What to Communicate in Science Communication

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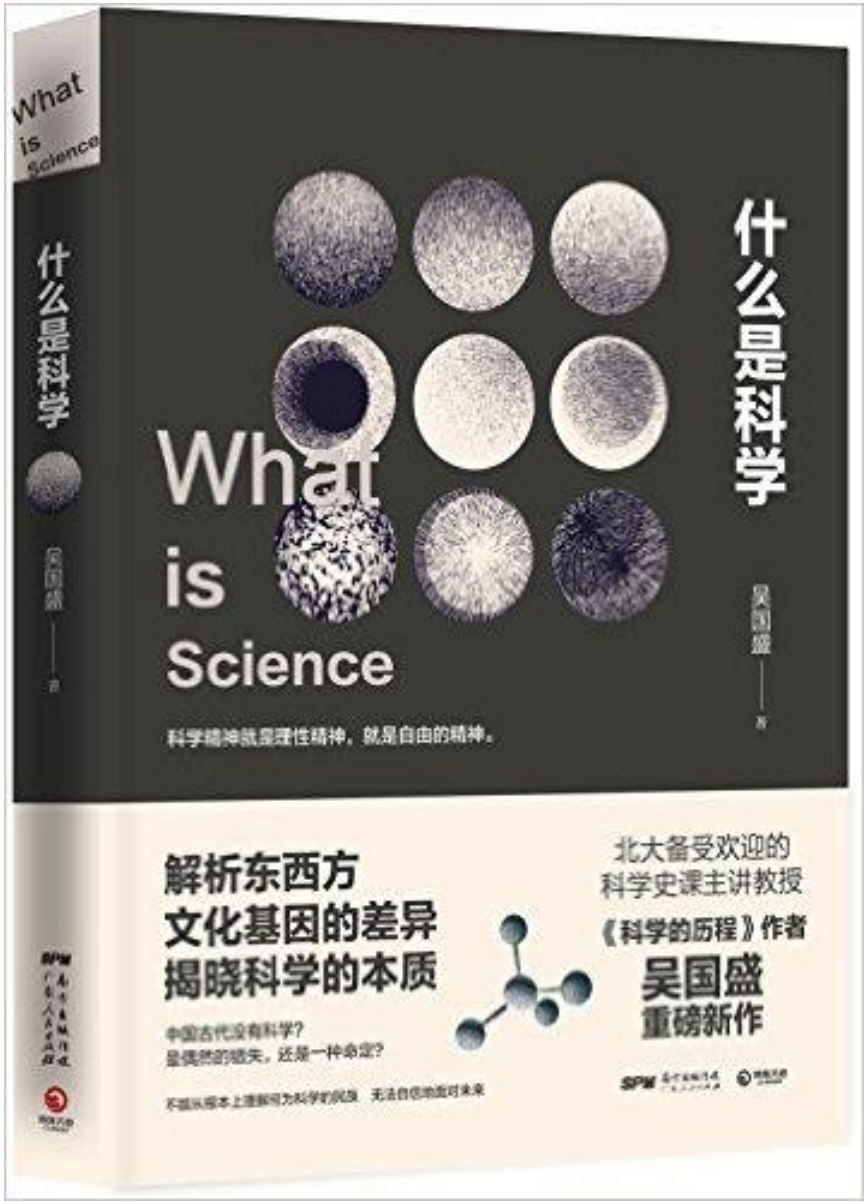
What Is Science?



2016

What Is Science?

Wu Guosheng

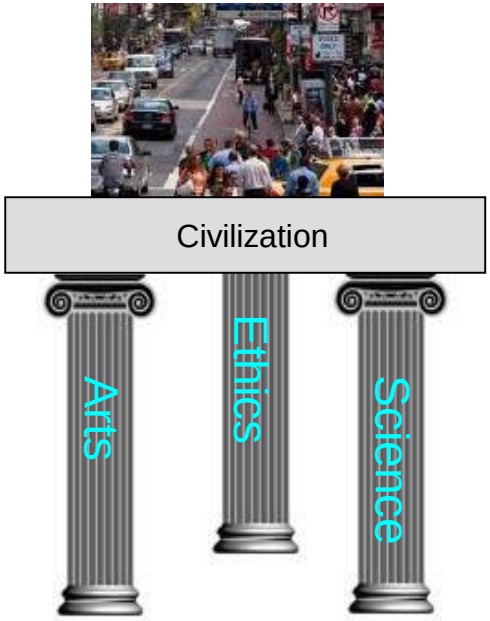
90% correct

Something About Science

- Science is the study of Nature
- Nature includes all material system (made up of atoms).
- Humans is a material system (evolved from simple living systems).

→ The study of things in Nature (humanities included) is part of science !

- But this understanding could be reached only in the last 100 years of so, after Darwin's theory of evolution (1859) and Einstein's Brownian motion paper (1905) proving the existence of atoms.
- Early stage of science (starting with Thales) involves observations and speculations; systematic approach appears only in the later, mature stages (in the modern science period of the last 400 years since Galileo).
- Ethics, Arts, Science are the 3 pillars supporting modern civilizations.

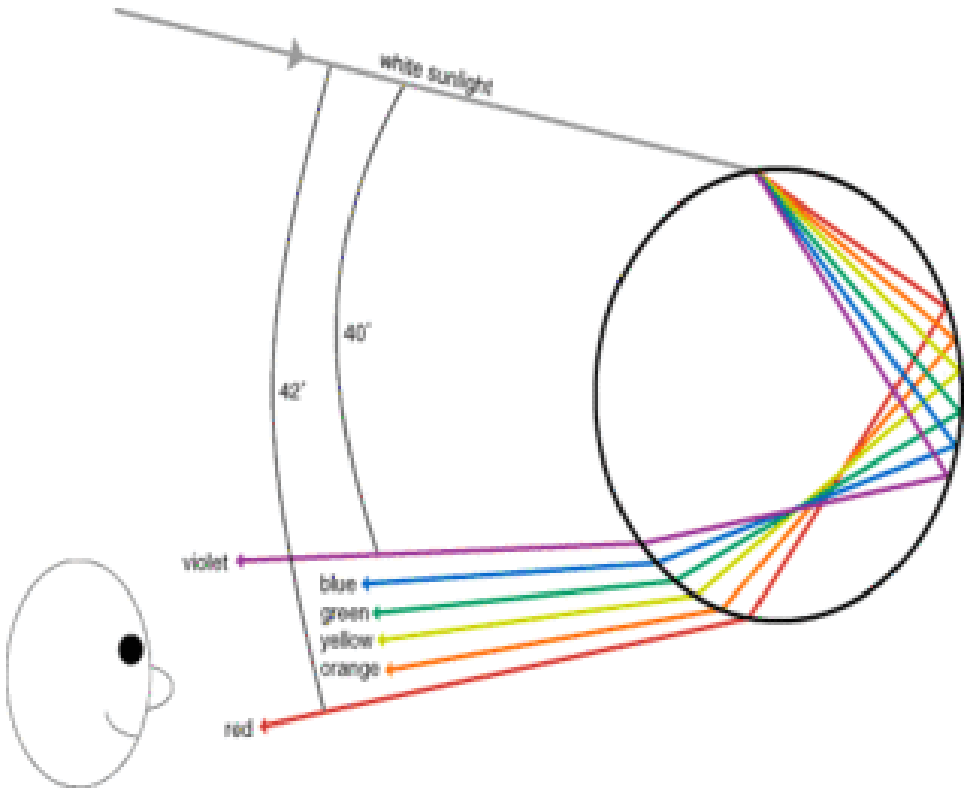


Rainbow and You

- Admiration only: Not yet a scientist
- Ask how the rainbow colors are produced: First step in becoming a scientist (but not yet)

