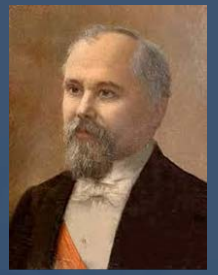
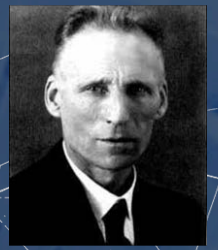
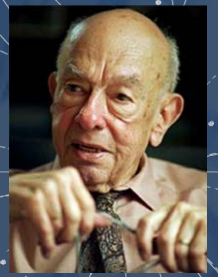
TRIUMF

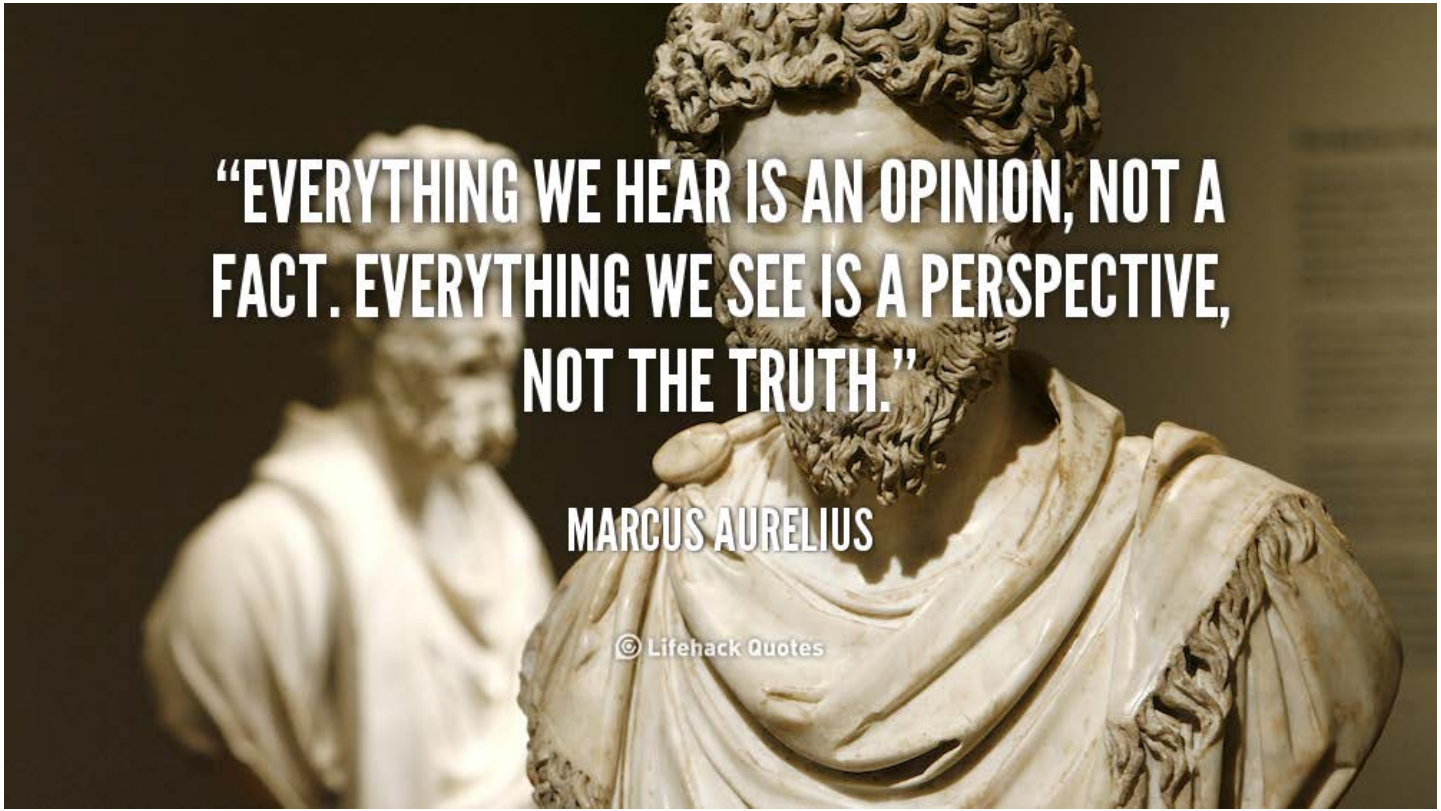
Canada's national laboratory
for particle and nuclear physics
and accelerator-based science

