Why Complexify?

Principles of Complex Systems
CSYS/MATH 300, Spring, 2013 | #SpringPoCS2013

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Outline

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 (⊞).

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.
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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 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,
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  - the earth’s mantle...
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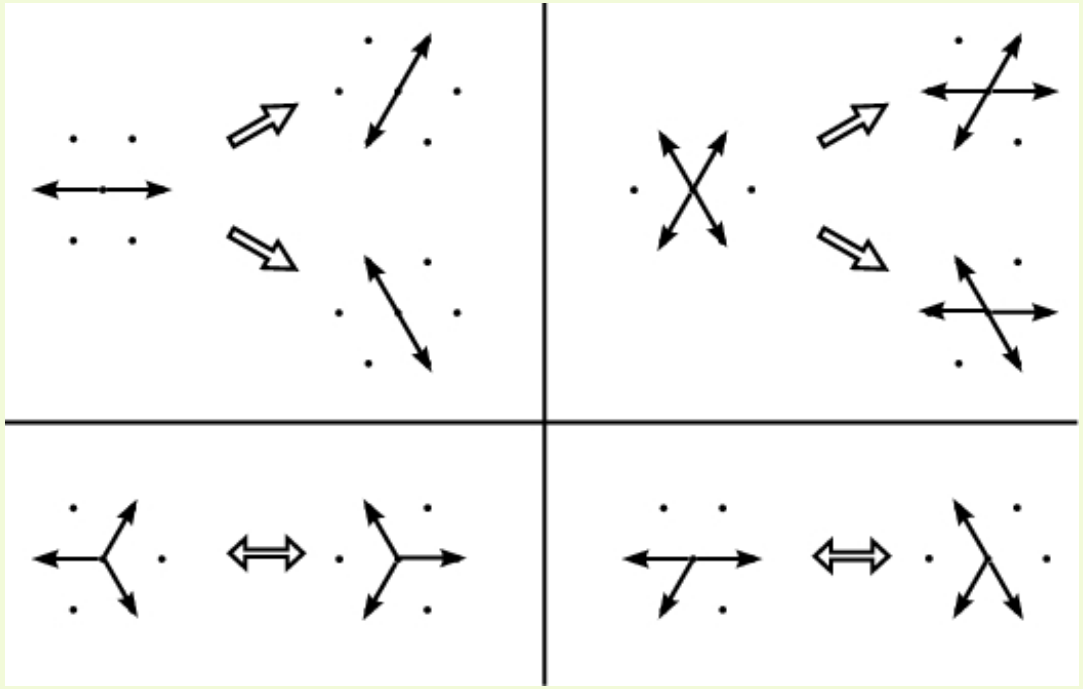

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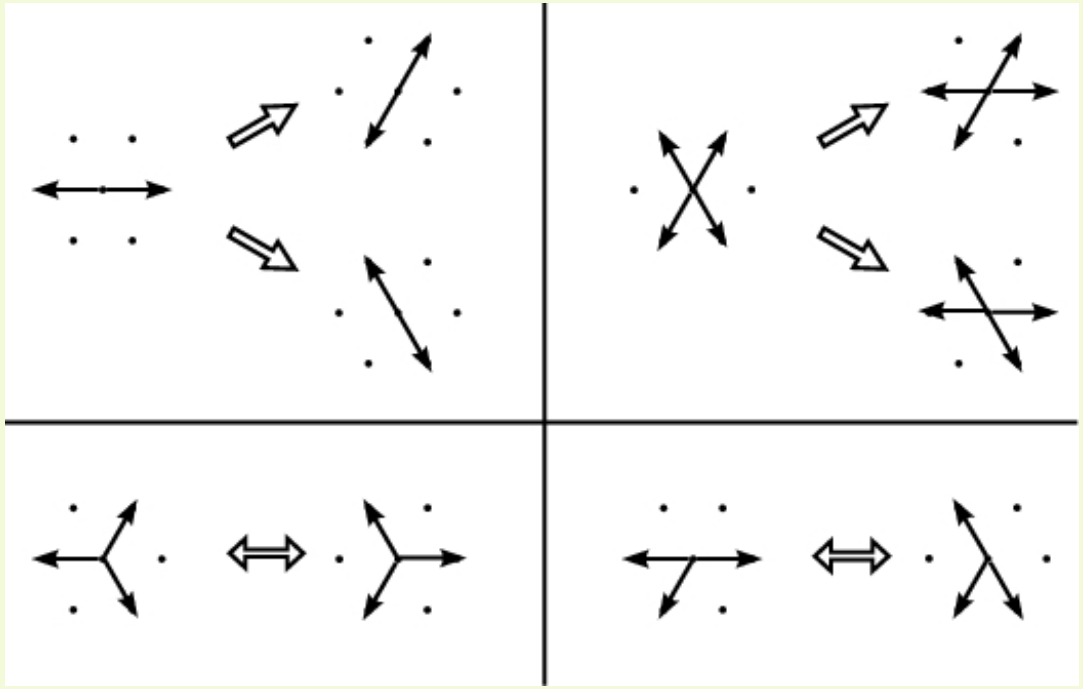

