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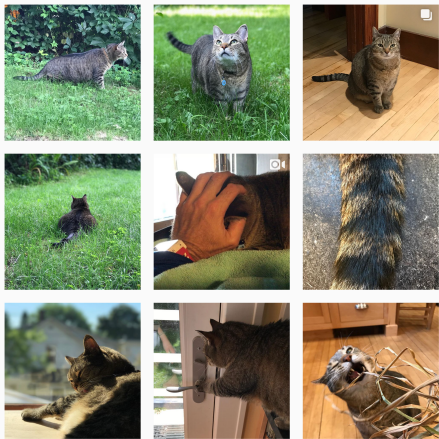
Course Overview for PoCS

Last updated: 2021/10/06, 20:26:04 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

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 On Instagram at pratchett_the_cat ⬈

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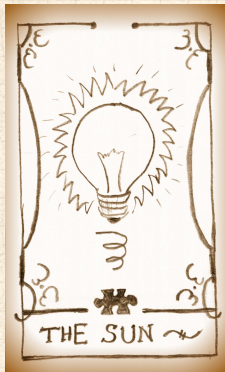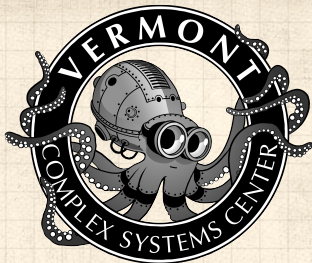THE SUN

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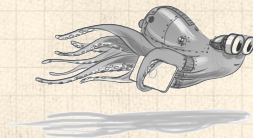The PoCSverse
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Describe | Explain | Create | Share | Ethos: Play

vermontcomplexsystems.org

Vermont Complex Systems Center (2006–):

Diverse research and teaching portfolio ($>$ 400 papers in 2010–2015).

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What's the Story?

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- 🐝 Connecting Graduate and Undergraduate Students across campus (SCRaPS).

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- Paper Shredder, Research Jam, and ComplexiTea.

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- Talkboctopus ☒

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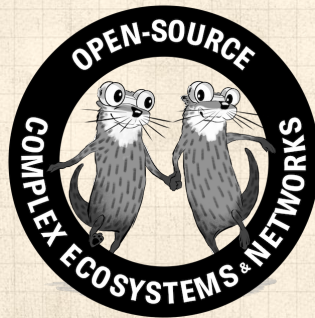What's the Story?

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/ ⧉

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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

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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

- 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.

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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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Framing (funfully):

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Science = Area of study + Instruments of study

📦 Stars and Telescopes

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Science = Area of study + Instruments of study

Stars and Telescopes = Astronomy

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Science = Area of study + Instruments of study

🎲 Stars and Telescopes = Astronomy

🎲 Rocks and Hammers

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Science = Area of study + Instruments of study

- Stars and Telescopes = Astronomy
- Rocks and Hammers = Geology

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Science = Area of study + Instruments of study

- Stars and Telescopes = Astronomy
- Rocks and Hammers = Geology
- Water and Partial Differential Equations

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Science = Area of study + Instruments of study

- ⬡ Stars and Telescopes = Astronomy
- ⬡ Rocks and Hammers = Geology
- ⬡ Water and Partial Differential Equations = Fluid Dynamics

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

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- Water and Partial Differential Equations = Fluid Dynamics
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- People and Deception

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- People and Deception = Social Psychology

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- Mathematics and Mathematics

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- Brains and Giant Imaging Machines = Neuroscience
- People and Deception = Social Psychology
- Mathematics and Mathematics = Pure mathematics

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- Mind and Mind

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Michael Arnold
Jane Adams
Todd DeLuca
Sophie Hodson
Sandhya Gopchandani
Anne Marie Stupinski
Summer Jiang

Tyler Gray
Aaron Schwartz
Eric Clark
Ben Emery
David Dewhurst
Colin Van Oort
Laura Jennings

