Why Complexify?

Principles of Complex Systems | @pocsvox CSYS/MATH 300, Fall, 2016 | #FallPoCS2016

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



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 1 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





990 2 of 31

Outline

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Universality

Symmetry Breaking

The Big Theory

Final words

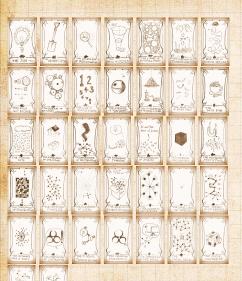
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References





200 3 of 31





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 4 of 31

Limits to what's possible: Universality C:

The property that the macroscopic aspects of a system do not depend sensitively on the system's details.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





290 5 of 31

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" PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

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Examples:

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Navier Stokes equation for fluids. Nature of phase transitions in statistical mechan PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 5 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 6 of 31

Sometimes details don't matter too much.

Suggests not all possible behaviors are availa at higher levels of complexity.

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Many-to-one mapping from micro to macro

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 6 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 6 of 31

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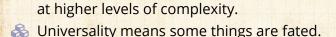
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The Big Theory

Final words

For your consideration

References



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Large questions:

How universal is universality? What are the possible long-time states (attractor for a universe?

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200 6 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 6 of 31

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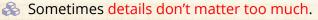
Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 6 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Fluid mechanics = One of the great successes of understanding complex systems.

Navier-Stokes equations: micro-macro system evolution. The big three: Experiment + Theory + Simulation Works for many very different 'fluids': the atmosphere, oceans, blood, the earth's mantle, galaxies





Dac 7 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 7 of 31

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Symmetry Breaking

The Big Theory

Final words

For your consideration





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The Big Theory

Final words

For your consideration





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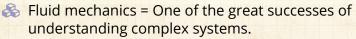
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Symmetry Breaking

The Big Theory

Final words

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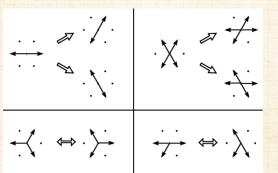


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 - 定 galaxies, ...
 - and ball bearings on lattices ...?





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 obta new or specific macro behaviours. PoCS | @pocsvox Why Complexify?

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The Big Theory

Final words

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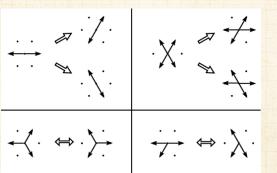
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200 8 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

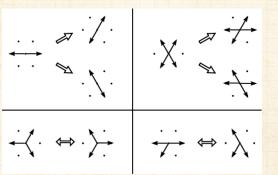
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200 8 of 31

Collision rules in 2-d on a hexagonal lattice:



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Universality

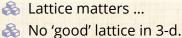
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The Big Theory

Final words

For your consideration

References

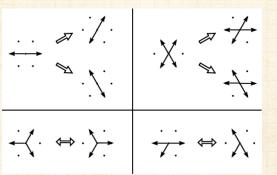






29 C 8 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Lattice matters ...
No 'good' lattice in 3-d.
Upshot: play with 'particles' of a system to obtain new or specific macro behaviours.





200 8 of 31

Hexagons—Honeycomb:



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





Orchestrated? Or an accident of bees working hard?

200 9 of 31

Hexagons—Honeycomb:



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



Orchestrated? Or an accident of bees working hard?
 See "On Growth and Form" by D'Arcy Wentworth Thompson C.^[6, 7]



200 9 of 31

Hexagons—Giant's Causeway:



http://newdesktopwallpapers.info

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





990 10 of 31

Hexagons—Giant's Causeway:



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

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Symmetry Breaking

The Big Theory

Final words

For your consideration

References





990 11 of 31

Saturn has a hexagon:

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Symmetry Breaking

The Big Theory

Final words

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References





👶 One side is longer than Earth's diameter 🗹

200 12 of 31

Hexagons run amok:

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Universality

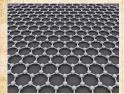
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The Big Theory

Final words

For your consideration

References





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





990 13 of 31

Triumph of the Hexagon

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Symmetry Breaking

The Big Theory

Final words

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From the remarkable Hexnet.org C, the Global Hexagonal Awareness Resource Center.

200 14 of 31





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





うへで 15 of 31

Symmetry Breaking

"More is different" P. W. Anderson, Science, **177**, 393–396, 1972.^[1]

Abdelson 3 argues against idea that the only real scientists are those working or the fundamental laws. Symmetry breaking → different laws/rules at different scales PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





990 16 of 31



Symmetry Breaking

"More is different" **C** P. W. Anderson, Science, **177**, 393–396, 1972.^[1] PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 16 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 16 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



Anderson C argues against idea that the only real scientists are those working on the fundamental laws.

Symmetry breaking \rightarrow different laws/rules at different scales ...

2006 study: "most creative physicist in the world"



DAC 16 of 31

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

- 💑 X
- solid state or many-body physics
 chemistry
- A molecular biology
 Cell biology
- Bychology
 Social sciences

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

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 17 of 31

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 constructionis hypothesis. Accidents of history and path dependence of matter. PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 18 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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200 18 of 31

Anderson:

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Universality

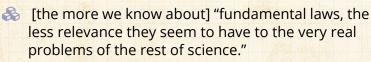
Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 18 of 31

Distance of the second second

"Critical Phenomena in Natural Sciences" **3** C by Didier Sornette (2003).^[4]

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Page 291–292 of Sornette^[5]: 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 PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





200 19 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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200 19 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



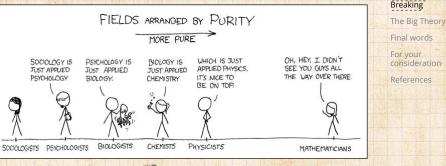


200 19 of 31

More is different:

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http://xkcd.com/435/





A real theory of everything anything: 1. Is not just about the ridiculously small stuf 2. It's about the increase of complexity

> Symmetry breaking/ Accidents of history

Second law of thermodynamics: we're toast in th long run.

