Outline

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References
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.

**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.
Universality

- Sometimes \textit{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.

Large questions:
- How universal is universality?
- What are the possible of long-time states (attractors) for a universe?
Fluids 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,
  - galaxies,
  - the earth’s mantle...
  - and ball bearings on lattices...?
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.
Hexagons—Honeycomb: (_hexagons)

- Orchestrated? Or an accident of bees working hard?
- See “On Growth and Form” by D’Arcy Wentworth Thompson (hexagons). [4, 5]
Hexagons—Giant’s Causeway: (田)

http://www.physics.utoronto.ca/
Hexagons run amok:

- **Graphene (囲)**: single layer of carbon molecules in a perfect hexagonal lattice (super strong).
- **Chicken wire (囲)** . . .
Whimsical but great example of real science:

“How Cats Lap: Water Uptake by *Felis catus*”


Amusing interview here
Symmetry Breaking

Philip Anderson — “More is Different,” Science, 1972

- 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”
Symmetry Breaking

“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
Symmetry Breaking

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.
Symmetry Breaking

- Page 291–292 of Sornette\textsuperscript{[3]}: 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).
More is different:

http://xkcd.com/435/ ( лишний символ)
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?
Complexification—the Big Transitions:

- Big Bang.
- Big Randomness.
- Big Replicate.
- Big Life.
- Big Evolve.
- Big Word.
- Big Story.
- Big Number.
- Big God.
- Big Make.
- Big Science.
- Big Data.
- Big Information.
- Big Algorithm.
- Big Connection.
- Big Social.
- Big Awareness.
Why complexify?

“Why do things become more complex?”[2]
Brian Arthur
Complexification ≡ evolution of algorithms?
Differential equations and stories ⊂ Algorithms.
Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?
Why complexify?

Driving complexity’s trajectory:
- Big Bang
- Randomness leads to replicating structures;
- Biological evolution;
- Sociocultural evolution;
- Technological evolution;
- Sociotechnological evolution.
Why Complexify?

Universality
Symmetry
Breaking

The Big Theory

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References
Homo narrativus—What’s the Story?:

- Mechanisms = Evolution equations, algorithms, stories, ...
- Rollover zing: “Also, all financial analysis. And, more directly, D&D.”

http://xkcd.com/904/ (⊞)
(Sir Terry) Pratchett’s Narrativium:

- “The most common element on the disc, although not included in the list of the standard five: earth, fire, air, water and surprise. It ensures that everything runs properly as a story.”
- “A little narrativium goes a long way: the simpler the story, the better you understand it. Storytelling is the opposite of reductionism: 26 letters and some rules of grammar are no story at all.”
- “Heroes only win when outnumbered, and things which have a one-in-a-million chance of succeeding often do so.”
The absolute basics:

Science in three steps:

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

Beware your assumptions:

Don’t use tools/models because they’re there, or because everyone else does...
Next:

Spring 2013: Complex Networks (CSYS/MATH 303)
- Branching networks (rivers, cardiovascular systems)
- Redistribution networks (airlines, post)
- Structure detection for complex systems
- Contagion
- Random networks-arama
- Distributed Search
- Organizational networks
- Deeper investigations of scale-free networks
- and more...
References I

More is different.  
[PDF](#) 

Why do things become more complex?  
[PDF](#) 

Critical Phenomena in Natural Sciences.  

On Growth and From.  
References II