networks
- Public Policy
- Social Contagion and Influence
- Climate
- Health and Medicine
- Happiness and Well-being
- Biology
- Brainz Brains
- Language and Stories
- Ecology
- Neuroscience
- Social unrest
- Geomorphology
- Food systems
- Conflict
- Space
- Epidemiology
- Robotics
- Complex Fluids
- Pandemics
- Artificial Intelligence
- (Smart) Power Grids
- Organizations
- Defense
- Critical infrastructure
- Economics
- Wealth inequality
- Financial Systems

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## Leveling up—Scaffolded educational mission:

- Data Science Undergrad.
- Graduate Certificate in Complex Systems and Data Science
- Fall, 2015-: MS in Complex Systems and Data Science
- Fall, 2018-: PhD in The Study of Interesting Things Complex Systems and Data Science



All the words: <http://vermontcomplexsystems.org>

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## Graduate Certificate in Complex Systems (and Data Science):

- Principles of Complex Systems is one of three core requirements for UVM's five course [Certificate of Graduate Study in Complex Systems](#).
- Prof. Laurent Hebert-Dufresne's "Modelling Complex Systems" (CSYS/CS 302).
- Prof. Jim Bagrow's "Data Science I" (STAT 287)
- The Sequel to PoCS: "Complex Networks" (CSYS/MATH 303).
- But really it's the PoCSverse: Principles of Complex Systems Vols. 1 and 2

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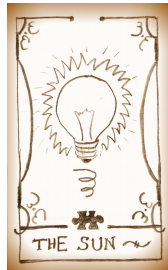
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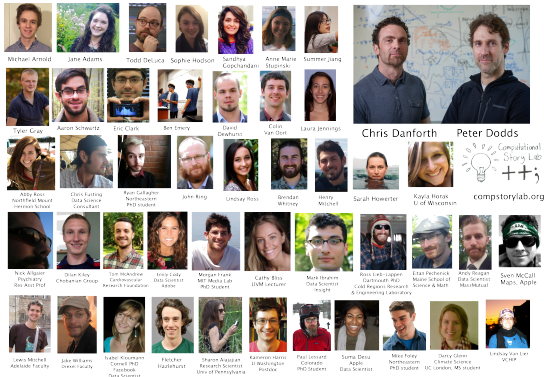
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# Framing (funfully):

Science = Area of study + Instruments of study

- Stars and Telescopes = Astronomy
- Rocks and Hammers = Geology
- Water and Partial Differential Equations = Fluid Dynamics
- Brains and Giant Imaging Machines = Neuroscience
- People and Deception = Social Psychology
- Mathematics and Mathematics = Pure mathematics
- Mind and Mind = Psychotherapy, Insight meditation, ...
- Complex Systems + Data Science = Postdisciplinary Systems Science



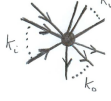
Funding: NSF, NIH, NIDA, NASA, MITRE, James S. McDonnell Foundation, ONR, DARPA, MassMutual, Google, Computer Associates; [YOUR WONDERFUL FUNDING AGENCY HERE]

## Outside

Inside the Lab that's Quantifying Happiness  
by Rowan Jacobsen, August 2017.  
(Reprinted in UVM Quarterly, 2018.)

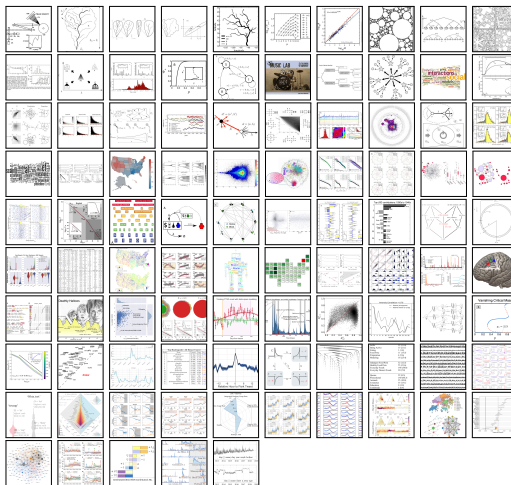


# Courses:



- 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



# Basics:

- Instructor: Prof. Peter Sheridan Dodds
- Lecture room and meeting times: Perkins 003, 10:05 am to 11:20 am
- Office: (in theory) The Ether and/or Innovation, fourth floor
- email: peter.dodds@uvm.edu
- Course Website: <https://pdodds.w3.uvm.edu/teaching/courses/2022-2023pocsvorse>
- Course Twitter handle: @pocsvox

