Why Complexify?

Principles of Complex Systems | @pocsvox
CSYS/MATH 300, Fall, 2017

Prof. Peter Dodds | @peterdodds

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

The University of Vermont

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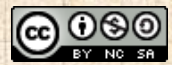
What's the Story?



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Outline

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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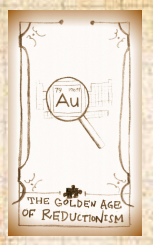
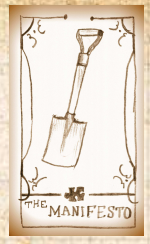
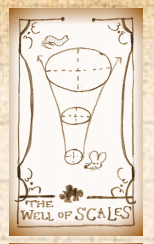
What's the Story?


THE SUN


Au
THE GOLDEN AGE OF REDUCTIONISM

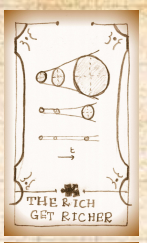

THE MANIFESTO

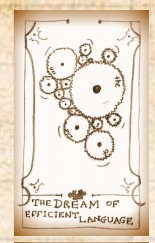

THE WELL OF SCALES


THE LAWS OF DECAYING POWER


MINISTRY OF RANDOM WALKS


THE UNEXPECTED TRANSFIGURATION


THE RICH GET RICHER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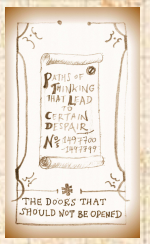
THE DATA POOR


THE POURING DATA


THE CHARMS OF THE MANY WRONG PATHS


THE KNOWLEDGE OF DEAD MONKS


THE DOORS THAT SHOULD NOT BE OPENED


THE EMERGENCE OF STRUCTURE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It was the best of times,
THE EMERGENCE OF STORIES


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THE THRESHOLDS OF PERCOLATION


THE NETWORKS COMPLEX


THE ELEMENTS OF WEBS


"I am the Monarch of the Sea."
THE ARK OF THE RANDOM NETWORK


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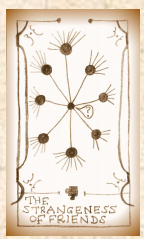
THE BIRDS OF NOT A FEATHER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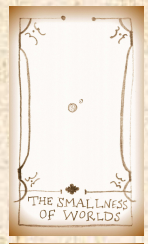
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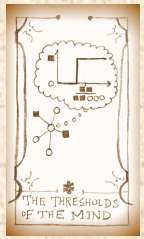
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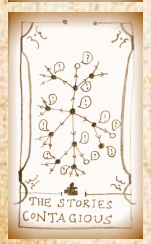
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THE TROUSERS OF BIFURCATING REALITIES


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THE UNKNOWN MECHANISM


THE JOHN DORY


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THE END


THE PATHS OF UNIVERSALITY

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:

$$P(x;\mu,\sigma)\mathrm{d}x = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\mu)^2/2\sigma^2}\mathrm{d}x\,,$$

- Navier Stokes equation for fluids.
- Nature of phase transitions in statistical mechanics.

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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

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- Navier-Stokes equations: micro-macro system evolution.
- The big three: Experiment + Theory + Simulations.
- Works for many very different ‘fluids’:
  - the atmosphere,
  - oceans,
  - blood,
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  - galaxies, ...
  - and ball bearings on lattices...?

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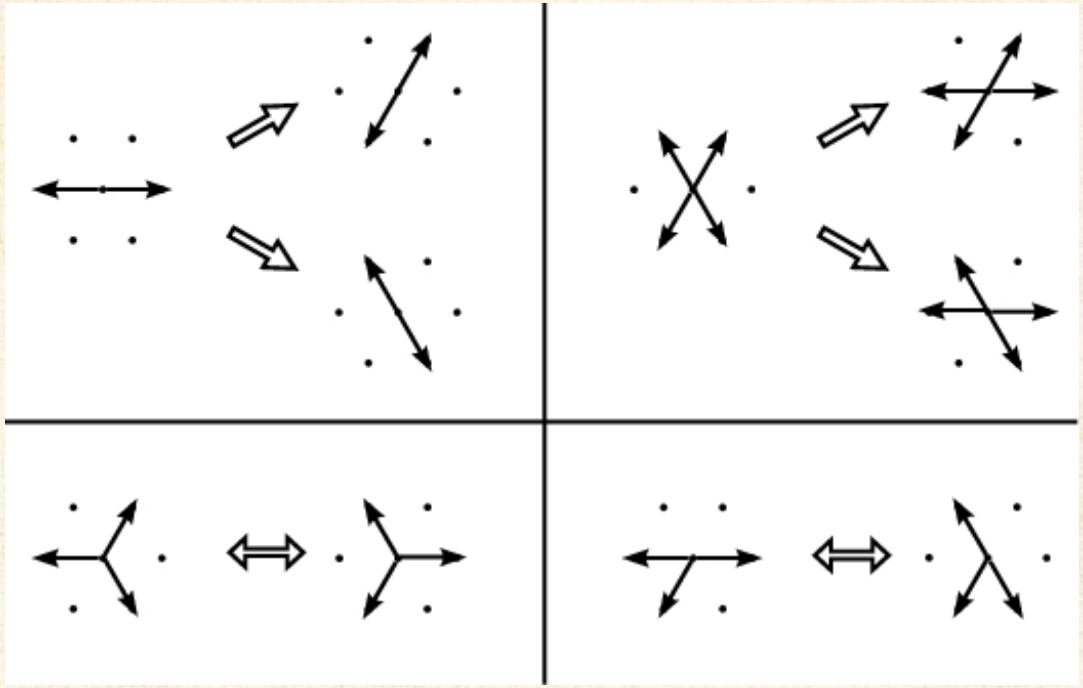
Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



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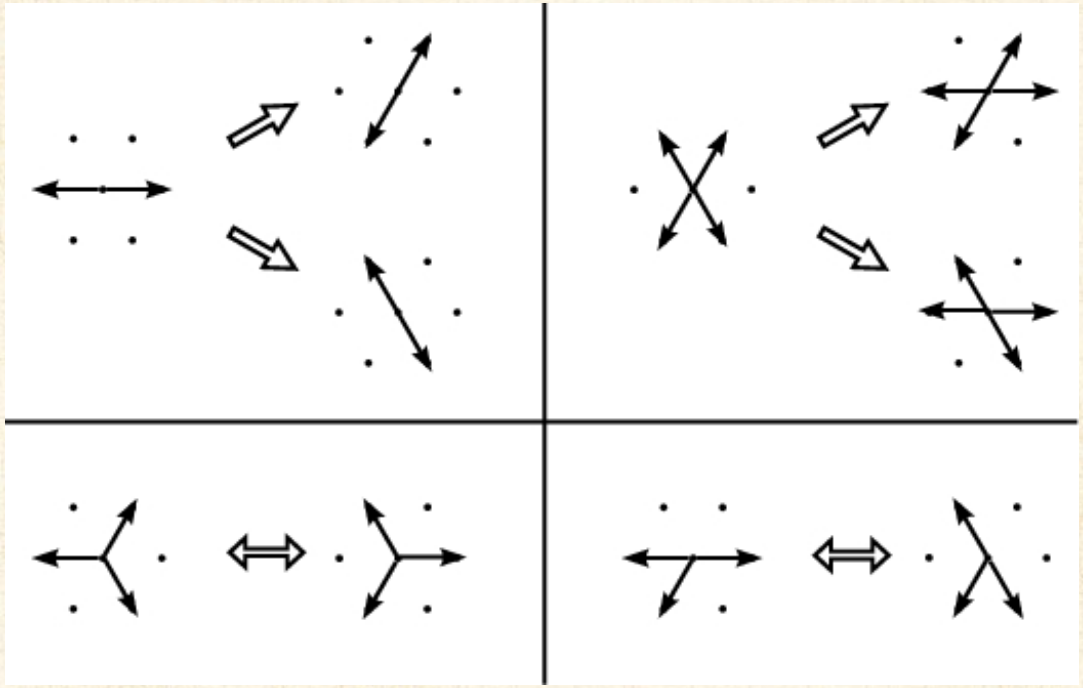

