

# Course Overview for PoCS

Last updated: 2018/08/28, 12:45:19

## Principles of Complex Systems | @pocsvox CSYS/MATH 300, Fall, 2018

Prof. Peter Dodds | @peterdodds

Orientation

Course Information

Centers, Books, Resources

Topics

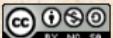
Narrative Arc

Tarot Cards

Projects

References

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



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# These slides are brought to you by:

Sealie & Lambie  
Productions



PoCS  
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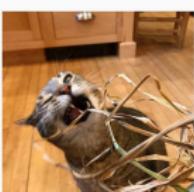
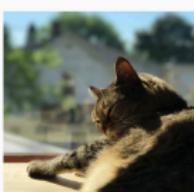
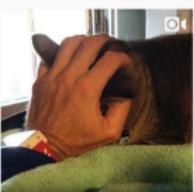
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## Special Guest Executive Producer



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On Instagram at [pratchett\\_the\\_cat](#)



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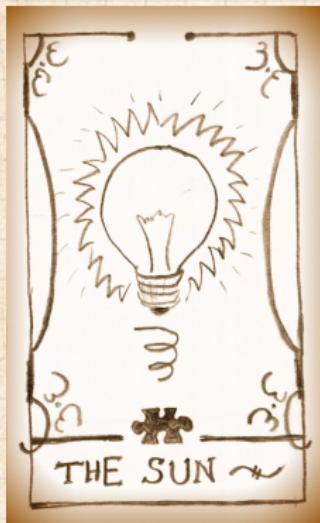
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Describe | Explain | Create | Share | Ethos: Play



## Vermont Complex Systems Center (2006–):

- ⬢ Diverse research and teaching portfolio (> 400 papers in 2010–2015).
- ⬢ Funding from many sources: NSF, NIH, DARPA, Microsoft, MITRE, Mass Mutual, Computer Associates, foundations.
- ⬢ Regular global press coverage: NYT, BBC, WaPo, NatGeo, ...
- ⬢ Conferences: “Big Data, Big Stories”, “Big Scale, Big Fail”, “Prediction: the Next Big Thing” and Flash Mob Research events. **NetSci 2019** and **ALife** are next.
- ⬢ Fully developed educational platform in Complex Systems and Data Science.
- ⬢ 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.



## 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         |  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       |
|  |  Critical infrastructure |  Economics           |
|  |  Defense                 |  Wealth inequality   |
|  |   |  Financial Systems   |



**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...](http://uvm.edu/rss/news/?Page...)



12:16 PM - 7 Aug 2017

**ca**  
technologies



Cognizant  
(In talks)

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What's the John Dory?



## 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



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

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

- ⬢ Principles of Complex Systems is one of two core requirements for UVM's five course Certificate of Graduate Study in Complex Systems ↗.
- ⬢ Other required course:  
Prof. Laurent Hebert-Dufresne's "Modelling Complex Systems" (CSYS/CS 302).
- ⬢ Unofficially required:  
Prof. Jim Bagrow's "Data Science I" (STAT 287)
- ⬢ The Sequel to PoCS:  
"Complex Networks" (CSYS/MATH 303).

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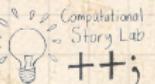
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## Peter Dodds

Computational  
Story Lab  
++;

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



**Nick Augsburger** Psychiatry  
**Dylan Kiley** Chobanian Group  
**Tom McAndrew** Cardiovascular  
**Emily Gaynor** Data Scientist  
**Morgan Frank** MIT Media Lab  
**Cathy Bliss** National Institute of  
Molecular Medicine  
**Mark Ibrahim** Boston Children's  
**Ross Lieb** Lappan Dartmouth  
**Ethan Peichnick** PhD  
**Maine School of  
Medicine**  
**Anny Seigal** Data Scientist  
**Sven McCann** Apple



