

Design and Analysis of Experiments

01 - What is Science

Version 2.11

Felipe Campelo

<http://www.cpdee.ufmg.br/~fcampelo>

Graduate Program in Electrical Engineering

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*“The most that can be expected from any model is that
it can supply a useful approximation to reality.
All models are wrong; some models are useful”*

George E.P. Box (1919 – 2013)
British statistician



What is science?

Some common misconceptions

- Science is a collection of facts; ✗
- Science is the creation of new gadgets; ✗
- Scientific ideas are absolute and unchangeable; ✗
- Scientific ideas are subject to change, therefore unreliable; ✗
- Observations give answers directly to the scientists; ✗
- Science **proves** stuff; ✗
- Science can only **disprove** stuff; ✗
- The scientist works to **show** that his/her theory is right; ✗

STAND BACK



I'M GOING TO TRY
SCIENCE

What is science?

A good operational definition

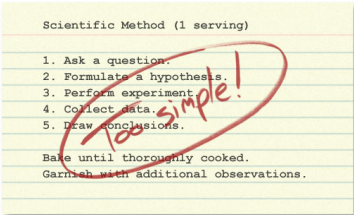


*“What do you think science is?
There’s nothing magical about science.
It is simply a systematic way for carefully
and thoroughly observing nature and
using consistent logic to evaluate results.”*

– Steven P. Novella

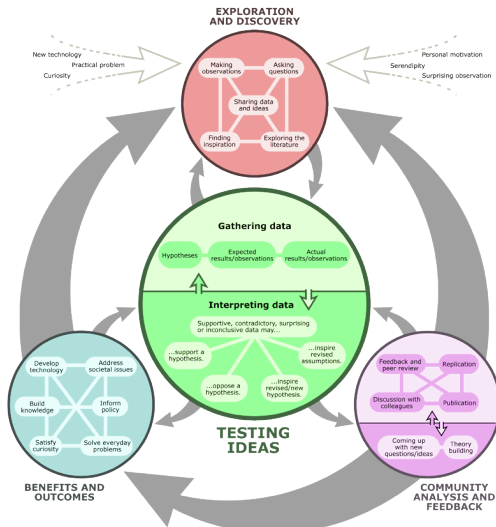
What is science?

The scientific process

- Normally shown as a flowchart or a sequence of steps;
 - Oversimplification of a complex and iterative process;
 - Suggests an “end” to the process.
- 
- Actually includes:
 - Several activities, performed at different stages;
 - Interaction with the scientific community;
 - Creative, “outside the box” thinking;
 - Preliminary conclusions, subject to revision as new and better data become available;
 - Learning from failures as much as from successes.

What is science?

The scientific process

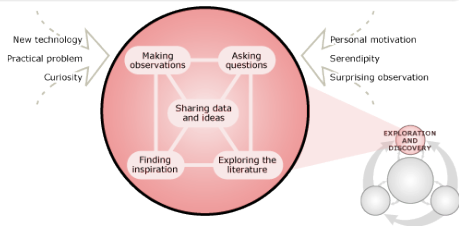


What is science?

The scientific process

“Dans les champs de l’observation le hasard ne favorise que les esprits préparés.” – **Louis Pasteur** (Univ. Lille, France, 1854).

- Observations → **questions**;
- Exploratory experimentation;
- Preparation + serendipity.



Benzene (1865)



Kekule

Radioactivity (1896)



Becquerel

Penicillin (1928)



Fleming

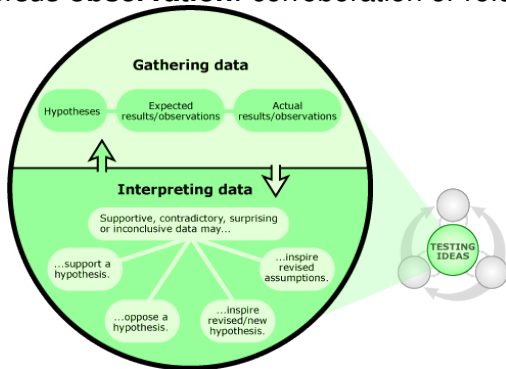
Top image: <http://goo.gl/fy8G1h> - (c) Understanding Science, 2015. Used with permission.

Scientists: <http://goo.gl/SG6sgp> | <http://goo.gl/rhLC9C> | <http://goo.gl/CFj8M1>

What is science?

The scientific process

- Drawing and testing hypotheses;
- Comparing alternative explanations;
- Accepting / rejecting ideas based on **evidence**;
- **Predictions** *versus* **observation**: corroboration or refutation?

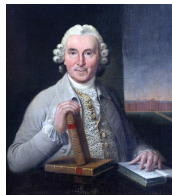


What is science?