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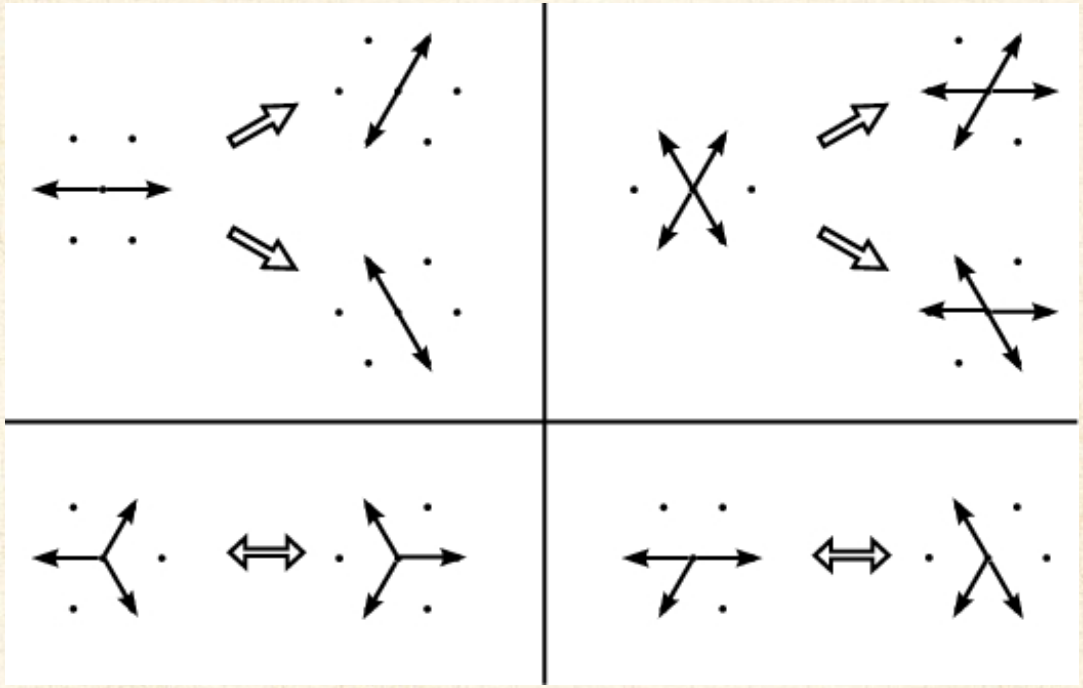

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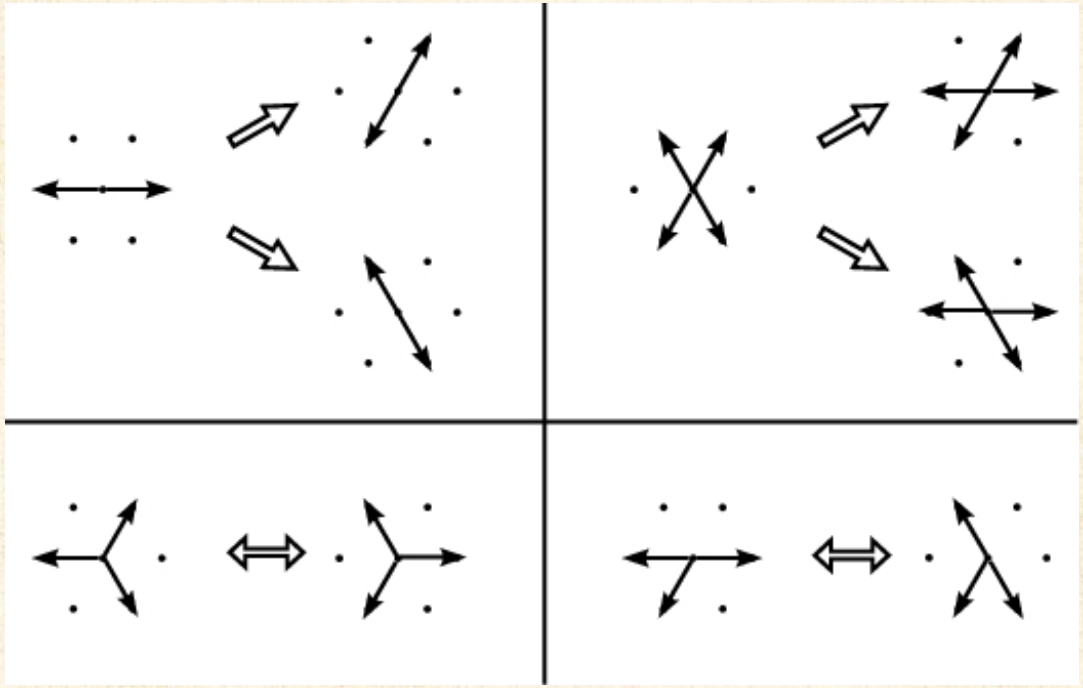

