PoCS
Principles of Complex Systems @pocsvox
What's the Story?

Principles of Complex Systems, Vols. 1 and 2

@pocsvox
CSYS/MATH 6701, 6713, & a pretend number
Unreliable Deliverator: Prof. Peter Sheridan Dodds

https://pdodds.w3.uvm.edu/teaching/courses/2025-2026pocsverse/

Basic stuff:

Regional Deliverator (RD): Prof. Peter Sheridan Dodds
Office: The Ether and/or Innovation, fourth floor
Office hours: See Teams calendar
Teams site: Set up internally
Source material: Journal papers and book excerpts
Assistant to the Regional Deliverator (ARD): Calla Beauregard
Contact: Message the RD and the ARD through Teams; Please use the main channels like General and Projects if messages will benefit others; DMs are okay too
Suggested text: No official textbook

Fall, 2025
Principles of Complex Systems. Vol. 1
Course number: 6701
Lecture room: Cohen, 101
Meeting times: 10:05 am to 11:20 am

Spring, 2026
Principles of Complex Systems. Vol. 2
Course number: 6713
Lecture room: TBA
Meeting times: 10:05 am to 11:20 am

Fall, 2025
Principles of Complex Systems, Vol. 3D
Not an official course.
Meeting place: Vermont Complex Systems Institute
Meeting times: TBA

Spring, 2026
Principles of Complex Systems, Vol. 4, Fourever
Not an official course.

Meeting place: Vermont Complex Systems Institute
Meeting times: TBA

Summer, 2026
Principles of Complex Systems, Vol. V for Vendetta
Not an official course.
Meeting place: Vermont Complex Systems Institute
Meeting times: TBA

If instructor's permission is required: Students are asked to please send a short message on Teams describing their interests (and their netid and/or 950 student number).

Synopsis:

PoCS Volume 1:

Many of the problems we face in the modern world revolve around comprehending, controlling, and designing multi-scale, interconnected systems. Networked systems, for example, facilitate the diffusion and creation of ideas, the physical transportation of people and goods, and the distribution and redistribution of energy. Complex systems such as the human body and ecological systems are typically highly balanced, flexible, and robust, but are also susceptible to systemic collapse. These complex problems almost always have economic, social, and technological aspects.

So what do we know about complex systems? The basic aim in these postdisciplinary courses is to impart knowledge of a suite of theories and ideas and tools that have been evolved over the last century in the pursuit of understanding complex systems.

We'll touch on everything from physics to sociology, from randomness to the fabric of meaning.

Throughout the course, we'll maintain a focus on (1) real small-scale mechanisms that give rise to observed macro phenomena, (2) scaling phenomena, (3) robustness, (4) the optimal structure of meaningfully partitioned systems, (5) complex networks, and (6) biological and social contagion. We will explore how seemingly disparate systems correspond—the phenomenon of universality—and, just as importantly, where tempting analogies break down.

In the section on contagion, and based on work done pre-COVID-19, we will show how pandemics are deeply unpredictable. Towards the end of the course, we will explore the social construction of reality, understand the mechanics of fame, and show that fate does not exist.

PoCS Vol. 2, The Storying:

The second PoCS course explores special topics potentially including (but not limited to) language, stories, emotion, happiness, and meaning, through a variety of operationalized, computational lenses.

A few major areas:

Telegnomics: The distant measurement of knowledge.

Hedonometrics: The distant measurement of happiness and sadness.

Emotion: The distant measurement

Ousiometrics: The measurement of essential meaning, and the compass of essential meaning.

Archetypometrics: The space of fictional characters, and their connections to real characters.

We will consider stories through measurements of narratives, plots, characters, language use, interaction networks, and more.

Prerequisites for PoCS, Vol. 2: By design, PoCS Vol. 1 is not required. The books can be read out of order. and consequently with all the prerequisites entailed.

PoCS Vols. 3D, 4 Fourever, and V for Vendetta:

The extended PoCSverse continues with an optional Independent Studies course optionally offered in the fall, spring, and summer. These meetings will may run as research groups.

The Extra PoCS will go further into ousiometrics and telegnomics, the distant measurement and scientific study of essential meaning, knowledge, and stories presented by large-scale texts or other media (e.g., video, animal communication, signals from algorithmic systems). Specific topics will vary depending on year.

A throughline for students will be bringing projects they have developed in PoCS Volumes 1 and 2 to the form of published papers.

Students will be expected to work in teams, with each student leading their own project.

The goal for each project will be to:

1. Submit a first-author paper to arXiv (and/or other arXivs such as socarXiv, etc.), and
2. Begin the publication/review process by submitting the paper to a first journal of choice.

Though not yet reviewed, the arXiv paper marks the start of the paper's existence. It is a citeable document and will be connected with a later published version on Google Scholar.

Students will work with the universal paper template created by Dodds in the late 1990s and evolved continuously from that time:

https://github.com/petersheridandodds/universal-paper-template

Students will learn "how to write a scientific paper" both in the writing itself and how to structure LaTeX papers (we use lualaTeX).

