1) On *Nature (Philosophy) of Research*

Jiming Liu

Chair Professor in Computer Science

Hong Kong Baptist University

www.Wikipedia.com

Meng Ke (Meng Zi)
(372-289 BC)

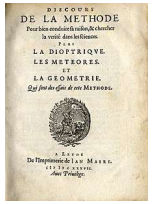
「學問之道 無他，
求其放心 而已矣。」

《孟子·告子上》

René Descartes
(1596–1650)

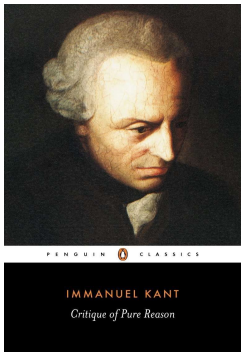
"I think; therefore I am."

- "Je pense, donc je suis"
- ***Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences*** (published in 1637)



- Since Descartes believed that all truths were ultimately linked, he sought to uncover the meaning of the natural world with a rational approach, through science and mathematics

www.Wikipedia.com
www.biography.com



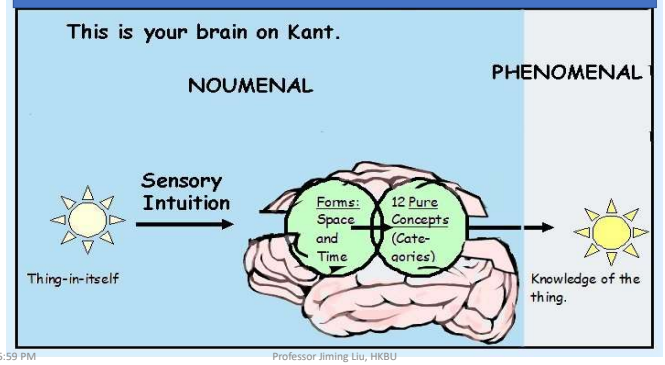
In ***Critique of Pure Reason*** (1781-1787), **Immanuel Kant** (1724-1804) tried to answer three questions:

1. **What can I know?**
2. What should I do?
3. What may I hope?

"All our knowledge begins with the senses, proceeds then to the understanding, and ends with reason. There is nothing higher than reason."

Immanuel Kant

"Thoughts without content are empty; intuitions without conceptions blind."
- Kant



http://win_corduan.tripod.com/hegel.html

Kant's 4 Categories of Pure Understanding (from his First Critique, 1781)				A New Look at Immanuel Kant @SourcePOV
A.Quantity	B.Quality	C.Relation	D.Modality	21st Century Interpretation?
[1A] UNITY (One)	[1B] REALITY	[1C] INHERENCE (Is A Property of)	[1D] POSSIBILITY	1. Conceptual Dimension — Archetypes of Philosophic Knowledge
[2A] PLURALITY (Many)	[2B] NEGATION (Disproof)	[2C] CAUSALITY (Causes)	[2D] NECESSITY (Proof)	2. Observable Dimension — Principles of Hypothetical, Empirical Science
[3A] TOTALITY (All)	[3B] LIMITATION (Constraint)	[3C] CORRELATION (Relates to)	[3D] CONTINGENCY (Adaptability & Emergence)	3. Intuitive Dimension — Dynamics of Real World Complexity

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Source: Britannica

William Blake
(1757–1827)

"To See a World..."

(from "*Auguries of Innocence*" by William Blake, 1803)

To see a **World** in a **Grain of Sand**
And a **Heaven** in a **Wild Flower**,
Hold **Infinity** in the **palm of your hand**
And **Eternity** in an **hour**.