- Record rainbow's shape and color distribution: A scientist at the empirical level
- Do theory or experiment to understand the formation mechanism:
  A scientist at the phenomenological level

Rainbow formation: Science at phenomenological level



- No God
- Rational thinking
- Need to ask why
- Consistent with lab experiments

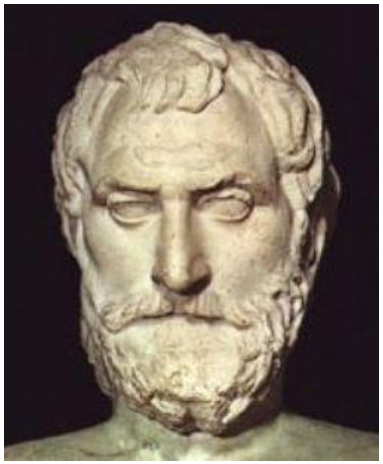
Three Research Levels in Science

Gas: An example

Need asking why

Empirical	Gas law: $P V = k T$
Phenomenological	From "conservation of momentum" and a few simple assumptions about the material (without the knowledge that gas are made up of molecules), can derive Navier-Stokes Equation: $\rho [\partial \mathbf{v}/\partial t + (\mathbf{v} \cdot \nabla)\mathbf{v}] = - \nabla p + \mu \nabla^2 \mathbf{v} + \mathbf{f}$
Bottom-Up	1. Kinetic gas theory [can re-derive the above equation and relate the parameters (ρ, μ) to molecular properties] 2. Monte Carlo simulations (starting from molecules)

Importance of Asking Why



Thales （c 624 - c 546 BC）

- Father of science
- Everything is made of water

Guanzi （ ? - 645 BC）

- Chinese philosopher
- Everything originates from water

〝地者,万物之本原,诸生之根菀也,美恶、贤不肖、愚俊之所生也。水者,地之血气,如筋脉之通流者也。故曰:水,具材也。〃

- Thales: Asks why and gives explanation
- Guanzi: Does not ask why

- The basic step in science is to ask why
- The Socrate's Method in science: Keep asking why

Not asking why is the major reason that ancient Chinese science remains at the empirical level (called Natural History in West and 博物学 in Chinese), without going deeper into analytic science like in the West.

Not asking why (encouraged by emperors) is part of the Chinese culture starting from ancient times since Confucius.

Science Is Built on Approximations

Theory means a confirmed hypothesis.

- Every theory is an approximation of "reality" (or a better theory later).
- For an "exact" theory, it is rare to find exact solutions.
- An equation is confirmed by measuring the quantities and showing that the left-hand-side of eq. is equal to the right-hand side.

$$F = ma$$

But every measurement has uncertainty (called error) dictated by the apparatus used.

And so the equation can only be confirmed approximately.

- It is a myth that "exact science" ever exists.
- Science never proves anything, rigorously speaking (in the mathematical sense of proof).
- Science lives and thrives with approximations.

Reality Check

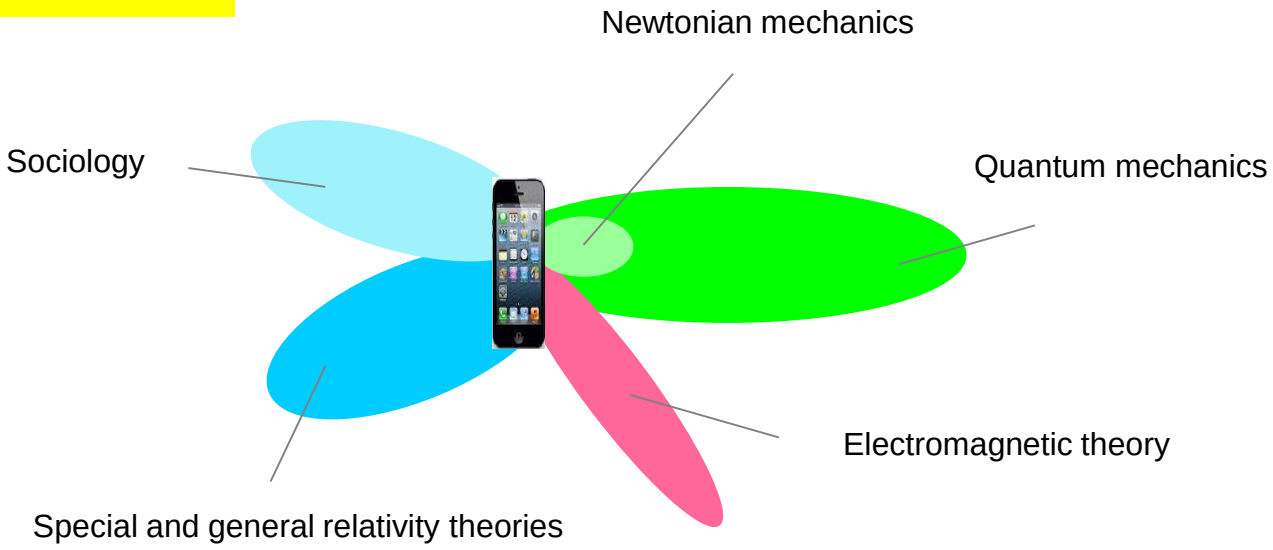
Why science is valued

- Science delivers.
- Science is the best game in town.

