

Overview of Complex Systems

Principles of Complex Systems | @pocsvox

CSYS/MATH 300, Fall, 2016 | #FallPoCS2016

Prof. Peter Dodds | @peterdodds

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



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What's the John
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Sealie & Lambie
Productions



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Outline

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What's the John
Dory?

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

Orientation

Course Information

Topics

Narrative Arc

Course Map

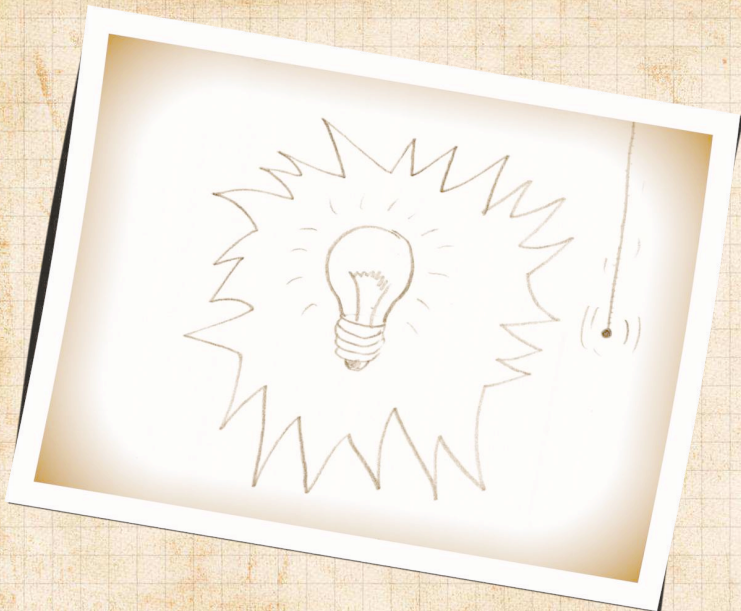
Projects

Centers, Books, Resources

References

References





Orientation

- Course Information
- Topics
- Narrative Arc
- Course Map
- Projects
- Centers, Books, Resources

References

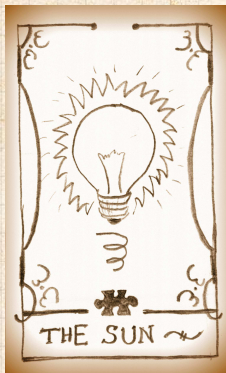


What's the John Dory?

Orientation

- Course Information
- Topics
- Narrative Arc
- Course Map
- Projects
- Centers, Books, Resources

References



What's the John Dory?



Peter Dodds



Andy Reagan



Nick Algaier



Eitan Pechenick



Chris Danforth



compstorylab.org

Orientation

Course Information
Topics
Narrative Arc
Course Map
Projects
Centers, Books, Resources

References



Sharon Alajajian



Dilan Kiley



Tom McAndrew



Kayla Horak



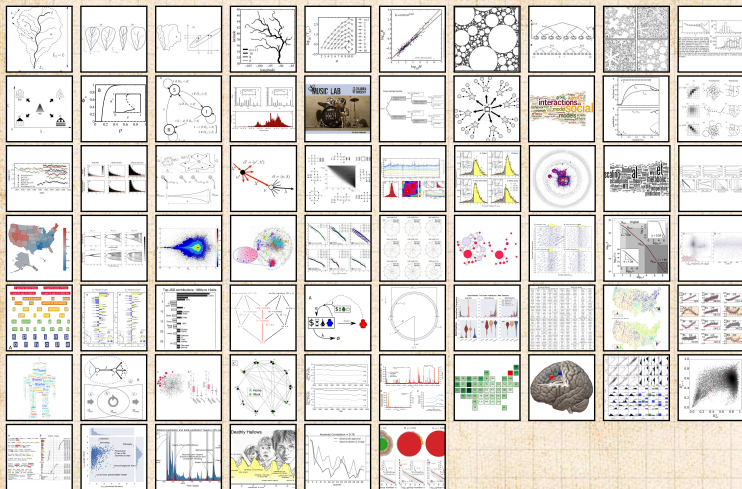
Eric Clark

Lewis Mitchell
(Adelaide)Mike Foley
(Northeastern)Morgan Frank
(MIT)Ross Lieb-Lappen
(Dartmouth)Isabel Kloumann
(Cornell)Kameron Harris
(Washington)Paul Lessard
(Colorado)Tyler Gray
(MIT)Suma Desu
(MIT)

Funding: NSF, NASA, MITRE.