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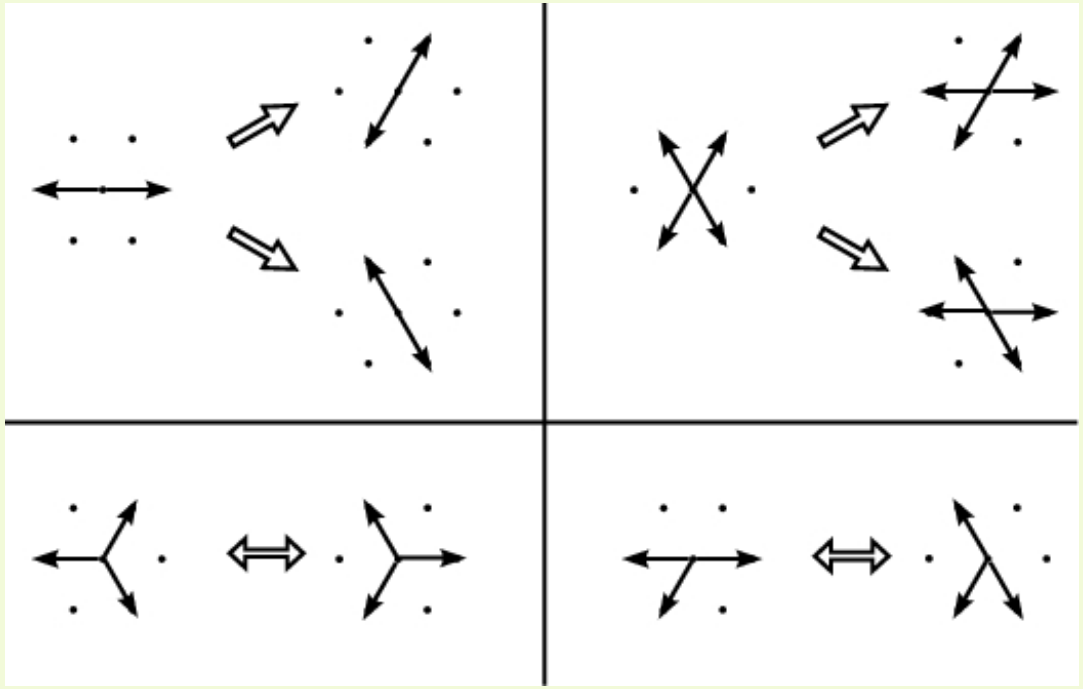

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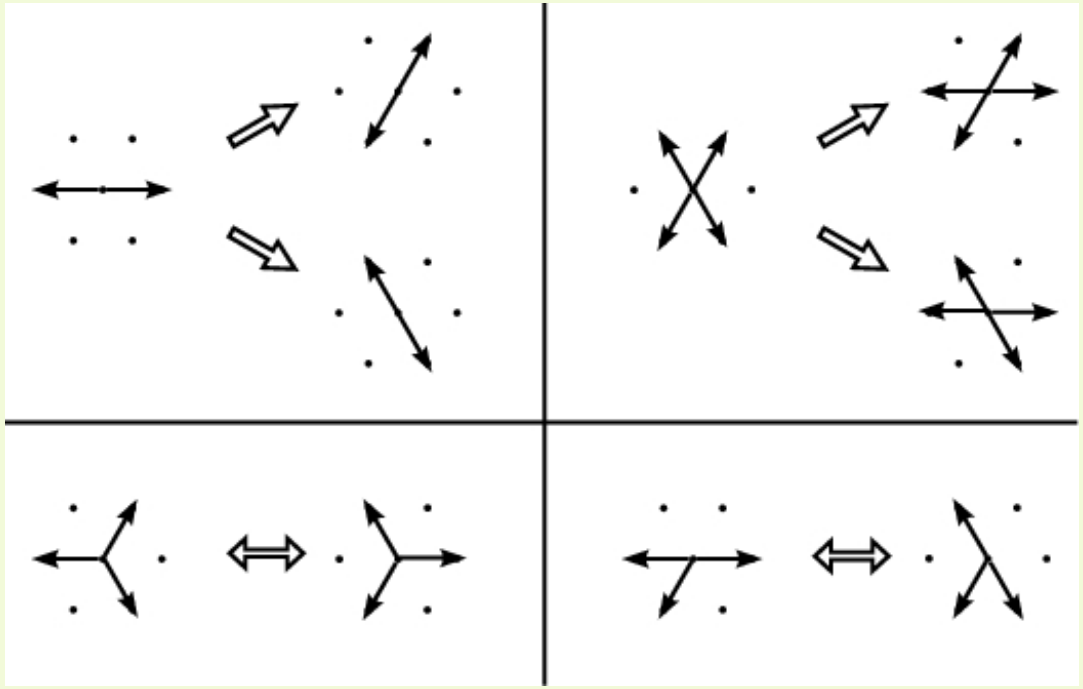