Bits and pieces are collected in this unfinished manuscript:

"(Scientific) Writing: Ways, Guides, and True Unbreakable Rules"

https://pdodds.w3.uvm.edu/share/notes-on-writing-essay.pdf

LaTeX is the most powerful writing tool we have, and it is extraordinarily vast in possibility, particularly when coupled with scripting languages (Python, Perl). Extra PoCS presents an excellent venue to help graduate students and advanced undergraduates develop their knowledge and skills.

As just one example that brings writing and LaTeX scripting together, Dodds will help students structure their LaTeX documents with sentences as a primary object, and equations (and other LaTeX features) laid out in readable code format that is rendered beautifully in readable text format. An explanation of is here: "Better writing, editing, and thinking through the power of line breaks."

https://pdodds.w3.uvm.edu/writings/
2015-05-13better-writing-editing-thinking-with-line-breaks/

The instructor will help students develop their papers within Overleaf and, optionally, also locally on their machines.

Prerequisites: Students must have taken both PoCS Vols. 1 and 2, or be taking PoCS Vol. 2 concurrently, and have established a project that is leading to one or more journal papers.

Notes:

Each Volume of Principles of Complex Systems is a 3 credit course.

Both courses are designed for graduates and advanced undergraduates.

Potential topics:

(Note: this list is undoubtedly incomplete, in no particular order, and subject to change; more detailed treatments of many of the topics that follow will appear in the advanced courses.)

1. Fundamentals
   (a) Manifesto
   (b) Emergence
   (c) Statistical mechanics and universality
   (d) Path dependence
2. Measures of complexity
   (a) The poles of randomness and order
   (b) Basic notions of entropy and information theory
3. Scaling phenomena
   (a) Zipf's law
   (b) Non-Gaussian statistics and power law size distributions
   (c) Sample mechanisms for power law size distributions
   (d) Scaling for organisms and organizations
   (e) Scaling of social phenomena: crime, creativity, and consumption.
   (f) Renormalization techniques
4. Multiscale complex systems
   (a) Hierarchies and scaling
   (b) Modularity
   (c) Form and context in design
5. Complexity in abstract models
   (a) The game of life
   (b) Cellular automata
   (c) Chaos and order—creation and maintenance
6. Integrity of complex systems
   (a) Generic failure mechanisms
   (b) Highly optimized tolerance: Robustness and fragility
   (c) Network robustness
7. Complex networks
   (a) Random networks
   (b) Small-world networks
   (c) Scale-free networks
   (d) Optimal distribution networks
8. Collective behavior and contagion in social and sociotechnical systems
   (a) Percolation and phase transitions
   (b) Disease spreading models

(c) Schelling's model of segregation

(d) Granovetter's model of imitation

(e) Contagion on networks

(f) Herding phenomena

(g) Cooperation

(h) Wars and conflicts

9. Large-scale Social patterns

   (a) Movement of individuals

10. Collective decision making

    (a) Theories of social choice

    (b) The role of randomness and chance

    (c) Systems of voting

    (d) Juries

    (e) Success inequality: superstardom

11. Information

    (a) Search in networked systems (e.g., the internet, social systems)

    (b) Search on scale-free networks

    (c) Knowledge trees, metadata and tagging

12. More on complex networks:

    (a) Structure and form of complex networks including physical branching networks (river networks and cardiovascular networks), neural networks, social networks, the Internet, the world wide web, transportation networks, and organizations;

    (b) distribution versus redistribution networks;

    (c) properties of networks including degree distributions, clustering, motifs, various measures of betweenness, modularity, the role of randomness, network dynamics, and multiscale structures;

    (d) multilayer networks;

    (e) HOT networks;

    (f) temporal networks;

    (g) community detection algorithms;

    (h) bipartite networks;

    (i) weighted networks;

    (j) partly random networks as models of real world networks;

    (k) generating function techniques;

    (l) universal models including scale-free networks, p-star networks, and generative models;

    (m) small-world networks;

    (n) impedance and flow in networks;

    (o) connections between delivery networks and energy usage in organisms;

    (p) search in networks as facilitated by network structure and search methods;

    (q) generalized notions of contagion in networks;

(r) network epidemiology and fad spreading;

(s) computation considerations for analysing networks.

13. Stories

    (a) Contagious stories

    (b) Adjacent narratives

    (c) Conspiracy theories

    (d) Power of stories

    (e) How stories are everything

    (f) The Big Story

14. (a) Stories

    (b) Meaning

    (c) Emotions

    (d) Hedonometrics: The distant measurement of happiness and sadness, good and bad

    (e) Ousiometerics: The distant measurement of essential meaning

    (f) Archetypometrics: The distant measurement of character

    (g) Telegnomics: The distant measurement of knowledge

Prerequisites: Familiarity with the following would be good but not completely necessary: standard calculus, differential equations, difference equations, linear algebra, and statistical methods.

Computing: Proficiency in coding (e.g., Julia, python, R, Matlab) will be necessary for some assignments and projects. Data visualization skills are most welcome.

In general, students are exhorted to develop their unix skills across the board in our Complex Systems and Data Science programs. Good places: Apple's OSX is a Unix system and The VACC runs on Linux. Installing Linux on a Windows machine is the option there.