What's the John Dory?



Orientation

- Course Information
- Topics
- Narrative Arc
- Course Map
- Projects
- Centers, Books, Resources

References



What's the John Dory?

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Basics:



Instructor: Prof. Peter Dodds



Lecture room and meeting times:

102 Perkins, Tuesday and Thursday, 11:40 am to
12:55 pm




Office: Farrell Hall, second floor, Trinity Campus



email: peter.dodds@uvm.edu



Course Website:

<http://www.uvm.edu/pdodds/teaching/courses/2016-08UVM-300> 



Course Twitter handle: @pocsvox



Course hashtag: #FallPoCS2016

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources


References



Potential paper products:

 The Syllabus  and a Poster .

Office hours:

 10:00 am to 11:55 am on Wednesdays,
Farrell Hall, second floor, Trinity Campus

Orientation

Course Information

Topics

Narrative Arc

Course Map



Projects


Centers, Books, Resources


References





Graduate Certificate in Complex Systems (and Data Science):


 Principles of Complex Systems is one of two core requirements for UVM's five course teaching-learning/certificate-of-study-in-complex-systems/Certificate of Graduate Study in Complex Systems .

 Other required course: Prof. Maggie Eppstein's "Modelling Complex Systems" (CSYS/CS 302).

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

New [movie voice]:

 MS in Complex Systems and Data Science (Fall 2015) 

 PhD in Complex Systems (Eventually ...)

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



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_YTeX , Beamer , perl , PerlTeX , fevered command-line madness , and an almost fanatical devotion  to the indomitable emacs .

#evilsuperpowers

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



More super exciting details:

Orientation

Course Information

Topics


Narrative Arc

Course Map


Projects

Centers, Books, Resources

References

 We use Open Sans and make math look good:

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


 Working towards putting the course on Github.







Yet more super exciting details:

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What's the John Dory?

 This is Season 10 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 .

Orientation

Course Information

Topics

Narrative Arc

Course Map





Projects

Centers, Books, Resources

References



Wonderful foundational support for PoCS and CoNKS has come from the NSF:

-  "CAREER: Explorations of Complex Social and Psychological Phenomena through Multiscale Online Sociological Experiments, Empirical Studies, and Theoretical Models." 2009–2015.
-  SES Division of Social and Economic Sciences
SBE Directorate for Social, Behavioral & Economic Sciences
-  Abstract is here .

-  People have said nice things about PoCS 

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects





Centers, Books, Resources

References



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.

Orientation

Course Information

Topics

Narrative Arc

Course Map


Projects


Centers, Books, Resources


References



Grading breakdown:

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

 **Assignments (60%)**—All assignments will be of equal weight and there will be 10 ± 1 of them.

 **General attendance/Class participation (4%)**

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects





Centers, Books, Resources

References



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.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Important things:

1. Classes run from Tuesday, August 30 to Tuesday, December 6.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, September 12.
3. Last day to withdraw—Monday, October 31 (Sadness!).
4. Reading and Exam period—Saturday, December 10 to Friday, December 16.

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.

Orientation

Course Information

Topics

Narrative Arc

Course Map


Projects

Centers, Books, Resources











References



The nature of PoCS:

 Transitional from standard coursework to research-focused work. **#alittle scary**

Major themes:

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

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

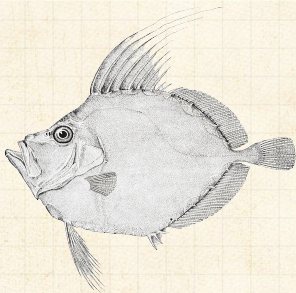
Centers, Books, Resources

References



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

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Scaling phenomena:

- 🧱 Allometry
- 🧱 Scaling of social phenomena: crime, creativity, and consumption.
- 🧱 Power law size distributions and non-Gaussian statistics
- 🧱 Zipf's law
- 🧱 Key mechanisms for generating power law size distributions
- 🧱 Scaling in biology (elephants and platypuses).
- 🧱 Law and Order—Theoricide Unit.
- 🧱 Dimensional Analysis and Renormalization.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects









Centers, Books, Resources

References





Topics:

Complex networks:

-  Structure and Dynamics
-  Statistical Mechanics
-  Phase transitions
-  Random Networks
-  Scale-free Networks
-  Small-world Networks
-  Multilayer networks
-  Much more in Complex Networks next semester

Multiscale complex systems:

-  Hierarchies and Scaling
-  Modularity

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects





Centers, Books, Resources

References







Topics:

Integrity of complex systems:

-  Generic failure mechanisms
-  Network robustness
-  Highly Optimized Tolerance (HOT): Robustness and fragility
-  Predictability

Information and Language:

-  Search in networked systems (e.g., the web, social systems)
-  Search on scale-free networks
-  Knowledge trees, metadata and tagging
-  Evolution and structure of natural languages

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Sociotechnical Systems:

- 🧱 Biological and social spreading models
- 🧱 Schelling's model of segregation ^[12]
- 🧱 Granovetter's model of imitation ^[7]
- 🧱 Collective behavior and Synchrony
- 🧱 Global cooperation from bad actors
- 🧱 Global conflicts from good actors
- 🧱 Stories (Homo Narrativus)
- 🧱 The Sociotechnocene

Orientation

Course Information

Topics

Narrative Arc

Course Map





Projects

Centers, Books, Resources





References



Large-scale social patterns:

-  Movement of individuals
-  Cities
-  Happiness
-  Twitter

Collective decision making:

-  Wisdom and madness of crowds
-  Systems of voting
-  The role of randomness and chance
-  Success inequality: superstardom

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



The Secret of Success will be revealed:

Orientation

Course Information

Topics

Narrative Arc

Course Map













Projects

Centers, Books, Resources

References



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.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Schedule in detail:

Week # (dates)	Tuesday	Thursday
1 (8/30 and 9/01)	Overview; Fundamentals: The Complexity Manifesto	Scaling
2 (9/06 and 9/08)	Power-law size distributions	Zipf's law; Fundamentals: Data, Emergence, Limits to Understanding
3 (9/13 and 9/15)	Projects; Power-law mechanisms: Randomness	Power-law mechanisms: Variable Transformation
4 (9/20 and 9/22)	Power-law mechanisms: The Rich-Get-Richer	Power-law mechanisms: Optimization
5 (9/27 and 9/29)	Robustness and Fragility	Fundamentals: Statistical Mechanics Language evolution
6 (10/04 and 10/06)	Robustness vs. SOC	Complex networks: Introduction Basics and Examples networks Small-world networks
7 (10/11 and 10/13)	Complex networks: Key Properties Generalized random	Complex networks: Small-world networks
8 (10/18 and 10/20)	Complex networks: Scale-free networks	Project presentations [†]
9 (10/25 and 10/27)	Project presentations [†]	Complex networks: Scale-free networks
10 (11/01 and 11/03)	Complex networks: Scale-free networks	Contagion: Introduction
11 (11/08 and 11/10)	Contagion	Biological Contagion
12 (11/15 and 11/17)	Social Contagion	Social Contagion
13 (11/22 and 11/24)	Thanksgiving	Thanksgiving
14 (11/29 and 12/01)	Voting and Success	The Sociotechnocene
15 (12/06)	The Big Story	—

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

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Dory?



