

# Why Complexify?

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

Prof. Peter Dodds | @peterdodds

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



These slides are brought to you by:

PoCS | @pocsvox

Why Complexify?

Sealie & Lambie  
Productions



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Outline

PoCS | @pocsvox

Why Complexify?

Universality

Universality

Symmetry  
Breaking

Symmetry Breaking

The Big Theory

Final words

The Big Theory

For your  
consideration

Final words

References

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 

 Kadanoff's retrospective: "Innovations in Statistics Physics" 

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

## Examples:

 The Central Limit Theorem:

$$P(x) \approx \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$


 Navier-Stokes equation for fluids.



 Nature of phase transitions in statistical mechanics.



# 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" 

## Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

## Examples:

 The Central Limit Theorem:

$$P(x) \approx \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$$


 Navier-Stokes equation for fluids.



 Nature of phase transitions in statistical mechanics.




# 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" [3]

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

## Examples:

 The Central Limit Theorem:

$$P(\xi) \approx \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{1}{2\sigma^2}(\xi - \mu)^2}$$

 Navier-Stokes equation for fluids.





 Nature of phase transitions in statistical mechanics.





# 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" <sup>[3]</sup>

## Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

## 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.



# 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" <sup>[3]</sup>

## Universality

Symmetry  
Breaking


The Big Theory

Final words

For your  
consideration

References

## 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.



# 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" <sup>[3]</sup>

## Universality

Symmetry  
Breaking


The Big Theory

Final words



For your  
consideration

References

## 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.





# 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" <sup>[3]</sup>

## Universality

Symmetry  
Breaking


The Big Theory

Final words



For your  
consideration

References

## 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 **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.
-  Universality means some things are fated.

## Large questions:

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

## Universality

Symmetry  
Breaking

The Big Theory





Final words

For your  
consideration

References



# 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.
-  Universality means some things are fated.

## Large questions:

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

## Universality

Symmetry  
Breaking

The Big Theory

Final words





For your  
consideration

References





# 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.
-  Universality means some things are fated.

## Large questions:

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

Universality

Symmetry  
Breaking

The Big Theory





Final words

For your  
consideration

References



# 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.
-  Universality means some things are fated.

## Large questions:

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

Universality

Symmetry  
Breaking

The Big Theory





Final words

For your  
consideration



References



# 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.
-  Universality means some things are fated.

## Large questions:

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

## Universality

Symmetry  
Breaking

The Big Theory

Final words





For your  
consideration

References







# 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.
-  Universality means some things are fated.

## Large questions:

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

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 + Simulations.

 Works for many very different 'fluids':

 the atmosphere,

 oceans,

 blood,

 the earth's mantle,

 galaxies, ...

 a) no ball bearings on lattices ...?

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 + Simulations.

 Works for many very different 'fluids':

 the atmosphere,

 oceans,

 blood,

 the earth's mantle,

 galaxies, ...

 a) no ball bearings on lattices...?

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 + Simulations.

🧱 Works for many very different 'fluids':

- 🧱 the atmosphere,
- 🧱 oceans,
- 🧱 blood,
- 🧱 the earth's mantle,
- 🧱 galaxies, ...
- 🧱 global bearings on lattices ...?

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 + Simulations.
- 🧱 Works for many very different 'fluids':
  - 🧱 the atmosphere,
  - 🧱 oceans,
  - 🧱 blood,
  - 🧱 the earth's mantle,
  - 🧱 galaxies, ...

🧱 and ball bearings on lattices ...?

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 + Simulations.
-  Works for many very different 'fluids':
  -  the atmosphere,
  -  oceans,
  -  blood,
  -  the earth's mantle,
  -  galaxies, ...
  -  **and ball bearings on lattices ...?**