Why science can deliver

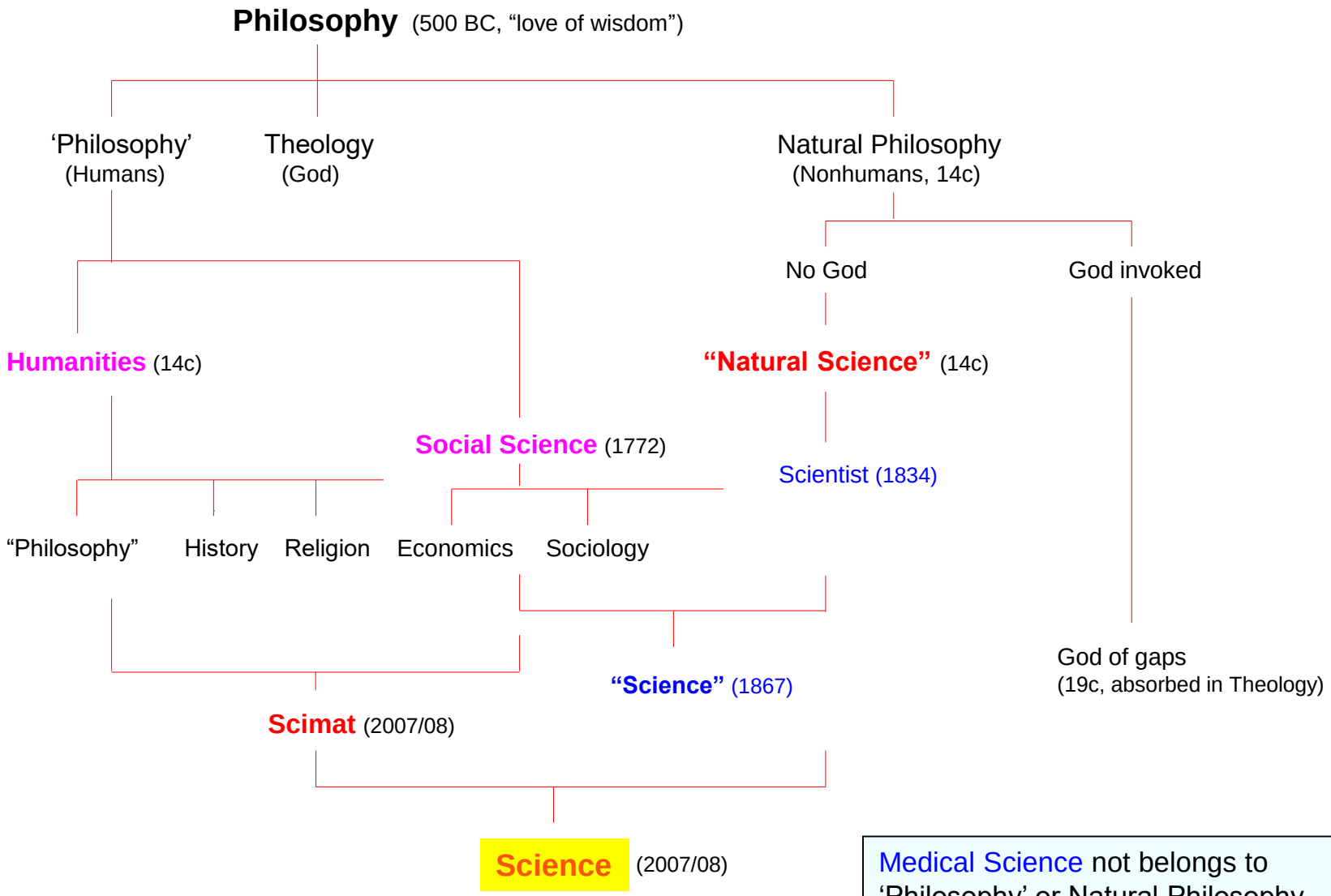
- Reality check means “confirmed” by experiments or practices, or, at the minimum, is consistent with established data.
- It is the RC that makes scientific knowledge unique among all forms of “knowledge”.

The cell-phone check



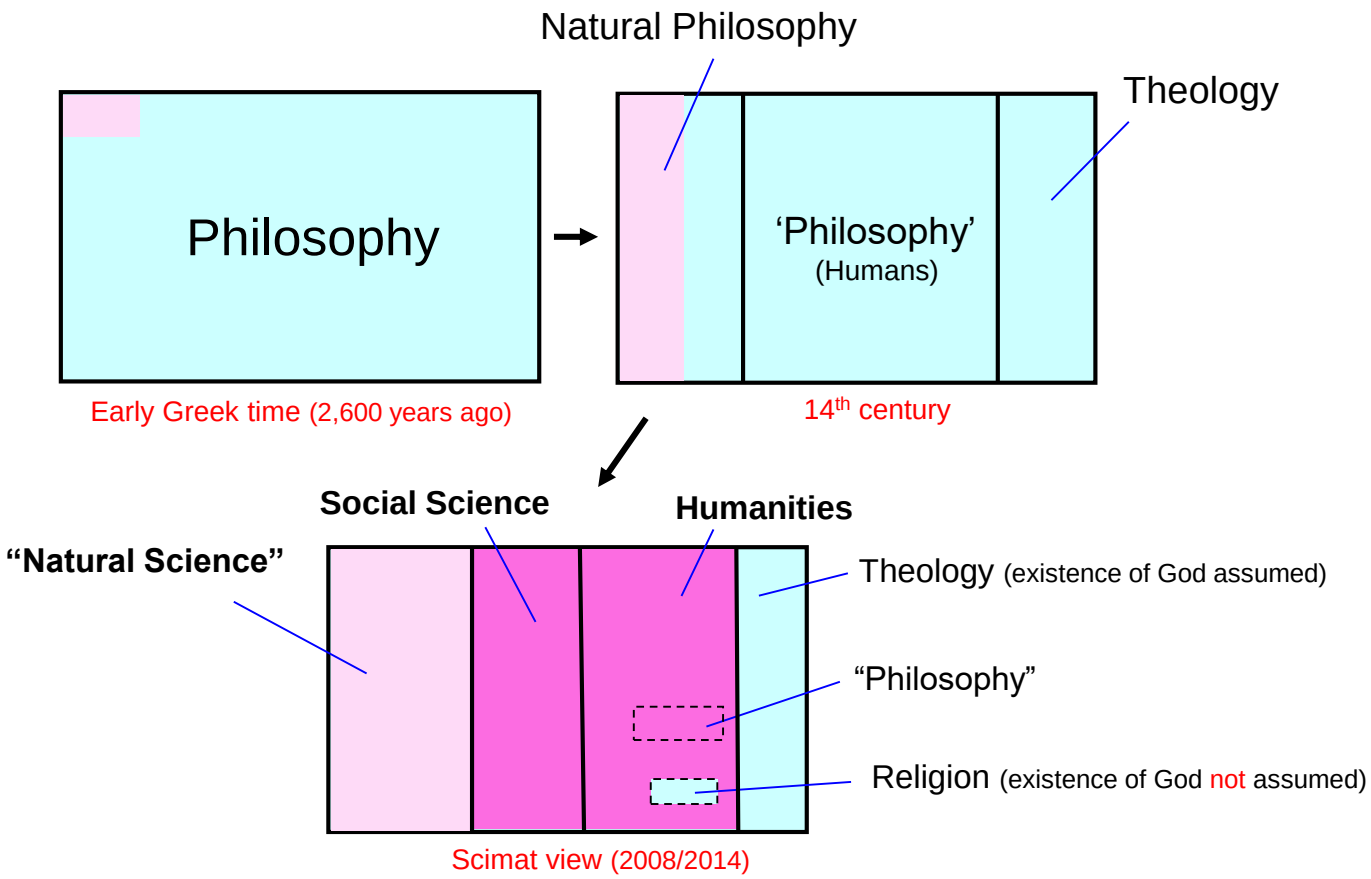
Defining Science

Birth of Disciplines and Science



Medical Science not belongs to ‘Philosophy’ or Natural Philosophy. It belongs to Scimat, which includes everything related to humans.

Retreat of God as Science Expands



Science, no God

God could be brought in

Scimat (= humanities + social science + medical science)

Science Defined

Science is humans' (earnest and honest) pursuit of knowledge about all things in Nature (which includes all human and nonhuman material systems) without bringing in God or any supernatural.

Humanities vs "Natural Science"

- "Natural science" did enlighten our understanding of Nature (e.g., Big Bang), make our living easier (cell phone), and help prolonging our life (for good or bad).
- But it is the humanities that determine our quality of life (e.g., to pollute or not to pollute) and bring us genuine happiness (human relationships, arts).
- Also, it is humans (through decision making, a branch of humanities) who controls the use of "natural science".
- And that is why the humanities (*the disciplines*) are more fundamental and important than "natural science".