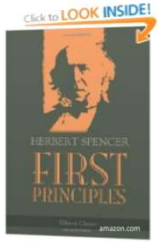
一沙一世界, 一花一天堂。
無限掌中置, 刹那成永恆。

徐志摩 譯

FIRST PRINCIPLES

Herbert Spencer: First Principles

Herbert Spencer
(1820-1903)



Principles of Biology
Principles of Psychology
Principles of Sociology
Principles of Ethics

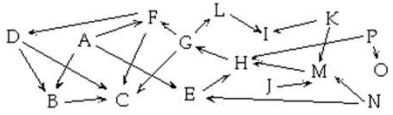
*"**Evolution** is definable as a change from an incoherent **homogeneity** to a coherent **heterogeneity**, accompanying the **dissipation of motion and integration of matter**. (Spencer, 1864)"*

- **Spencer**'s synthetic philosophy
- Sciences are classified according to the decreasing simplicity and generality:
  - Mathematics, astronomy, physics, chemistry, **biology** and **sociology**

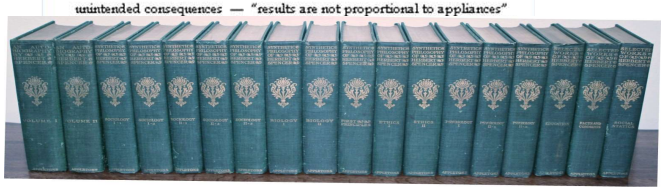
PRINCIPLE OF NON-INTERVENTION

Society is more like an ECOSYSTEM than an organism,
and it is more COMPLEX than any organism or ecosystem

ECOSYSTEM : set of interacting species-populations:



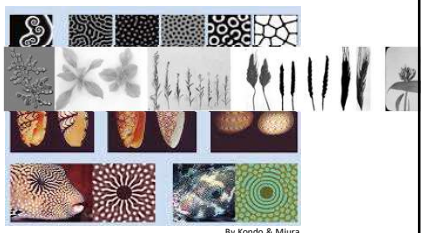
unintended consequences — "results are not proportional to appliances"



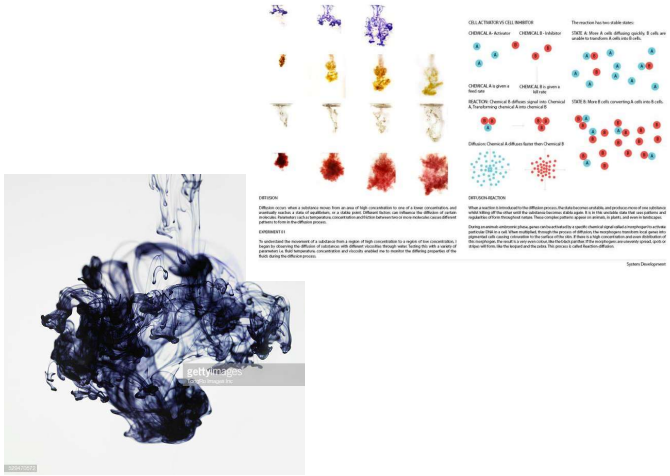
www.walkaboutbooks.net www.edstephan.org/Sociology

Alan Turing: How Nature Works

?



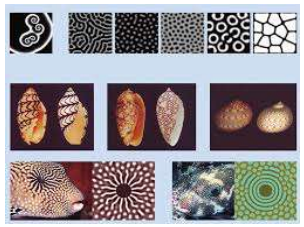
By Kondo & Miura



Alan Turing: How Nature Works

Reaction-Diffusion Systems
(Turing Systems)

$$\partial_t \boldsymbol{q} = \underline{\boldsymbol{D}}\Delta \boldsymbol{q} + \boldsymbol{R}(\boldsymbol{q})$$



THE CHEMICAL BASIS OF MORPHOGENESIS

By A. M. TURING, F.R.S. *University of Manchester*

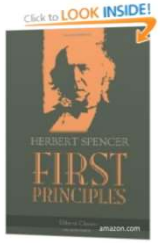
(*Received* 9 *November* 1951—*Revised* 15 *March* 1952)

It is suggested that a system of chemical substances, called morphogens, reacting together and diffusing through a tissue, is adequate to account for the main phenomena of morphogenesis. Such a system, although it may originally be quite homogeneous, may later develop a pattern or structure due to an instability of the homogeneous equilibrium, which is triggered off by random disturbances. Such reaction-diffusion systems are considered in some detail in the case of an isolated ring of cells, a mathematically convenient, though biologically unusual system.