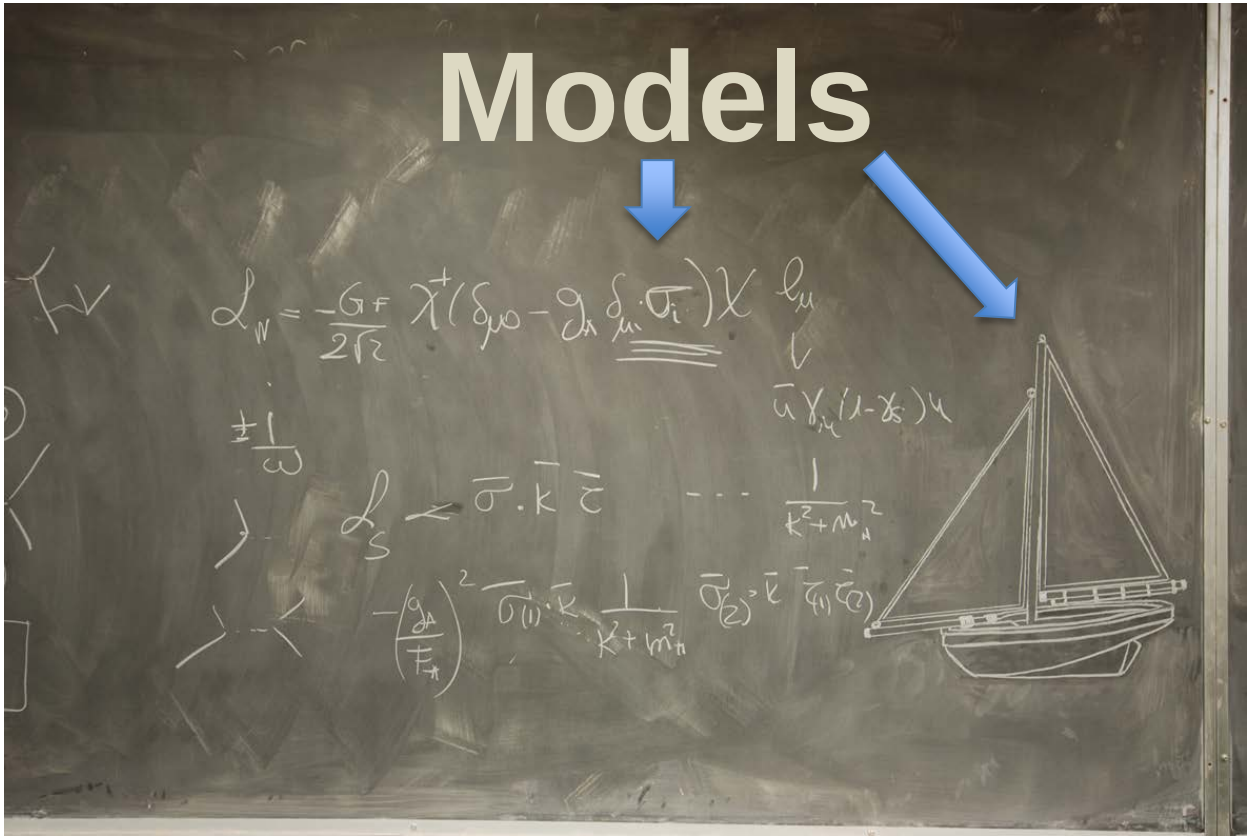






- On the Nature of Science
- What is Science?
- Observationally constrained model building
-
- Byron Jennings | TRIUMF


“EVERYTHING WE HEAR IS AN OPINION, NOT A FACT. EVERYTHING WE SEE IS A PERSPECTIVE, NOT THE TRUTH.”
MARCUS AURELIUS
© Lifehack Quotes