Science and Scimat

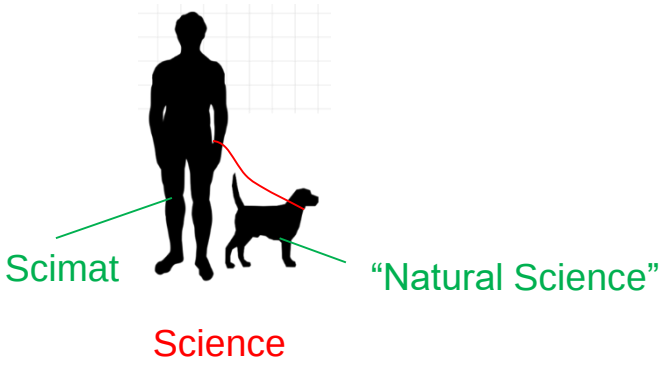
Scimat (人科), invented by Lui Lam in 2007/2008, is a new multidiscipline that focuses on the science of humans.

Science = Natural Science

= Science of nonhumans + Science of Humans

"Natural Science" Scimat

Humanities + Social Science + Medical Science



Scimat Website: www.sjsu.edu/people/lui.lam/scimat

Essence of Science

- Science's characteristics are its **secularity** and the **reality check**.
- The necessary Reality Check is what makes science useful and distinctively different from humans' other types of inquiry.
- Uncertainty is unavoidable in human matters.

One culture, two systems, three levels !

- One scientific culture
- Two kinds of systems (simple and complex)
- Three research levels (empirical, phenomenological, bottom-up)

What *Not* to Communicate

Misconceptions about Science

Wrong: Science is about the systematic study of repeatable and controlled experiments.

Correct: The backbone of science is the collection of (interrelated) theories and controlled experiments; historical sciences (like astronomy and paleontology) advance by comparing their findings with results from controlled experiments.

Wrong: There is a set of well defined procedures making up the Scientific Method.

Correct: Scientific Method in this sense does not exist. Science is about open-mindedness, honesty, earnest, admitting errors, and peer reviewing/checking. There is “scientific tradition” or “scientific experience” but no “scientific method”.

Wrong: Science is a social phenomenon (Hitler).

Correct: The science process is human dependent (and a social phenomenon) but the end result of nonhuman systems (like law of gravity) is human-independent.

Wrong: Important scientific laws or theories are always expressed in mathematical equations.

Correct: Not true, even in physics. Example: Third Law of Thermodynamics (It is impossible to reach the absolute zero in a finite number of steps). Also: Darwin's Evolutionary Theory (The fittest survives).

Wrong: Scientists are always right.

Correct: Scientists are humans. Even Einstein made mistakes. But good scientists speaking on their expertise have higher chance to be right than novices.

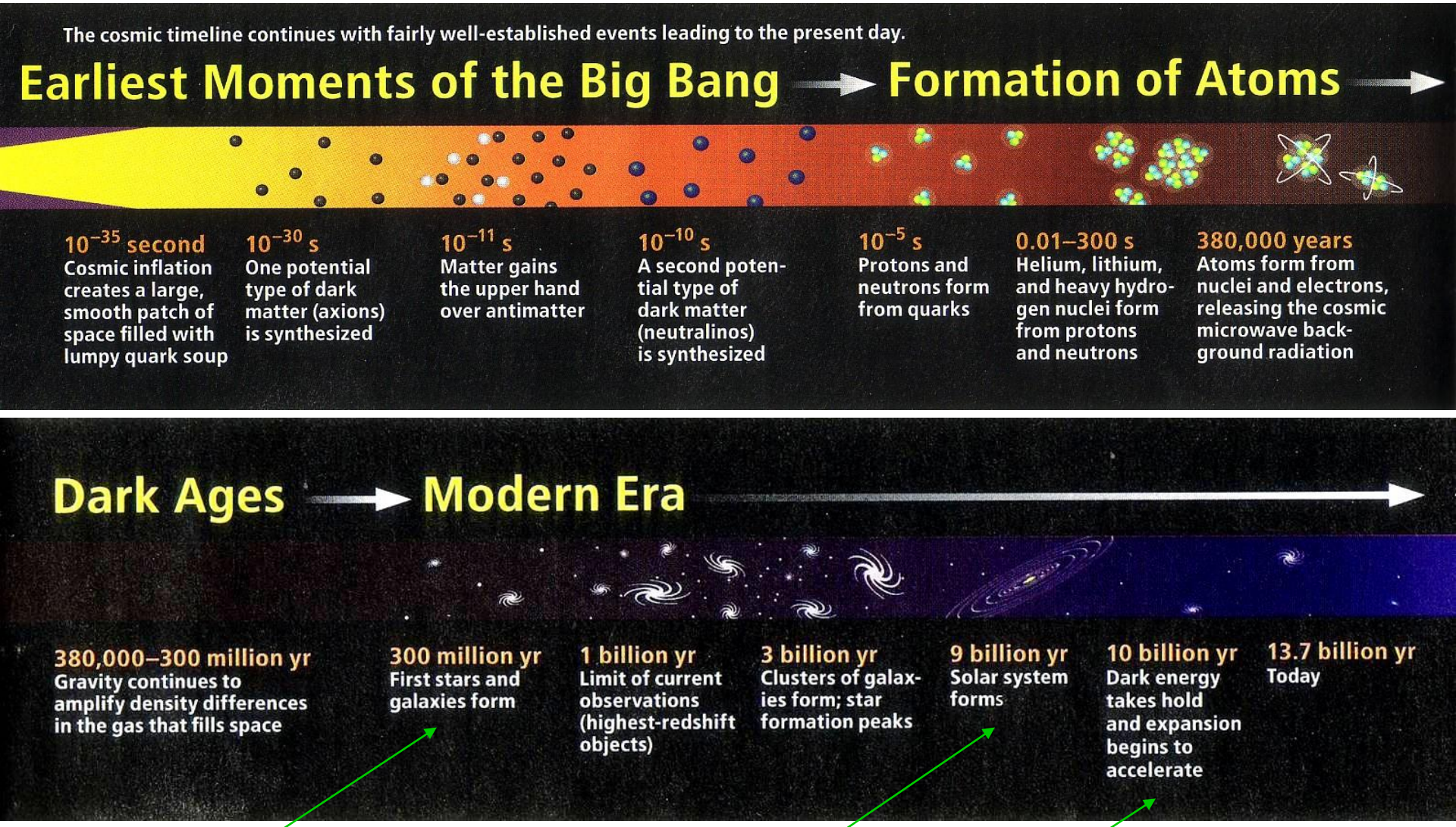
Wrong: It is scientific and so must be right.

Correct: It depends on who is the one calling it scientific. Good experts? Administrators? Reporters? Also, scientific results evolve with time and could be wrong in the future (when new evidences emerge, like in some medicine).

What to Communicate 1

Basic Messages

Basic Message 1: Everything Begins with Big Bang



Everything on Earth is made of atoms (come chiefly from stars) !