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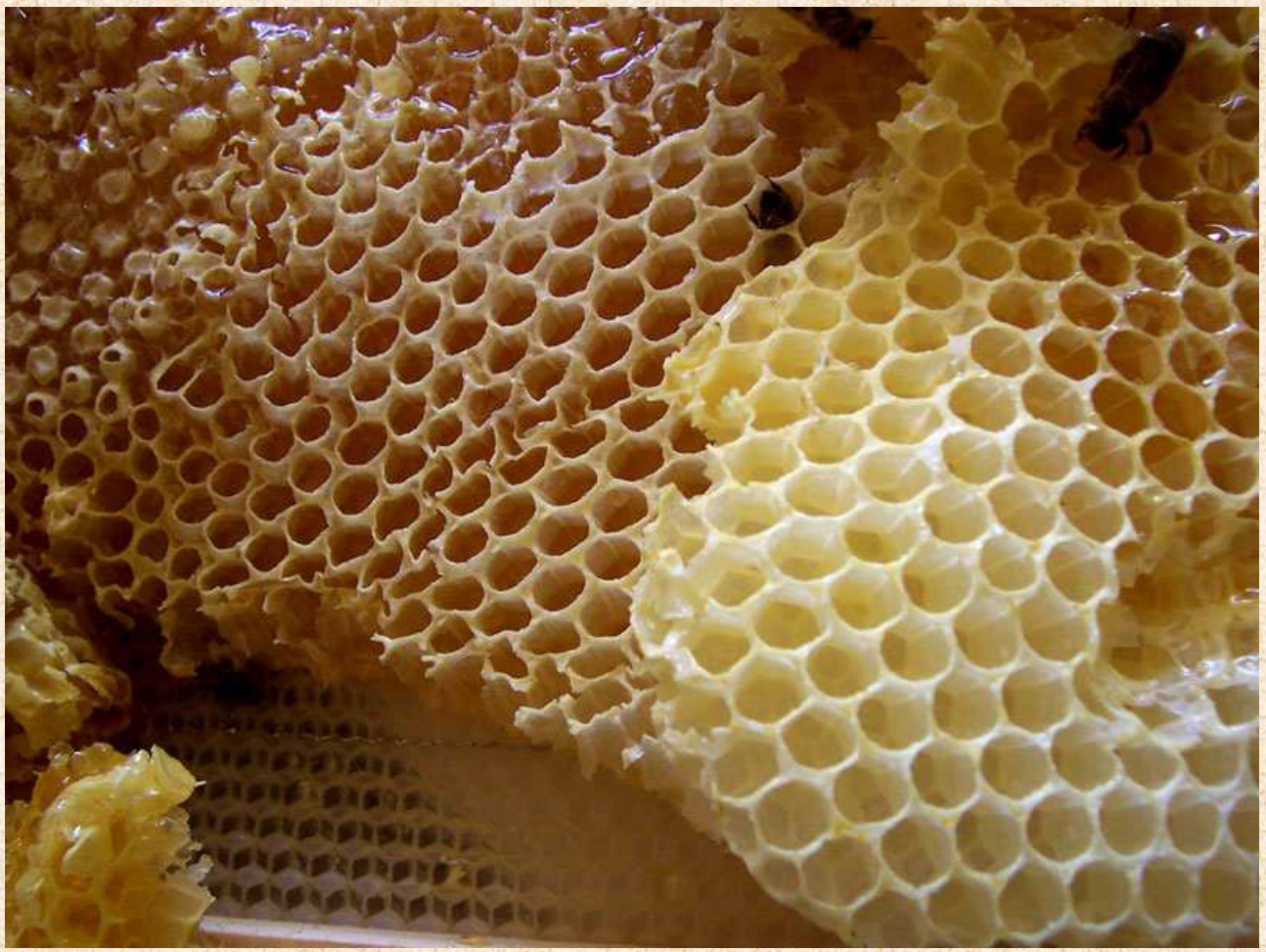
Hexagons—Honeycomb:



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- See "On Growth and Form" by D'Arcy Wentworth Thompson [6, 7]

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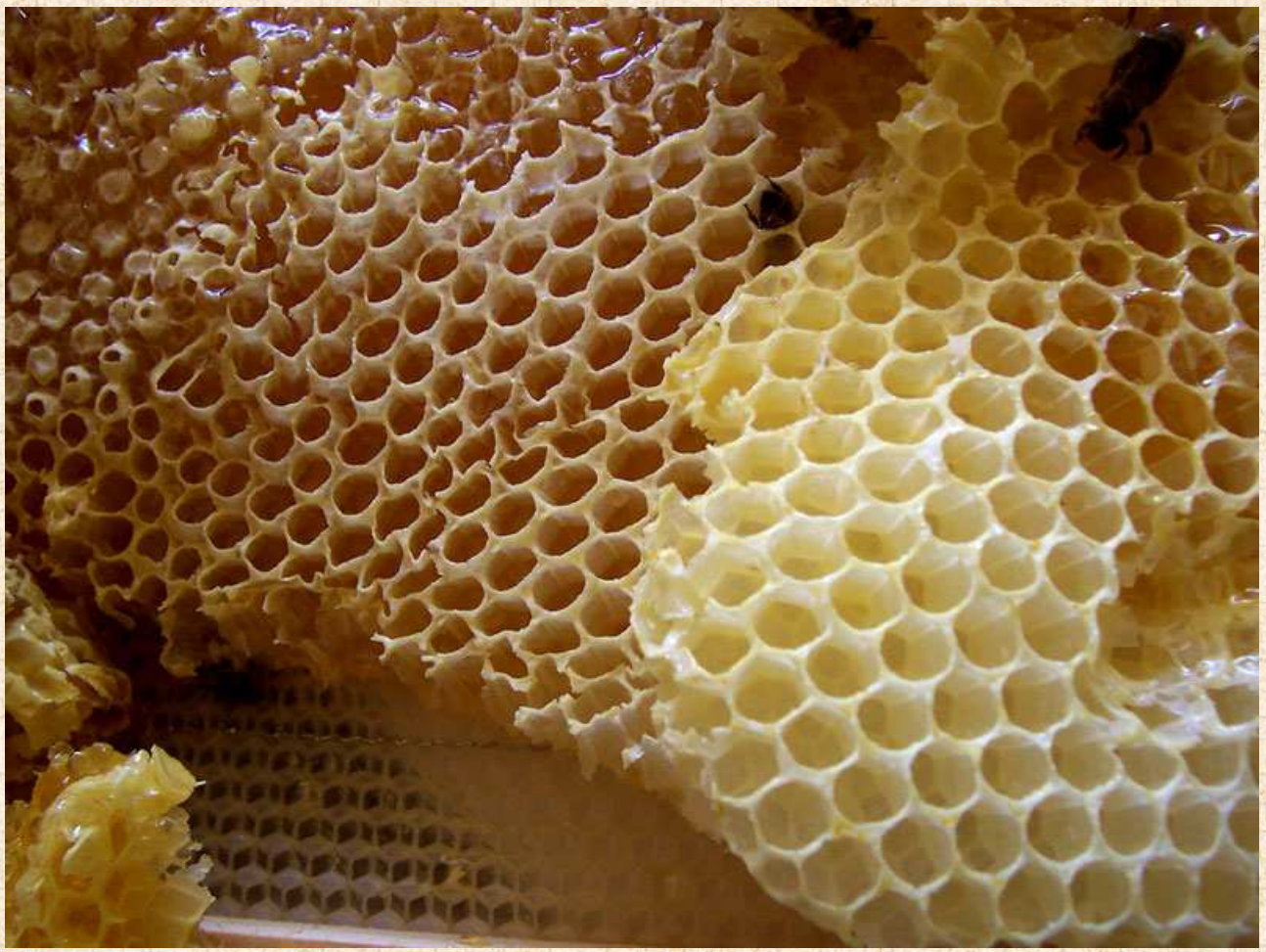