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

Course Information

Topics

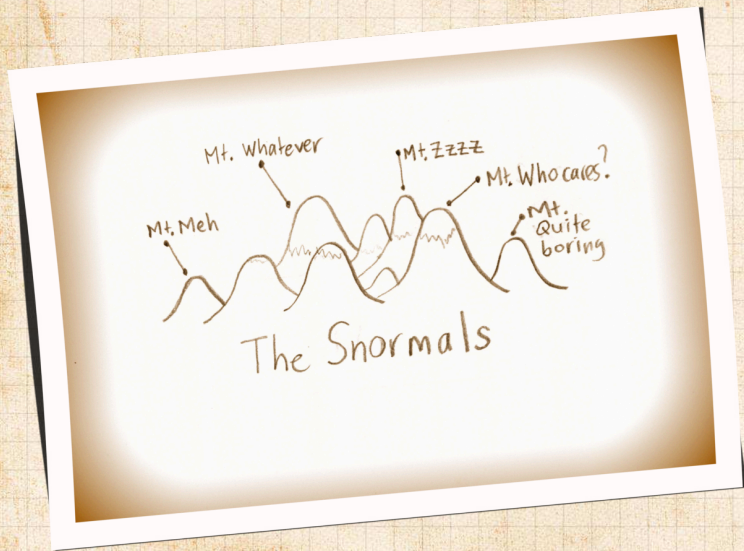
Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

[Course Information](#)

[Topics](#)

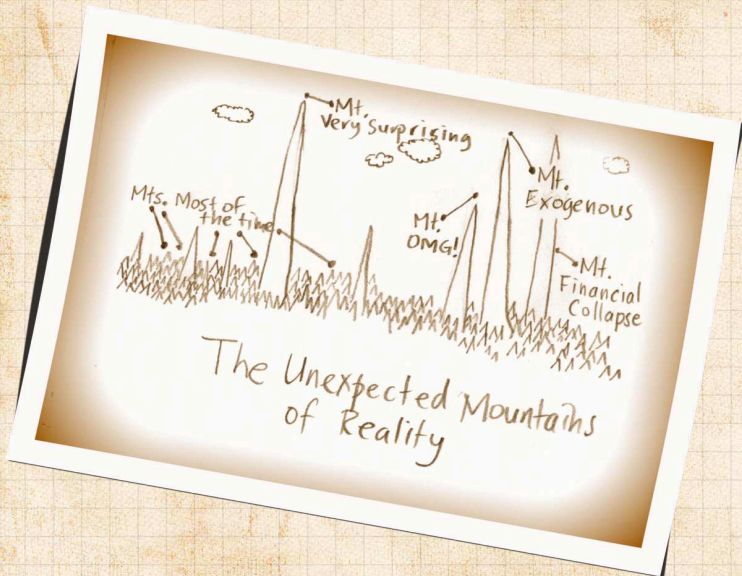
[Narrative Arc](#)

[Course Map](#)

[Projects](#)

[Centers, Books, Resources](#)

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

Course Information

Topics

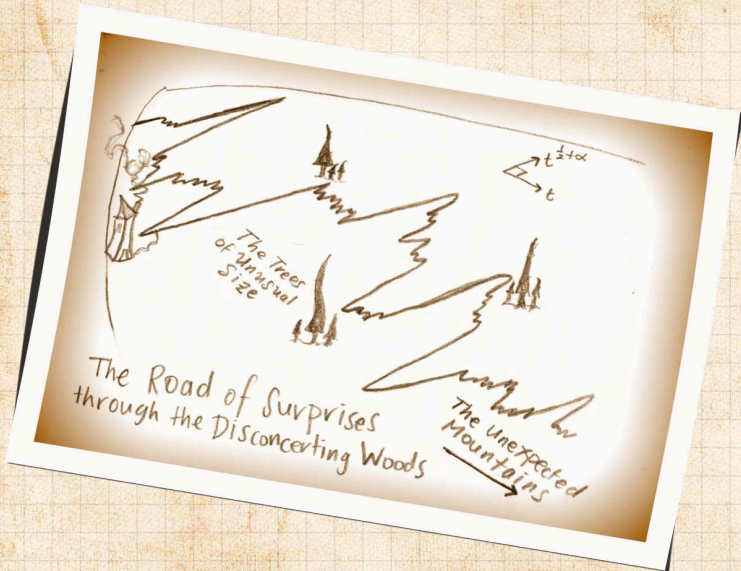
Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