Lewi Mitchell  
Aldatice Faure  
  
Jake Williams  
Dressel Faure  
  
Isabel Kloumann  
Cornell PhD  
  
Fletcher Hazlehurst  
  
Sharon Alajanian  
Research Scientist  
  
Kameron Harris  
U Washington  
  
Paul Lessard  
Colorado  
  
Suma Desa  
Apple  
  
Mike Foy  
University of  
Guelph  
  
Darcie Glenn  
University of  
Michigan  
  
James Van Lier  
VCHIR

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

## Adjacent: Strava Story Lab team

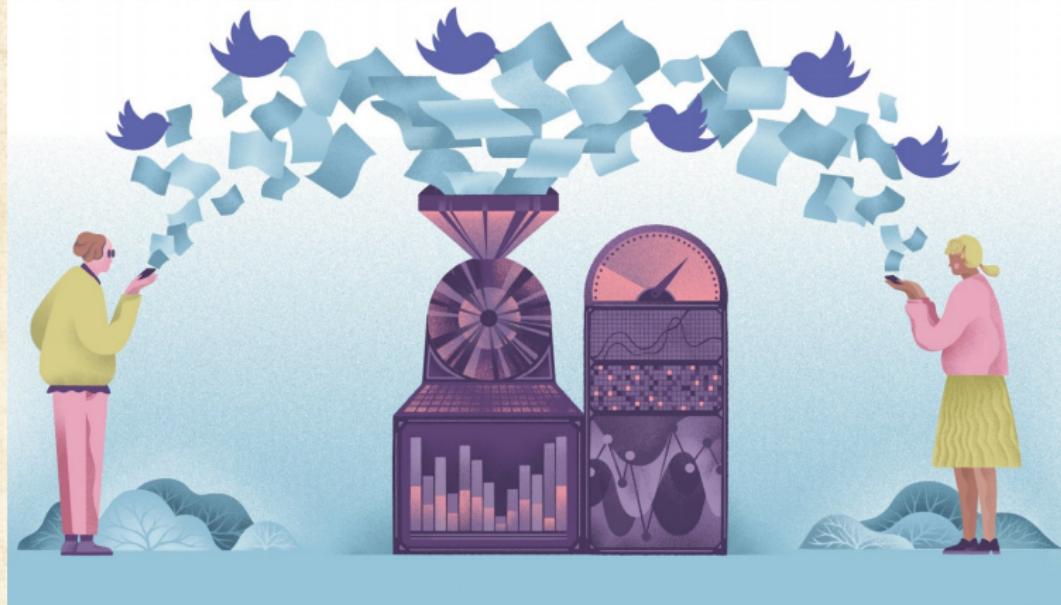


# Outside

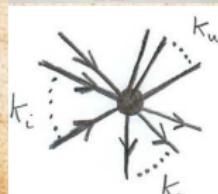
Inside the Lab that's Quantifying Happiness ↗

by Rowan Jacobsen, August 2017.

(Reprinted in UVM Quarterly, 2018.)



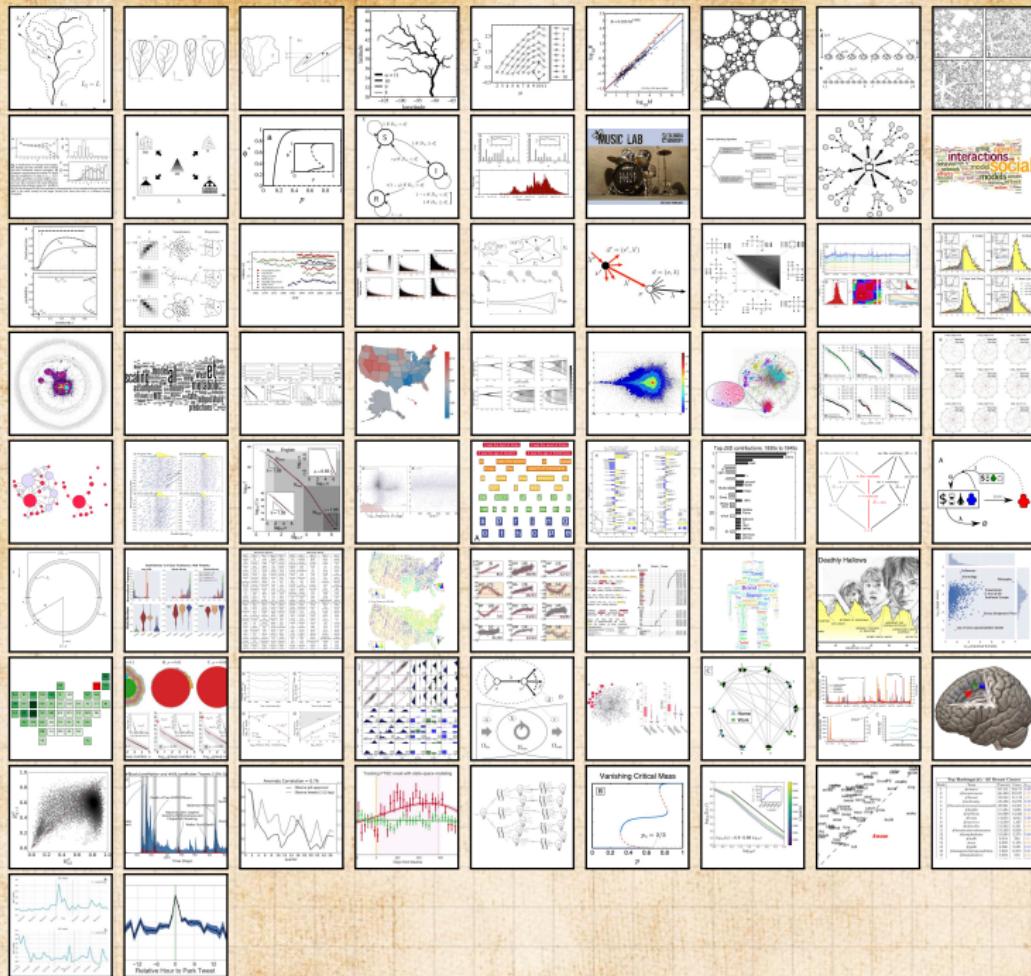
# Courses:



