

Why Complexify?

Principles of Complex Systems | @pocsvox
CSYS/MATH 300, Fall, 2016 | #FallPoCS2016

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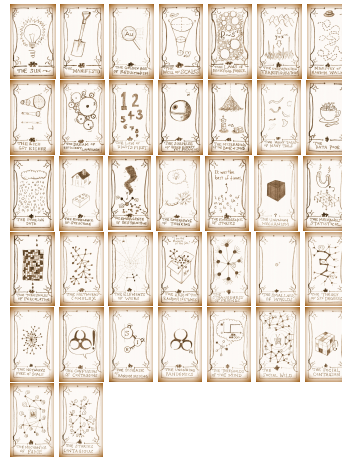
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Why Complexify?

- Universality
- Symmetry Breaking
- The Big Theory
- Final words
- For your consideration
- References



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Limits to what's possible:

Universality

- The property that the macroscopic aspects of a system do not depend sensitively on the system's details.
- Key figure: [Leo Kadanoff](#)
- Kadanoff's retrospective: "Innovations in Statistics Physics" [3]

Examples:

- The Central Limit Theorem:

$$P(x; \mu, \sigma) dx = \frac{1}{\sqrt{2\pi\sigma}} e^{-(x-\mu)^2/2\sigma^2} dx.$$
- Navier Stokes equation for fluids.
- Nature of phase transitions in statistical mechanics.

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Outline

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Universality

- Sometimes **details don't matter too much.**
- Many-to-one mapping from micro to macro
- Suggests not all possible behaviors are available at higher levels of complexity.
- Universality means some things are fated.

Large questions:

- How universal is universality?
- What are the possible long-time states (attractors) for a universe?

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Fluid mechanics

- 🔗 Fluid mechanics = One of the great successes of understanding complex systems.
- 🔗 Navier-Stokes equations: micro-macro system evolution.
- 🔗 The big three: Experiment + Theory + Simulations.
- 🔗 Works for many very different 'fluids':
 - 📦 the atmosphere,
 - 📦 oceans,
 - 📦 blood,
 - 📦 the earth's mantle,
 - 📦 galaxies, ...
 - 📦 **and ball bearings on lattices ...?**

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Hexagons—Giant's Causeway: [↗](#)



<http://newdesktopwallpapers.info>

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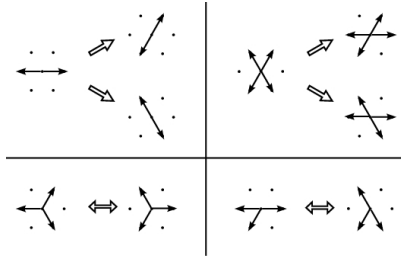
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Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



- 🔗 Lattice matters ...
- 🔗 No 'good' lattice in 3-d.
- 🔗 Upshot: play with 'particles' of a system to obtain new or specific macro behaviours.

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Hexagons—Giant's Causeway: [↗](#)



<http://www.physics.utoronto.ca/>

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Hexagons—Honeycomb: [↗](#)



- 🔗 Orchestrated? Or an accident of bees working hard?
- 🔗 See "On Growth and Form" by D'Arcy Wentworth Thompson [↗](#). [6, 7]

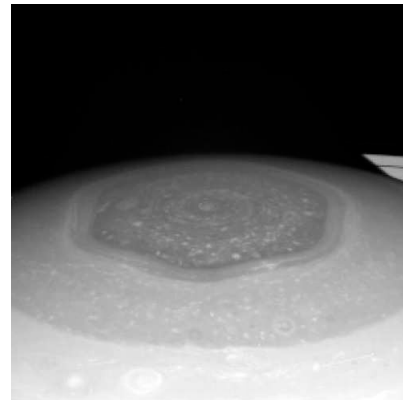
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Saturn has a hexagon: [↗](#)



- 🔗 One side is longer than Earth's diameter [↗](#)

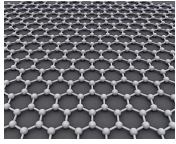
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Hexagons run amok:



[Graphene](#): single layer of carbon molecules in a perfect hexagonal lattice (super strong).



[Chicken wire](#) ...

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Symmetry Breaking



“More is different”
P. W. Anderson,
Science, **177**, 393–396, 1972. [1]



Anderson argues against idea that the only real scientists are those working on the fundamental laws.

Symmetry breaking → different laws/rules at different scales ...

2006 study: “most creative physicist in the world”

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“Elementary entities of science X obey the laws of science Y”

X
 solid state or many-body physics
 chemistry

 molecular biology
 cell biology
:
 psychology
 social sciences

Y
 elementary particle physics
 solid state many-body physics
 chemistry
 molecular biology
:
 physiology
 psychology

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Anderson:

[the more we know about] “fundamental laws, the less relevance they seem to have to the very real problems of the rest of science.”

Scale and complexity thwart the constructionist hypothesis.

Accidents of history and path dependence matter.

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Triumph of the Hexagon

From the remarkable [Hexnet.org](#), the Global Hexagonal Awareness Resource Center.



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Symmetry Breaking



“Critical Phenomena in Natural Sciences” [4]
by Didier Sornette (2003). [4]

- Page 291–292 of Sornette [5]: Renormalization \equiv Anderson’s hierarchy.
- But Anderson’s hierarchy is not a simple one: the rules change.
- Crucial dichotomy between evolving systems following stochastic paths that lead to (a) inevitable or (b) particular destinations (states).