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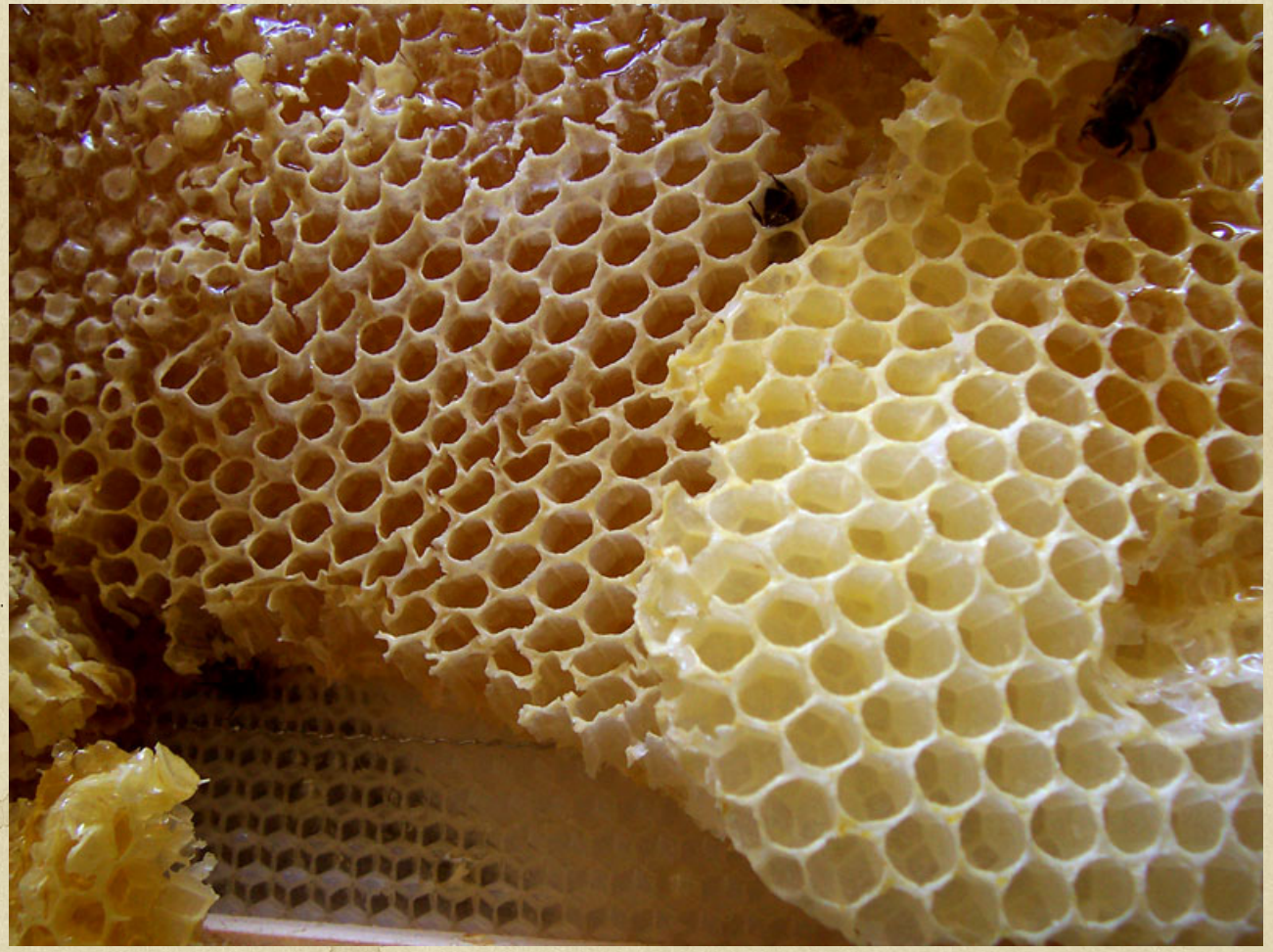

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- See "On Growth and Form" by D'Arcy Wentworth Thompson (⊞). [4, 5]