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

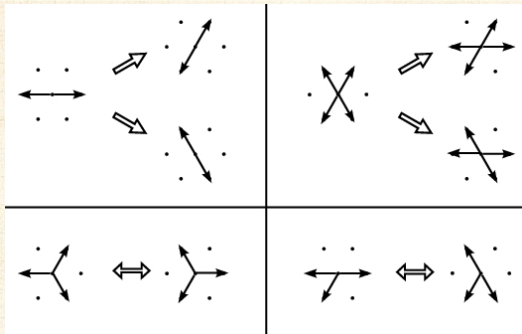
References





# Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

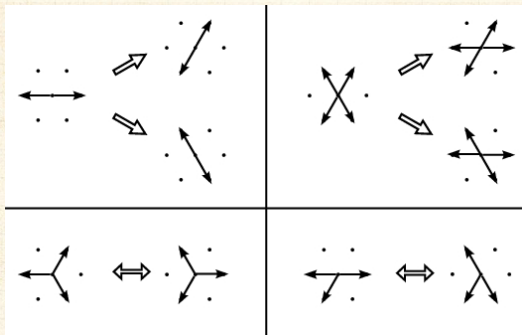
References

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



# Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



Lattice matters ...



No 'good' lattice in 3-d.

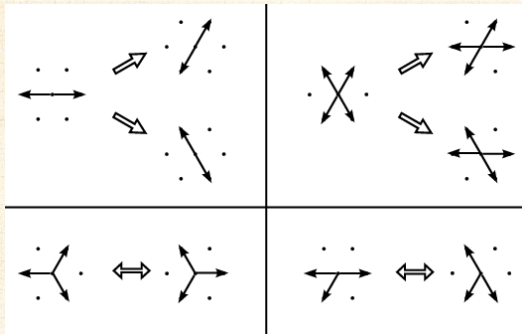


Upshot: play with 'particles' of a system to obtain new or specific macro behaviours.



# Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



Lattice matters ...



No 'good' lattice in 3-d.



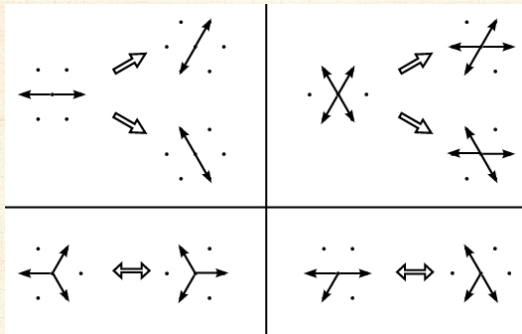
Upshot: play with 'particles' of a system to obtain new or specific macro behaviours.





# Lattice gas models

Collision rules in 2-d on a hexagonal lattice:



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.



# Hexagons—Honeycomb:

PoCS | @pocsvox  
Why Complexity?



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



Orchestrated? Or an accident of bees working hard?

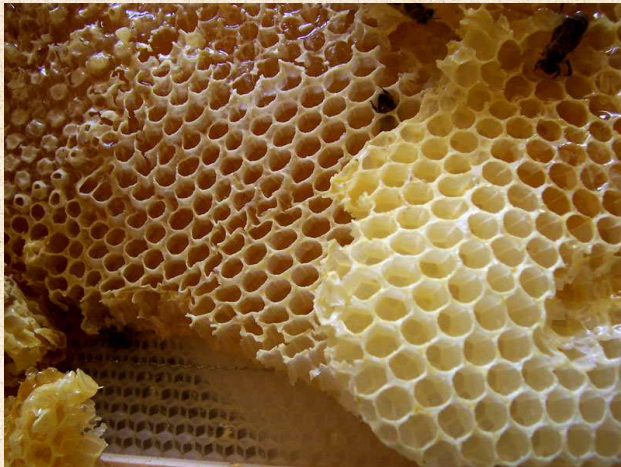


See "On Growth and Form" by D'Arcy Wentworth Thomson  



# Hexagons—Honeycomb:

PoCS | @pocsvox  
Why Complexity?



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



Orchestrated? Or an accident of bees working hard?



