Course Overview for PoCS

Last updated: 2021/10/06, 20:25:28 EDT

Principles of Complex Systems, Vols. 1 & 2
CSYS/MATH 300 and 303, 2021–2022| @pocsvox
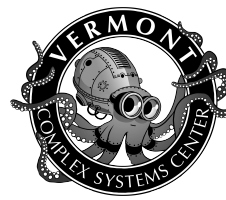
Prof. Peter Sheridan Dodds | @peterdodds

Computational Story Lab | Vermont Complex Systems Center
Vermont Advanced Computing Core | University of Vermont

Outline

Orientation
- Course Information
- Centers, Books, Resources
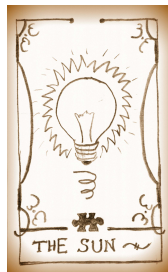- Topics
- Narrative Arc
- Tarot Cards
- Projects

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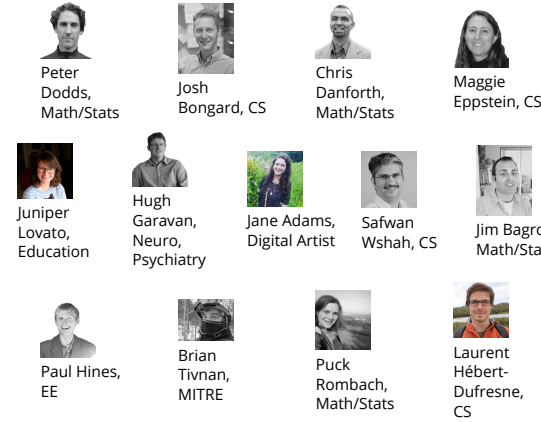Topics
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VERMONT COMPLEX SYSTEMS CENTER

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, 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.
- Talkboctopus

Major support:

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

MASSMUTUAL CENTER OF EXCELLENCE IN COMPLEX SYSTEMS AND DATA SCIENCE · UVM

OPEN-SOURCE COMPLEX ECOSYSTEMS & NETWORKS

Vermont Complex Systems Center—Misfit toys:

- Peter Dodds, Math/Stats
- Josh Bongard, CS
- Chris Danforth, Math/Stats
- Maggie Eppstein, CS
- Juniper Lovato, Education
- Hugh Garavan, Neuro, Psychiatry
- Jane Adams, Digital Artist
- Safwan Wshah, CS
- Jim Bagrow, Math/Stats
- Paul Hines, EE
- Brian Tivnan, MITRE
- Puck Rombach, Math/Stats
- Laurent Hébert-Dufresne, CS

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
- Complex Networks
- Climate
- Biology
- Ecology
- Geomorphology
- Space
- Complex Fluids
- (Smart) Power Grids
- Critical infrastructure
- Defense
- Public Policy
- Health and Medicine
- ~~Brainz~~ Brains
- Neuroscience
- Food systems
- Epidemiology
- Pandemics
- Organizations
- Economics
- Wealth inequality
- Financial Systems

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.

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

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, ...
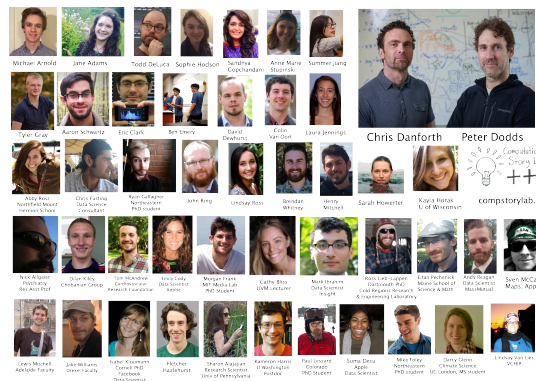- Complex Systems + Data Science = Postdisciplinary Systems Science

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

- Adjacent: Strava Story Lab team

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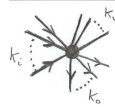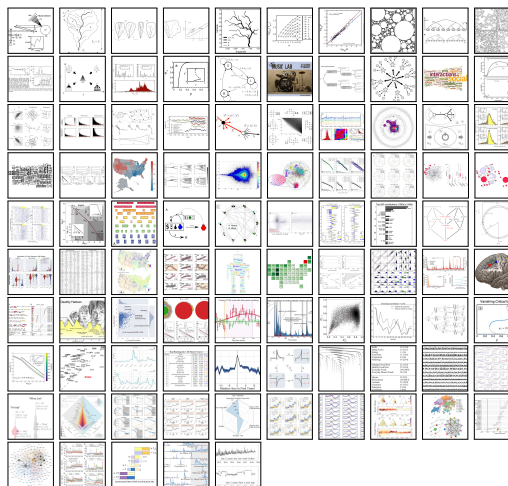
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Outside

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 (60+)

Basics:

- Instructor: Prof. Peter Sheridan Dodds
- Lecture room and meeting times: Perkins 003, 10:05 am to 11:20 am
- Office: (in theory) Innovation, fourth floor
- email: peter.dodds@uvm.edu
- Course Website: https://pdodds.w3.uvm.edu/teaching/courses/2021-2022principles-of-complex-systems
- Course Twitter handle: @pocsvox
- Course hashtag: #FallPoCS2021

Potential paper products:

- The Syllabus and a Poster.