Models

The Nature of the Problem

- Most scientists have a good operational understanding of science
  - Well duh!
- Lack a formal understanding
  - Has changed over time
  - Can lead to misunderstandings and wasted effort
  - Hampers the selling of science
  - The philosophic community not particularly helpful
- Science provides an operational definition knowledge
  - Not just a means of obtaining it
  - Philosophical pragmatism

- Different definitions of knowledge
  - Justified true belief (Plato, traditional definition)
  - What one can convince people is true (Protagoras and the Sophists)
  - Information that helps us make correct predictions and control our environment (pragmatic philosophic tradition)
    - The standard model of particle physics, despite not being completely true, is knowledge since it helps us predict and control our environment.
    - Science, engineering, and business management are (should be?) defined by this common paradigm for knowledge.

- Global warming and CO_2 levels
- Alternate medicine
  - Vaccination and autism
  - Cell phones and cancer
- Size of salmon runs (or dying shellfish)
  - Reoccurring themes in BC
- Evolution and creationism
  - The elephant on the room

Mankind's Greatest Achievement

- Learned how the universe works
- Changed our conception of man’s role in the universe
- Big history
  - Big bang, evolution, etc
- Laid the foundation for technology
  - Increased life expectancy
  - The cell phone
- Basis of good management practices (PDCA cycle)
  - International Standards Organization (ISO), ANSI

- Skepticism – the academic left
  - The philosophers Galileo fought all his life
  - And those who reject any standards
- Dogmatism – the religious right
  - The Catholic Church which put Galileo under house arrest
    - Encouraged by the contemporary philosophers
  - And all those who dislike the results of a specific scientific investigation.
- Common sense
  - All new discoveries violate common sense based on past understandings

- Protagoras (490 BCE – 420 BCE): Sophistry
- Plato (424 BCE – 348 BCE): Shadows in the cave
- Descartes (1596 – 1650): Methodological Skepticism
- Hume (1711 – 1776): Scientific induction does not exist
- Kierkegaard (1813 – 1855), Nietzsche (1844 – 1900): Post-modernism
- Feyereband (1924 – 1994) Against Method: Outline of an Anarchistic Theory of Knowledge

- I think therefore I am.
  - Criticized by Friedrich Nietzsche and Bertrand Russell
- Euclid's postulates
  - The whole is greater than the part.
  - It is possible to extend a finite straight line indefinitely.
- This is sentence is the sum total of all 100% certain knowledge.
  - And I am not even sure about that.
- Justified true belief is a mirage

Responses to Skepticism

- Sophistry: Argument rather that knowledge
  - Replace knowledge with rhetoric.
- Idealism: It is all in the mind.
  - Plato: Ideals (ideas, forms)
  - Descartes (1596 – 1650): What I perceive clearly and distinctly as being true is true.
  - Berkeley (1685 – 1753): To be is to be perceived
  - Kant (1724 – 1804): Synthetic a priori knowledge
- Science: Pragmatic rather than certain.
  - We may be studying the reflections on a wall (as Plato suggested) but at least we do a good job of it.

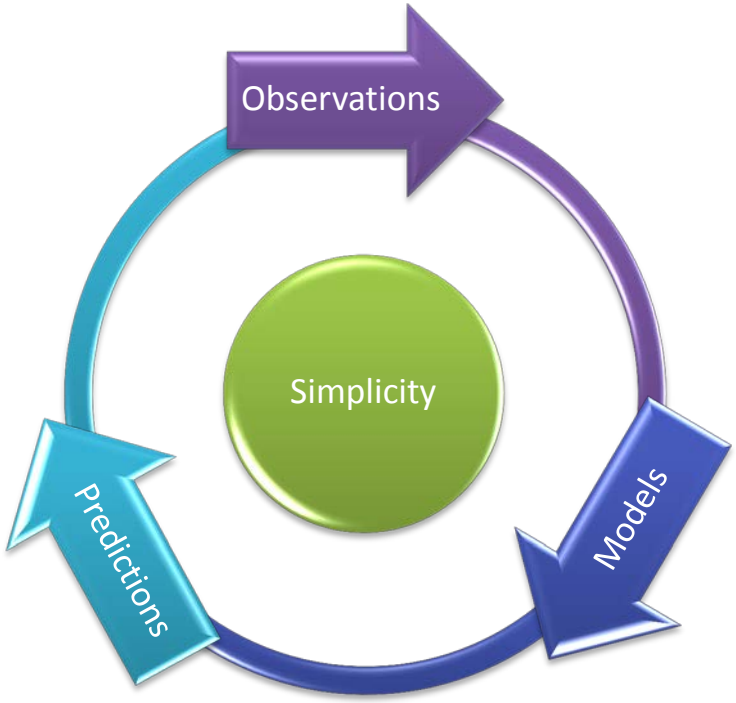
- Disconnect from reality
  - Creationism
  - Global warming