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# Potential paper product:

- The Syllabus

# Office hours:

- TBD, The Ether and/or Innovation, fourth floor

# Exciting details regarding these slides:

- Three servings (all in pdf):
  - Fresh: For in-class Delivery.
  - On toast: Flattened for page-turning joy.
  - Freeze-dried: Pack-and-go, 3x3 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.<sup>[1]</sup>
- 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  $\text{X}_{\text{y}}\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ , Beamer, perl, PerlTeX, fevered command-line madness, and an almost fanatical devotion to the indomitable emacs. #totallynormal

# 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}
```
- Still working towards putting the course on Github/Gitlab
- And finishing writing the books ...

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## Yet more super exciting details:

- ☞ This is Season 18 of Principles of Complex Systems, Vols. 1, 2, & 3D.
- ☞ In-person lectures will be called Stories (a more elevated framing than “Streams of consciousness”)
- ☞ Slide-specific curated episodes are online, and are broken into clips.
- ☞ Goal for all in-person lectures: Record with ScreenFlow, curate, send to Youtube.
- ☞ Office hours will run over Teams and be recorded.
- ☞ Some new clips may be recorded in a pretend studio.
- ☞ All lectures are [bottle episodes](#).
- ☞ [Other tropes](#) will be involved.
- ☞ Last season's Episodes are [here](#).

Wonderful foundational support for PoCS Vol. 1, ~~CoNKs~~ ~~CoCoNuTs~~ PoCS Vol. 2, and PoCS Vol. 3D, 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 also [said nice things about PoCS](#)

## Team PoCS

### Microsoft Teams + Slack

- ☞ Teams = main place for discussions about all things PoCS including assignments and projects.
- ☞ Slack = main place for students and faculty in Complex Systems and Data Science to talk about everything.
- ☞ Teams—Automatic if enrolled in the course.
- ☞ Slack—Once invited, please sign up here: <https://csdsgrads.slack.com/>
- ☞ Very good: Install Microsoft and Slack apps on laptops, tablets, phone, cats, dogs. Nothing will go wrong.
- ☞ Everyone will behave wonderfully.



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## Grading breakdown:

- ☞ **Assignments (75%)**—All assignments will be of equal weight and there will be  $10 \pm 1$  of them.
- ☞ **Projects/talks (24%)**—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: 8% for the first talk, 8% for the final talk, and 8% for the written project.
- ☞ **General attendance/Class participation (1%)**—Everyone is expected to behave well.

## 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.

## Important things:

1. Classes run from Tuesday, August 31 to Thursday, December 9.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 13.
3. Last day to withdraw—Monday, November 1 (Sadness!).
4. Reading and Exam period—Saturday, December 11 to Friday, December 17.

**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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## Popular Science Books:

### Historical artifact:



“Complexity: The Emerging Science at the Edge of Order and Chaos” [a](#) [🔗](#)  
by M. Mitchell Waldrop (1993).<sup>[16]</sup>

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



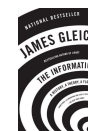
## Popular Science Books:



“Simply Complexity: A Clear Guide to Complexity Theory” [a](#) [🔗](#)  
by Neil F. Johnson (2009).<sup>[9]</sup>



“Complexity: A Guided Tour” [a](#) [🔗](#)  
by Melanie Mitchell (2009).<sup>[12]</sup>



“The Information: A History, A Theory, A Flood” [a](#) [🔗](#)  
by James Gleick (2011).<sup>[6]</sup>

## Books on Complexification:



“Scaling, self-similarity, and intermediate asymptotics” [a](#) [🔗](#)  
by G. I. Barenblatt (1996).<sup>[3]</sup>



“Creation of the Universe” [a](#) [🔗](#)  
by Zhi and Xian (1989).<sup>[17]</sup>

See [Freeman Dyson's The Key to Everything](#) [🔗](#).

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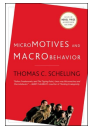
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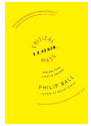
## On complex sociotechnical systems:



"Human Behaviour and the Principle of Least-Effort" [a](#) [🔗](#)  
by G. K. Zipf (1949). [18]