- ⬢ CSYS/MATH 300: Principles of Complex Systems (@poctsvox ↗)
- ⬢ 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 ↗ (45+)

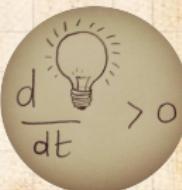




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# Basics:

PoCS  
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What's the John  
Dory?

-  **Instructor:** Prof. Peter Dodds
-  **Lecture room and meeting times:**  
101 Perkins, Tuesday and Thursday, 8:30 am to 9:45 am
-  **Office:** Farrell Hall, second floor, Trinity Campus
-  **email:** pdodds+pocs@uvm.edu
-  **Course Website:**  
<http://www.uvm.edu/pdodds/teaching/courses/2018-08UVM-300> 
-  **Course Twitter handle:** @pocsvox
-  **Course hashtag:** #FallPoCS2018

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## Potential paper products:

- ❖ The Syllabus ↗ and a Poster ↗.

## Office hours:

- ❖ 10:15 am to 11:30 am, Tuesday and Thursday,  
Farrell Hall, second floor, Trinity Campus



# Exciting details regarding these slides:

## Three versions (all in pdf):

1. Presentation,
2. Flat Presentation,
3. Handout (3x2 slides per page).

## Presentation versions are [hyperly navigable](#):

⌚⌚⌚ back + search + forward.

## Web links look [like this ↗](#).

## References in slides link to full citation at end. [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 [X<sub>L</sub>AT<sub>E</sub>X ↗](#), Beamer ↗, perl ↗, PerlTeX ↗, fevered command-line madness ↗, and an almost fanatical devotion ↗ to the indomitable emacs ↗.

#evilsuperpowers



# More super exciting details:

- ➊ We use Open Sans and make math look good:

```
\setmainfont[Ligatures=TeX]{Open Sans}  
\setsansfont[Ligatures=TeX]{Open Sans}  
\usefonttheme[onlymath]{serif}
```

- ➋ Still working towards putting the course on Github.
- ➌ And finishing writing the books ...



# Yet more super exciting details:

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- ⬢ This is Season 12 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 ↗.



# Welcome to DodecaPoCS

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What's the John  
Dory?

Twelve ↗ is a hero:

- ⬢ 12 is a superior highly composite number ↗, highly totient ↗, and super abundant ↗.
- ⬢ 12 is one of only two known sublime numbers ↗, for which both the number and sum of their positive factors are perfect numbers ↗ (6 and 28).
- ⬢ Compositeness means the Duoedecimal System is for Winners: 12 hours in half a day, 12 inches in a foot.<sup>1</sup>
- ⬢ 'Twelve', 'twelfth', and 'twelvish' all have excellent speekfeel ↗.
- ⬢ And 'dozen'. 'Dozen', 'dozen', 'dozen'.
- ⬢ Related: The Rampaging On-Line Encyclopedia of Integer Sequences, <https://oeis.org> ↗.

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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 also said nice things about PoCS ↗

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# Team PoCS

We'll continue to try out Slack:

- Place for discussions about all things PoCS including assignments and projects.
- Once invited, please sign up here:  
<http://teampocs.slack.com>
- Very good: Install Slack app on laptops, tablets, phone.
- Everyone will behave wonderfully.