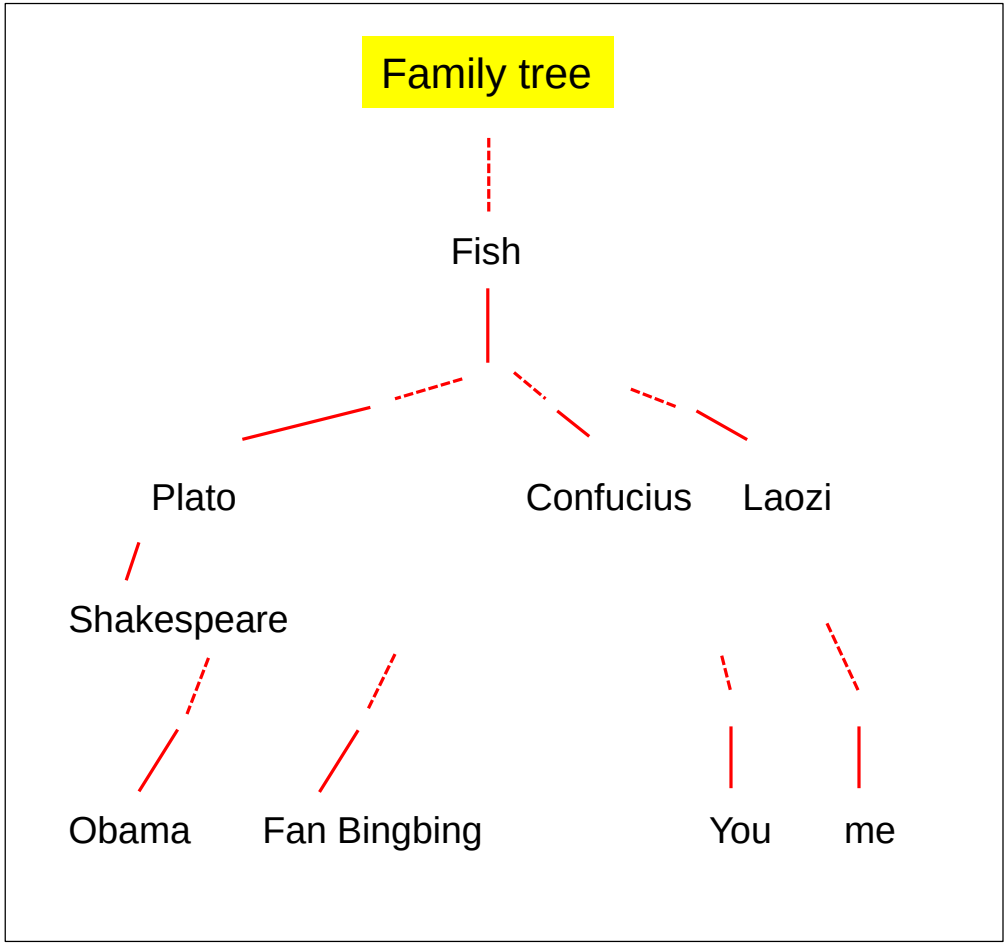
Basic Message 2: We Are One Family

Our ancestor

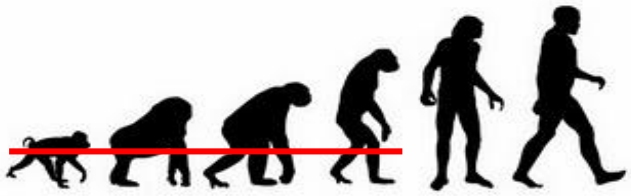
Microbrachius

8 cm, 0.4 billion year ago

Family tree

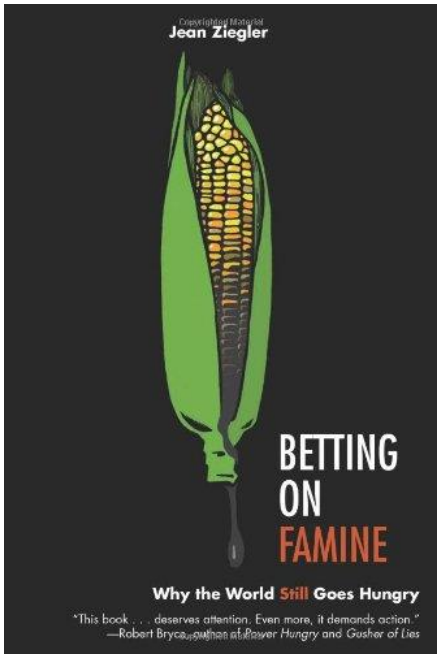


Darwin's evolutionary theory (1859)



Basic Message 3: Humanities Are Part of Science

Importance of humanities (*the disciplines*) could be seen:



1. If all present "science" research is stopped, the world is still the same—chaos and tragedies will continue—because it is the humanities (underdeveloped in the last 2600 years since Plato) that matters in human affairs.

2. Another way of seeing this is through the lesson of Apple company.

   Putting a good humanist among "scientists"/engineers could create great companies—good for the economy.

What to Communicate 2

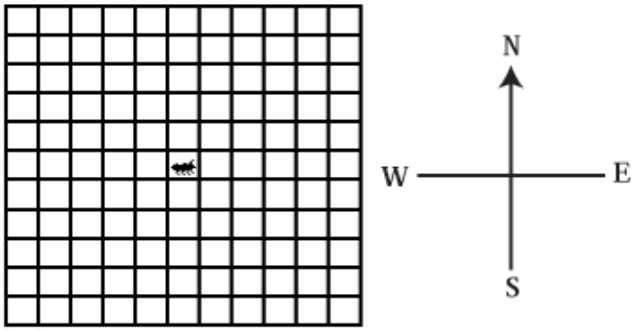
Uncertainty and Complex System

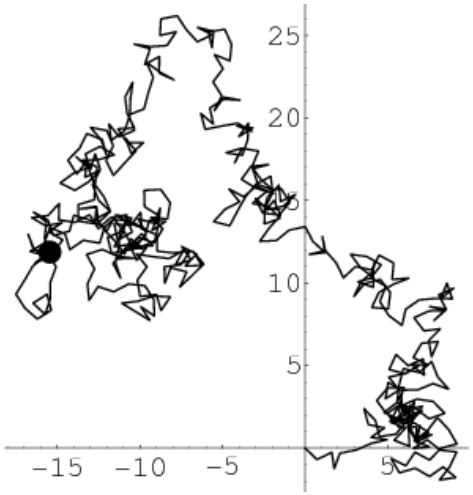
The Human World Is Probabilistic

The human world is stochastic, i.e., probability is involved.

Non-deterministic system: has to ask different questions

Random Walk: An example





- The exact trajectory is different each time: can't be predicted.
- But, e.g., average distance traveled is proportional to square root of time—can be predicted.

Louis Bachelier

PhD thesis in economics (1900)

Einstein

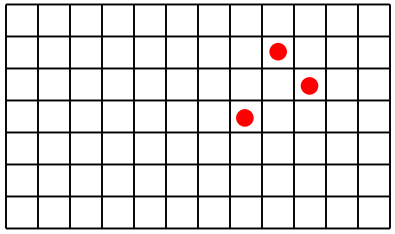
Brownian motion paper (1905)

Probability and Uncertainty

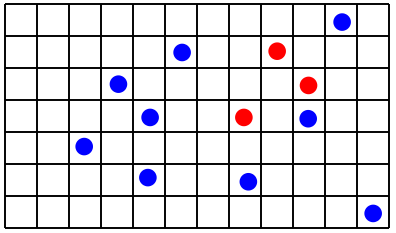
Why eventually there always is a winner in Lotto ?

Lotto first prize
→ one box will be hit

Winner is the one whose box is hit



1st round

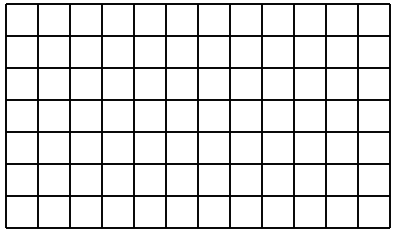


2nd round

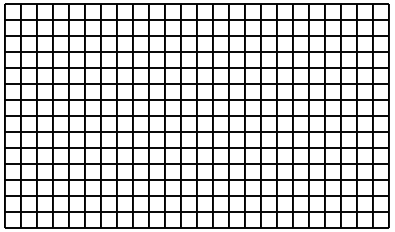
Events with small probability, no matter how small, could actually happen.

