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.
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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.

**Large questions:**
- How universal is universality?
- What are the possible of long-time states (attractors) for a universe?
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- 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,
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  - galaxies,
  - the earth’s mantle...
  - and ball bearings on lattices...?
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Collision rules in 2-d on a hexagonal lattice:

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- No ‘good’ lattice in 3-d.
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Hexagons—Honeycomb: (亻)

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Hexagons—Giant’s Causeway: (田)
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http://www.physics.utoronto.ca/
Hexagons run amok:

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

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

Amusing interview [here](#) (⊞)

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A Study of Cat Lapping

Adult cats and dogs are unable to create suction in their mouths and must use their tongues to drink. A dog will scoop up liquid with the back of its tongue, but a cat will only touch the surface with the smooth tip of its tongue and pull a column of liquid into its mouth.

1. Liquid sticks to smooth tip.
2. A single lap is about \( \frac{3}{100} \) tsp.

Source: *Science*

THE NEW YORK TIMES; IMAGES FROM VIDEO BY ROMAN STOCKER, SUNGHWAN JUNG, JEFFREY M. ARISTOFF AND PEDRO M. REIS
Symmetry Breaking

Philip Anderson (—you) — “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...
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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
  - 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.
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Renormalization $\equiv$ Anderson’s hierarchy.

But Anderson’s hierarchy is not a simple one: the rules change.

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A real theory of everything anything:
1. Is not just about the ridiculously small stuff...
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<thead>
<tr>
<th>Symmetry breaking/</th>
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</tr>
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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 $\equiv$ evolution of algorithms?
▶ Differential equations and stories $\subset$ Algorithms.
▶ Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?
Driving complexity’s trajectory:

- Big Bang
- Randomness leads to replicating structures;
- Biological evolution;
- Sociocultural evolution;
- Technological evolution;
- Sociotechnological evolution.
3 Frames for Complexity:

1. Why Complexify? "Theory of anything"
   - "Hard" sciences
   - "Soft" & squishy sciences
   - Randomness stories and evolution stories
   - Emergence

2. Universality
   - Framing of systems conceptually-qualitative
   - Visualizing micro-macro stories
   - Differences & algorithms

3. Symmetry
   - Breaking

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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.”

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http://xkcd.com/904/ (⊞)
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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...
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- Redistribution networks (airlines, post)
- Structure detection for complex systems
- Contagion
- Random networks-aroma
- Distributed Search
- Organizational networks
- Deeper investigations of scale-free networks
- and more...
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More is different.  

Why do things become more complex?  
*Scientific American*, 268:92, 1993. [pdf](#)

Critical Phenomena in Natural Sciences.  

On Growth and From.  
References II