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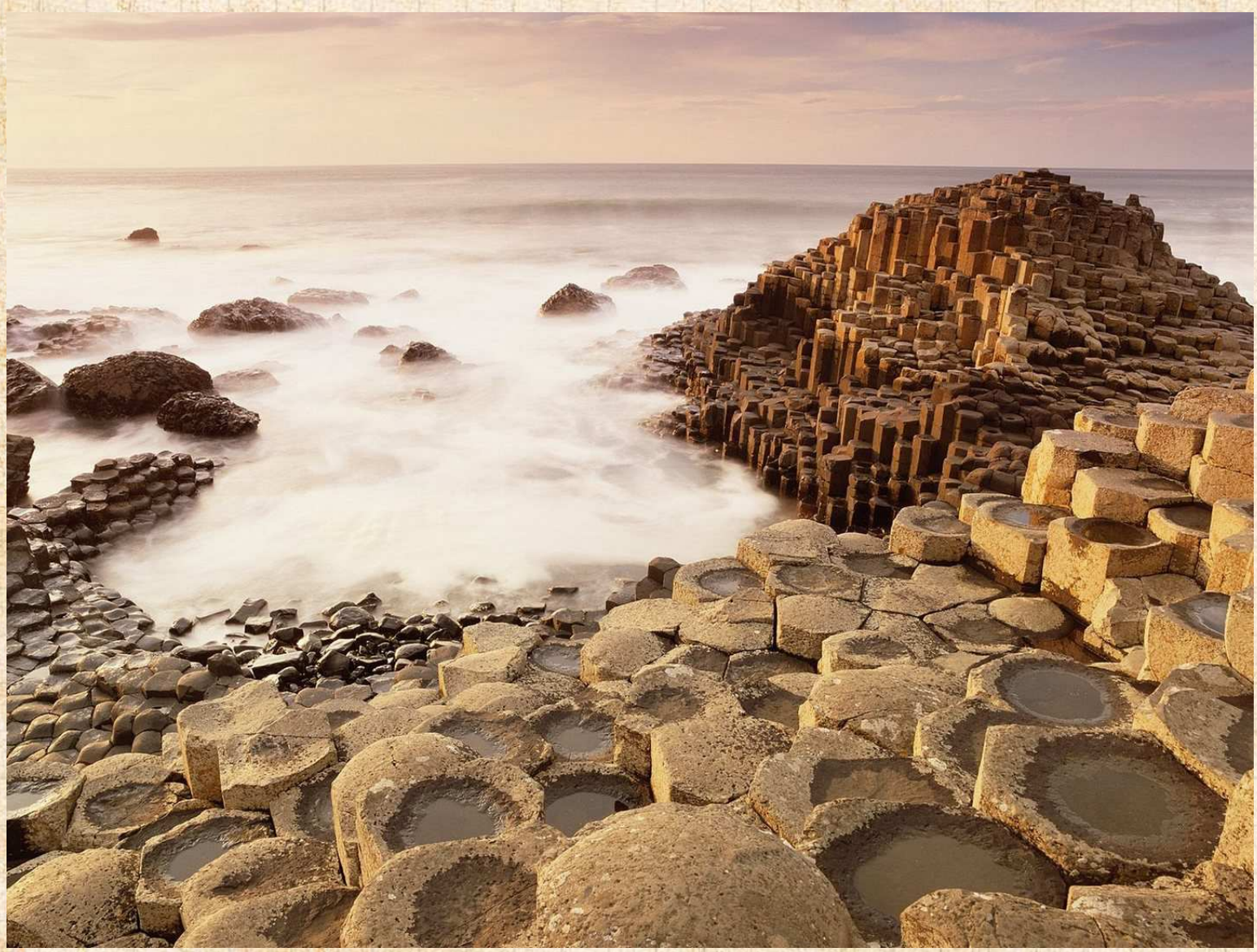
Hexagons—Giant's Causeway:

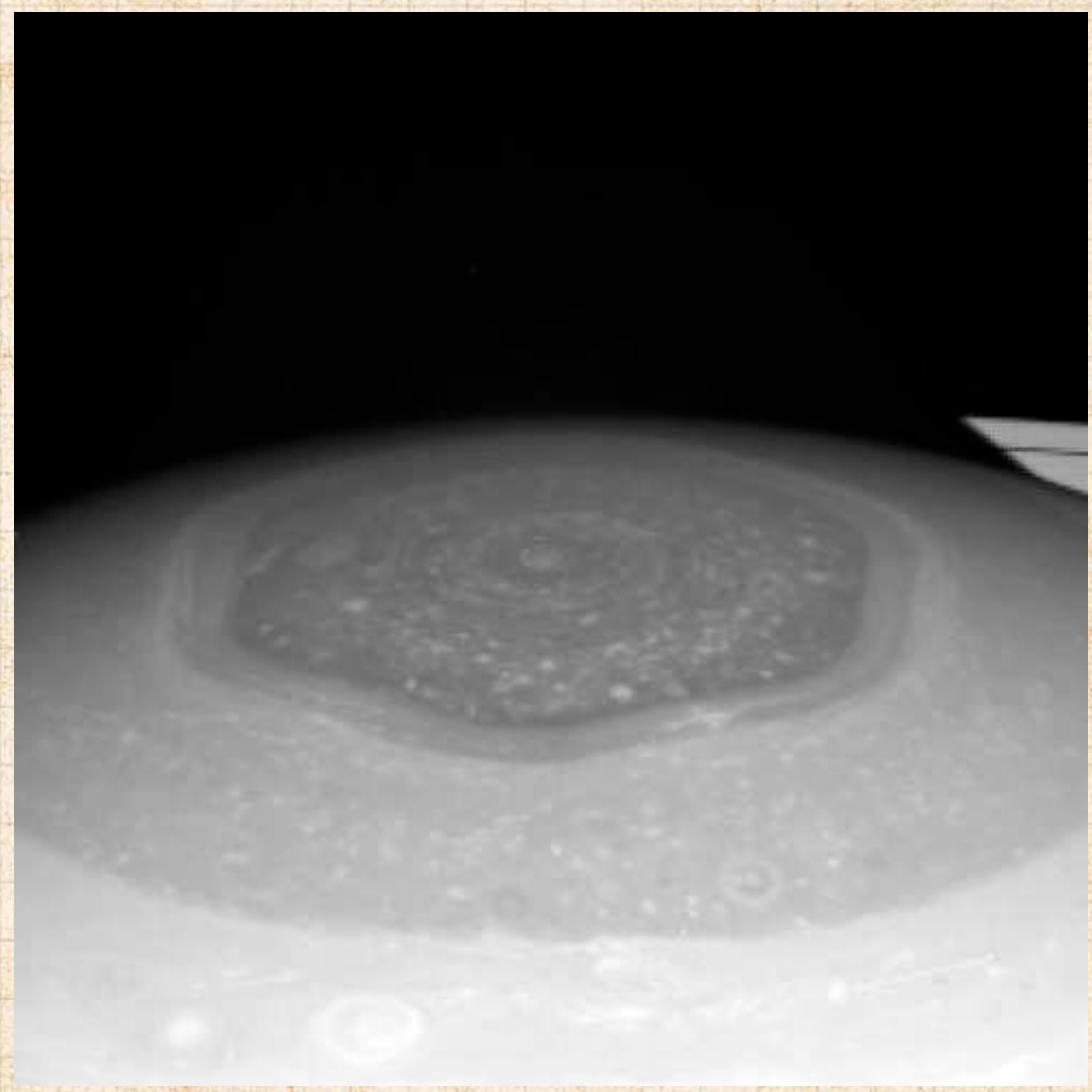


http://newdesktopwallpapers.info

Hexagons—Giant's Causeway:

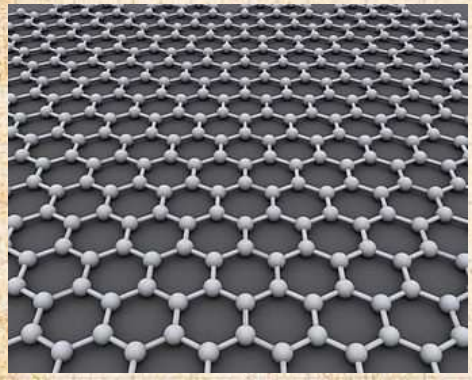
http://www.physics.utoronto.ca/

Saturn has a hexagon:



One side is longer than Earth's diameter

Hexagons run amok:



- Graphene: single layer of carbon molecules in a perfect hexagonal lattice (super strong).
- Chicken wire ...

Triumph of the Hexagon

http://www.youtube.com/watch?v=xyY0ymMYXPo?rel=0

From the remarkable Hexnet.org, the Global Hexagonal Awareness Resource Center.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THE DEPENDENT PATHS

Symmetry Breaking


SCIENCE

More Is Different

Broken symmetry and the nature of the hierarchical structure of science.

P. W. Anderson

"More is different"
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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 ...


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2006 study: "most creative physicist in the world"

Symmetry Breaking

"Elementary entities of science X obey the laws of science Y"

X	Y
solid state or many-body physics	elementary particle physics
chemistry	solid state many-body physics
molecular biology	chemistry
cell biology	molecular biology
⋮	⋮
psychology	physiology
social sciences	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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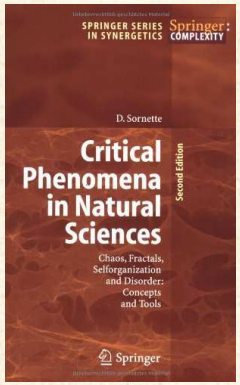

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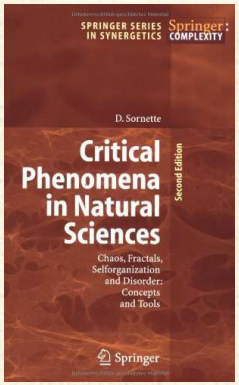

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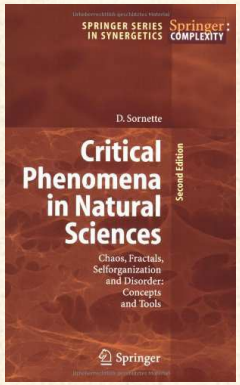

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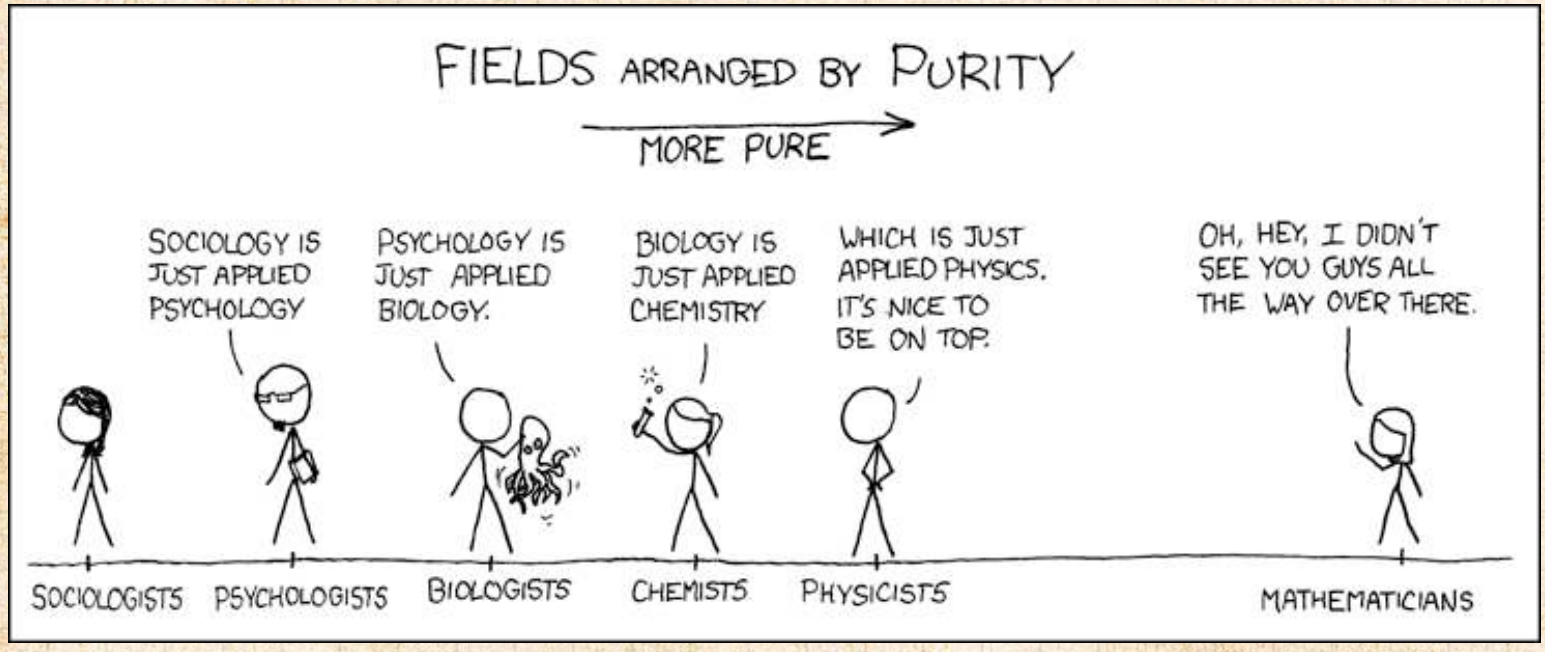
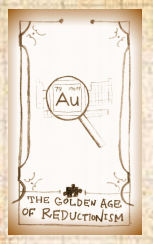
- But Anderson's hierarchy is not a simple one: the rules change.
- Crucial dichotomy between evolving systems following stochastic paths that lead to (a) inevitable or (b) particular destinations (states).