Office hours:

- TBD, Innovation, fourth floor

Exciting details regarding these slides:

- Three servings (all in pdf):
  1. Fresh: For in-class Deliveration.
  2. On toast: Flattened for page-turning joy.
  3. 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. [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 X꙰LATEX, 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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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.

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 (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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Yet more super exciting details:

- This is Season 17 of Principles of Complex Systems, Vols. 1 & 2.
- Lectures will be called Episodes.
- Episodes will be broken into clips.
- Goal for all lectures: Stream and record on Teams and record with ScreenFlow and send to Youtube.
- Office hours will run over Teams and be recorded.
- Some new clips will be recorded in a pretend studio.
- All lectures are bottle episodes.
- Other tropes will be involved.
- Last season's Episodes are here.

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Grading breakdown:

- Assignments (75%)—All assignments will be of equal weight and there will be 10 ± 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.

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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). [16]

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

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Wonderful foundational support for PoCS Vol. 1 and ~~CoNKS CocoNuTs~~ PoCS Vol. 2 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 ⬀

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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.
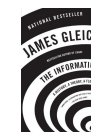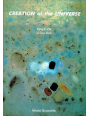- 1 = needs major revisions.
- 0 = way off.

Popular Science Books:

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

"Complexity: A Guided Tour" a ⬀ by Melanie Mitchell (2009). [T2]

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

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Books on Complexification:

"Scaling, self-similarity, and intermediate asymptotics" 🅐 ↗
by G. I. Barenblatt (1996). [3]

Have to strongly disrecommend "Scale" by West. No.

"Creation of the Universe" 🅐 ↗
by Zhi and Xian (1989). [17]

See Freeman Dyson's ↗ The Key to Everything ↗.

On complex sociotechnical systems:

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

"Micromotives and Macrobehavior" 🅐 ↗
by Thomas C. Schelling (1978). [14]

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

It's all about algorithms (stories):

"The Engine of Complexity: Evolution as Computation" 🅐 ↗
by John E. Mayfield (2013). [10]

"On the Origin of Stories: Evolution, Cognition, and Fiction" 🅐 ↗
by Brian Boyd (2010). [5]

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

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A few textbooky books (dated):

"Complex Adaptive Systems: An introduction to computational models of social life" 🅐 ↗
by Miller and Page (2007). [11]

"Critical Phenomena in Natural Sciences" 🅐 ↗
by Didier Sornette (2003). [15]

"Modeling Complex Systems" 🅐 ↗
by Nino Boccara (2004). [4]

Eventually: "Principles of Complex Systems"

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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 ↗

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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. #alittlescary

Major themes:

- 🐾 The Complexity Manifesto ↗;
- 🐾 Complex Systems ≡ 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?
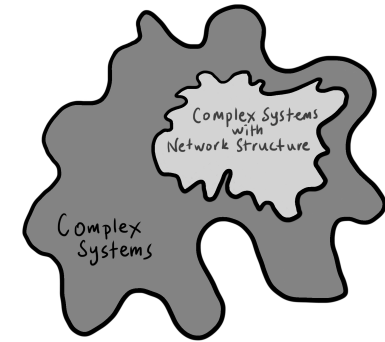- 🐾 It's all about stories.

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Complex Systems are the Big Story:

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

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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 ⇒ Edward Lears ⇒ Edwards.
- 🐾 Also: Taxis ⇒ Boris Spasskies ↗ ⇒ Borises

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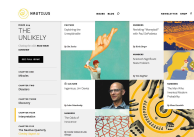
Topics:

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.

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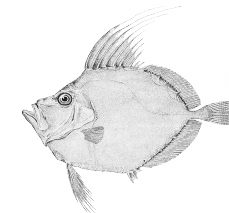
Topics:

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 [17]).

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.

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Topics:

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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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

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- 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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[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.
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The Storytelling Animal: How Stories Make Us Human.
Mariner Books, 2013.

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Threshold models of collective behavior.
Am. J. Sociol., 83(6):1420–1443, 1978. pdf 🗗

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Columbia University Press, New York, 2013.

[11] J. H. Miller and S. E. Page.
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[12] M. Mitchell.
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Oxford University Press, New York, NY, 2009. pdf 🗗

[13] T. C. Schelling.
Dynamic models of segregation.
J. Math. Sociol., 1:143–186, 1971. pdf 🗗

[14] T. C. Schelling.
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Norton, New York, 1978.

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Critical Phenomena in Natural Sciences.
Springer-Verlag, Berlin, 2nd edition, 2003.

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[16] M. M. Waldrop.
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Simon & Schuster, New York, NY, 1993.

[17] F. L. Zhi and L. S. Xian.
Creation of the Universe.
World Scientific Publishing Company, 1989.

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

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