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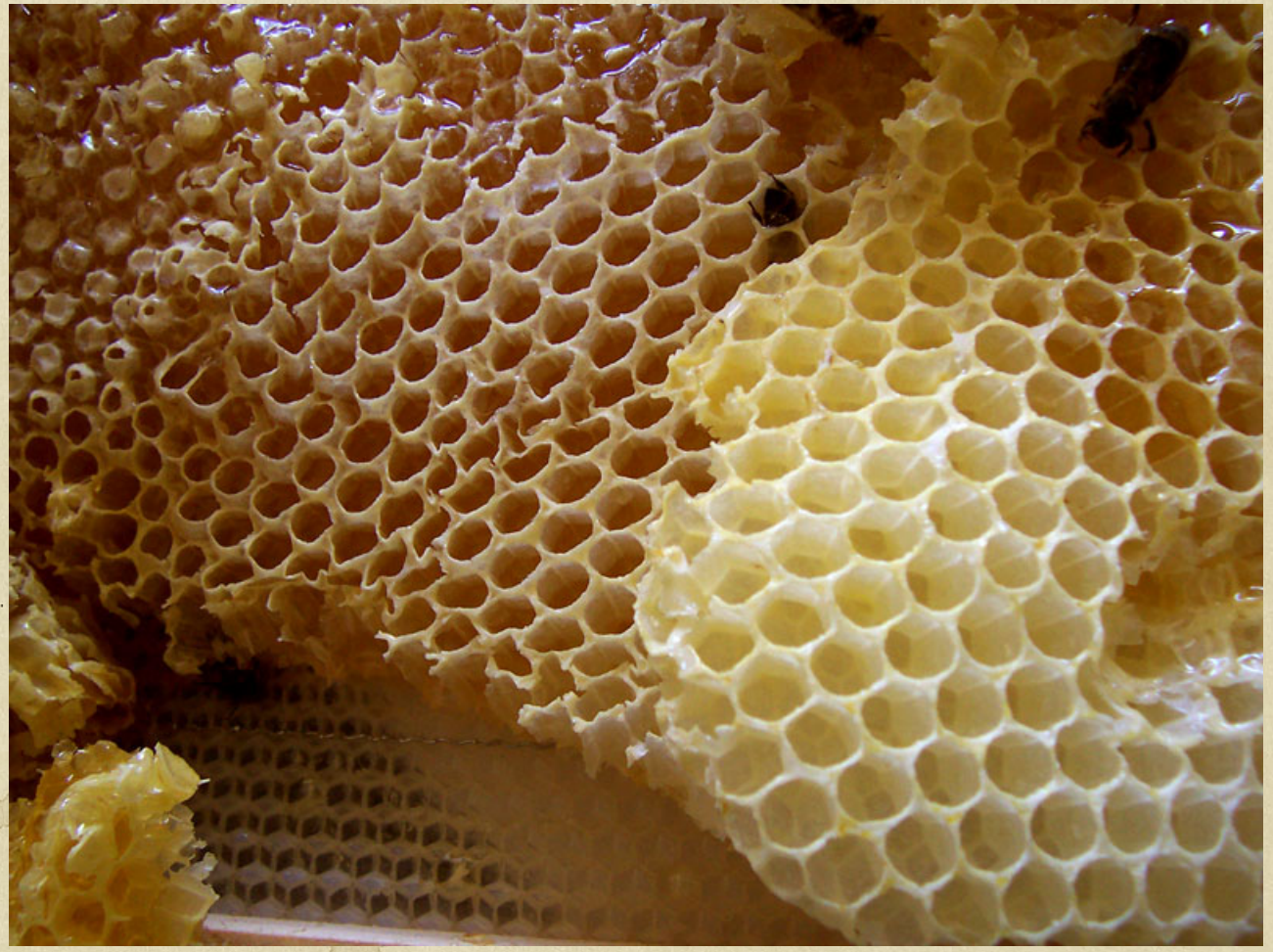

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Hexagons—Giant's Causeway: (⊞)

http://newdesktopwallpapers.info

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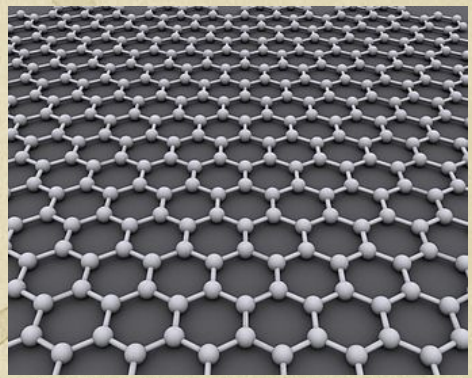
Hexagons run amok:

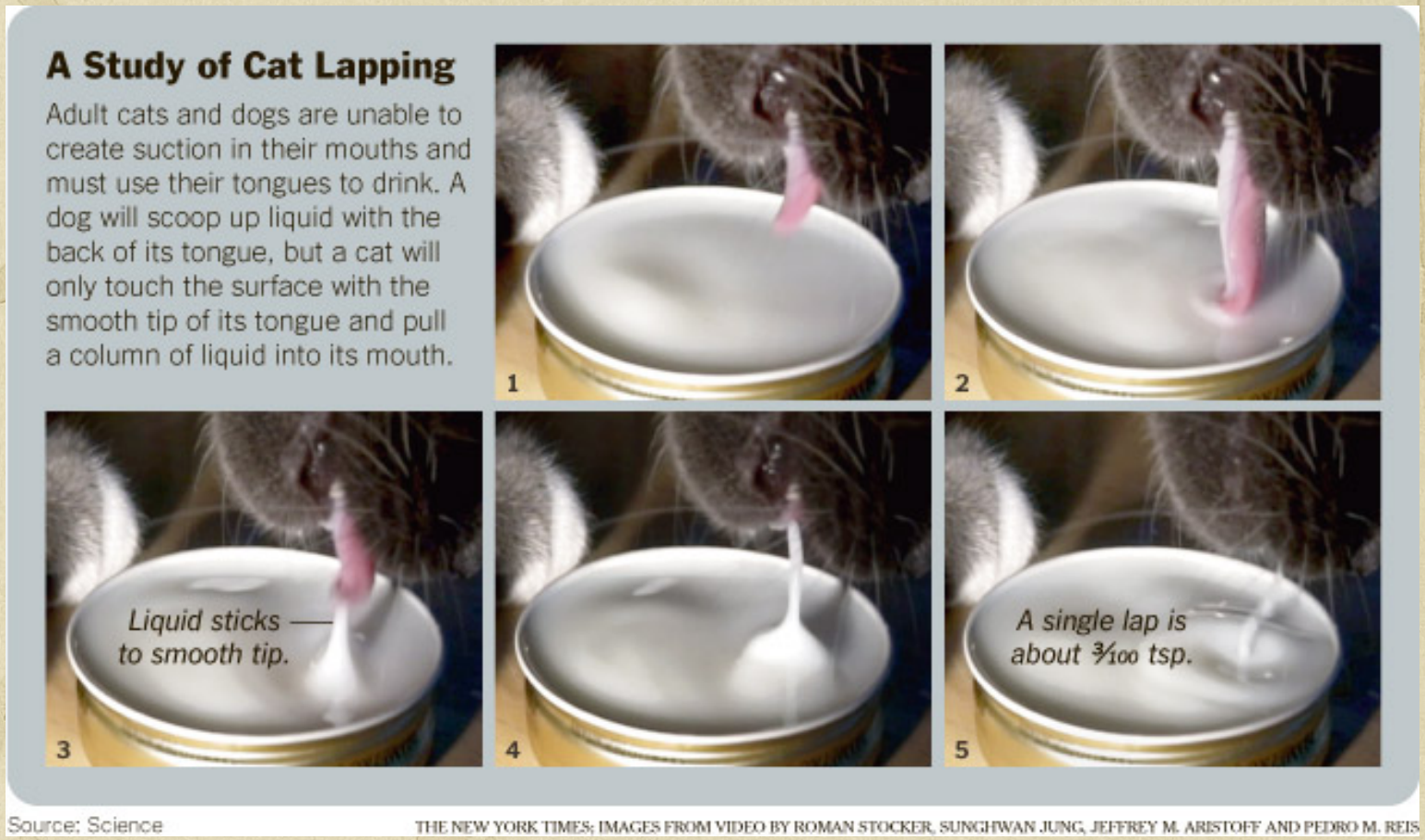


- Graphene (⊞): single layer of carbon molecules in a perfect hexagonal lattice (super strong).
- Chicken wire (⊞) . . .

Whimsical but great example of real science:

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

Reis et al., *Science*, 2010.



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.
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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

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.
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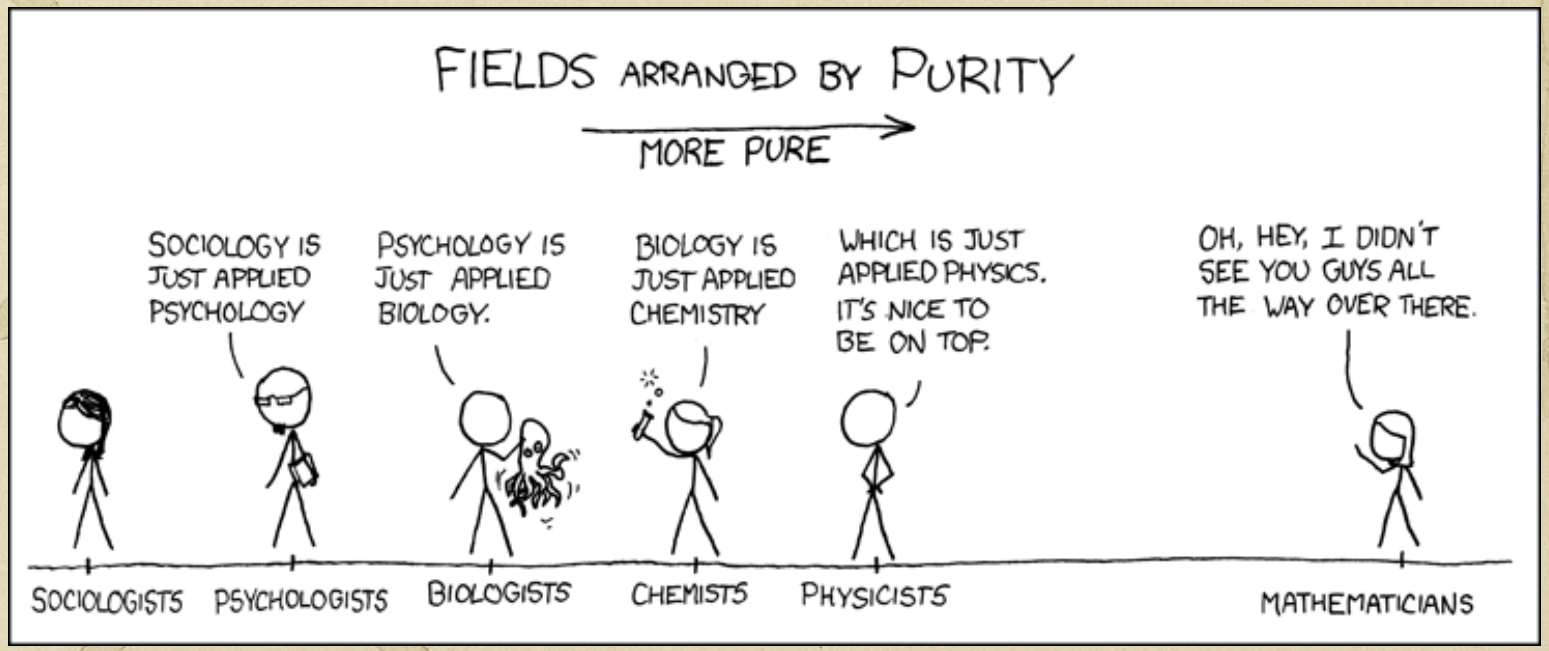