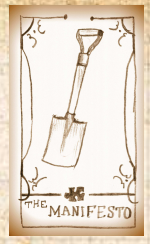
More is different:

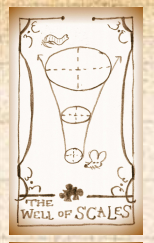


http://xkcd.com/435/


THE SUN


Au
THE GOLDEN AGE OF REDUCTIONISM

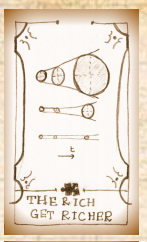

THE MANIFESTO

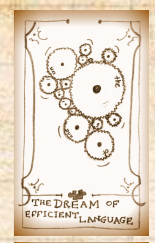

THE WELL OF SCALES


THE LAWS OF DECAYING POWER


MINISTRY OF RANDOM WALKS


THE UNEXPECTED TRANSFIGURATION


THE RICH GET RICHER


THE DREAM OF EFFICIENT LANGUAGE


THE LAW OF DIGITS FIRST


THE SURPRISE OF BEING BORN TO A FAMILE


THE MISREADING OF THE BOOK OF SAND


THE SUPPLY MOST FAIR


THE SUPPLY TO THE MOST


THE MANY TALES OF MANY TAILS

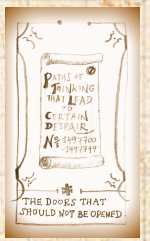

THE MEASURING


THE DATA POOR


THE POURING DATA


THE CHARMS OF THE MANY WRONG PATHS


THE KNOWLEDGE OF DEAD MONKS

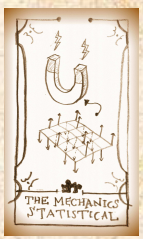

PATHS OF THINKING THAT LEAD TO CERTAIN DESPAIR
THE DOORS THAT SHOULD NOT BE OPENED

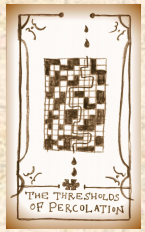

THE EMERGENCE OF STRUCTURE


THE EMERGENCE OF DESTRUCTION


THE EMERGENCE OF THINKING


It was the best of times,
THE EMERGENCE OF STORIES


THE MECHANICS STATISTICAL


THE THRESHOLDS OF PERCOLATION

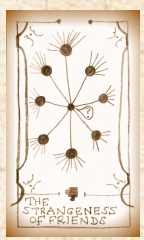

THE NETWORKS COMPLEX

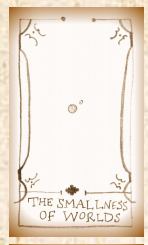

THE ELEMENTS OF WEBS


"I am the Monarch of the Sea."
THE ARK OF THE RANDOM NETWORK


THE BIRDS OF A FEATHER


THE BIRDS OF NOT A FEATHER


THE STRANGENESS OF FRIENDS


THE SMALLNESS OF WORLDS


THE THEORY OF SIX DEGREES


THE NETWORKS FREE OF SCALE


CLASSIFIED PHOENIX BIO HAZARD
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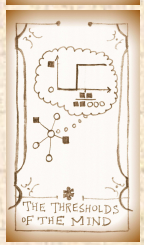
THE DISEASE OF RANDOM MIXING


THE UNENDING PANDEMICS


THE RATIO OF GAIN


THE THRESHOLDS OF THE MIND


THE SOCIAL WILD


THE SOCIAL CONTAGION


THE MECHANICS OF FAME


THE STORIES CONTAGIOUS


THE PATHS OF UNIVERSALITY

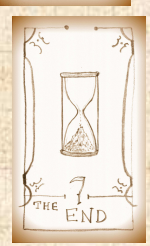

THE DEPENDENT PATHS

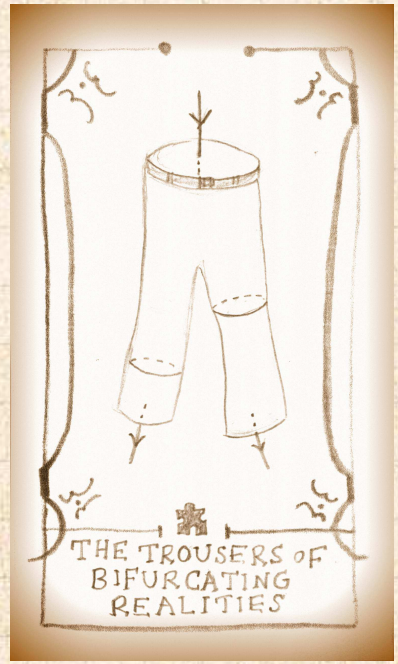

?
THE UNKNOWN MECHANISM


THE JOHN DORY


THE STORYTELLERS


THE ADJACENT NARRATIVES


7
THE END


THE TROUSERS OF BIFURCATING REALITIES

A real science of complexity:

A real theory of ~~everything~~ anything:

1. Is not just about the ridiculously small stuff …
2. 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?


ESSAY

Why Do Things Become More Complex?

"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 ≡ evolution of algorithms?
- Differential equations and stories ⊂ Algorithms.
- Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

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Why complexify?

Driving complexity's trajectory:

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

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What's the Story?

Complexification—the Big Transitions:

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

PoCS
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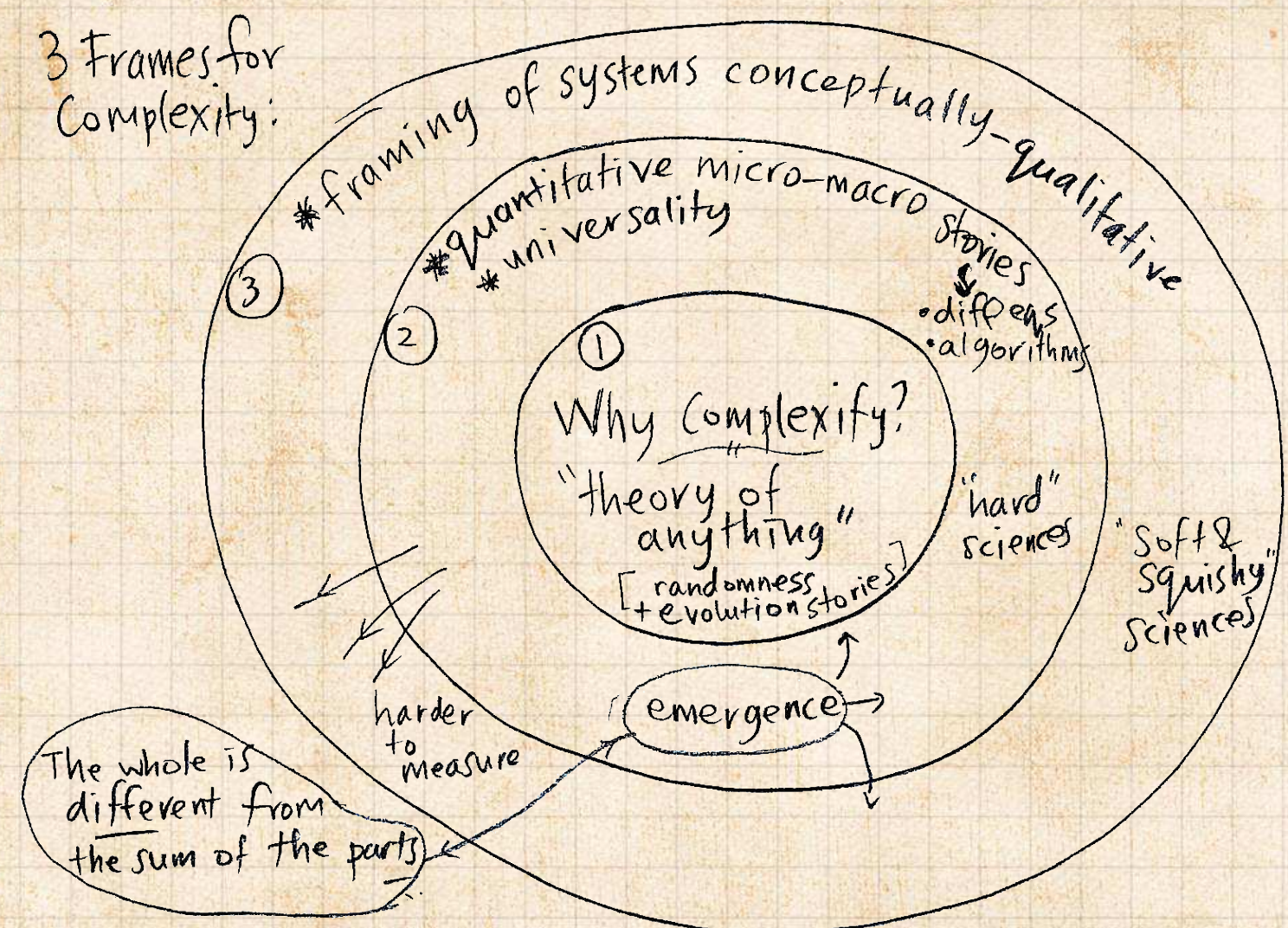
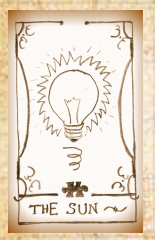
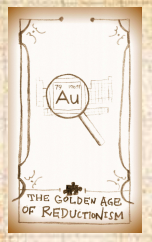
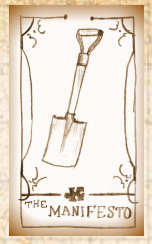
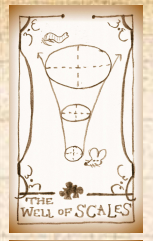
What's the Story?