So how likely is the local complexification o structure we enjoy? How likely are the Big Transitions? PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





20 0 21 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Symmetry breaking/ Accidents of history

Universality

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Symmetry breaking/ Accidents of history

Universality

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Symmetry breaking/ Accidents of history

Universality

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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990 21 of 31

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Symmetry breaking/ Accidents of history

Universality

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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"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)? PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration





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Universality

Symmetry Breaking

The Big Theory

Final words

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Symmetry Breaking

The Big Theory

Final words

For your consideration





Driving complexity's trajectory:

- \delta Big Bang
- Randomness leads to replicating structures;
- Biological evolution;
- 🚳 Sociocultural evolution;
- Technological evolution;
- line contechnological evolution.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Ranc ness. Big Structure

3

Big Bang.

Big Replicate, Big Life. Big Evolve.



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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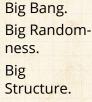
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The Big Theory

Final words

For your consideration

References



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Big Replicate. Big Life. Big Evolve.





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

 Big Structure.
 Big Replicate.
 Big Life.

ness.

Big Bang.

Big Random-

3





うへで 24 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Random-3 ness. Big -Structure. Big Replicate. 3 Big Life.

Big Bang.

3





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Big Structure.
Big Replicate.
Big Life.
Big Evolve.

Big Bang.



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うへで 24 of 31

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Symmetry Breaking

The Big Theory

Final words

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References

Big Randomness.
 Big Structure.
 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

Big Word.

8

Big Story. Big Number. Big Farm. Big God. Big Make. Big City. Big Culture



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The Big Theory

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References

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 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

🚳 Big Word. 🚴 Big Story.





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Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Big Life.
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Big Word.
Big Story.
Big Number.
Big Farm.
Big God.
Big Make.
Big City.



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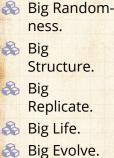
Symmetry Breaking

The Big Theory

Final words

For your consideration

References



Big Bang.

 Big Word.
 Big Story.
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 Big Farm.
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Big Make. Big City. Big Culture Big Data. Big Information Big Algorithm. Big Connection Big Social. Big Awareness. Big Spread. Big ...?

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Replicate.
Big Life.
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Structure.

Big Bang.

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Big Random-

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Big Word.
Big Story.
Big Number.
Big Farm.
Big God.
Big Make.



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Randomness. 3 Big Structure. Big Replicate. Big Life. 3 Big Evolve.

Big Bang.

🚳 Big Word. 🚴 Big Story. 💑 Big Number. 3 **Big Farm.** Big God. A. Big Make. 3



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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Randomness.
 Big Structure.
 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

Big Word.
Big Story.
Big Number.
Big Farm.
Big God.
Big Make.
Big City.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Randomness.
 Big Structure.
 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Randomness.
 Big Structure.
 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Randomness.
 Big Structure.
 Big Replicate.
 Big Life.
 Big Evolve.

Big Bang.

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Big Information Big Algorithm. Big Connection Big Social. Big Awareness. Big Spread. Big ...?





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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DQC 24 of 31

Big Bang. **Big Random**ness. Big -Structure. Big Replicate. Big Life. Big Evolve.

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Pocs



Dac 24 of 31

Big Bang. **Big Random**ness. Big -Structure. Big Replicate. Big Life. 3 Big Evolve.

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PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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Big Random-

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Big Bang.

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Dac 24 of 31

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

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Dac 24 of 31

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Big Replicate.
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DAC 24 of 31

PoCS | @pocsvox Why Complexify?

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References

Structure. Big Replicate. Big Life. Big Evolve.

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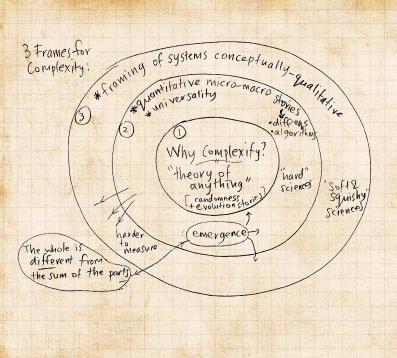
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ク へ 24 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References









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Symmetry Breaking

The Big Theory

Final words

For your consideration

References



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Modern basic science in three steps:

Find interesting/meaningful/important phenomen optionally involving spectacular amounts of data.

Explain it.

Inlocks our (littited) ability to: Create, predict, and control.

And be good people:

Beware vounessumptions: Don't use too's/models because they're there, or because everyone else does.....

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Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





うへで 27 of 31

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

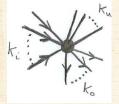
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This is a thing that could be next:

CoNKs: The PoCS strikes back:



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Optimal (re)distribution networks (hospitals, coffee shops, airlines, post, Internet).

Structure detection for comple systems.

Moar Contagion.

Random networks-arama

Distributed Search. Organizational networks. Deeper investigations of scalenetworks.

and more .

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References



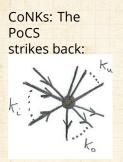


990 28 of 31

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44



Branching networks (rivers, cardiovascular systems).

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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References





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Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

References







Universality

Symmetry Breaking

The Big Theory

Final words

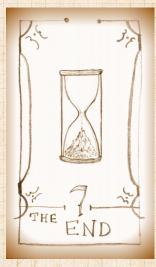
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Universality

Symmetry Breaking

The Big Theory

Final words

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Symmetry Breaking

The Big Theory

Final words

For your consideration

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200 31 of 31