The aide [to Bush] said that guys like me were "in what we call the reality-based community," which he defined as people who "believe that solutions emerge from your judicious study of discernible reality." ... "That's not the way the world really works anymore," he continued. "We're an empire now, and when we act, we create our own reality. And while you're studying that reality—judiciously, as you will—we'll act again, creating other new realities, which you can study too, and that's how things will sort out. We're history's actors…and you, all of you, will be left to just study what we do.

Science
The reality based community

Solutions only emerge from your judicious study of discernible reality.

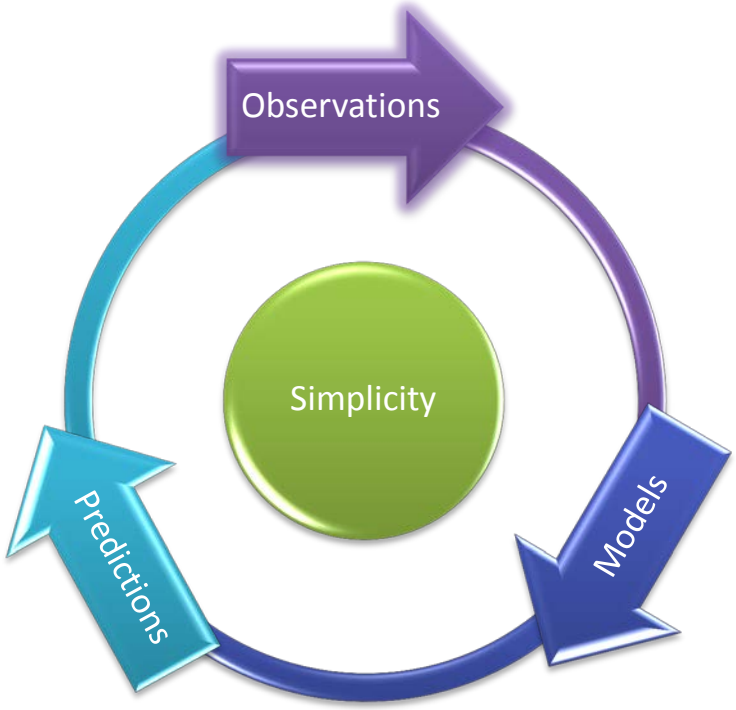
The Scientific Method



- Begin with a set of observations.
- Create a model to explain the observations.
- Make testable predictions using the model.
- Compare the predictions to new observations.
- Use the comparison to assess and modify the model.
- Repeat as required..

Simplicity selects one preferred model from the many possible models that describe any set of observations.