http://xkcd.com/435/ (⊞)

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.
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- How likely are the Big Transitions?

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Complexification—the Big Transitions:

- Big Bang.
- Big Random-ness.
- 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
  Scientific American, 268, 92, 1993.
- 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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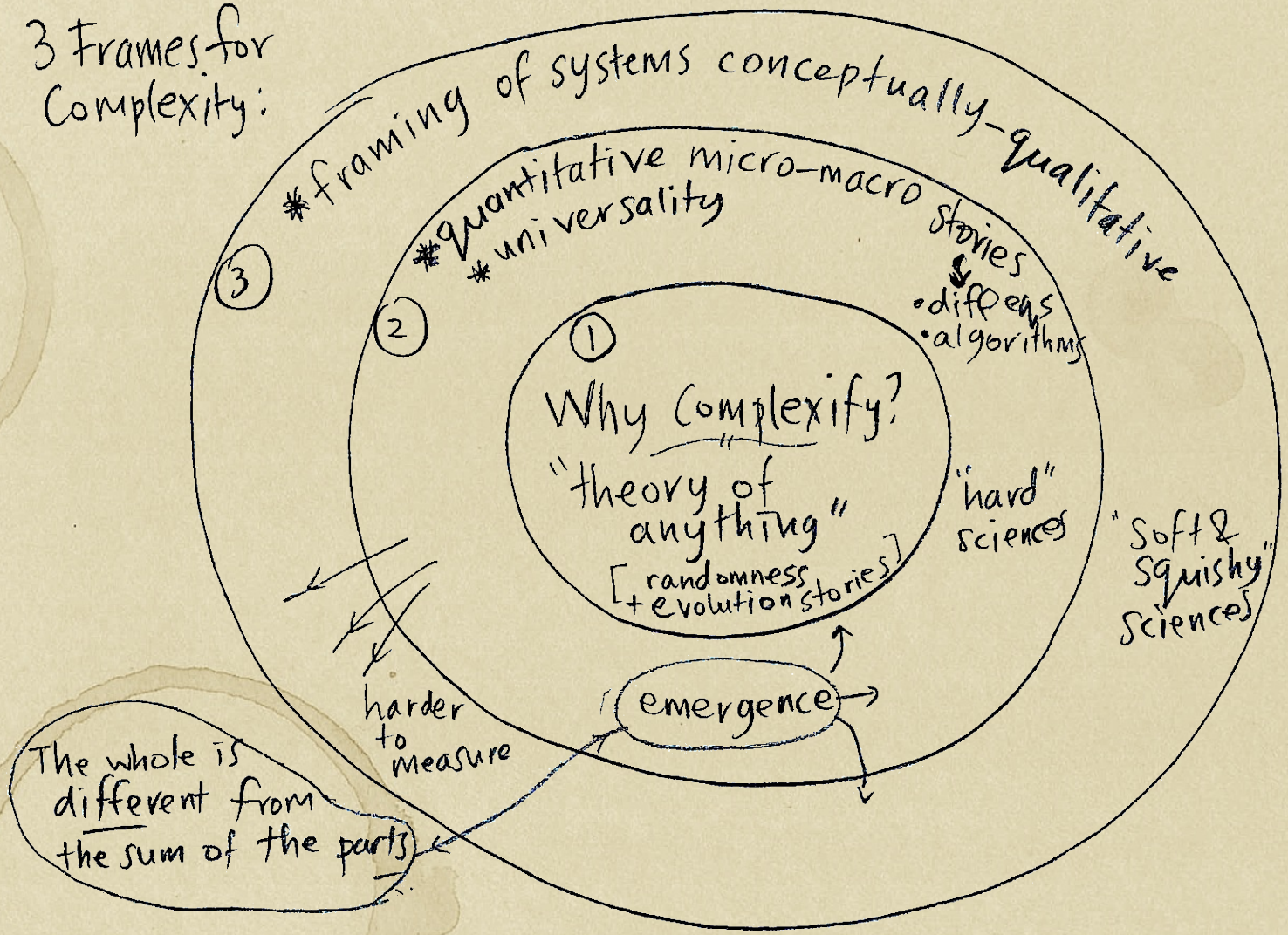
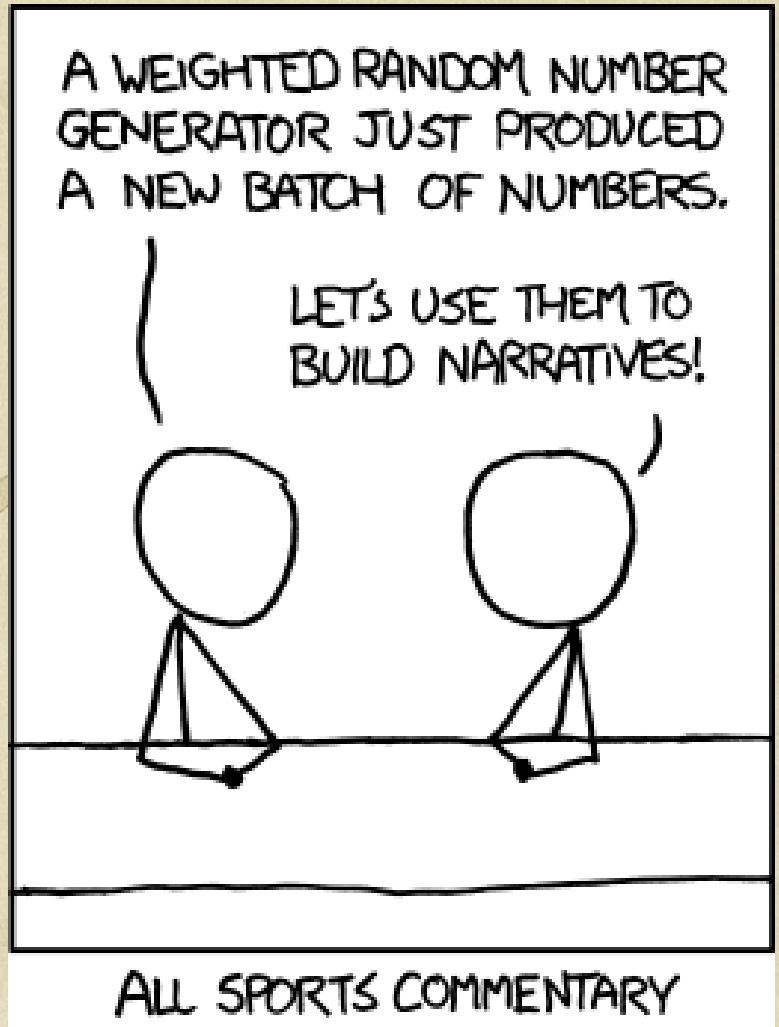
Driving complexity's trajectory:

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



Homo narrativus—What's the Story?:



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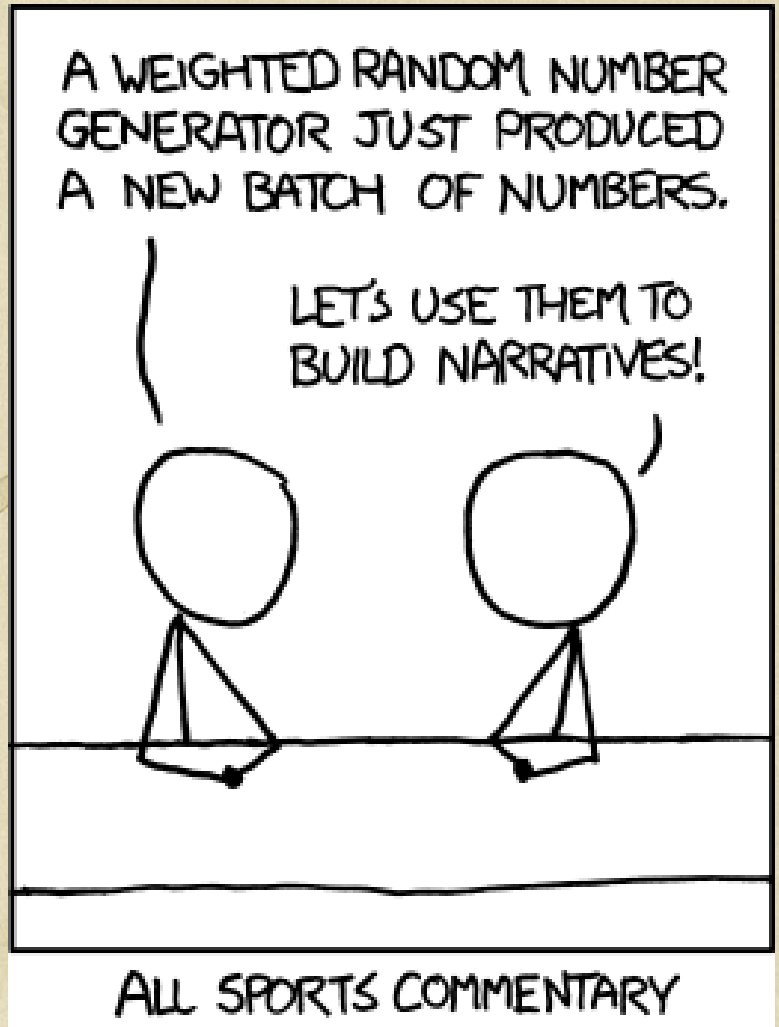