Chris Danforth
Peter Dodds

Computational Story Lab ++;
compstorylab.org

Abby Ross
Northfield Mount Hermon School
Chris Fusting
Data Science Consultant
Ryan Gallagher
Northeastern PhD student
John Ring
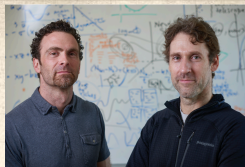Lindsay Ross
Brendan Whitney
Henry Mitchell
Sarah Howerter
Kayla Horak
U of Wisconsin

Nick Allgaier
Psychiatry
Res Asst Prof
Dilan Kiley
Chobanian Group
Tom McAndrew
Cardiovascular
Research Foundation
Emily Cody
Data Scientist
Adobe
Morgan Frank
MIT Media Lab
PhD Student
Cathy Bliss
UVM Lecturer
Mark Ibrahim
Data Scientist
Insight
Ross Lieb-Lappen
Dartmouth PhD
Cold Regions Research
& Engineering Laboratory
Eitan Pechenick
Maine School of
Science & Math
Andy Reagan
Data Scientist
MassMutual
Sven McCall
Maps, Apple

Lewis Mitchell
Adelaide Faculty
Jake Williams
Drexel Faculty
Isabel Kloumann
Cornell PhD,
Facebook
Data Scientist
Fletcher
Hazelhurst
Sharon Alajajian
Research Scientist
Univ of Pennsylvania
Kameron Harris
U Washington
Postdoc
Paul Lessard
Colorado
PhD student
Suma Desu
Apple
Data Scientist
Mike Foley
Northeastern
PhD student
Darcy Glenn
Climate Science
UC London, MS student
Lindsay Van Der
VCHIP

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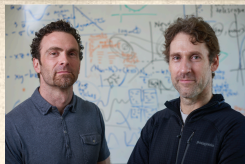Narrative Arc
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Michael Arnold · Jane Adams · Todd DeLuca · Sophie Hodson · Sandhya Gopchandani · Anne Marie Stupinski · Summer Jiang

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compstorylab.org

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Nick Allgaier, Psychiatry Res Asst Prof · Dilan Kiley, Chobanian Group · Tom McAndrew, Cardiovascular Research Foundation · Emily Cody, Data Scientist Adobe · Morgan Frank, MIT Media Lab PhD Student · Cathy Bliss, UVM Lecturer · Mark Ibrahim, Data Scientist Insight · Ross Lieb-Lappen, Dartmouth PhD Cold Regions Research & Engineering Laboratory · Eitan Pechenick, Maine School of Science & Math · Andy Reagan, Data Scientist MassMutual · Sven McCall, Maps, Apple

Lewis Mitchell, Adelaide Faculty · Jake Williams, Drexel Faculty · Isabel Kloumann, Cornell PhD, Facebook Data Scientist · Fletcher Hazlehurst · Sharon Alajajian, Research Scientist Univ of Pennsylvania · Kameron Harris, U Washington Postdoc · Paul Lessard, Colorado PhD student · Suma Desu, Apple Data Scientist · Mike Foley, Northeastern PhD student · Darcy Glenn, Climate Science, UC London, MS student · Lindsay Van Der VCHIP
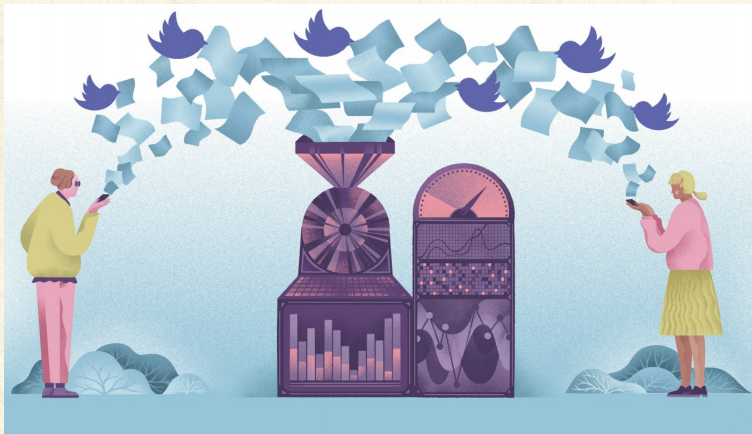
Adjacent: Strava Story Lab team