"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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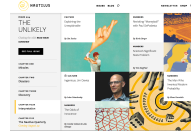
## Centers:

- 🔗 Santa Fe Institute (SFI)
- 🔗 Networks Institute at Northeastern
- 🔗 Northwestern Institute on Complex Systems (NICO) [🔗](#)
- 🔗 MIT Institute for Data, Systems, AND Society
- 🔗 New England Complex Systems Institute (NECSI)
- 🔗 Michigan's Center for the Study of Complex Systems (CSCS) [🔗](#)
- 🔗 Some Data Science groups (highly variable)
- 🔗 Also: Indiana, Davis, Brandeis, University of Illinois, Duke, Warsaw, Melbourne, ...
- 🔗 Us!!!: [Vermont Complex Systems Center](#) [🔗](#)



## Other inputs:

🔗 Complexity Digest:  
<http://www.comdig.org>  
<https://twitter.com/cxdig>



🔗 Nautilus Magazine:  
<http://nautil.us/>

- 🔗 Aeon: <http://aeon.co/>
- 🔗 Quanta Magazine:  
<https://www.quantamagazine.org/>

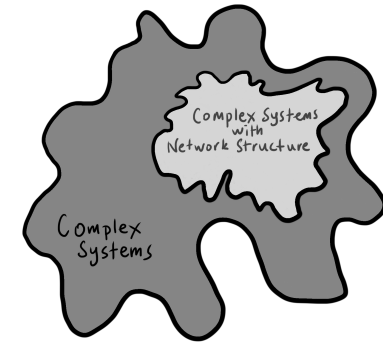
## The nature of PoCS:

- 🔗 Transitional from standard coursework to research-focused work. #allittlescary

## Major themes:

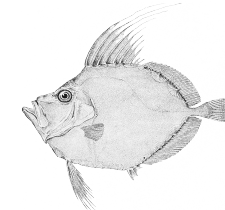
- 🔗 The Complexity Manifesto [🔗](#);
- 🔗 Complex Systems  $\equiv$  Modern, Normal Science;
- 🔗 Roles and limits of Data, Theory, and Experiment;
- 🔗 Emergence;
- 🔗 Universality and Accidents of History;
- 🔗 Structure and Stories: Micro-to-macro Mechanisms;
- 🔗 Elements: Scaling, Surprise, Networks,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

## Complex Systems are the Big Story:



- 🔗 Only a bit networky: Fluids-at-large (the atmosphere, oceans, ...), organism cells, ...

## 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

## Topics:

### Scaling phenomena:

- 🔗 Allometry.
- 🔗 Scaling of social phenomena: crime, creativity, and consumption.
- 🔗 Scaling in biology (elephants and platypuses).
- 🔗 Dimensional Analysis and Renormalization.
- 🔗 Power law size distributions and non-Gaussian statistics.
- 🔗 The 80/20 rule, the 1%.
- 🔗 Zipf's law.
- 🔗 Order from randomness.
- 🔗 Fundamental mechanisms for generating power law size distributions.
- 🔗 The rich-get-richer mechanism.

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



"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]

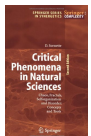


"The Storytelling Animal: How Stories Make Us Human" [a](#) [🔗](#)  
by Jonathan Gottschall (2013). [7]

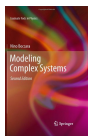
## A few textbook books (dated):



"Complex Adaptive Systems: An introduction to computational models of social life" [a](#) [🔗](#)  
by Miller and 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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## Topics:

### Robustness—Integrity of complex systems:

- Generic failure mechanisms.
- Highly Optimized Tolerance (HOT): Robustness and fragility.
- How to build optimal forests.
- Minimization of risk as a driver of heterogeneous structures in complex systems.
- How to optimally locate facilities: hospitals, schools, and coffee shops.

### Fundamentals of Complexity:

- Emergence: More is Different.
- Measurement and mismeasurement.
- Universality versus path dependence.
- Complexification (it all starts with gravity<sup>[17]</sup>).

## Topics:

### Complex networks:

- Statistical Mechanics
- Structure and Dynamics
- Phase transitions
- Random Networks
- Scale-free Networks
- Small-world Networks
- Why your friends are better than you.
- More in PoCS, Vol. 2 in the spring.

## Topics:

### Sociotechnical Systems:

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

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## Topics:

### Collective decision making:

- Wisdom and madness of crowds.
- Systems of voting.
- The role of randomness and chance.
- Success inequality.
- The paradox of unpredictable global fame.
- Bonus knowledge: How to make things spread.
- Bonus knowledge: Fate does not exist in a world of fame.

### Large-scale social patterns (maybe):

- Movement
- Cities
- Happiness
- Social media

### 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 and the Rise of Algorithms

## Projects

- Semester-long projects, teams.
- 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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## 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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