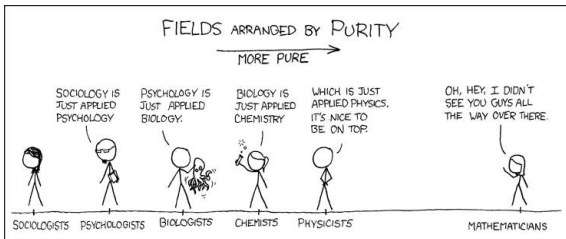
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More is different:



<http://xkcd.com/435/>

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A real science of complexity:

A real theory of everything anything:

- Is not just about the ridiculously small stuff ...
- It's about the increase of complexity

Symmetry breaking/
Accidents of history vs. Universality

- Second law of thermodynamics: we're toast in the long run.
- So how likely is the local complexification of structure we enjoy?
- How likely are the Big Transitions?

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Why complexify?



“Why do things become more complex?”
W. Brian Arthur,
Scientific American, 268, 92, 1993. [2]

- Argues that evolution toward increased performance brings a ratcheting cycle of complexification and simplification.
- Jet engine replaced the complex piston engine and then itself became more complex.
- Complexification \equiv evolution of algorithms?
- Differential equations and stories \subset Algorithms.
- Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

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Driving complexity's trajectory:

- Big Bang
- Randomness leads to replicating structures;
- Biological evolution;
- Sociocultural evolution;
- Technological evolution;
- Sociotechnological evolution.

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Complexification—the Big Transitions:

- | | | |
|-----------------|--------------|------------------|
| Big Bang. | Big Word. | Big Science. |
| Big Randomness. | Big Story. | Big Data. |
| Big Structure. | Big Number. | Big Information. |
| Big Replicate. | Big Farm. | Big Algorithm. |
| Big Life. | Big God. | Big Connection. |
| Big Evolve. | Big Make. | Big Social. |
| | Big City. | Big Awareness. |
| | Big Culture. | Big Spread. |
| | | Big ...? |

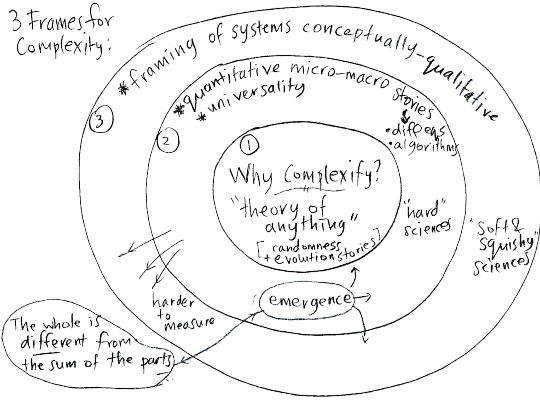
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3 Frames for Complexity:

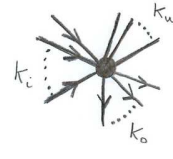


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This is a thing that could be next:

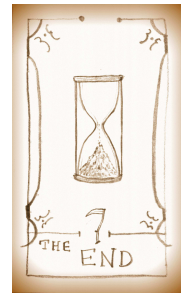
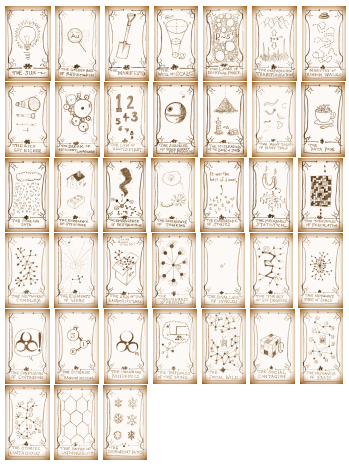
CoNKs: The PoCS strikes back:



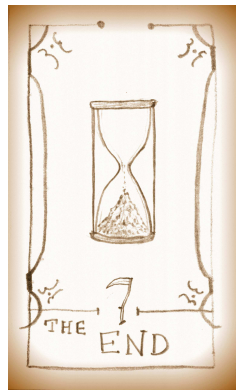
CSYS/MATH 303:
Complex Networks
@networksvox

- ☄ Branching networks (rivers, cardiovascular systems).
- ☄ Optimal (re)distribution networks (hospitals, coffee shops, airlines, post, Internet).
- ☄ Structure detection for complex systems.
- ☄ Moar Contagion.
- ☄ Random networks-arama.
- ☄ Distributed Search.
- ☄ Organizational networks.
- ☄ Deeper investigations of scale-free networks.
- ☄ and more ...

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The absolute basics:

Modern basic science in three steps:

1. Find interesting/meaningful/important phenomena, optionally involving spectacular amounts of data.
2. Describe what you see.
3. Explain it.

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions: Don't use tools/models because they're there, or because everyone else does ...

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References I

- [1] P. W. Anderson. More is different. [Science, 177\(4047\):393-396, 1972. pdf](#)
- [2] W. B. Arthur. Why do things become more complex? [Scientific American, 268:92, 1993. pdf](#)
- [3] L. P. Kadanoff. Innovations in statistical physics, 2014. [http://arxiv.org/abs/1403.6464. pdf](http://arxiv.org/abs/1403.6464)
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- [5] D. Sornette.
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- [6] D. W. Thompson.
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- [7] D. W. Thompson.
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