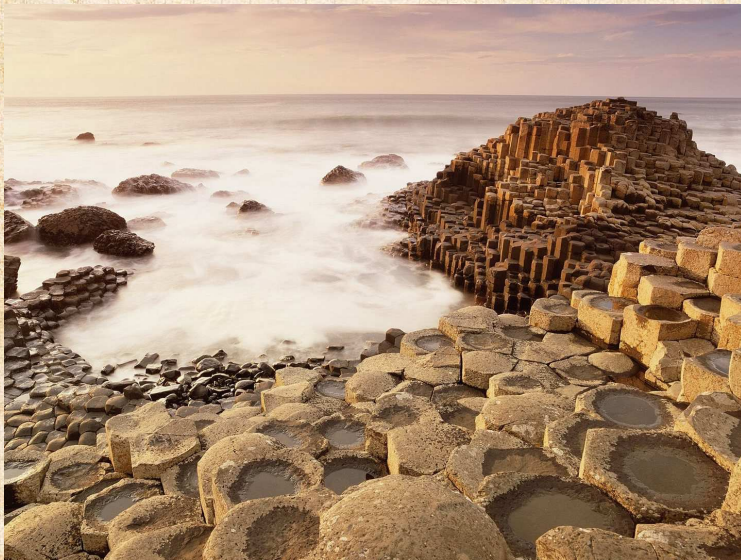
See “On Growth and Form” by D’Arcy Wentworth Thompson . [6, 7]





# Hexagons—Giant's Causeway: ↗

PoCS | @pocsvox  
Why Complexify?



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

<http://newdesktopwallpapers.info>



# Hexagons—Giant's Causeway: ↗

PoCS | @pocsvox  
Why Complexity?



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

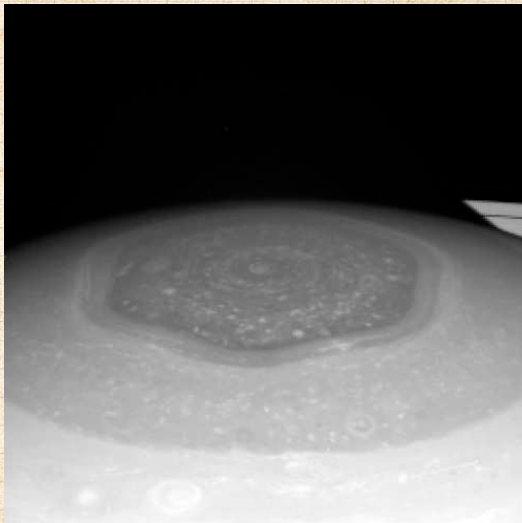
References

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



# Saturn has a hexagon:

PoCS | @pocsvox  
Why Complexify?



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

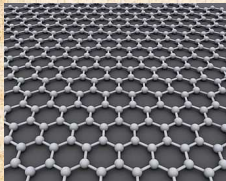




One side is longer than Earth's diameter 







# Hexagons run amok:



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

 Chicken wire  ...



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Triumph of the Hexagon

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

From the remarkable [Hexnet.org](http://Hexnet.org), the Global Hexagonal Awareness Resource Center.



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References





# Symmetry Breaking



"More is different" ↗

P. W. Anderson,  
Science, **177**, 393–396, 1972. <sup>[1]</sup>



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

Symmetry breaking → different laws/rules at different scales ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Symmetry Breaking



"More is different" ↗

P. W. Anderson,  
Science, **177**, 393–396, 1972. [1]



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



Symmetry breaking → different laws/rules at different scales ...

Universality

Symmetry  
Breaking

The Big Theory

Final words


For your  
consideration

References






# Symmetry Breaking



"More is different"   
P. W. Anderson,  
Science, **177**, 393–396, 1972. <sup>[1]</sup>



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

 Symmetry breaking → different laws/rules at different scales ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration


References









# Symmetry Breaking



"More is different"   
P. W. Anderson,  
Science, **177**, 393–396, 1972. <sup>[1]</sup>



-  Anderson  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" 

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# 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

Universality

Symmetry  
Breaking

The Big Theory


Final words

For your  
consideration


References



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.

Universality

Symmetry  
Breaking

The Big Theory

Final words


For your  
consideration


References







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.

Universality

**Symmetry  
Breaking**

The Big Theory





Final words

For your  
consideration

References



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.

Universality

**Symmetry  
Breaking**

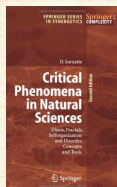
The Big Theory

Final words

For your  
consideration

References





“Critical Phenomena in Natural Sciences” [a](#) [↗](#)  
by Didier Sornette (2003). [4]

- 📦 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).

