UFMG
UNIVERSIDADE FEDERAL
DE MINAS GERAIS

Design and Analysis of Experiments

01 - What is Science

Version 2.12.2018b

Felipe Campelo
http://orcslab.cpdee.ufmg.br/

Graduate Program in Electrical Engineering

Belo Horizonte
August 2018

CC BY NC SA

"*Science and everyday life cannot and should not be separated.*"

Rosalind Franklin (1920 – 1958)
English Chemist and X-ray crystallographer

Image: https://commons.wikimedia.org/wiki/File:Rosalind_Franklin_CC-BY-SA.png

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; ×

- Facts *vs* hypotheses *vs* theories *vs* laws;

Essential reading: Common Misconceptions About Science: `http://goo.gl/TN7k9B`

Image: `http://xkcd.com`

What is science?

A good operational definition

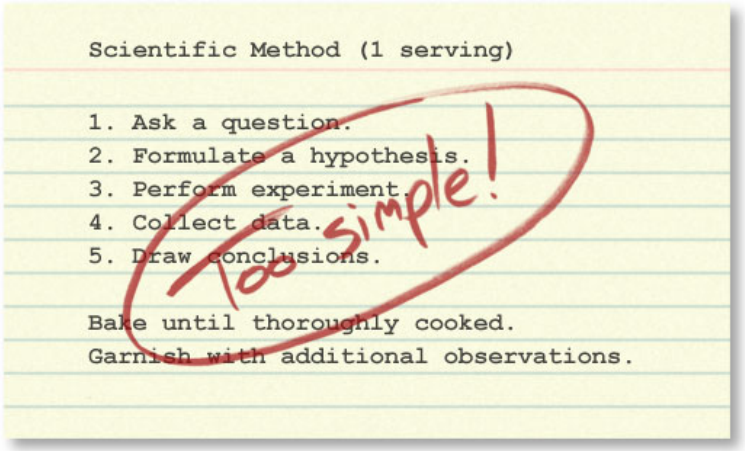
> *"What do you think science is?*
> *There's nothing magical about science.*
> *It is simply a systematic way for carefully*
> *and thoroughly observing nature and*
> *using consistent logic to evaluate results."*
>
> – Steven P. Novella

Image: `http://www.relativelyinteresting.com/definition-science-steven-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.

Image: `http://goo.gl/7cCGaz` - (c) Understanding Science, 2015. Used with permission.

What is science?