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Outside

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

Courses:

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- CSYS/MATH 300: Principles of Complex Systems (@pocsvox ⬀)

- CSYS/MATH 303: Complex Networks (@networksvox ⬀)

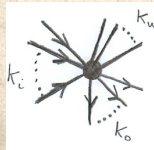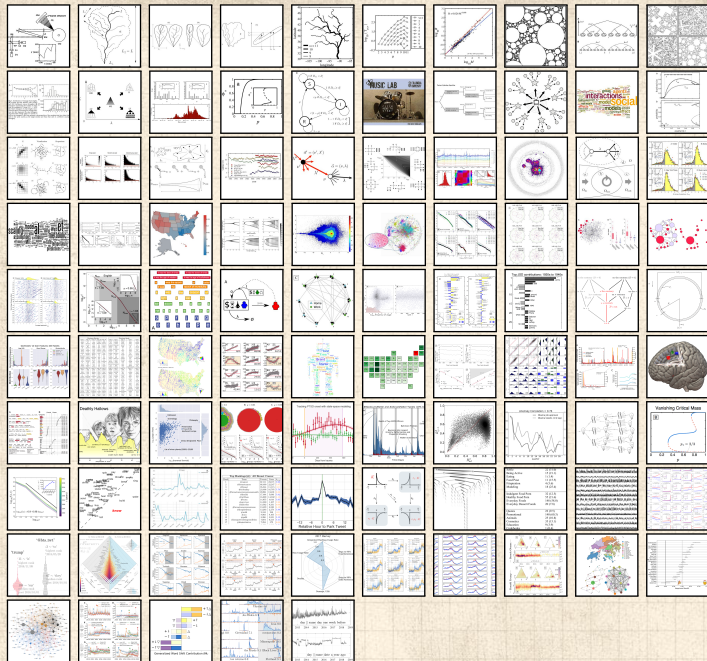- MATH 124/122: Matrixology (Linear Algebra) (@matrixologyvox and @svdthematrices ⬀)

- 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+)

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- 🎲 **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 ☑.

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Office hours:

🎲 TBD,
Innovation, fourth floor

Exciting details regarding these slides:

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Tarot Cards
Projects

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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.

# Exciting details regarding these slides:

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- ~~Presentation versions are~~ hyperly navigable:
  ~~◌◌◌≡ back + search + forward.~~

# Exciting details regarding these slides:

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- ⬢ Web links look like this ⬀.

Exciting details regarding these slides:

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- ♣ Web links look like this.

- ♣ References in slides link to full citation at end. [1]

# Exciting details regarding these slides:

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- Citations contain links to pdfs for papers (if available).

Exciting details regarding these slides:

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  ~~≋ 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.

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~~back + search + forward.~~

♻ Web links look like this☑.

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♻ Brought to you by a frightening melange of
X∃LATEX☑, Beamer☑, perl☑, PerlTeX☑, fevered
command-line madness☑, and an almost
fanatical devotion☑ to the indomitable emacs☑.

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- ♣ Some books will be linked to on Amazon.
- ♣ Brought to you by a frightening melange of XƎLATEX ↗, 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 ...

Yet more super exciting details:

Yet more super exciting details:

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- This is Season 17 of Principles of Complex Systems, Vols. 1 & 2.

THE SUN

Yet more super exciting details:

- This is Season 17 of Principles of Complex Systems, Vols. 1 & 2.
- Lectures will be called Episodes.

THE SUN

Yet more super exciting details:

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- This is Season 17 of Principles of Complex Systems, Vols. 1 & 2.
- Lectures will be called Episodes.
- Episodes will be broken into clips.