Turing, A., On the chemical basis of morphogenesis, in *Philosophical Transactions of the Royal Society of London*, Series B, 237, 1952, pp.37-72.

Herbert Spencer: First Principles

Herbert Spencer
(1820-1903)



Principles of Biology
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"Evolution is definable as a change from an incoherent homogeneity to a coherent heterogeneity, accompanying the dissipation of motion and integration of matter. (Spencer, 1864)"

First Principles should be
sound & insightful

George Zipf
(1902-1950)

Zipf's law

- Observation: frequent words and rare words
  - "of" and "the" make up 10% of all occurrences
  - hardly ever see "aardvark"
- Rank words by frequency
- Zipf's law:
  - rank of the word times its probability (frequency) is approximately a constant

$$r \times P_r \approx const$$

Word	*Freq.*	*r*	P_r(%)
the	2,420,778	1	6.49
of	1,045,733	2	2.80
to	968,882	3	2.60
a	892,429	4	2.39
and	865,644	5	2.32
in	847,825	6	2.27
said	504,593	7	1.35
for	363,865	8	0.98
that	347,072	9	0.93

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Least effort principle

- Let C_j be the cost of transmitting the j-th most frequent word

$$C_j \sim \log_m j$$

- The average cost is

$$C = \sum_{j=1}^{n} p_j C_j$$

- The average information content is

$$H = -\sum_{j=1}^{n} p_j \log_2 p_j$$

- Minimizing cost per information unit C/H yields

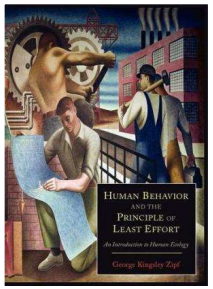
$$p_j \sim j^{-a}$$

slideplayer.com/slide/7440155/

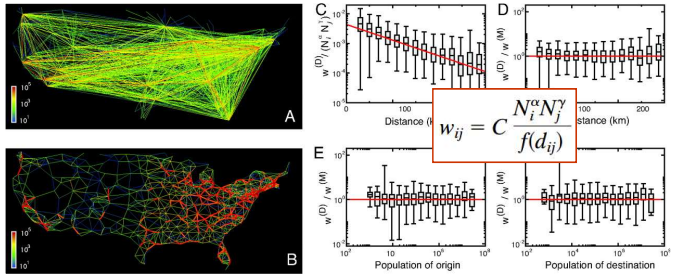
George Zipf
(1902-1950)

Human Behavior and the Principle of Least Effort

- Crashes in financial markets
- Dynamics of online popularity
- Scientific correspondence
- Human mobility patterns
- Spread of infectious diseases



Multi-Scale Mobility Networks and Gravity Law Fit



Duygu Balcan et al. PNAS 2009;106:21484-21489

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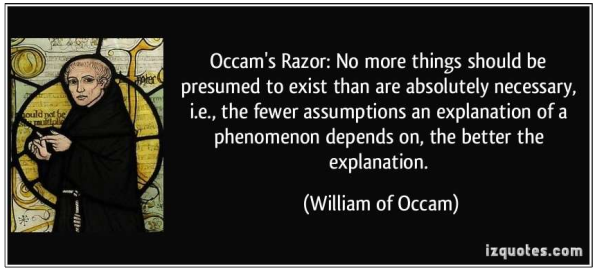
Conventional Wisdom…



"…In physics, parsimony was an important heuristic in Albert Einstein's formulation of special relativity, in the development and application of **the principle of least action** by Pierre Louis Maupertuis and Leonhard Euler, and in the development of quantum mechanics by Max Planck, Werner Heisenberg and Louis de Broglie."

wikipedia.org