Given: a (zero-size) raindrop will fall on this graph paper

p = probability that a box will be hit



p = 1/84 = 0.012 (1.2%)



p = $1/(84)^2$ = 0.00014 (0.014%)

- Probability is an intrinsic part of the human world.
- We simply have to go on living with uncertainty, more *wisely* and *humbly*.

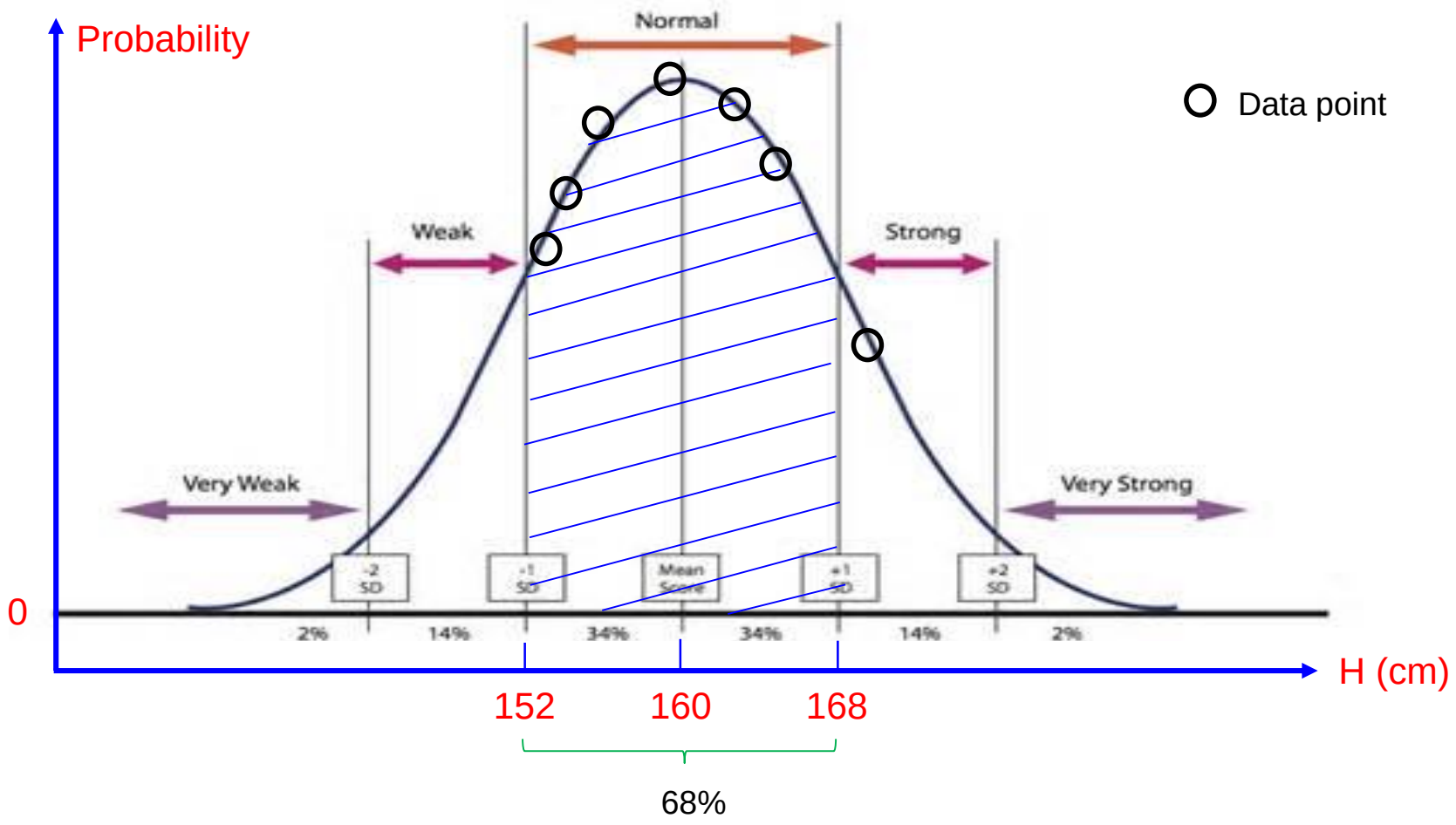
Error Bar and the Bell Curve

What it means to say the *height of students in class* H is given by

$$H = 160 \pm 8 \text{ cm}$$

It does not mean
$152 \leq H \leq 168$ cm

Mean = 160 cm
Standard deviation (SD) = 8 cm



Communicate Complex Systems

Steven Hawking:

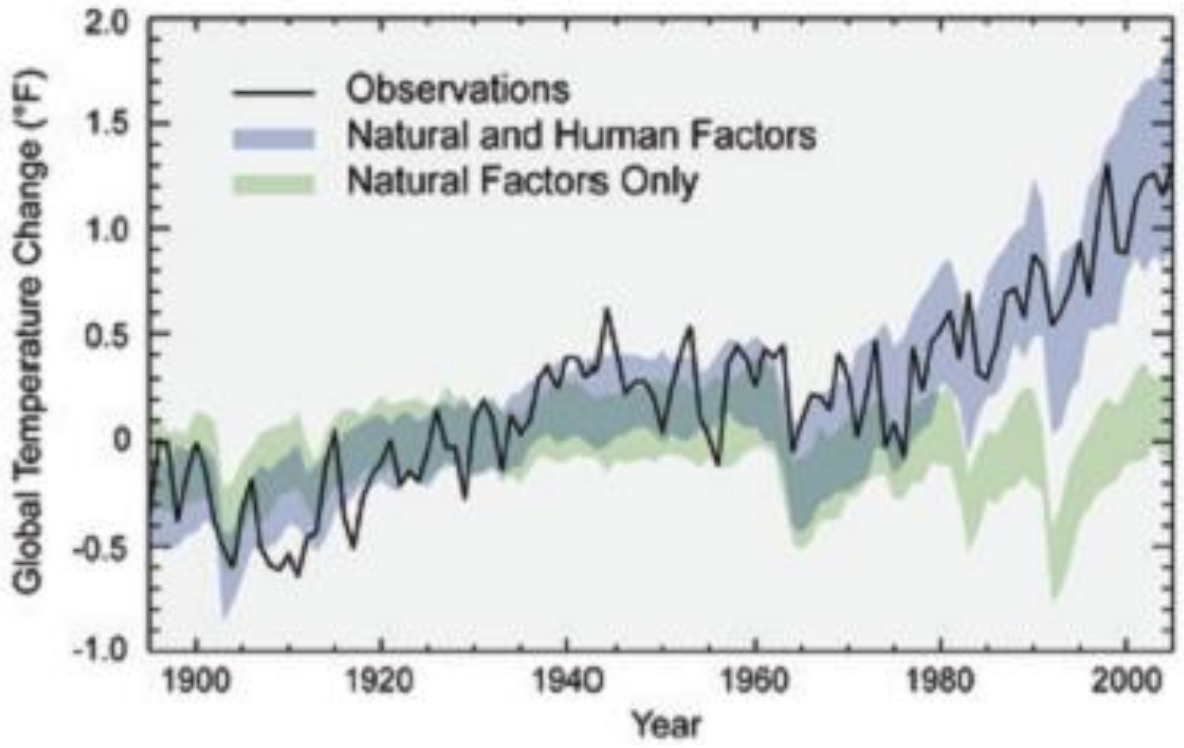
"Complex systems is the most important science in the 21th century."