The scientific process

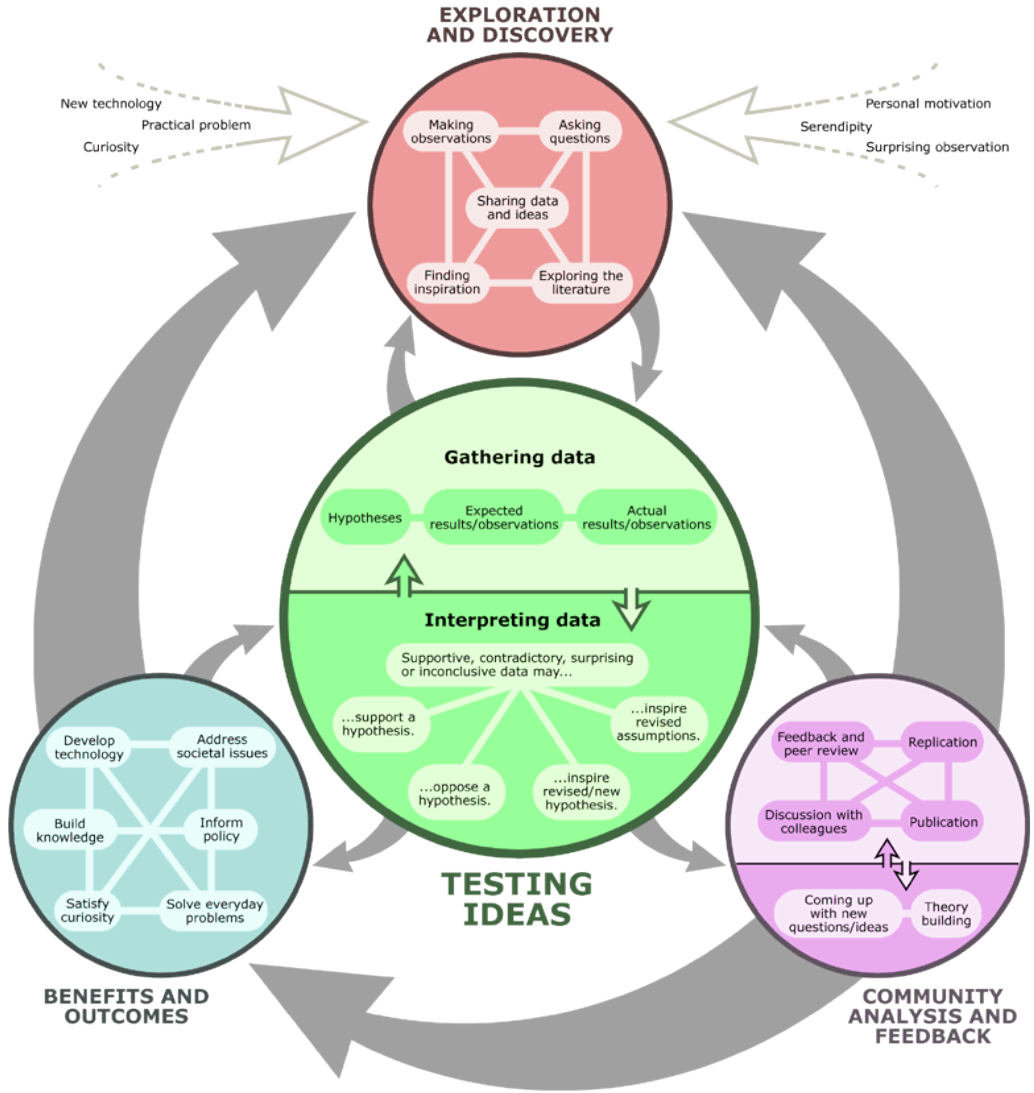


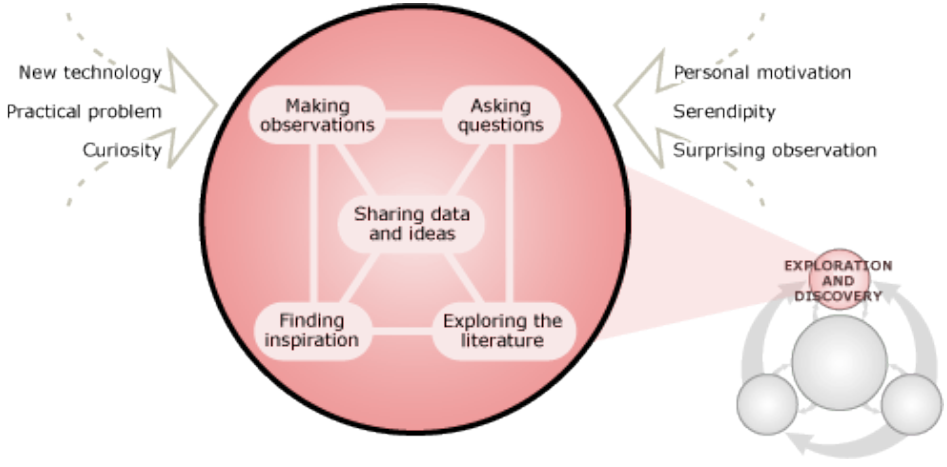
Image: `http://goo.gl/VglXc5` - (c) Understanding Science, 2015. Used with permission.

What is science?

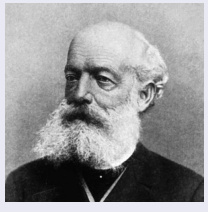
The scientific process

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

- Observations $\rightarrow$ **questions**;
- Exploratory experimentation;
- Preparation + serendipity.

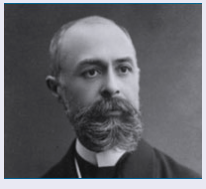


Benzene (1865)



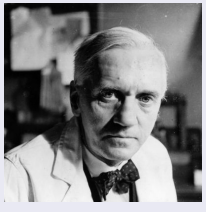
Kekule

Radioactivity (1896)



Becquerel

Penicillin (1928)



Fleming

Top image: `http://goo.gl/fy8Glh` - (c) Understanding Science, 2015. Used with permission.

Scientists: `http://goo.gl/SG6sgp` | `http://goo.gl/rhLC9C` | `http://goo.gl/CFj8Ml`

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?