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# Grading breakdown:

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Projects/talks (36%)—Students will work on semester-long projects. Students will develop a proposal in the first few weeks of the course which will be discussed with the instructor for approval. Details: 12% for the first talk, 12% for the final talk, and 12% for the written project.

Assignments (60%)—All assignments will be of equal weight and there will be  $10 \pm 1$  of them.

General attendance/Class participation (4%)—Everyone is expected to behave well.

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# How grading works:

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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 28 to Friday, December 7.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 10.
3. Last day to withdraw—Monday, October 29 (Sadness!).
4. Reading and Exam period—Saturday, December 8 to Friday, December 14.

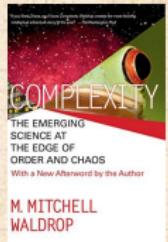
**Do** check the course Twitter account, @pocsvox, for updates regarding the course (part of the course site).

**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.



# Popular Science Books:

Historical artifact:

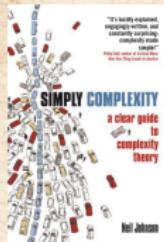


"Complexity: The Emerging Science at the Edge of Order and Chaos" ↗ [16]  
by M. Mitchell Waldrop (1993).

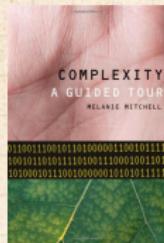
Shout-out: Dr. Andrew P. Morokoff ↗,  
MBBS PhD FRACS D.Thau (Bug) ↗



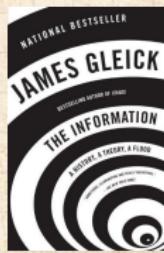
# Popular Science Books:



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



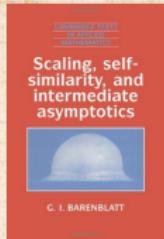
"Complexity: A Guided Tour" [a ↗](#)  
by Melanie Mitchell (2009). [12]



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

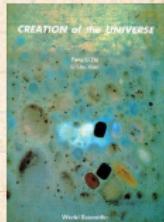


# Books on Complexification:



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

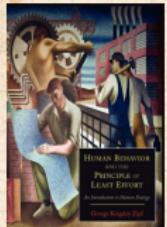
Have to strongly disrecommend "Scale" by West. No.



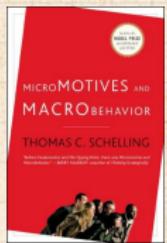
"Creation of the Universe" [🔗](#)  
by Zhi and Xian (1989). [\[17\]](#)

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

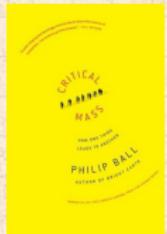




"Human Behaviour and the Principle of Least-Effort" [a ↗](#) [18]  
by G. K. Zipf (1949).



"Micromotives and Macrobbehavior" [a ↗](#) [14]  
by Thomas C. Schelling (1978).



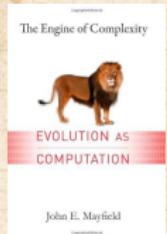
"Critical Mass: How One Thing Leads to Another" [a ↗](#) [2]  
by Philip Ball (2004).



# It's all about algorithms (stories):

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

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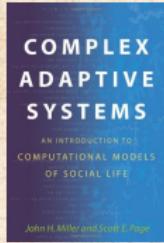
"On the Origin of Stories: Evolution, Cognition, and Iewefowef Fiction" [a ↗](#)  
by Brian Boyd (2010). [5]



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

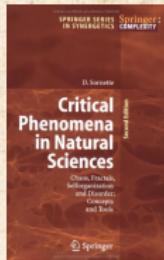


# A few textbooky books (dated):



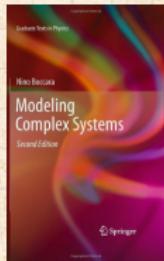
"Complex Adaptive Systems: An introduction to computational models of social life" [a](#) [↗](#)

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"

# Centers:

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

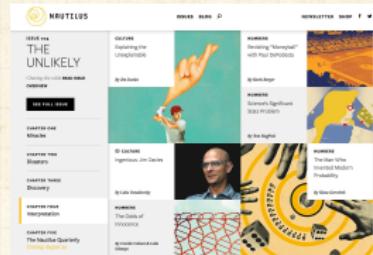


# Other inputs:

## 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/> ↗

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## The nature of PoCS:

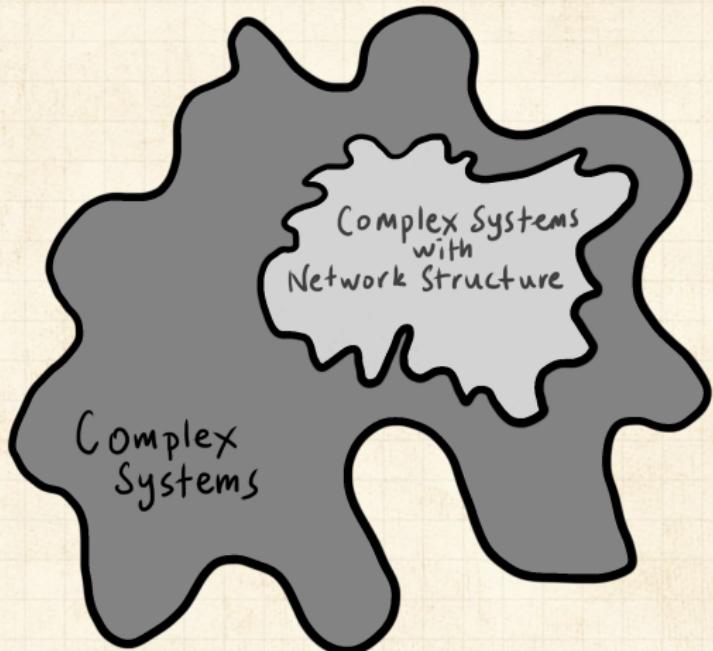
- ❖ Transitional from standard coursework to research-focused work. **#alittlescary**

## Major themes:

- ❖ The Complexity Manifesto ↗;
- ❖ Complex Systems ≡ Modern, Normal Science;
- ❖ Roles and limits of Data, Theory, and Experiment;
- ❖ 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:



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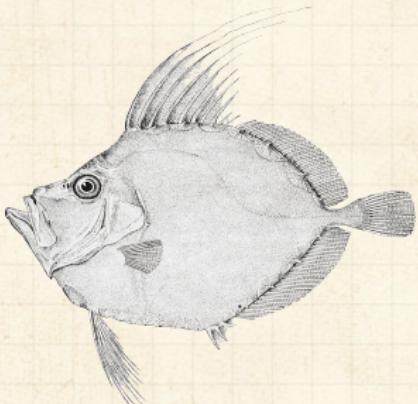


- Only a bit networky: Fluids-at-large (the atmosphere, oceans, ...), organism cells, ...



# Cryptolect:

Course mascot:



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- .getBlockIcon(3) What's the Story?
- .getBlockIcon(3) What's the John Dory?
- .getBlockIcon(3) What's the John Dory for Rhyming Slang ↗?
- .getBlockIcon(3) Hemiteleia: beers ⇒ Edward Lears ⇒ Edwards.
- .getBlockIcon(3) 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.



# 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:

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What's the John  
Dory?

## 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 CocoNuTS in the Spring of 2019 (but it's going to be really Storology)

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# Topics:

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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



# 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



# The Secret of Success will be revealed:

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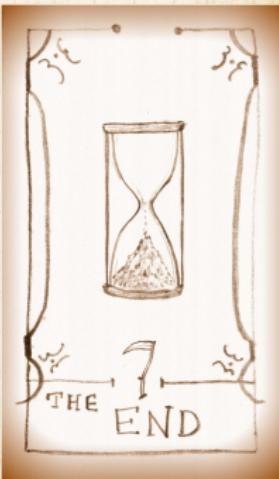
<http://www.youtube.com/watch?v=tcRudbIV-eM&rel=0> ↗



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

- cube Overview of Complex Systems with bonus Manifesto ↗.
- cube Thread of Understanding Sociotechnical Systems.
- cube Allometric scaling in complex systems.
- cube Size distributions of system elements:
  - cube Power-law size distributions.
  - cube Description and Mechanisms of Becoming.
- cube Robustness of Complex Systems.
- cube Complex networks—how system elements are connected:
  - cube Structure, Growth Mechanisms, Processes on Networks.
  - cube Social Contagion, Voting, Fame and Fate, Stories.
- cube Complexification: The Theory of Anything and the Rise of Algorithms





# Projects

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Dory?

- ❖ 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.



# 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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