Course Information

Topics

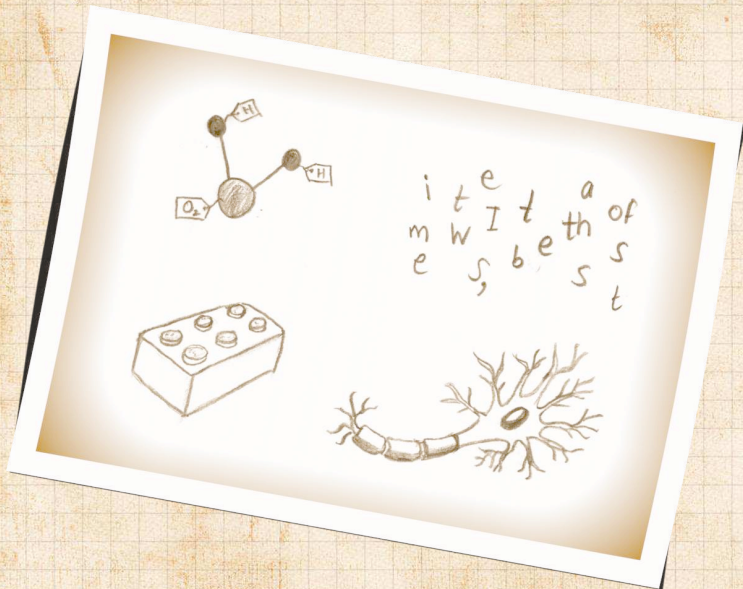
Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

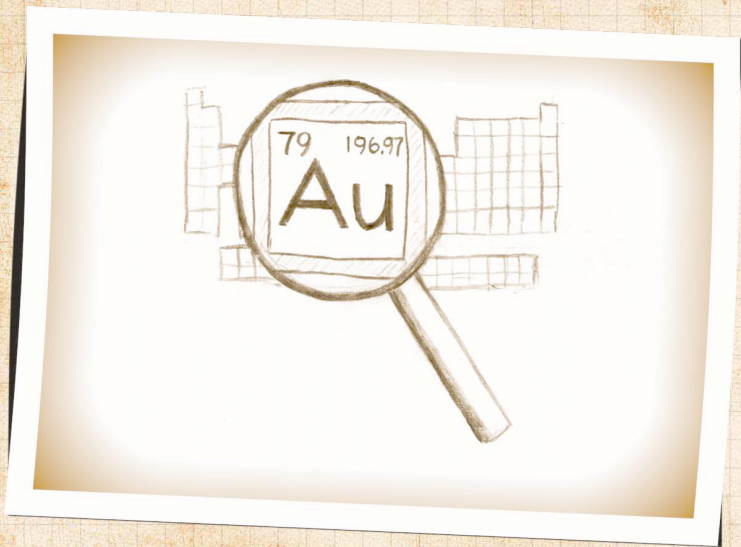
References



Course map:

PoCS | @pocsvox

What's the John Dory?



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



Course map:

PoCS | @pocsvox

What's the John Dory?