THE SUN


Au
THE GOLDEN AGE OF REDUCTIONISM

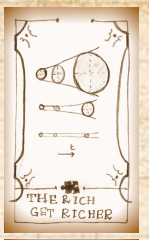

THE MANIFESTO

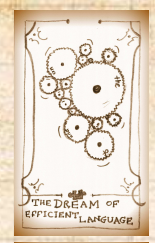

THE WELL OF SCALES


THE LAWS OF DECAYING POWER


MINISTRY OF RANDOM WALKS


THE UNEXPECTED TRANSFIGURATION


THE RICH GET RICHER


THE DREAM OF EFFICIENT LANGUAGE


THE LAW OF DIGITS FIRST


THE SURPRISE OF BEING BORN TO FRAGILE


THE MISREADING OF THE BOOK OF SAND


THE SUPPLY MOST FAIR


THE SUPPLY TO THE MOST


THE MANY TALES OF MANY TAILS

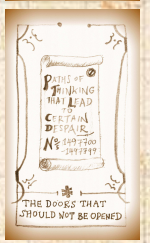

THE MEASURING


THE DATA POOR


THE POURING DATA


THE CHARMS OF THE MANY WRONG PATHS

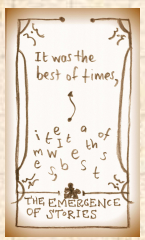

THE KNOWLEDGE OF DEAD MONKS

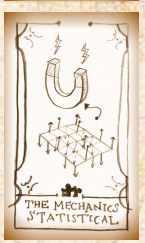

PATHS OF THINKING THAT LEAD TO CERTAIN DESPAIR
THE DOORS THAT SHOULD NOT BE OPENED

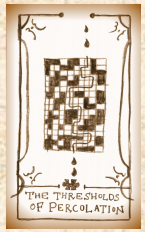

THE EMERGENCE OF STRUCTURE


THE EMERGENCE OF DESTRUCTION


THE EMERGENCE OF THINKING


It was the best of times,
THE EMERGENCE OF STORIES


THE MECHANICS STATISTICAL


THE THRESHOLDS OF PERCOLATION

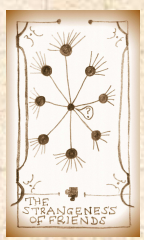

THE NETWORKS COMPLEX

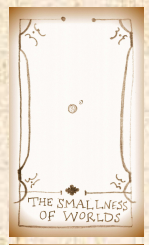

THE ELEMENTS OF WEBS


"I am the Monarch of the Sea."
THE ARK OF THE RANDOM NETWORK


THE BIRDS OF A FEATHER


THE BIRDS OF NOT A FEATHER


THE STRANGENESS OF FRIENDS

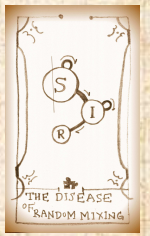

THE SMALLNESS OF WORLDS


THE THEORY OF SIX DEGREES


THE NETWORKS FREE OF SCALE


CLASSIFIED PHOENIX BIO HAZARD
THE CONTAGION


THE CONFUSION OF CONTAGIONS


THE DISEASE OF RANDOM MIXING


THE UNENDING PANDEMICS

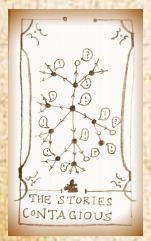

THE RATIO OF GAIN


THE THRESHOLDS OF THE MIND


THE SOCIAL WILD

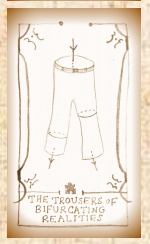

THE SOCIAL CONTAGION


THE MECHANICS OF FAME


THE STORIES CONTAGIOUS


THE PATHS OF UNIVERSALITY


THE DEPENDENT PATHS

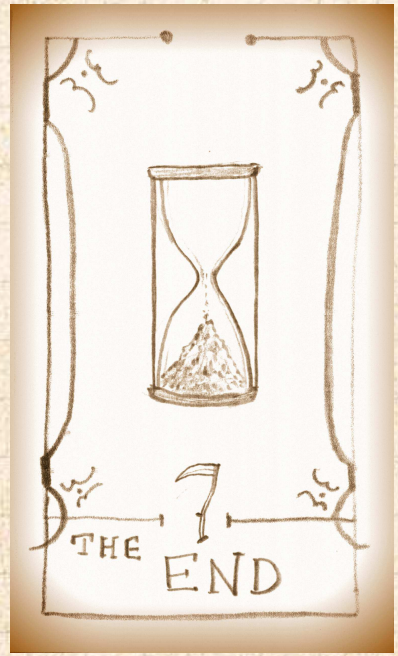

THE TROUSERS OF BIFURCATING REALITIES


?
THE UNKNOWN MECHANISM


THE JOHN DORY


THE STORYTELLERS


THE ADJACENT NARRATIVES


THE END

The absolute basics:

Modern basic science in three steps:

1. Find interesting/meaningful/important phenomena, optionally involving spectacular amounts of data.
2. Taste matters. Develop taste in research.
3. Describe what you see.
4. Explain it.