THE SUN

Yet more super exciting details:

- This is Season 17 of Principles of Complex Systems, Vols. 1 & 2.
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- Goal for all lectures: Stream and record on Teams and record with ScreenFlow and send to Youtube.

THE SUN

Yet more super exciting details:

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Yet more super exciting details:

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- All lectures are bottle ☑ episodes ☑.

Yet more super exciting details:

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- 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.

Yet more super exciting details:

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- 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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References

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 ⬀.

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- 🎲 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

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Microsoft Teams + Slack

Teams = main place for discussions about all things PoCS including assignments and projects.

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- Teams = main place for discussions about all things PoCS including assignments and projects.
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Microsoft Teams   slack

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Microsoft Teams   slack

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Microsoft Teams

slack

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- Very good: Install Microsoft and Slack apps on laptops, tablets, phone, cats, dogs. Nothing will go wrong.

Team PoCS

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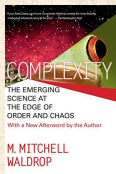Centers, Books, Resources
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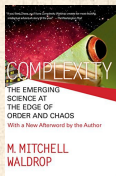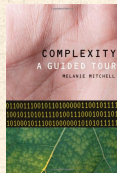References

Microsoft Teams + Slack

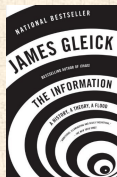- Teams = main place for discussions about all things PoCS including assignments and projects.
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- Very good: Install Microsoft and Slack apps on laptops, tablets, phone, cats, dogs. Nothing will go wrong.
- Everyone will behave wonderfully.

Microsoft Teams   slack

Grading breakdown:

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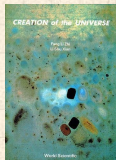
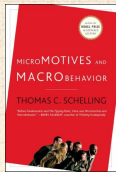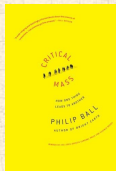References

🎲 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.

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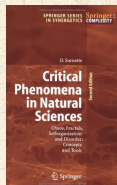
1. Classes run from Tuesday, August 31 to Thursday, December 9.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 13.
3. Last day to withdraw—Monday, November (Sadness!).
4. Reading and Exam period—Saturday, December 11 to Friday, December 17.

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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Popular Science Books:

Historical artifact:

"Complexity: The Emerging Science at the Edge of Order and Chaos" 🅰 ⬈ by M. Mitchell Waldrop (1993). [16]

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Popular Science Books:

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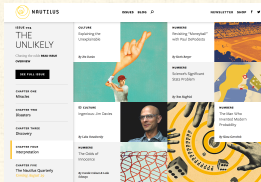Centers, Books, Resources
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References

Historical artifact:

"Complexity: The Emerging Science at the Edge of Order and Chaos" 🅐 ☐
by M. Mitchell Waldrop (1993). [16]

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

Popular Science Books:

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

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

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

Books on Complexification:

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"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" 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]

It's all about algorithms (stories):

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

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

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

A few textbooky books (dated):

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"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"

Centers:

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- 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:

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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/ ↗

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@pocsvox
What's the Story?

The nature of PoCS:

🎲 Transitional from standard coursework to research-focused work.

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The nature of PoCS:

Transitional from standard coursework to research-focused work. #alittlescary

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What's the Story?

The nature of PoCS:

♟ Transitional from standard coursework to research-focused work. #alittlescary

Major themes:

The nature of PoCS:

🎲 Transitional from standard coursework to research-focused work. #alittlescary

Major themes:

🎲 The Complexity Manifesto 🗗;

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The nature of PoCS:

- Transitional from standard coursework to research-focused work. #alittlescary

Major themes:

- The Complexity Manifesto ☑;
- Complex Systems $\equiv$ Modern, Normal Science;

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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;

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Major themes:

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🧊 Emergence;

PoCS
Principles of
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What's the Story?