All human problems and the world around us are complex systems.

Predictions, when possible, are (mostly) probabilistic.

Only 15 years ago, complex systems science had to justify its existence. Today it is taking the world by storm. Networks, big data, cascading crises, extreme events, the word "systems," and many other ideas are widely accepted.

Climate Change: An Example



Observational data fit the trend of a combination of natural and human factors (rather than natural factors only).

That is, human factors are important.

Melillo et al, "Human and natural influences on climate" (2014)

- Climate is a complex system with intrinsic uncertainty.
- No exact theory (computer results only).
- Any prediction is probabilistic.
- Any decision about global warming is an educated gamble (because "black swan" outcomes could actually happen) and thus should be made by the whole human race → science communication has important role to play.

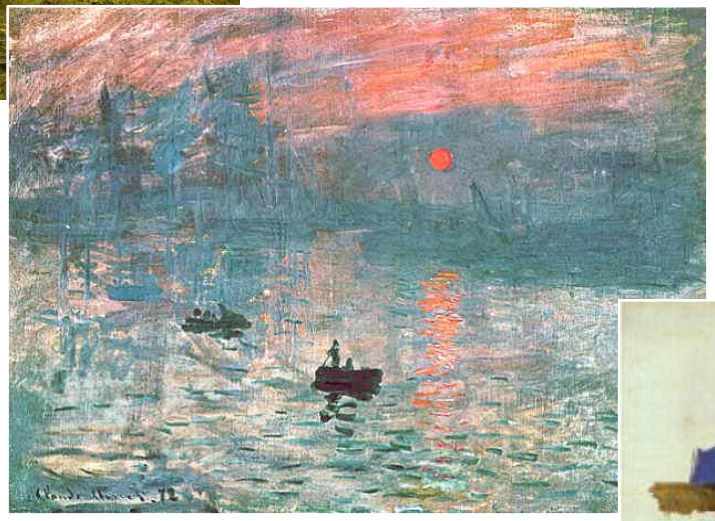
What to Communicate 3

Science of Innovation

Innovation in Art

Realism

Need no verification



Expressionism

Modernism

Innovation in Business

Need “quick” verification

Facebook

Fun

↓

Discover vacuum

↓

Fill the vacuum

Innovation in Science

Science has two parts: Scientific process + Scientific results

… Innovation… ⟷ Produce breakthrough, original works

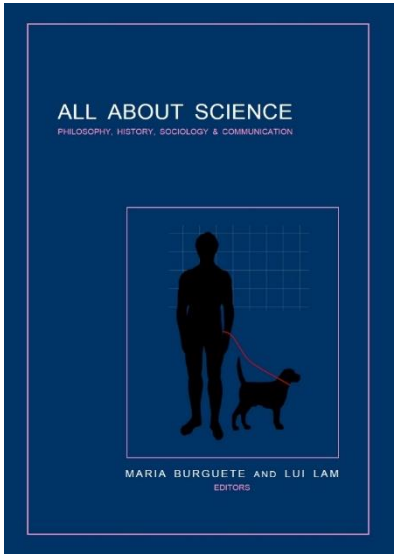
↓

Human dependent → Scimat

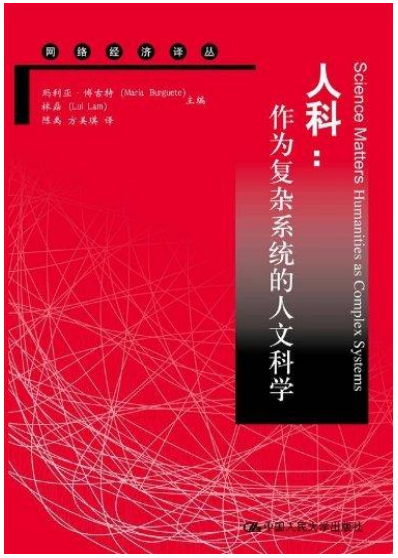
Need verification

Innovation is a branch of scimat !

All human matters are probabilistic.
Exceptions could and do occur !



2014



2013

Science of Innovation

- Left brain controls language, logical thinking, rationality
- Right brain controls innovation, imagination, sensuality
- Mind: 10% conscious; 90% subconscious (→ innovation not come from smartness alone)
- Innovation happening
  - Stimulated by environment (usually at initial stage)
  - Intense thinking + subconscious induced thought "jumping" (usually at middle stages)
    - → Necessity of intermittent relaxation

Innovation not a purely deductive process (but involves left and right brains, rationality and sensuality)

Psychologists' experimental results

- Individual thinking better than collective thinking
- Individuals more efficient than groups
- Small groups better than large groups
- Bonus is counterproductive

These unexpected results contradict our common sense.

Innovation process

- Janusian
- Sepcon
- Homospatial

- ***Flight from Wonder****: An Investigation of Scientific Creativity,* A. Rothenberg (Oxford U P, 2015)
- ***The Creative Crisis****: Reinventing Science to Unleash Possibility*, R. B. Ness (Oxford U P, 2015)
- ***How to Fly a Horse****: The Secret History of Creation, Invention, and Discovery*, K. Ashton (Doubleday, 2015)

Optimizing Innovation

In China, innovation obstacles come from too many rules restricting attempted innovators, not because of insufficient funding.

As individual

- Control time usage (simplify life, don't cook, rest suitably, write less papers…)
- Bulk the trend (don't do hot topics unless you have a good idea)
- Don't follow others (don't use other's method doing same problem unless…)
- Try more, have fun (follow your own interest, review failures)
- Physical strength (exercise, be healthy)

Picking topics

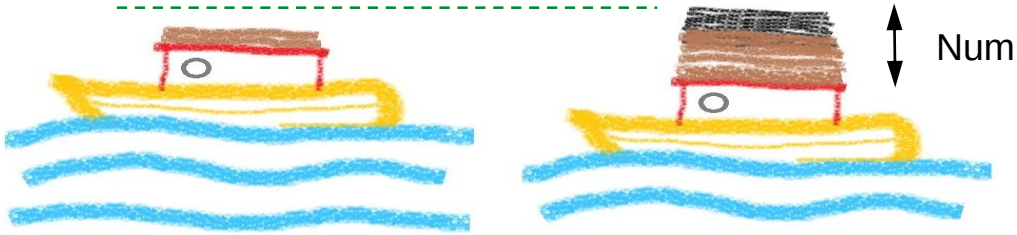
As organization

- Continue to support big science/national labs
- Prepare to support individuals
- Protect independent-minded, "strange" individuals
- Raise the basic salary of all scientists to upper middle level
- Don't add trouble (don't count papers; lower the threshold of scientific frauds)

Paper Counting and Innovation

Increasing publications

Irrelevant to innovation



Number of papers

Paper and wine

Cheering

Suitable number of papers

Innovation impossible

Drunk

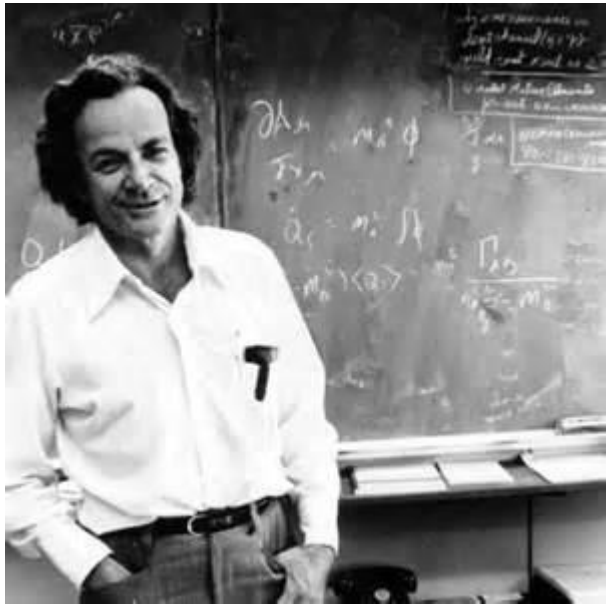
Too many papers

Zombie

Fraud

Less Paper the Better for Innovation

Richard Feynman (1918-1988)



1965 Nobel Prize in Physics
Quantum Electrodynamics

125 articles
54 research papers

1938

[1] With M.S. Vallarta. Scattering of cosmic rays by the stars of a galaxy. **Phys. Rev.** 55: 340-343.