Textbooks: There is no specific textbook for the class. The course will draw on material from a wide range of sources and will provide students with journal papers as appropriate to supplement lecture notes.

Grading breakdown for PoCS, Vol. 1:

1. **Assignments (66%)**—All assignments will be of equal weight and there will be ten of them. Aside from correctness, clarity in thinking, writing, and presentation will be taken into account in grading.

   In general, 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.

   Assignments will be submitted via Brightspace

2. **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. Projects may take the form of novel research, investigation of an established area of complex systems, or both. Graduate students already pursuing appropriate research topics are welcom to use the class as a venue to present their work.

   A list of possible projects will be provided though individuals are encouraged and free to choose their own. Project content may range from novel research to a review of research relevant to the course. The hope here is for some work to percolate up to the level of journal publications. Students will give two brief presentations in the middle of the semester and a longer one at the end (length of talks will depend on class size). Students will also be required to hand in a report on their investigations.

   The grade breakdown will be 4% for the first talk, 8% for the final talk, and 12% for the written project.

3. **General attendance/Class participation (10%)**—it is highly desirable that students attend class and office hours. If the course is online, then the equivalent will be taking in videos/slides and attending online office hours through Microsoft Teams. Class presence/involvement will be taken into account if a grade is borderline.

Grading breakdown for PoCS, Vol. 2:

1. **Assignments (45%)**—All assignments will be of equal weight and there will around five or six of them. Aside from correctness, clarity in thinking, writing, and presentation will be taken into account in grading.

   In general, 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.

   Assignments will be submitted via Brightspace.

2. **Projects/talks (45%)**—Students will work on semester-long projects, continuing on from PoCS, Vol. 1.

   The grade breakdown will be 10% for the first talk, 15% for the final talk, and 20% for the written project.

3. **General attendance/Class participation (10%)**—it is required that students attend class and office hours. If the course is online, then the equivalent will be taking in videos/slides and attending online office hours through Microsoft Teams. Class presence/involvement will be taken into account if a grade is borderline.

   Each student has two free passes to not show up (but will still be expected to take in the relevant recorded class).

   Missed class without qualifying written reason (illness, sports, etc.): 1 percentage point deducted.

Grading breakdown for PoCS, Vol. 3 (if graded):

1. **Projects/talks (90%)**—Students will work on semester-long projects, leading to papers, and continuing on from PoCS, Vol. 1 and 2.

2. **General attendance/Class participation (10%)**.

Schedule for Volume 1 (ordering and topics may change):

Week #	Tuesday	Thursday
1	Overview; Fundamentals: The Complexity Manifesto	Scaling
2	Power-law size distributions	Zipf's law; Fundamentals:
3	Allotaxonometry	Power-law mechanisms: Randomness
4	Power-law mechanisms: Variable Transformation	Power-law mechanisms: The Rich-Get-Richer
5	Power-law mechanisms: Optimization	Fundamentals: Statistical Mechanics;
6	Robustness and Fragility	Optimal distribution networks
7	Fundamentals: Data, Emergence, Limits to Understanding;	First project presentations
8	Complex networks: Introduction Basics and Examples	Complex networks: Key Properties Generalized random networks
9	Complex networks: Small-world networks	Complex networks: Small-world networks
10	Complex networks: Scale-free networks	Contagion: Introduction
11	The Unpredictability of Pandemics	COVID-19
12	Social contagion	Social Contagion
13	Social Contagion	Voting, Success, Fame
14	Thanksgiving	Thanksgiving
15	Stories	The Big Story: Complexification

Schedule for Volume 2:

Adaptive.

Schedule for Volume 3D, 4 Fourever, and V for Vendetta:

Adaptive.

Final projects:

Final project presentations will likely be given in the final exam period for the relevant semester for Vols. 1 and 2.

Times may be adjusted based on class size.

Do check Instructions on the course's site for updates regarding the course.

The other place to check is Teams.

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.

Being good people: In class there will be no unnecessary electronic gadgetry, no cell phones, no beeping, no text messaging, etc. You really just need your brain, some paper, and a writing implement. ~~Those who beep in an annoying fashion will be fined one organic banana by the lecturer.~~

We encourage you to use the course's Teams site to ask questions, share ideas, comments, etc., about the class and assignments but request that you please do so in a respectful fashion.

No laptops in class. Please take notes with paper or a flat tablet.

All interactions with classmates during lectures and office hours or in any way related to being part of PoCS should be respectful. As in all UVM classes, **Academic honesty** will be expected and departures will be dealt with appropriately. We will follow UVM's community standards and guidelines. See https://www.uvm.edu/cses/.

Late policy: Unless in the case of an emergency (a real one) or if an absence has been predeclared and a make-up version sorted out, assignments that are not turned in on time or tests that are not attended will be given 0%.

Grades:

A+	97–100	B+	87–89	C+	77–79	D+	67–69
A	93–96	B	83–86	C	73–76	D	63–66
A-	90–92	B-	80–82	C-	70–72	D-	60–62