Overview of Systems Thinking: what it is, its development in the history of science and why it is important.

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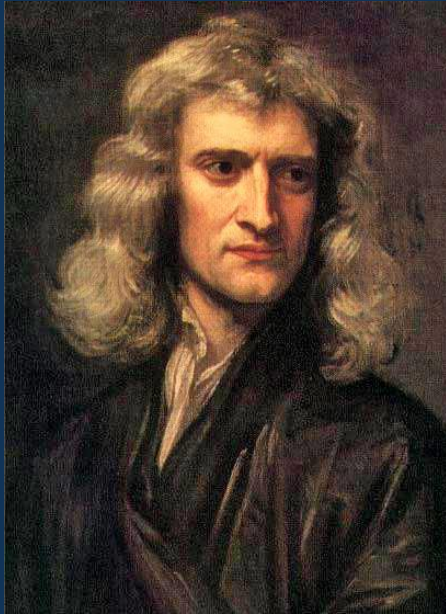
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Science as philosophy
Brief history

Newton

Smith

Forrester

Ecological, economic & social applications (systems dynamics)
- **World1 and World2 (Forrester)**
- **Limits to Growth (1972) – World3**
- **Resource constraints: sharing a finite world (IFoA) (2013)…**

Systems Thinking
Underlying principles

- Holistic
- Linkages and interactions between elements
- Disciplinary applications

    - social systems theory

    - systems biology

    - systems dynamics

    - systems ecology

    - systems engineering

    - systems psychology

Systems science Application

- ## Non linear complex systems

  - Small perturbations approximated using linear thinking

  - Large perturbations dominated by complex multi-interactions

- ## 'Divisibility' of the system

- ## *(all pre-dating computers/models)*

- Stocks and flows
- Negative feedback (dampen)
- Positive feedback (magnify)
- Emergent behaviours (out of the aggregate rather than individual)
- What it isn't…
  - Near equilibrium
  - Deterministic
  - Single agent

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Systems models Limitations

- Sensitivity to initial conditions
- Sensitivity to connecting functions (how does 'A' impact 'B')
- Sensitivity to impacts of perturbation (e.g. limits)
- Massively complex systems are massively complex

Systems models Applications

- Explore patterns & behaviours (not predictions)
- Non-divisibility of the system
- Explore larger perturbations away from equilibrium
- Emergent behaviour (financial cycles/crashes, civil unrest, ecology)
- Adaptive and learnt behaviours (inc. herding)
- Predictability – small perturbations can cause large deviations

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PLACES & SPACES MAPPING SCIENCE
More about the Complexity Map

KENT STATE UNIVERSITY

Sociology and Complexity Website

BLOG Complexity Science

Complexity in Health and Infrastructure Group

Map of the Complexity Sciences
by Brian Castellani

Timeline columns: 1940-1950s | 1960's | 1970's | 1980's | 1990's | 2000's | 2020

Foundational figures:
- Issac Newton (The Calculus) [1642 - 1727]
- Henri Poincaré (Algebraic Topology) [1854 - 1912]
- Ludwig von Bertalanffy (Systems Theory Founder & Systems Biology)
- Gregory Bateson (ecology of mind)
- Anatol Rapoport (mathematical psychology)
- Margaret Mead (anthropology)
- Kenneth Boulding (economics)
- Norbert Wiener (Cybernetics Mathematics)
- W. Ross Ashby (Cybernetics of Mind)
- Claude Shannon (Information theory)
- Walter Pitts (Founder)
- Frank Rosenblatt (Connectionism)
- Warren McCulloch (Founder)

Other Intellectual Lineages

Major nodes / fields:
- Dynamical Systems Theory
- Systems Science
- General Systems Theory
- Ecological Systems Theory
- Complex Living Systems
- Fractal Geometry
- Chaos Theory
- Nonlinear Systems
- Physics and Computation in Complex Systems
- Multi-level Complex Systems
- Managerial Organizational Complexity
- Systems Biology
- Computational Biology
- Complex Systems Theory
- Self-Organization
- Complex Adaptive Systems
- Autopoiesis and Adaptation
- Swarm Behavior
- Emergence
- Dynamics in Systems
- Robustness/Control
- Scaling/Self-Similarity
- Network Science
- Global Network Society
- Spatial/Geographical Complexity
- Cybernetics
- 2nd Order Cybernetics
- Systems Science Engineering
- Social Systems Theory
- Socio-Cybernetics
- Complexity Theory/Epistemology
- Economics and Behavioral Dynamics
- Social Complexity
- E-Science
- Visual Complexity
- Data Science
- Artificial Intelligence / Cognitive Science
- Connectionism
- Cellular Automata
- Computational Complexity Theory
- Artificial Life
- Genetic Algorithms
- Fuzzy Logic
- Agent Based Modeling
- Robotics/Multi-Agent Modeling
- Data Mining
- Computational Modeling
- Case-Based Complexity
- Intersectionality