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Major themes:

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🧊 Complex Systems ≡ Modern, Normal Science;

🧊 Roles and limits of Data, Theory, and Experiment;

🧊 Emergence;

🧊 Universality and Accidents of History;

PoCS
Principles of
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♣ Roles and limits of Data, Theory, and Experiment;

♣ Emergence;

♣ Universality and Accidents of History;

♣ Structure and Stories: Micro-to-macro Mechanisms;

PoCS
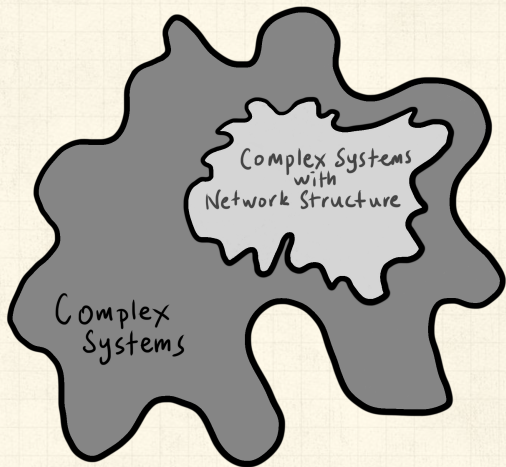Principles of
Complex Systems
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What's the Story?

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.

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⛭ The Theory of Anything: Why Complexify?

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- Elements: Scaling, Surprise, Networks, Robustness, Failure, and Spreading.
- The Theory of Anything: Why Complexify?
- It's all about stories.

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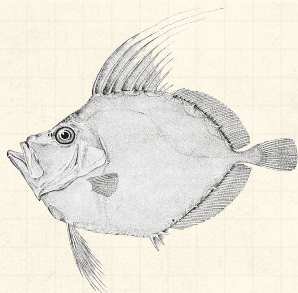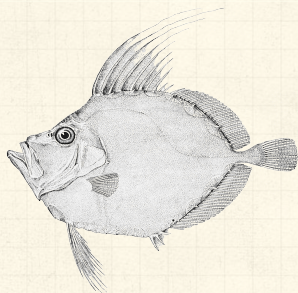References

Complex Systems
with
Network Structure

Complex
Systems

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

Cryptolect:

Course mascot:

🧊 What's the Story?

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Cryptolect:

Course mascot:

🧊 What's the Story?

🧊 What's the John Dory?

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Course mascot:

- What's the Story?
- What's the John Dory?
- What's the John Dory for Rhyming Slang ?

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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.

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- 🎲 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

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.

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Fundamentals of Complexity:

♻ Emergence: More is Different.

♻ Measurement and mismeasurement.

♻ Universality versus path dependence.

♻ Complexification (it all starts with gravity [17]).

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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.

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- 🎲 The paradox of unpredictable global fame.
- 🎲 Bonus knowledge: How to make things spread.

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- 🎲 The role of randomness and chance.
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- 🎲 The paradox of unpredictable global fame.
- 🎲 Bonus knowledge: How to make things spread.
- 🎲 Bonus knowledge: Fate does not exist in a world of fame.

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- 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

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

🎲 Overview of Complex Systems with bonus Manifesto ⬀.

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- 🎲 Thread of Understanding Sociotechnical Systems.

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- Thread of Understanding Sociotechnical Systems.

- Allometric scaling in complex systems.

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- 🧊 Thread of Understanding Sociotechnical Systems.

- 🧊 Allometric scaling in complex systems.

- 🧊 Size distributions of system elements:

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- Size distributions of system elements:
  - Power-law size distributions.

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  - Description and Mechanisms of Becoming.

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

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- 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:

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- 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.

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- Social Contagion, Voting, Fame and Fate, Stories.

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- 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.

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- Semester-long projects, teams.
- Develop proposal in first few weeks.

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- Develop proposal in first few weeks.
- May range from novel research to investigation of an established area of complex systems.

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- Two talks + written piece.

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- Massive data sets available, including Twitter.

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- Possible: Work with Twitter data and Story Lab on socially meaningful problems.

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- 🎲 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!

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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.

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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