The Scientific Method



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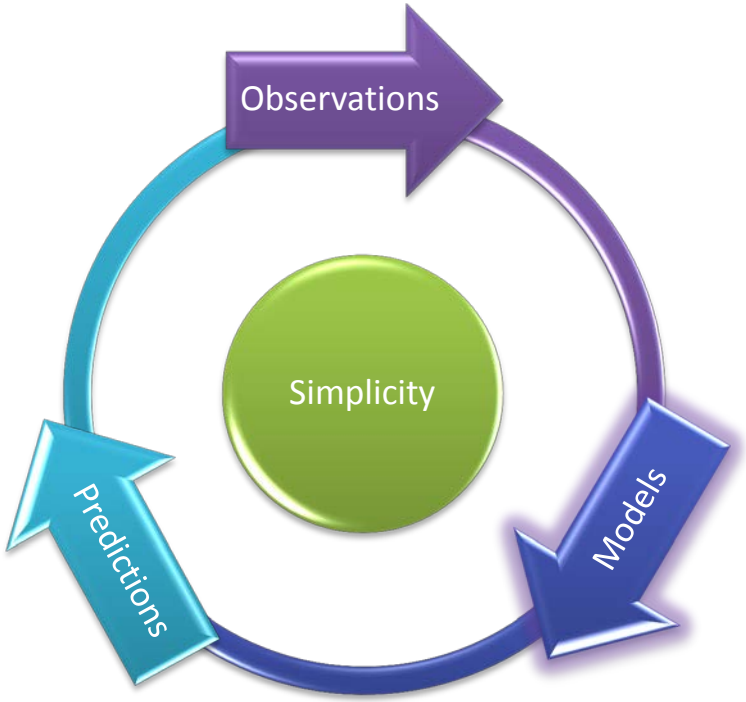
Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house.

Henri Poincare (1854 –1912)

One important idea is that science is a means whereby learning is achieved, not by mere theoretical speculation on the one hand, nor by the undirected accumulation of practical facts on the other, but rather by a motivated iteration between theory and practice.

George Box (1919 – 2013)

The Scientific Method



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- Not reality but human constructs to allow us to predict the future
  - Shell model in nuclear physics
  - Standard model of particle physics
    - Including QCD
  - String theory
  - Classical mechanics
  - Quantum mechanics
  - Special theory of relativity
  - The theory of evolution
    - Common descent and natural selection
  - Germ theory of disease
  - Ptolemaic model of the solar system

Paradigm – The Main Model

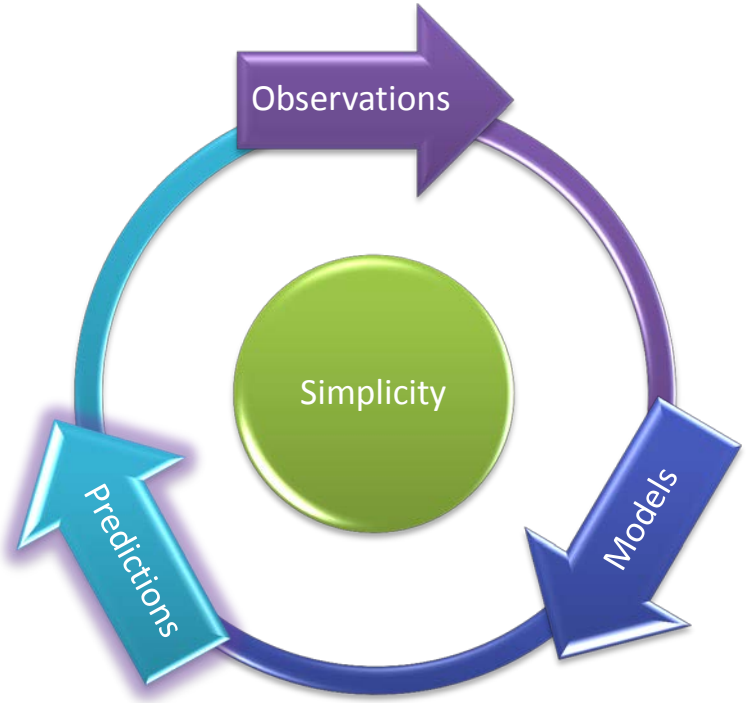
- Provides the framework for a given field
  - J. H. Poincare – Science and Hypothesis – 1904
    - Importance of the framework
  - C.I. Lewis – Mind and the World Order – 1929
    - Used the term paradigm in a similar context
  - T.S. Kuhn – The Structure of Scientific Revolutions – 1962
    - *what* is to be observed and scrutinized
    - the kind of *questions* that are supposed to be asked and probed for answers in relation to this subject
    - *how* these questions are to be structured
    - *how* the results of scientific investigations should be interpreted