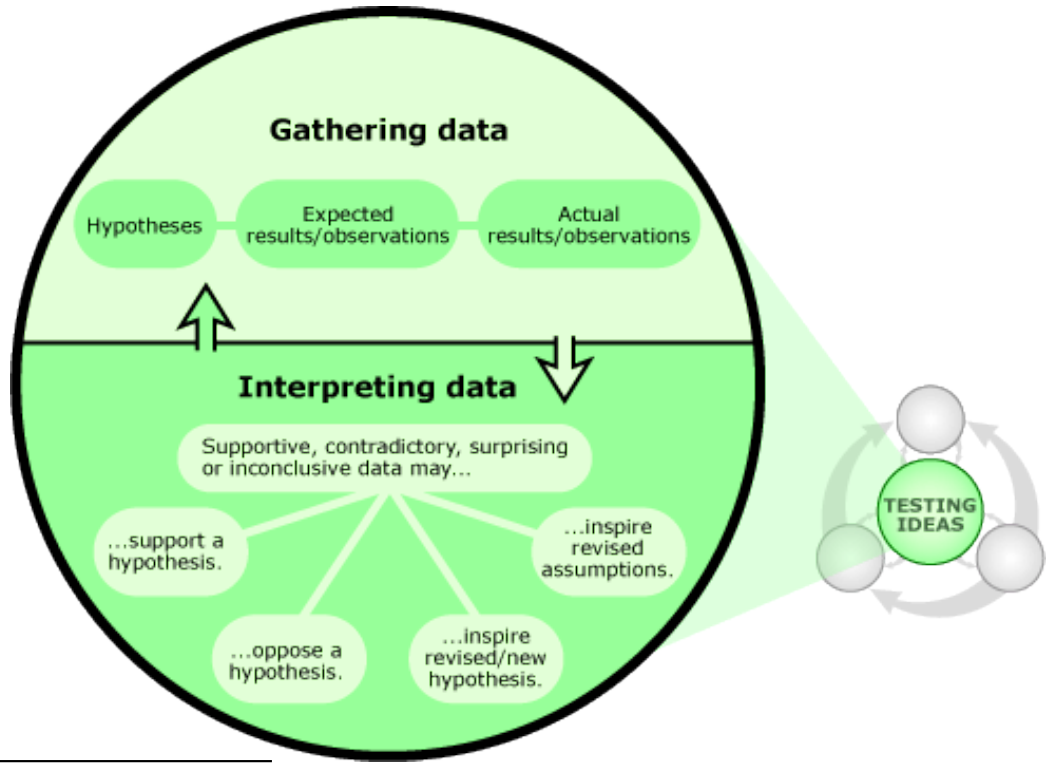


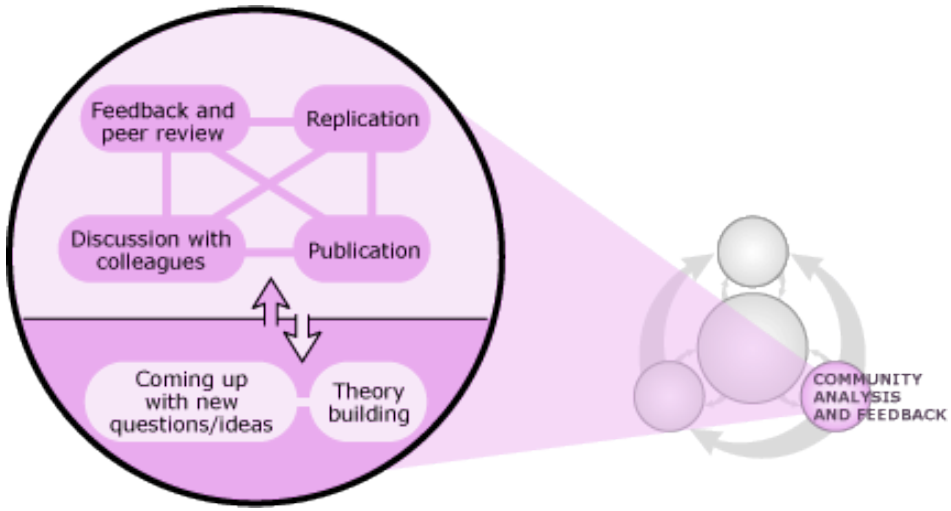
Image: `http://goo.gl/aOgSqT` - (c) Understanding Science, 2015. Used with permission.

What is science?

