

A Complex Systems Manifesto

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DOI:

Principles of Complex Systems,
Vols. 1, 2, 3D, 4 Fourever, V for Vendetta

Deliverator: Calla Beauregard

Showrunner: Prof. Peter Sheridan Dodds

Computational Story Lab | Vermont Complex Systems Institute
University of Vermont | Santa Fe Institute



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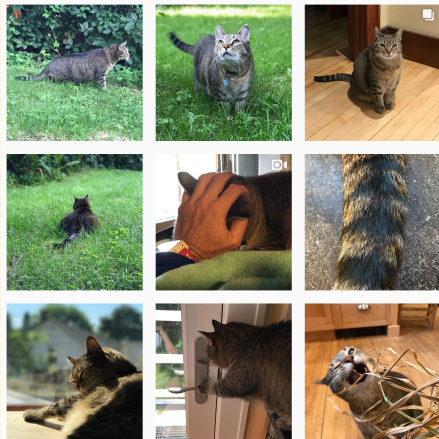
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Outline

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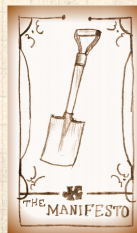
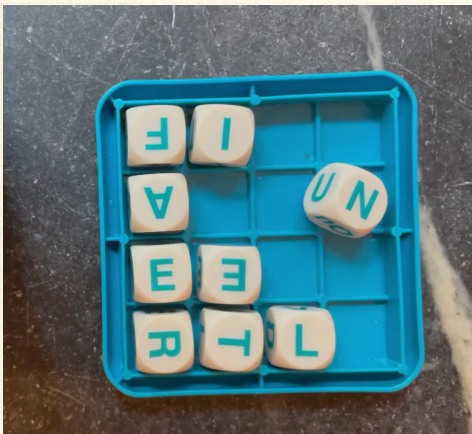
References

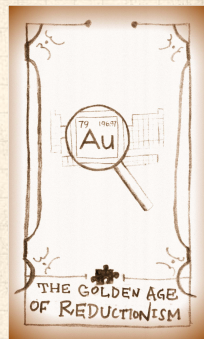
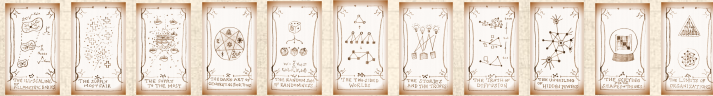
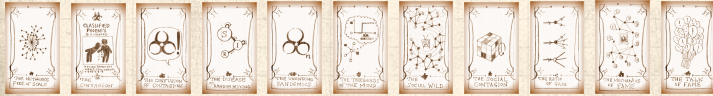
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The Boggoracle Speaks:





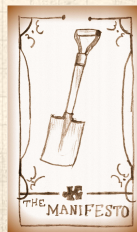
Definitions

Complex: (Latin = with + fold/weave (com + plex))



Adjective:

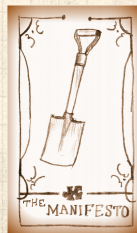
1. Made up of multiple parts; intricate or detailed.
2. Not simple or straightforward.



Complicated versus Complex:



Complicated: Mechanical watches, airplanes, ...



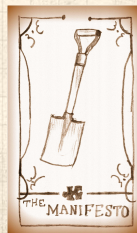
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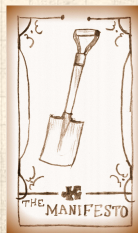


Engineered systems can be made to be **highly robust but not adaptable.**



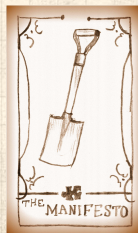
Complicated versus Complex:

-  Complicated: Mechanical watches, airplanes, ...
-  Engineered systems can be made to be **highly robust but not adaptable**.
-  But engineered systems can become complex (power grid, planes).



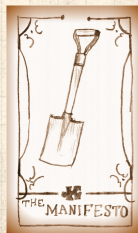
Complicated versus Complex:

- ❏ Complicated: Mechanical watches, airplanes, ...
- ❏ Engineered systems can be made to be **highly robust but not adaptable**.
- ❏ But engineered systems can become complex (power grid, planes).
- ❏ They can also **fail spectacularly**.



Complicated versus Complex:

-  Complicated: Mechanical watches, airplanes, ...
-  Engineered systems can be made to be **highly robust but not adaptable**.
-  But engineered systems can become complex (power grid, planes).
-  They can also **fail spectacularly**.
-  Explicit distinction: **Complex Adaptive Systems**.



Definitions

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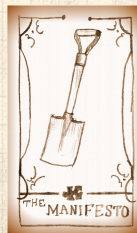
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References

The definition of a Complex System:

-  Distributed system of many interrelated (possibly networked) parts with no or limited centralized control exhibiting emergent behavior.