Universality

Symmetry Breaking

The Big Theory

Final words

For your consideration

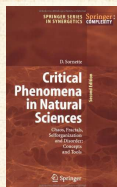
References





# Symmetry Breaking

PoCS | @pocsvox  
Why Complexify?



“Critical Phenomena in Natural Sciences” [a](#) [↗](#)  
by Didier Sornette (2003). [4]

- 🧱 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).

Universality

Symmetry  
Breaking

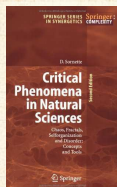
The Big Theory

Final words

For your  
consideration




References





“Critical Phenomena in Natural Sciences” [a](#) [↗](#)

by Didier Sornette (2003). [4]

-  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).

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# More is different:

PoCS | @pocsvox

Why Complexify?

Universality

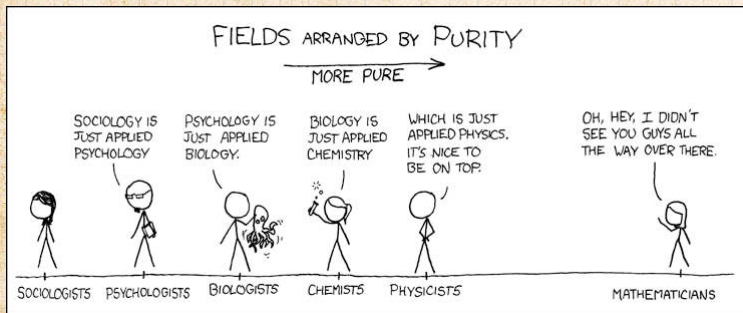
Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



<http://xkcd.com/435/>





# A real science of complexity:

PoCS | @pocsvox

Why 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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

☞ 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?



# A real science of complexity:

PoCS | @pocsvox  
Why Complexify?

## 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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

☞ 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?



# 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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

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?





# 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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

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?



# A real science of complexity:

PoCS | @pocsvox  
Why Complexity?

## A real theory of ~~everything~~ anything:

1. Is not just about the ridiculously small stuff ...
2. It's about the increase of complexity

Universality

Symmetry  
Breaking


The Big Theory


Final words

For your  
consideration

References

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?



# 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

Universality


Symmetry  
Breaking


The Big Theory

Final words

For your  
consideration

References

 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?








# 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?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Why complexify?



"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  $\equiv$  evolution of algorithms?



Differential equations and stories  $\subset$  Algorithms.



Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Why complexify?



"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  $\equiv$  evolution of algorithms?
- Differential equations and stories  $\subset$  Algorithms.
- Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References





# Why complexify?



"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  $\equiv$  evolution of algorithms?

Differential equations and stories  $\subset$  Algorithms.

Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Why complexify?



"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  $\equiv$  evolution of algorithms?
- Differential equations and stories  $\subset$  Algorithms.

Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# Why complexify?



"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  $\equiv$  evolution of algorithms?
- Differential equations and stories  $\subset$  Algorithms.
- Life is a loaded word: The Search for Extraterrestrial Algorithms (SETA)?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References





# Why complexify?

Universality

Symmetry  
Breaking







The Big Theory

Final words

For your  
consideration

References


## Driving complexity's trajectory:

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



# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

 Big Bang.

 Big Randomness.

 Big Structure.

 Big Replicate.

 Big Life.

 Big Evolve.

 Big Word.

 Big Story.

 Big Number.

 Big Farm.

 Big God.

 Big Make.

 Big City.

 Big Culture.

 Big Science.

 Big Data.

 Big Information.

 Big Algorithm.

 Big Connection.

 Big Social.

 Big Awareness.

 Big Spread.

 Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words



For your  
consideration

References



# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

 Big Bang.  
 Big Randomness.

 Big Structure.

 Big Replicate.

 Big Life.

 Big Evolve.

 Big Word.

 Big Story.

 Big Number.

 Big Farm.

 Big God.

 Big Make.

 Big City.

 Big Culture.

 Big Science.

 Big Data.