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

And be good people: Share.

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

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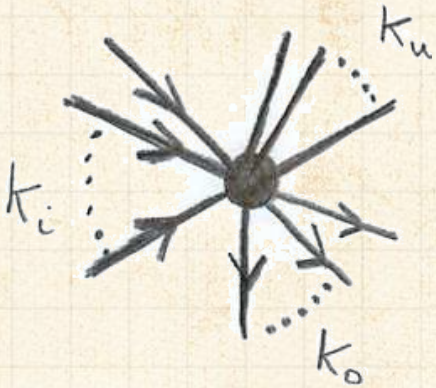
This is a thing that could be next:

CocoNuTs:
The PoCS strikes back



- 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 ...

CSYS/MATH 303:
Complex Networks
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@storyologyvox

PoCS
Principles of Complex Systems
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What's the Story?

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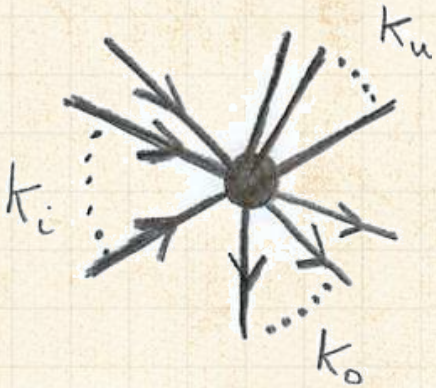

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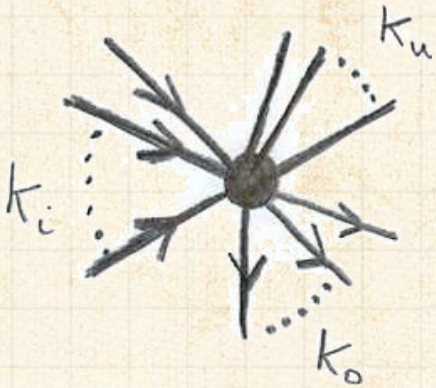

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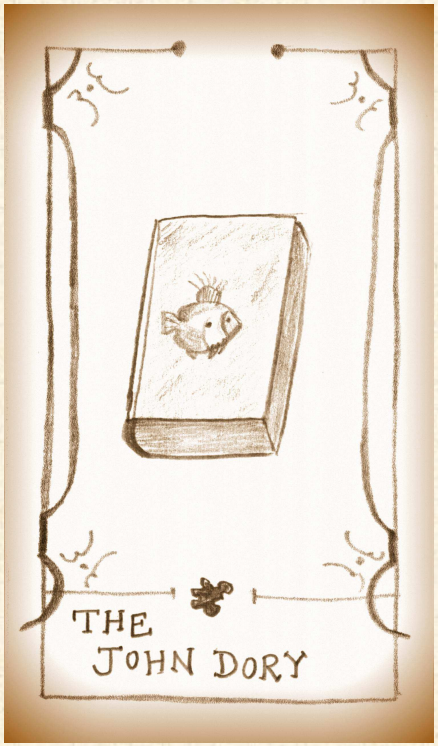
What's the Story?

This is also a thing that could be next:

Storyology
Episode VI:
PoCS with ewoks



- Exploring texts of all kinds, centrality of stories.
- News, social media, fiction, Twitter.
- Dark arts of text parsing, cleaning, regular expression.
- Measuring happiness and sadness through text.
- Measuring and understanding cultural evolution through texts: legal and government texts, music lyrics, news.
- Structure, dynamics, and evolution of stories.
- Possible expansion to other storytelling realms: Music, images, audio, video, sports, games.

CSYS/MATH ???:
@storyologyvox

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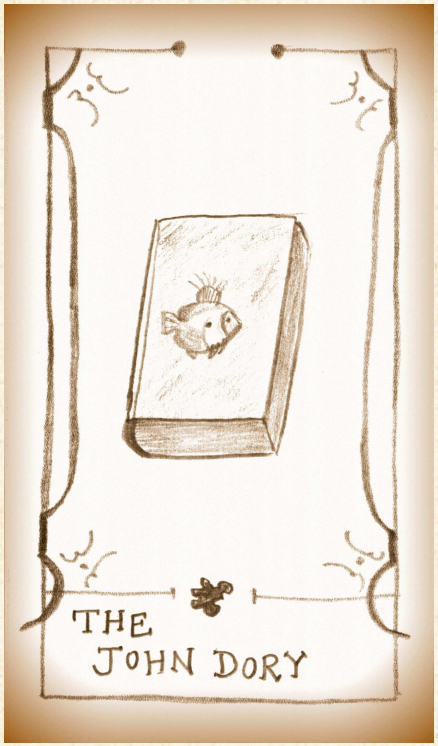

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CSYS/MATH ???:
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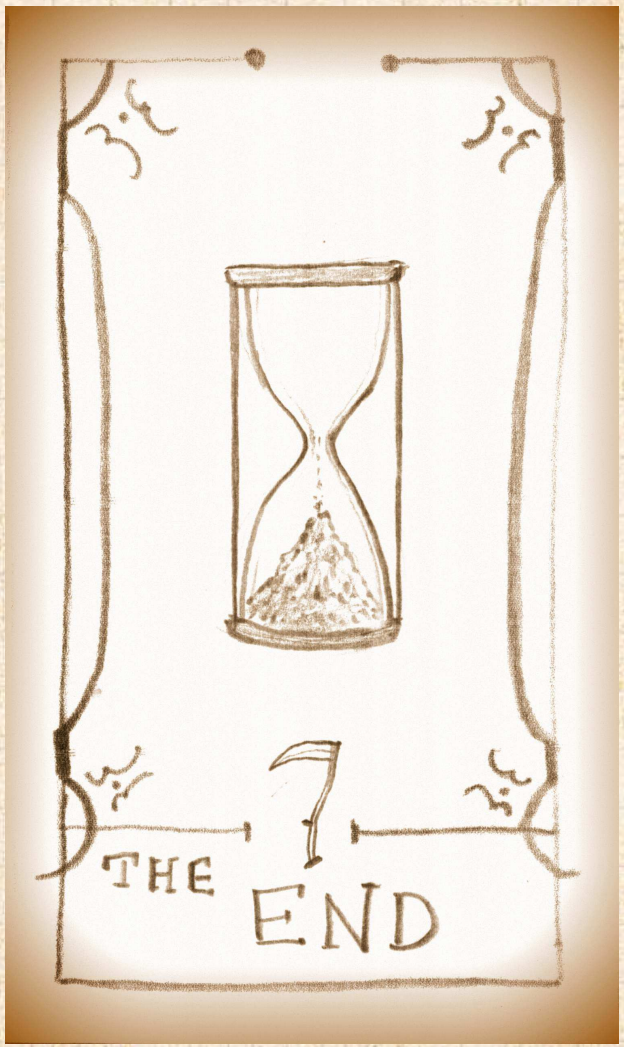

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