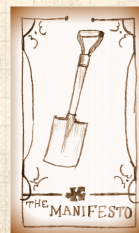
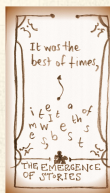
Definitions

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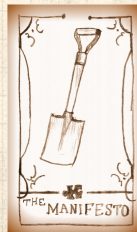
-  Distributed system of many interrelated (possibly networked) parts with no or limited centralized control exhibiting emergent behavior.

Emergence—‘More is Different’^[1]:

There’s no tornado in a water molecule,
no financial collapse in a dollar bill,
no love in a carbon atom.

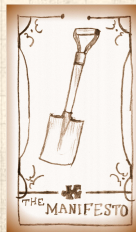


A few other features/aspects of complex systems:



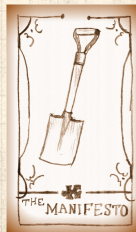
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-  Presence of feedback loops.



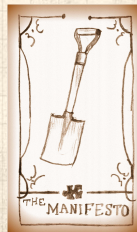
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-  Open or driven, opaque boundaries.



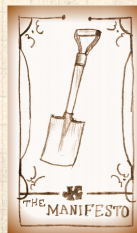
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-  Memory.



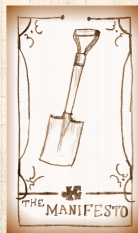
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-  Modular (nested)/multiscale structure.



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-  Explicit nonlinear relationships.
-  Presence of feedback loops.
-  Open or driven, opaque boundaries.
-  Memory.
-  Modular (nested)/multiscale structure.
-  Mechanisms range from being purely physical to purely algorithmic in nature.



Examples of Complex Systems:

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human societies



financial systems



cells



ant colonies



fluids, weather systems



ecosystems



power grids



animal societies



disease ecologies



brains



social insects



geophysical systems



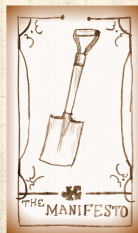
forests



Internet + Web



i.e., everything that's interesting ...



Relevant fields:

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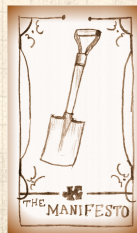
References

 Physics
 Economics
 Sociology
 Psychology
 Information
Sciences

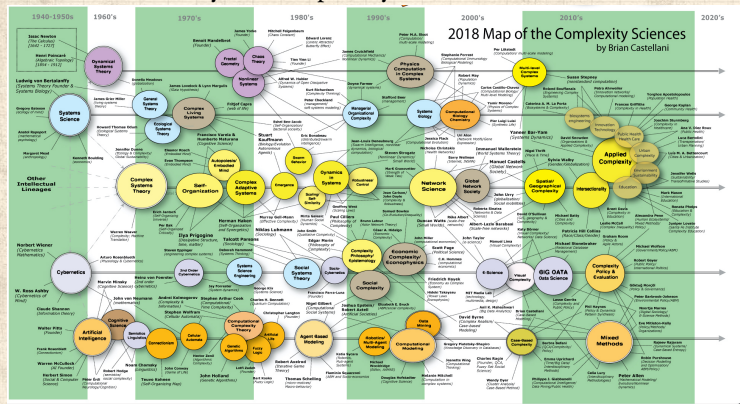
 Cognitive
Sciences
 Biology
 Ecology
 Geosciences
 Geography

 Medical
Sciences
 Systems
Engineering
 Computer
Science
 Data Science
 ...

 i.e., everything that's interesting ...



A visualized history of Complex Systemsish fields:



"Complexity Map" by Brian Castellani, Kent State



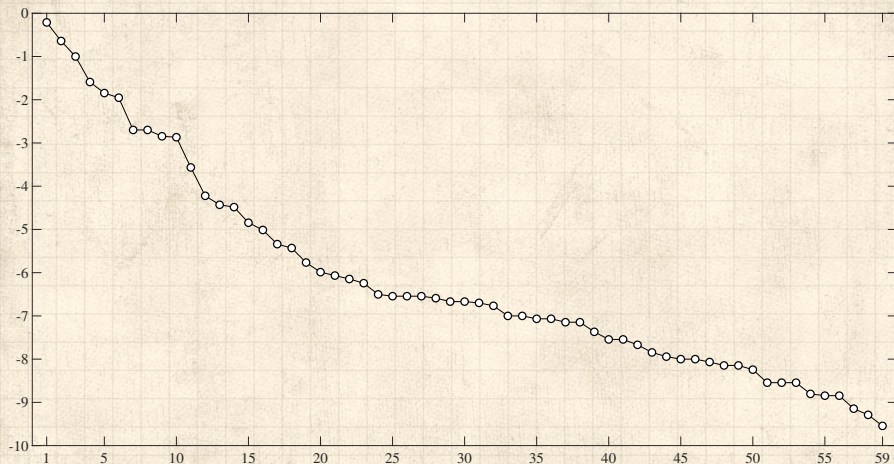
Online [here](https://art-sciencefactory.com), at art-sciencefactory.com.