 Big Information.

 Big Algorithm.

 Big Connection.

 Big Social.

 Big Awareness.

 Big Spread.

 Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration







References





# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration

References



# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration

References




# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration







References






# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory







Final words

For your  
consideration

References



# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration

References




# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration







References






# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory







Final words








For your  
consideration

References



# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration

References



# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration









References






# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration









References



# Complexification—the Big Transitions:

PoCS | @pocsvox  
Why Complexify?

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration


References



# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory

Final words
























For your  
consideration

References





# Complexification—the Big Transitions:

- |  |  |  |
|--|--|--|
|  Big Bang.            |  Big Word.      |  Big Science.     |
|  Big Random-<br>ness. |  Big Story.     |  Big Data.        |
|  Big<br>Structure.    |  Big<br>Number. |  Big Information. |
|  Big<br>Replicate.    |  Big Farm.      |  Big Algorithm.   |
|  Big Life.            |  Big God.       |  Big Connection.  |
|  Big Evolve.          |  Big Make.      |  Big Social.      |
|  |  Big City.      |  Big Awareness.   |
|  |  Big Culture.   |  Big Spread.      |
|  |  |  Big ...?         |

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration









References



# Complexification—the Big Transitions:

-  Big Bang.
-  Big Randomness.
-  Big Structure.
-  Big Replicate.
-  Big Life.
-  Big Evolve.

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

-  Big Science.
-  Big Data.
-  Big Information.
-  Big Algorithm.
-  Big Connection.
-  Big Social.
-  Big Awareness.
-  Big Spread.
-  Big ...?

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration








References



# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration









References






# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration





References



# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration

References



# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory

Final words







For your  
consideration









References





# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration

References



# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory







Final words









For your  
consideration

References



# Complexification—the Big Transitions:

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

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

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

Universality

Symmetry  
Breaking

The Big Theory

Final words

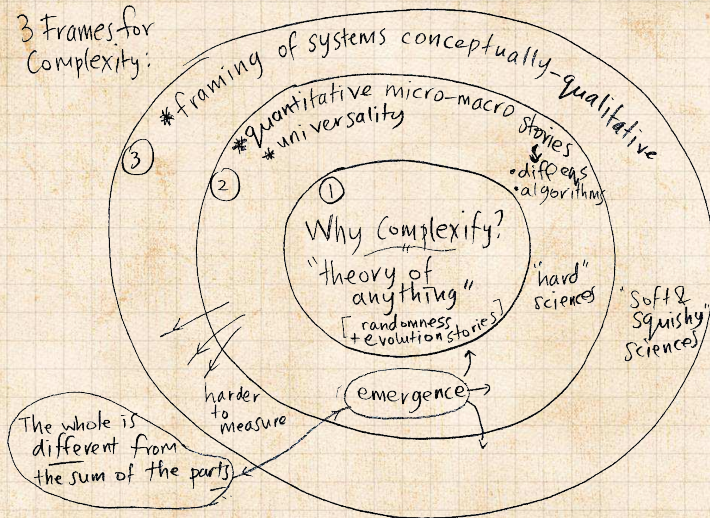
For your  
consideration

References





3 Frames for Complexity:



Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



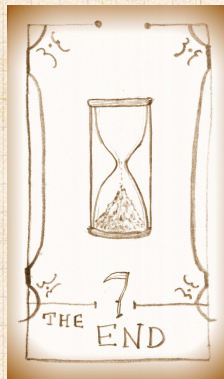
Universality

Symmetry  
Breaking

The Big Theory

Final wordsFor your  
consideration

References



# The absolute basics:

## Modern basic science in three steps:

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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...





# The absolute basics:

## Modern basic science in three steps:

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

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# The absolute basics:

## Modern basic science in three steps:

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

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# The absolute basics:

## Modern basic science in three steps:

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

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...





# The absolute basics:

## Modern basic science in three steps:

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

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# The absolute basics:

## Modern basic science in three steps:

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

Unlocks our (limited) ability to: Create, predict, and control.

And be good people: Share.