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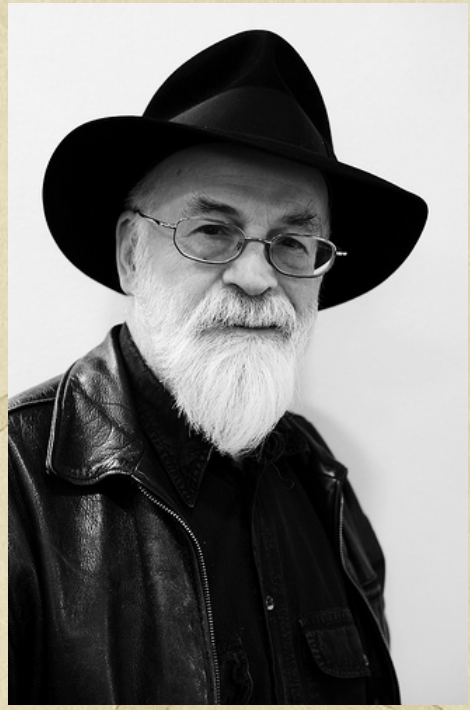

- "The most common element on the disc, although not included in the list of the standard five: earth, fire, air, water and surprise. It ensures that everything runs properly as a story."
- "A little narrativium goes a long way: the simpler the story, the better you understand it. Storytelling is the 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."

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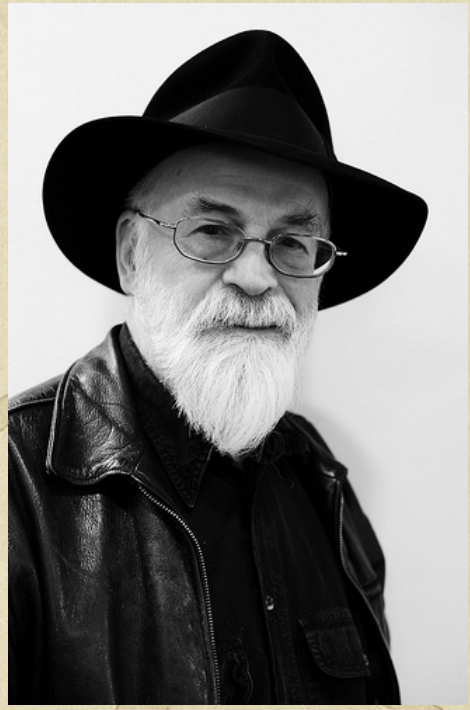

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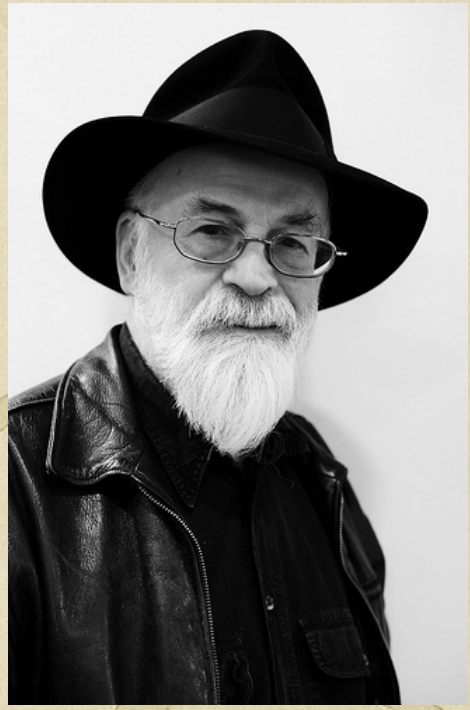

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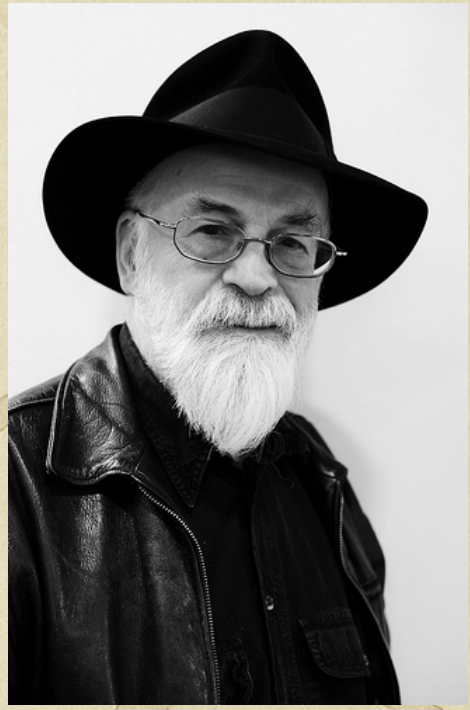

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2. Describe what you see.
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