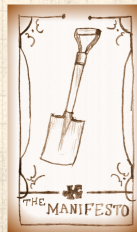
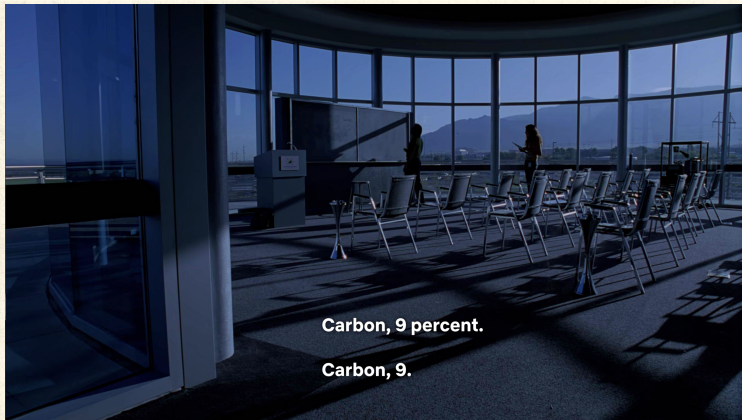
Complex Systems is bigger than this (e.g., fluid dynamics; more later).



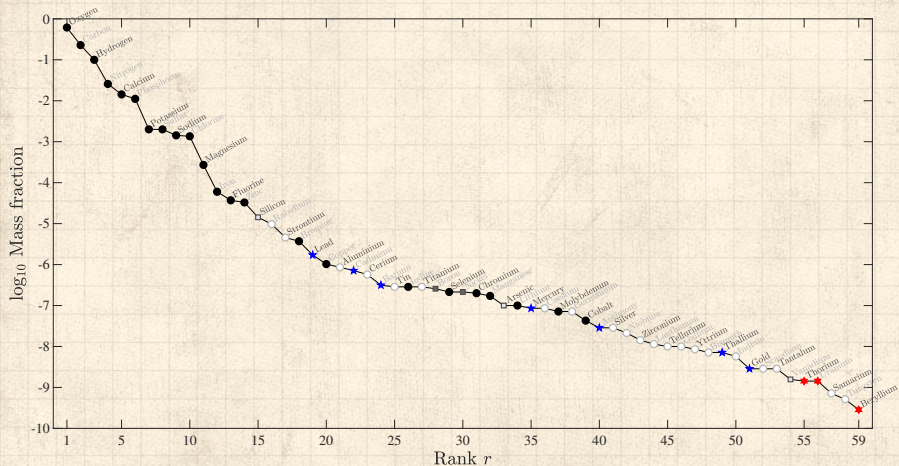
Cryptograph—What's being plotted here?:



A hint¹  



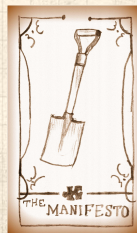
Fractional weight of typical human body by atomic species: ↗



Baking soda and vinegar¹

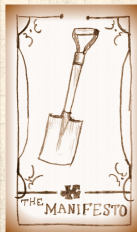


We are a somewhat difficult LEGO™ set:



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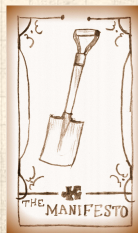
 Written on the box: “Nearly 10^{27} of 29 kinds of pieces!”



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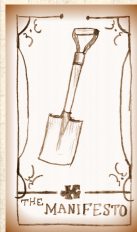
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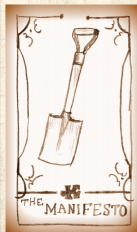
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-  Next 5 elements make up $\approx 0.85\%$: Potassium, sulfur¹, sodium, chlorine, and magnesium.



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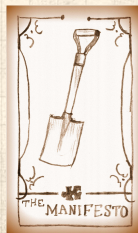
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¹Naturally varies with evilness

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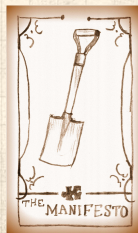
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-  Next 5 elements make up $\approx 0.85\%$: Potassium, sulfur¹, sodium, chlorine, and magnesium.
-  Remaining 18 necessary elements are trace elements.
-  Could be worse: A box with three packets containing up quarks, down quarks, and electrons.



¹Naturally varies with evilness

Best to see people as more than some kind of cleverly cooled quark soup:

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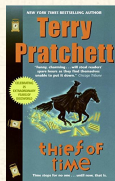
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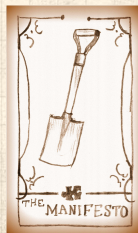
References

“It was hard to deal with people when a tiny part of you saw them as a temporary collection of atoms that would not be around in another few decades.”

