Why Complexify?
Principles of Complex Systems
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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 (□).

Examples:
- The Central Limit Theorem:
  \[ P(x; \mu, \sigma) dx = \frac{1}{\sqrt{2\pi \sigma}} e^{-\frac{(x - \mu)^2}{2\sigma^2}} dx. \]
- Navier Stokes equation for fluids.
- Nature of phase transitions in statistical mechanics.

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.

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

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,
  - 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: (□)

- Orchestrated? Or an accident of bees working hard?
- See “On Growth and Form” by D’Arcy Wentworth Thompson (□).[4, 5]

Hexagons—Giant’s Causeway: (□)

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

Whimsical but great example of real science:


Amusing interview here (□)
Symmetry Breaking

Philip Anderson (⊛)—“More is Different,” Science, 1972 [1]

- 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
  - biology

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

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

More is different:

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

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

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?
Why Complexify?

Universality
Symmetry
Breaking
The Big Theory
Final words
For your consideration
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Homo narrativus—What’s the Story?:

“A weighted random number generator just produced a new batch of numbers. Let’s use them to build narratives!”

Mechanisms =
Evolution equations, algorithms, stories, ...

Rollover zing: “Also, all financial analysis. And, more directly, D&D.”

(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.”

Driving complexity’s trajectory:

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

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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)?

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The absolute basics:

Modern basic 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 2014: 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


References II