The scientific process

James Lind (1747):

- Observation: scurvy in sailors;
- Conjecture: Caused by the body rottenning;
- Idea: attempt to avoid/reverse effects with acidic substances;



Separation of a group of 12 affected sailors in six groups with identical diets, except for the addition of a supplement:

Group 1

Cider.

Group 2

Vitriol.

Group 3

Vinegar.

Group 4

Sea water.

Group 5

Oranges and lemons.

Group 6

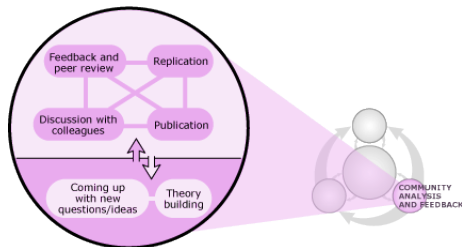
Tea.

What is science?

The scientific process

Interaction with the scientific community is **fundamental**:

- Colleagues;
- Collaborators;
- Reviewers;
- Rivals;



This interaction plays essential roles for the progress of research:

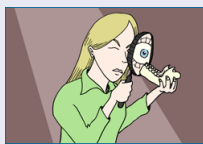
Criticism



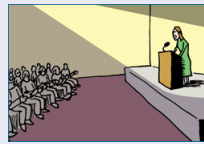
Inspiration



Vigilance



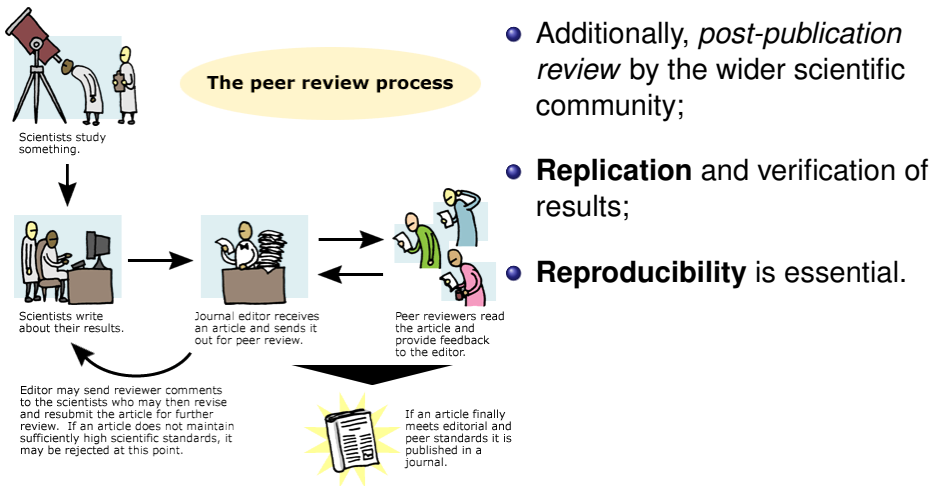
Motivation



What is science?

The scientific process

Publication and peer review.

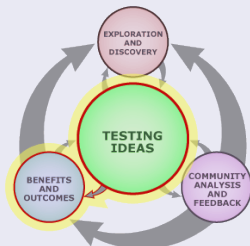
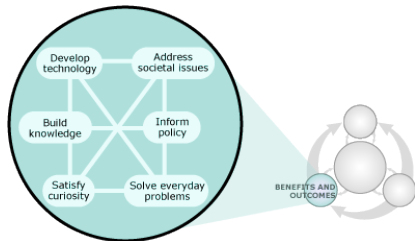


What is science?

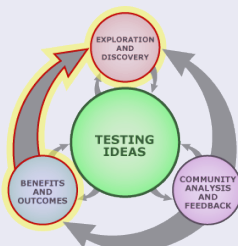
The scientific process

The scientific process is a way of building knowledge:

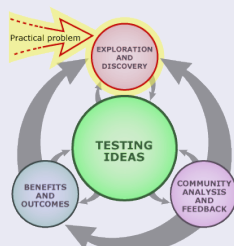
- Generate and test new ideas about how the world works;
- Iteratively increasing the reliability of the knowledge;



Knowledge → Applications



Technologies → Discovery



Applications → Investigation

What is science?

To wrap it up



“It is important to be literate in the scientific method, not only for the sake of your own research. We are also agents of change in the population and, as such, we need to be aware of good and bad science, and able to point the difference to the society.”

– Claus C. Aranha

Bibliography

Required reading

- 1 *Understanding Science*. 2014. University of California Museum of Paleontology. 3 January 2014. - <http://www.understandingscience.org>
- 2 F.L.H. Wolfs, *APPENDIX E: Introduction to the Scientific Method*. - <http://goo.gl/osGpU>

Recommended reading

- 1 Carl Sagan, *The demon-haunted world: science as a candle in the dark*, Random House, 1996.
- 2 The Skeptics Guide to the Universe. - <http://www.theskepticsguide.org>

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Online: <https://github.com/fcampelo/Design-and-Analysis-of-Experiments>

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