Beware your assumptions! Don't use tools/models because they're there, or because everyone else does ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# The absolute basics:

## Modern basic science in three steps:

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

**Unlocks our (limited) ability to:** Create, predict, and control.

And be good people: **Share.**

**Beware your assumptions:** Don't use tools/models because they're there, or because everyone else does ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

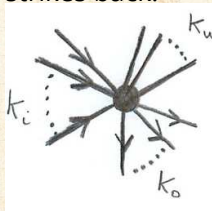






# This is a thing that could be next:

PoCS | @pocsvox  
Why Complexify?

CoNKs: The  
PoCS  
strikes back:



CSYS/MATH 303:  
Complex  
Networks   
@networksvox 

- Branching networks (rivers, cardiovascular systems).
- Optimal (re)distribution networks (hospitals, coffee shops, airlines, post, Internet).
- Structure detection for complex systems.
- Moar Contagion.
- Random networks-arama.
- Distributed Search.
- Organizational networks.
- Deeper investigations of scale-free networks.
- and more ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

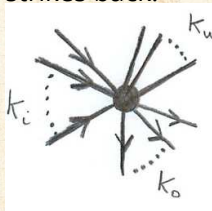
For your  
consideration

References













# This is a thing that could be next:

CoNKs: The  
PoCS  
strikes back:



CSYS/MATH 303:

Complex  
Networks   
[@networksvox](#) 

-  Branching networks (rivers, cardiovascular systems).
-  Optimal (re)distribution networks (hospitals, coffee shops, airlines, post, Internet).
-  Structure detection for complex systems.
-  Moar Contagion.
-  Random networks-arama.
-  Distributed Search.
-  Organizational networks.
-  Deeper investigations of scale-free networks.

 and more ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

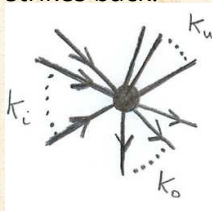
For your  
consideration

References














# This is a thing that could be next:

CoNKs: The  
PoCS  
strikes back:



CSYS/MATH 303:

Complex  
Networks   
[@networksvox](#) 

-  Branching networks (rivers, cardiovascular systems).
-  Optimal (re)distribution networks (hospitals, coffee shops, airlines, post, Internet).
-  Structure detection for complex systems.
-  Moar Contagion.
-  Random networks-arama.
-  Distributed Search.
-  Organizational networks.
-  Deeper investigations of scale-free networks.
-  and more ...

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References





Universality

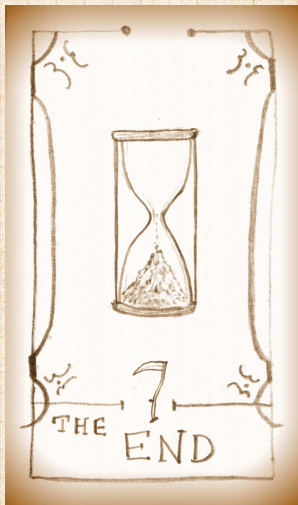
Symmetry  
Breaking

The Big Theory




Final words

For your  
consideration

References



# References I

- [1] P. W. Anderson.  
More is different.  
[Science](#), 177(4047):393–396, 1972. pdf 
  
- [2] W. B. Arthur.  
Why do things become more complex?  
[Scientific American](#), 268:92, 1993. pdf 
  
- [3] L. P. Kadanoff.  
Innovations in statistical physics, 2014.  
<http://arxiv.org/abs/1403.6464>. pdf 
  
- [4] D. Sornette.  
Critical Phenomena in Natural Sciences.  
[Springer-Verlag](#), Berlin, 2nd edition, 2003.

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References



# References II

- [5] D. Sornette.  
Critical Phenomena in Natural Sciences.  
Springer-Verlag, Berlin, 1st edition, 2003.
- [6] D. W. Thompson.  
On Growth and Form.  
Cambridge University Pres, Great Britain, 2nd  
edition, 1952.
- [7] D. W. Thompson.  
On Growth and Form — Abridged Edition.  
Cambridge University Press, Great Britain, 1961.

Universality

Symmetry  
Breaking

The Big Theory

Final words

For your  
consideration

References