Orientation

Course Information

Topics

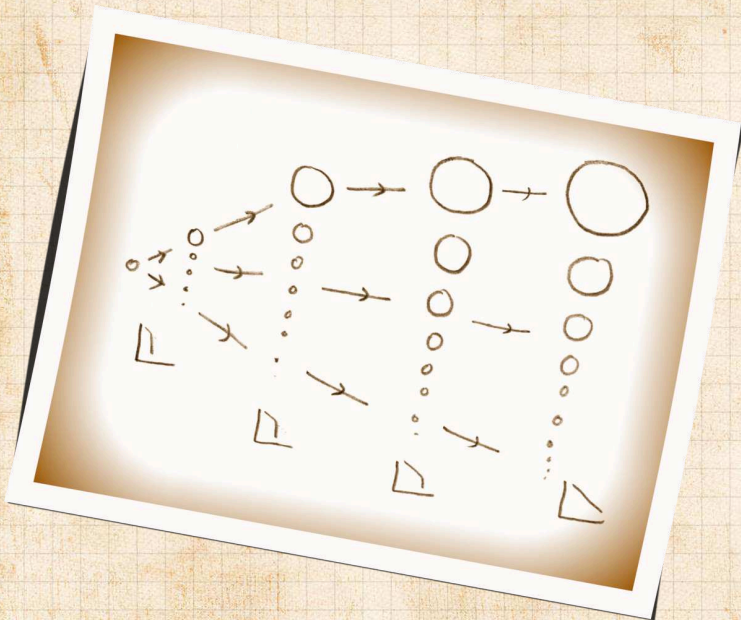
Narrative Arc

Course Map

Projects

Centers, Books, Resources

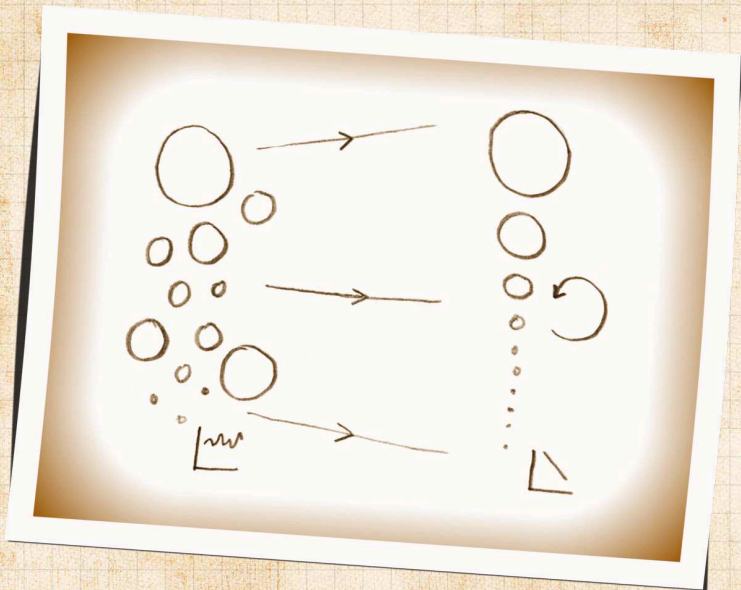
References



Course map:

PoCS | @pocsvox

What's the John Dory?



Orientation

Course Information

Topics

Narrative Arc

Course Map



Projects

Centers, Books, Resources

References



Projects

- ❏ Semester-long projects, individual or in pairs.
- ❏ 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.
- ❏ 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.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects


Centers, Books, Resources


References





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,

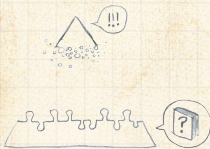
 short paper, essay,

 long paper,

 chapter,

 book,

 ...



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References

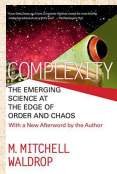


Popular Science Books:

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What's the John Dory?

Historical artifact:



“Complexity: The Emerging Science at the Edge of Order and Chaos” [a](#) [↗](#)
by M. Mitchell Waldrop (1993). ^[15]

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References

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



Popular Science Books:

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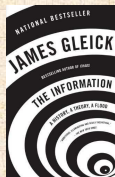
What's the John Dory?



“Simply Complexity: A Clear Guide to Complexity Theory” [a](#) [🔗](#)
by Neil F. Johnson (2009). [8]



“Complexity: A Guided Tour” [a](#) [🔗](#)
by Melanie Mitchell (2009). [11]



“The Information: A History, A Theory, A Flood” [a](#) [🔗](#)
by James Gleick (2011). [5]

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



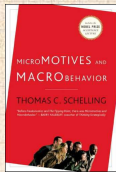
On complex sociotechnical systems:

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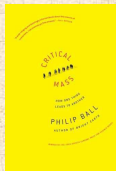
What's the John Dory?



“Human Behaviour and the Principle of Least-Effort” [a](#) [↗](#)
by G. K. Zipf (1949). [16]



“Micromotives and Macrobehavior” [a](#) [↗](#)
by Thomas C. Schelling (1978). [13]



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

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



It's all about algorithms (stories):

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What's the John Dory?