People / contributors (labels):
- James Yorke (Founder)
- Mitchell Feigenbaum (Chaos Constant)
- Benoit Mandelbrot (Founder)
- Edward Lorenz (Lorenz Attractor/Butterfly Effect)
- Tien Yien Li (Founder)
- James Crutchfield (Computational Mechanics/ Nonlinear Dynamics)
- Stephanie Forrest (Computational Immunology/ Biological Modeling)
- Donella Meadows (globalization)
- Fritjof Capra (web of life)
- Alfred W. Hubler (Dynamics of Open Dissipative Systems)
- Doyne Farmer (dynamical systems)
- Robert May (Population Dynamics)
- Carlos Castillo-Chavez (Computational Biology/ Multi-level Modeling)
- James Grier Miller (living systems theory)
- Kurt Richardson (Complexity Thinking)
- Per Lötstedt (Computation/ multi-scale modeling)
- James Lovelock & Lynn Margulis (IGaia Hypothesis)
- Peter Checkland (management/ soft systems modeling)
- Stafford Beer (management)
- Howard Thomas Odum (Ecological Systems Theory)
- Eshel Ben-Jacob (Self-Organization/ Bacterial sociality)
- Uri Alon (Network Motifs/Gene Expression)
- Yamir Moreno (Physics of Complex Systems)
- Francisco Varela & Humberto Maturana (Cognitive Science)
- Per Bak (Self-Organized Critically)
- Stuart Kauffmann (Biology/Evolution Autonomous Agents)
- Eric Bonabeau (distributed/swarm intelligence)
- Yaneer Bar-Yam (Dynamics of Complex Systems)
- Jean-Louis Deneubourg (Swarm Intelligence, nonlinear dynamics, biological computation)
- Nicholas Christakis (Health Networks)
- Immanuel Wallerstein (World Systems Theory)
- Nigel Thrift (Complexity, Place, Time)
- Steve Strogatz (Small World)
- Mark Granovetter (Strength of Weak Ties)
- Barry Wellman (Internet, INSNN)
- Manuel Castells (Global Network Society)
- Erich Jantsch (Self-Organizing Universe)
- Herman Haken (Self-Organization and Synergetics)
- Murray Gell-Mann (Effective Complexity)
- Geoffrey West (Scaling Laws)
- Jean Carlson/John Doyle (Complexity & Robustness)
- Samuel Bowles (Dynamics of Human Systems)
- John Urry (globalization/ Social mobilities)
- Rèka Albert (scale-free networks)
- Albert-Lazlo Barabasi (Scale-free networks)
- David O'Sullivan (GIS, geography & Complexity)
- Michael Batty (Cities and Complexity)
- Warren Weaver (Organized & Disorganized Complexity; Machine Translation)
- Ilya Prigogine (Dissipative Structure, time, matter)
- Talcott Parsons (Sociology)
- Niklas Luhmann (Sociology)
- John Smith/Chris Jenks (Qualitative Complexity)
- Edgar Morin (Philosophy of Complexity)
- Paul Cilliers (Philosophy of Complexity)
- Bruno Latour (Actor Network Theory)
- Duncan Watts (Small Worlds)
- John Miller (computational economics)
- Scott Page (Political Science)
- John Taylor (e-science)
- Manuel Lima (Visual Complexity)
- Katy Börner (Visual Complexity/ Networks/ Data Science)
- Arturo Rosenblueth (Physiology & Cybernetics)
- Deborah Hammond (History of Systems Thinking)
- Heinz von Foerster (2nd order cybernetics)
- Jay Forrester (System dynamics)
- George Klir (Systems Science)
- Francisco Parra-Luna (Founder)
- Friedrich Hayek (Economy as Complex System)
- MIT Media Lab (technology, multimedia, design)
- Norbert Wiener (Cybernetics Mathematics)
- Andrei Kolmogorov (Complexity & Information)
- Stephen Arthur Cook (Computational/ Time Complexity)
- Charles H. Bennett (Quantum Computation)
- Nigel Gilbert (Computational Social Systems)
- Joshua Epstein/Robert Axtell (Artificial Societies)
- Slyvia Walby (Gender/Globalization/ Complexity)
- David Byrne (Complex Realism/ Case-based Modeling)
- Patricia Hill Collins (Race/Class/Gender/Sexual Identity/Nationality)
- John von Neumann (mathematics)
- Stephen Wolfram (Complexity/ Cellular Automata)
- Christopher Langton (Founder)
- Brian Castellani/Rajeev Rajaram (Case-Based Modeling)
- Leslie McCall (Complex Inequality)
- Teuvo Kohonen (Self-Organizing Map)
- John Conway (Game of Life)
- Hector Zenil (Algorithmic Complexity/ Computational Biology)
- Katia Sycara (Robotics, Multi-agent Systems)
- Michael Wooldridge (Editor, AAMAS)
- Gregory Piatetsky-Shapiro (Knowledge Discovery in Databases)
- Jeanette Wing (Computational Thinking)
- Emma Uprichard (Time/Complexity/ Interdisciplinary Methods)
- Bart Kosko (Fuzzy Logic)
- Lotfi Zadeh (Founder)
- John Holland (Genetic Algorithms)
- Thomas Schelling (micromotives/ Macrobehavior)
- Robert Axelrod (Iterative Game Theory)
- Douglas Hofstadter (Cognitive Science)
- Melanie Mitchell (Computation in complex systems)
- Charles Ragin (Founder, QCA, Fuzzy Set Social Science)
- Lasse Gerrits (Complexity and Public Policy)

Systems thinking today

- **Model types**

  - Systems dynamics

  - ABMs

  - Chaos theory

  - Fuzzy logic

  - Genetic algorithms

- **Model applications**

  - First model use for GE manufacturing

  - Industrial management

  - Optimising fuel consumption

  - Spread of epidemics

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Systems thinking tomorrow

- ## Model development and use becoming mainstream
  - UK & EU research funding (e.g. CECAN, MEDEAS)
  - Economic risk (esp. herding and emergent risk)
- ## Model applications
  - Financial crisis
  - Stock markets and equity/commodity valuations
  - Social interactions (e.g. terrorism)
  - The weather…

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