The scientific process

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

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

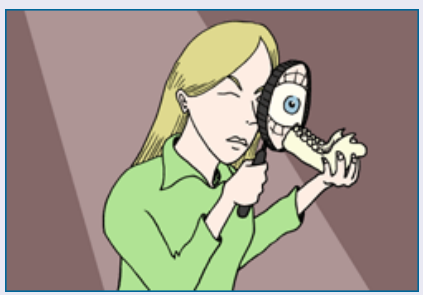


This interaction plays essential roles for the progress of research:

Criticism

Inspiration

Vigilance



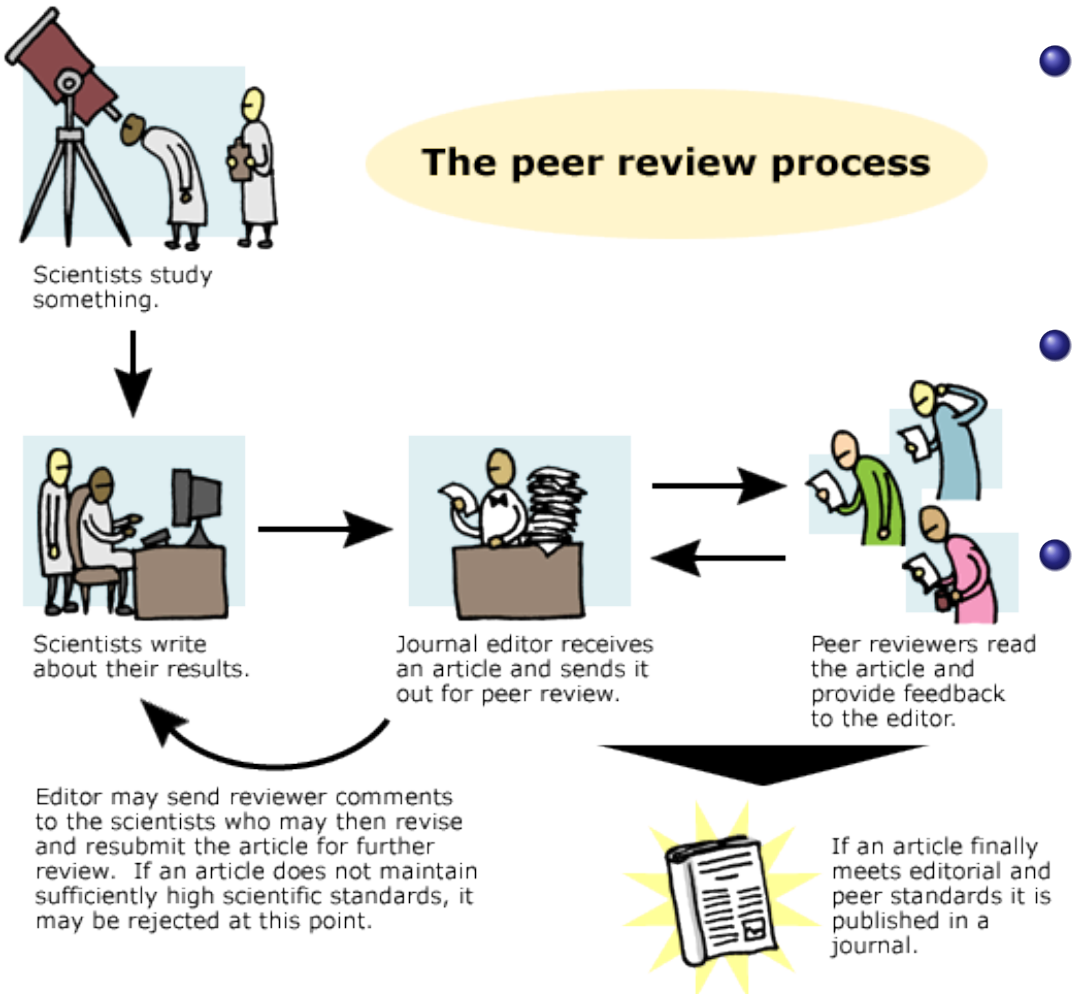
Motivation

All images: `http://goo.gl/9pSCTG` - (c) Understanding Science, 2015. Used with permission.

What is science?

The scientific process

Publication and peer review.



- Additionally, *post-publication review* by the wider scientific community;
- **Replication** and verification of results;
- **Reproducibility** is essential.