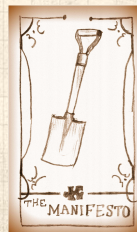
—Susan Sto Helit  (who is a “little bit immortal”)



“Thief of Time”  
by Terry Pratchett (2002). ^[7]



Or:¹  



Reductionism:

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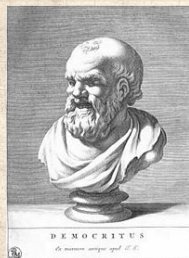
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Democritus 

(ca. 460 BC – ca. 370 BC)



Atomic hypothesis



Atom ~ a (not) – temnein (to cut)



Plato allegedly wanted his books burned.



John Dalton 

1766–1844



Chemist, Scientist



Developed atomic theory



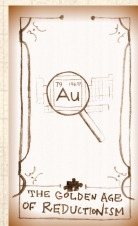
First estimates of atomic weights



Ludwig Boltzmann , 1844–1906. Atomic Theory.



“Boltzmann’s kinetic theory of gases seemed to presuppose the reality of atoms and molecules, but almost all German philosophers and many scientists like Ernst Mach and the physical chemist Wilhelm Ostwald disbelieved their existence.”



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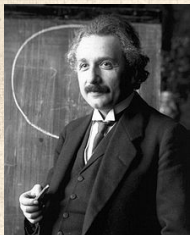


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See: epigenetics ↗.





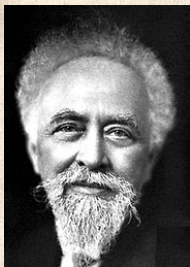
Albert Einstein 1879–1955



Annus Mirabilis paper:  “the Motion of Small Particles Suspended in a Stationary Liquid, as Required by the Molecular Kinetic Theory of Heat” [3, 4]



Showed Brownian motion  followed from an atomic model giving rise to diffusion.



Jean Perrin 1870–1942



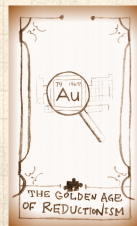
1908: Experimentally verified Einstein’s work and Atomic Theory.



Feynman in

The Feynman Lectures on Physics, Volume I ^[5]:

“If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words?



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“I believe it is the atomic hypothesis that all things are made of atoms—little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. “In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied.”



An unpleasantry:

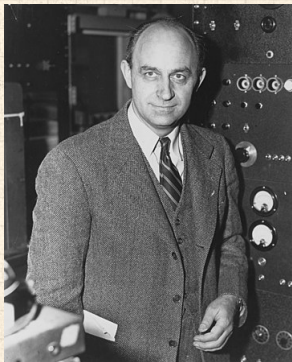
Fermi ↗

contained
bosons ↗

and

Bose ↗

contained
fermions ↗.



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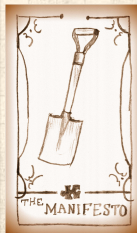
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References



Don't name scientific truths after people.



The Science of Complex Systems Manifesto:

1. Systems are ubiquitous and systems matter.

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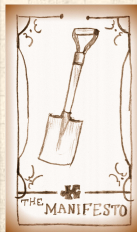
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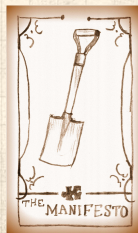
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Atoms!, sub-atomic particles, DNA, genes, people, ...



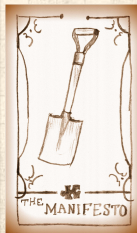
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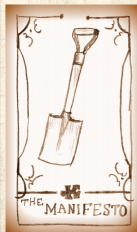
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Atoms!, sub-atomic particles, DNA, genes, people, ...
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4. Universality : systems with quantitatively different micro details exhibit qualitatively similar macro behavior (fate, but real and limited)



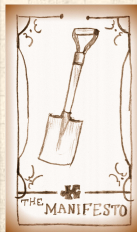
The Science of Complex Systems Manifesto:

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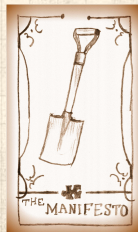
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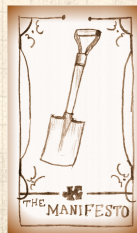
More:



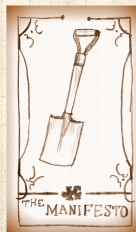
“The Three Books of Science” 

Peter Sheridan Dodds,

arXiv preprint arXiv:2511.00368, , , 2025. ^[2]

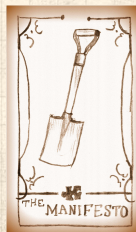


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[Science](#), 177(4047):393–396, 1972. [pdf](#) 
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