"The Engine of Complexity: Evolution as Computation" [a](#) [↗](#)
by John E. Mayfield (2013). [9]



"On the Origin of Stories: Evolution, Cognition, and Fiction" [a](#) [↗](#)
by Brian Boyd (2010). [4]



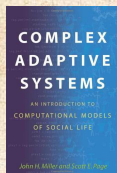
"The Storytelling Animal: How Stories Make Us Human" [a](#) [↗](#)
by Jonathan Gottschall (2013). [6]

Orientation
Course Information
Topics
Narrative Arc
Course Map
Projects
Centers, Books, Resources

References

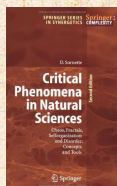


A few textbooky books:



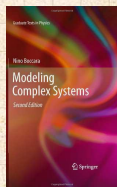
“Complex Adaptive Systems: An introduction to computational models of social life” [a](#) [↗](#)

by John H. Miller and Scott E. Page and John H. Miller and Scott E. Page (2007). ^[10]



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

by Didier Sornette (2003). ^[14]



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

by Nino Boccara (2004). ^[3]

Eventually: “Principles of Complex Systems”



Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References

Relevant online courses:



Melanie Mitchell (Santa Fe Institute):

Introduction to Complexity



Lada Adamic (Facebook):










Social Network Analysis



**Principles of Complex Systems and Complex
Networks**



Centers:

-  Santa Fe Institute (SFI)
-  New England Complex Systems Institute (NECSI)
-  Michigan's Center for the Study of Complex Systems ([CSCS](#) )
-  Northwestern Institute on Complex Systems ([NICO](#) )
-  Also: Indiana, Davis, Brandeis, University of Illinois, Duke, Warsaw, Melbourne, ...
-  [Vermont Complex Systems Center](#) 

Orientation

[Course Information](#)

[Topics](#)

[Narrative Arc](#)

[Course Map](#)

[Projects](#)

[Centers, Books, Resources](#)

References



References I

- [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.
Farra, Straus, and Giroux, New York, 2004.
- [3] N. Boccara.
Modeling Complex Systems.
Springer-Verlag, New York, 2nd edition, 2004.
- [4] B. Boyd.
On the Origin of Stories: Evolution, Cognition, and
Fiction.
Belknap Press, 2010.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



References II

- [5] J. Gleick.
The Information: A History, A Theory, A Flood.
Pantheon, 2011.
- [6] J. Gottschall.
The Storytelling Animal: How Stories Make Us
Human.
Mariner Books, 2013.
- [7] M. Granovetter.
Threshold models of collective behavior.
Am. J. Sociol., 83(6):1420–1443, 1978. pdf ↗
- [8] N. F. Johnson.
Simply Complexity: A Clear Guide to Complexity
Theory.
Oneworld Publications, London, UK, 2009. pdf ↗

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



References III

- [9] J. E. Mayfield.
The Engine of Complexity: Evolution as Computation.
Columbia University Press, New York, 2013.
- [10] J. H. Miller and S. E. Page.
Complex Adaptive Systems: An introduction to computational models of social life.
Princeton University Press, Princeton, NJ, 2007.
- [11] M. Mitchell.
Complexity: A Guided Tour.
Oxford University Press, New York, NY, 2009.
[pdf](#) 
- [12] T. C. Schelling.
Dynamic models of segregation.
J. Math. Sociol., 1:143–186, 1971. [pdf](#) 

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References



References IV

- [13] T. C. Schelling.
Micromotives and Macrobehavior.
Norton, New York, 1978.
- [14] D. Sornette.
Critical Phenomena in Natural Sciences.
Springer-Verlag, Berlin, 2nd edition, 2003.
- [15] M. M. Waldrop.
Complexity: The Emerging Science at the Edge of
Order and Chaos.
Simon & Schuster, New York, NY, 1993.
- [16] G. K. Zipf.
Human Behaviour and the Principle of
Least-Effort.
Addison-Wesley, Cambridge, MA, 1949.

Orientation

Course Information

Topics

Narrative Arc

Course Map

Projects

Centers, Books, Resources

References