1948

[7] Space-time approach to non-relativistic quantum mechanics. **Rev. Mod. Phys**. 20: 367- 387.
[8] A relativistic cut-off for classical electrodynamics. **Phys. Rev.** 74: 939-946.
[9] Relativistic cut-off for quantum electrodynamics. **Phys. Rev**. 74: 1430-1438.

1949

[10] With J.A. Wheeler. Classical electrodynamics in terms of direct interparticle action**. Rev. Mod. Phys**. 21: 425-433.
[11] With N. Metropolis and E. Teller. Equations of state of elements based on the generalized Fermi-Thomas theory. **Phys. Rev**. 75: 1561-1573.
[12] The theory of positrons. **Phys. Rev**. 76: 749-759.
[13] Space-time approach to quantum electrodynamics. **Phys. Rev**. 76: 769-789.

1988

[122] An outsider's inside view of the Challenger inquiry. **Physics Today** 41(2): 26-37.

Conclusion: Modernize Science Communication

- In science communication (scicomm),

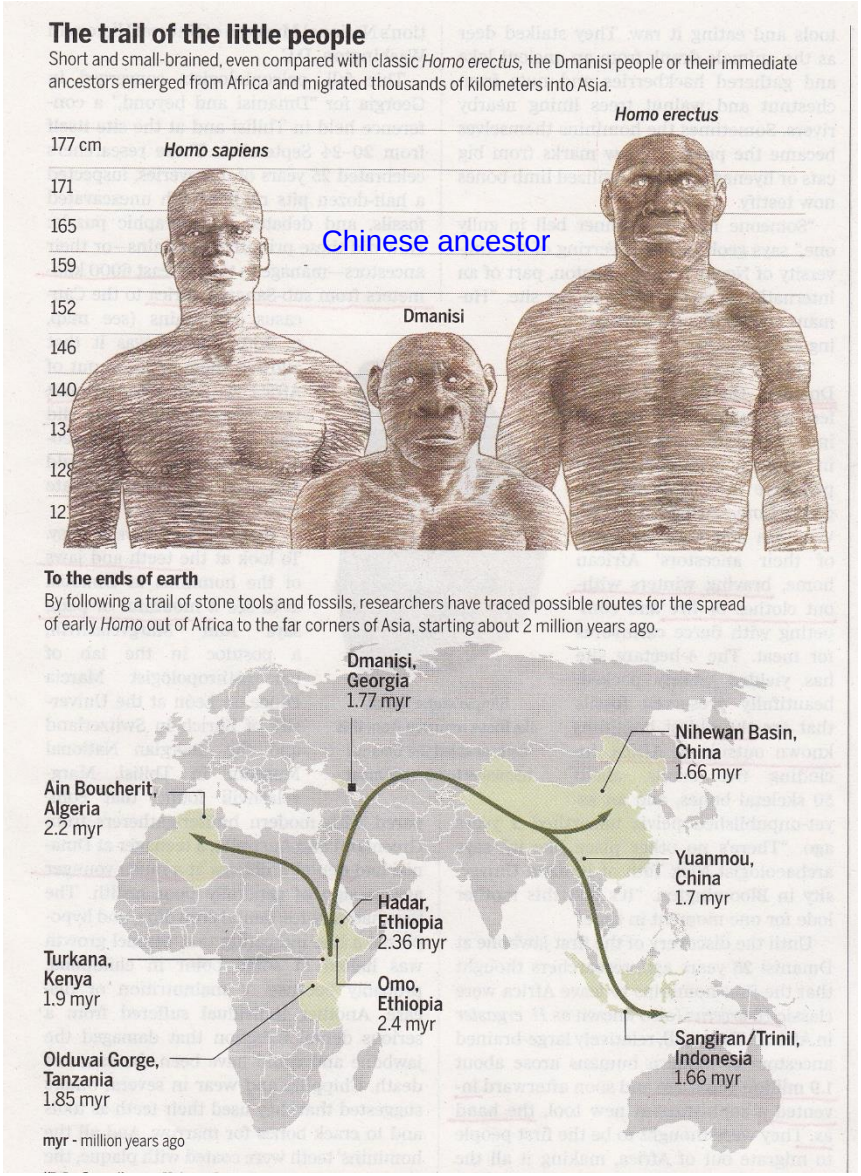
  the essence of the so-called "scientific method" (such as the scientific spirit and scientific tradition) and the knowledge of human-related parts of science (concepts of uncertainty and probability, the humanities and social sciences) could be more important than those about non-living systems.

- Popularizing complex systems will help the public to understand complex issues (e.g., global climate change) and be better, responsible citizens, and will make China the leader in the field of science communication.

- Communicating the science of innovation will help China's change in economical structure.

Zhu Ming 朱銘

Human Migration



Earliest known migration out of Africa

Approaches in Ancient Philosophies

Greece	China
About anything	Mostly about social harmony/stability
Freedom of speech Supported by slavery	Lack of freedom of speech "Feudal" kingdoms
Analytic	Fuzzy/circular arguments (*hu you,* intentionally mislead) Philosophers never wrote clearly or argued convincingly
Debate Socratic method	No (or not much) debate

Ancient Greek Philosophies

- Ancient Greek philosophers didn't need a regular job and lived in a democracy, and so were free in picking topics in pursuing acknowledge.

- Ancient Greek philosophers cared about everything in daily life (and the Universe) and wanted to understand (analytically) and solve problems.

- In ancient Greece, philosophy was the only discipline of learning which actually was very successful (all disciplines today branched out from it).

Ancient Chinese Philosophies

- In ancient China, unlike in Greece, philosophy was not conducted analytically. They are more like Buddhist verses or "chicken soups" (called "Chinese wisdom" by others).
- The philosophers, unlike the Greeks, never wrote clearly or argued convincingly.
- When pressed, they will appeal to the will of Tian ("heaven") or the good old ways of the (barely existent) ancient dynasties.
- All, except Zhuangzi, concentrated in ethics/morality issues because that was the way to find a (government) job, unlike the ancient Greeks who didn't need a job.
- Mozi (not Confucius) is most relevant to China today.
- Ancient Chinese philosophy is *huyouism* (忽悠主义), aiming to maintain social harmony/stability instead of finding out the "truth" or advancing knowledge.
- But it is "useful" to a certain extent (the longest dynasty—Tang from AD 618–907, lasts 289 years).