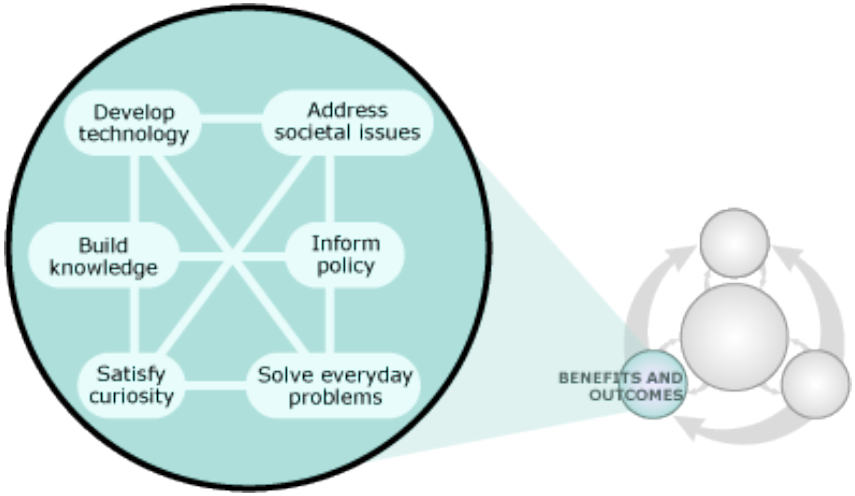
Image: `http://goo.gl/VWCVkK` - (c) Understanding Science, 2015. Used with permission.

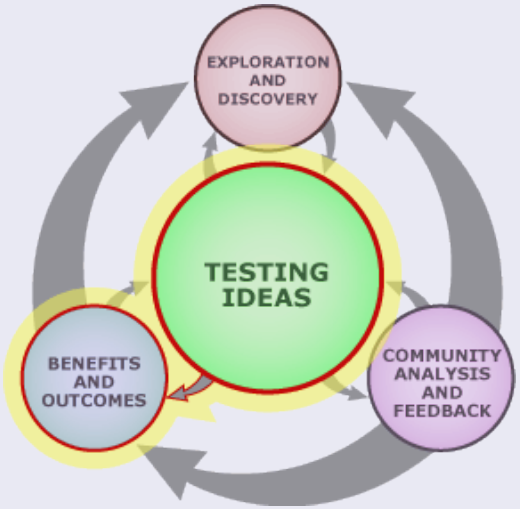
What is science?

The scientific process

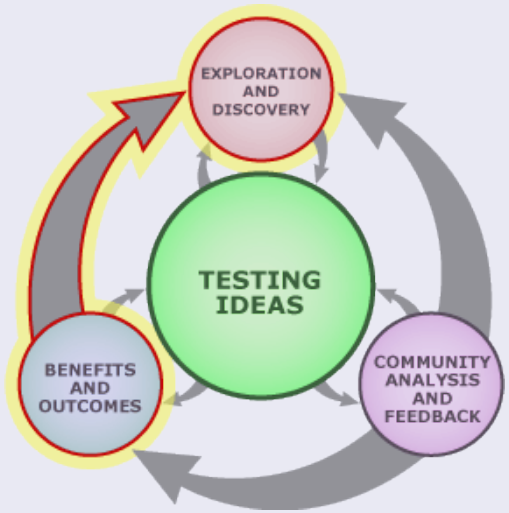
The scientific process is a way of building knowledge:

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

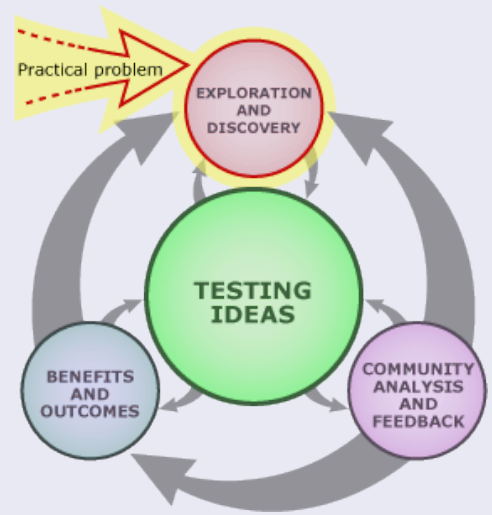




Knowledge→Applications



Technologies→Discovery



Applications→Investigation

All images: `http://goo.gl/IBRSoQ` - (c) Understanding Science, 2015. Used with permission.

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`

About this material

Conditions of use and referencing

This work is licensed under the Creative Commons CC BY-NC-SA 4.0 license (Attribution Non-Commercial Share Alike International License version 4.0).

http://creativecommons.org/licenses/by-nc-sa/4.0/

Please reference this work as:

Felipe Campelo (2018), *Lecture Notes on Design and Analysis of Experiments*.
Online: https://github.com/fcampelo/Design-and-Analysis-of-Experiments
Version 2.12. Creative Commons BY-NC-SA 4.0.

```
@Misc{Campelo2018,
  title={Lecture Notes on Design and Analysis of Experiments},
  author={Felipe Campelo},
  howPublished={\url{https://github.com/fcampelo/Design-and-Analysis-of-Experiments}},
  year={2018},
  note={Version 2.12. Creative Commons BY-NC-SA 4.0.},
}
```