Paradigm Example

- Traditional philosophy and science (pragmatism) are **competing** paradigms for what knowledge is
  - **Thomas Kuhn:** Aristotle versus Newton
  - **Bertrand Russell:** “Change” in philosophy when science discovered
  - **David Wootton:** The scientific revolution was the revolt of the mathematicians against the philosophers.
- Scientists know very little about the what philosophers of science are doing. And the ones that do:
  - **Carl Sagan**: Plato delayed the development of science by two millennia.
  - **Richard Feynman:** Philosophy of science is about as useful to scientists as ornithology is to birds.
  - **Lawrence Krauss:** It has no impact on physics what so ever.

- Philosophy (in the western tradition)
  - Based on **rational** arguments and word definitions
  - Pure thought not observation
- Science (pragmatic tradition)
  - Based on observation
    - Construct models based on the observation of past observations and test based on predictions for future observations.
    - A rational argument is one that can be used to predict future observations.
  - Build models that work
    - Make successful predictions

The Scientific Method



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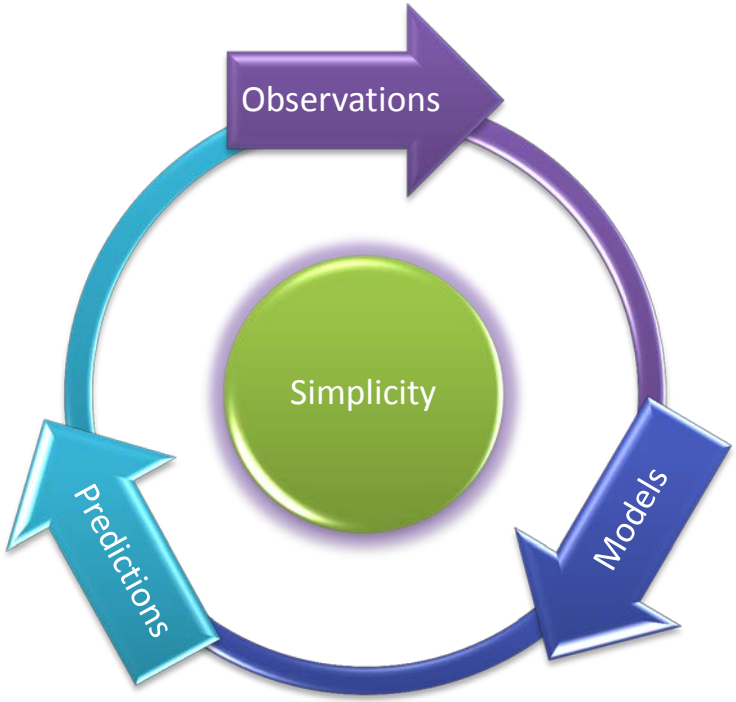
- Demarcation criteria for science.
  - Statements or systems of statements, in order to be ranked as scientific, must be capable of conflicting with possible, or conceivable observations. Karl Popper (1902 – 1994)
    - Scientific models must make testable predictions
- Duham-Quine Thesis: Any statement in isolation can be taken as true or false
    - Omphalos
    - The problem of evil

- Omphalos: An Attempt to Untie the Geological Knot (1857)
  - Phillip Gosse (1810 –1888)
    - Frist rate naturalist
      - Salt water aquarium
      - Corresponded with Darwin
    - Fundamentalist Christian
  - World created 6000 years ago but with the appearance of great age.
    - Any act of special creation implies a false history.
    - The universe can be assumed to be created at any point in time.
  - Published two years before Origin of the Species
- Interpretation of history
  - like interpretations of quantum mechanics

- Problem of Evil
  - Statement of the Problem (Epicurus about 300 BC)
    - If an all-powerful and perfectly good god exists, then evil does not.
    - There is evil in the world.
    - Therefore, an all-powerful and perfectly good god does not exist.
  - Gottfried Leibnitz's solution
    - This is the best of all possible worlds
- Always possible to avoid falsification by reducing the potential for predictions
  - Technique also used in physics

The Scientific Method



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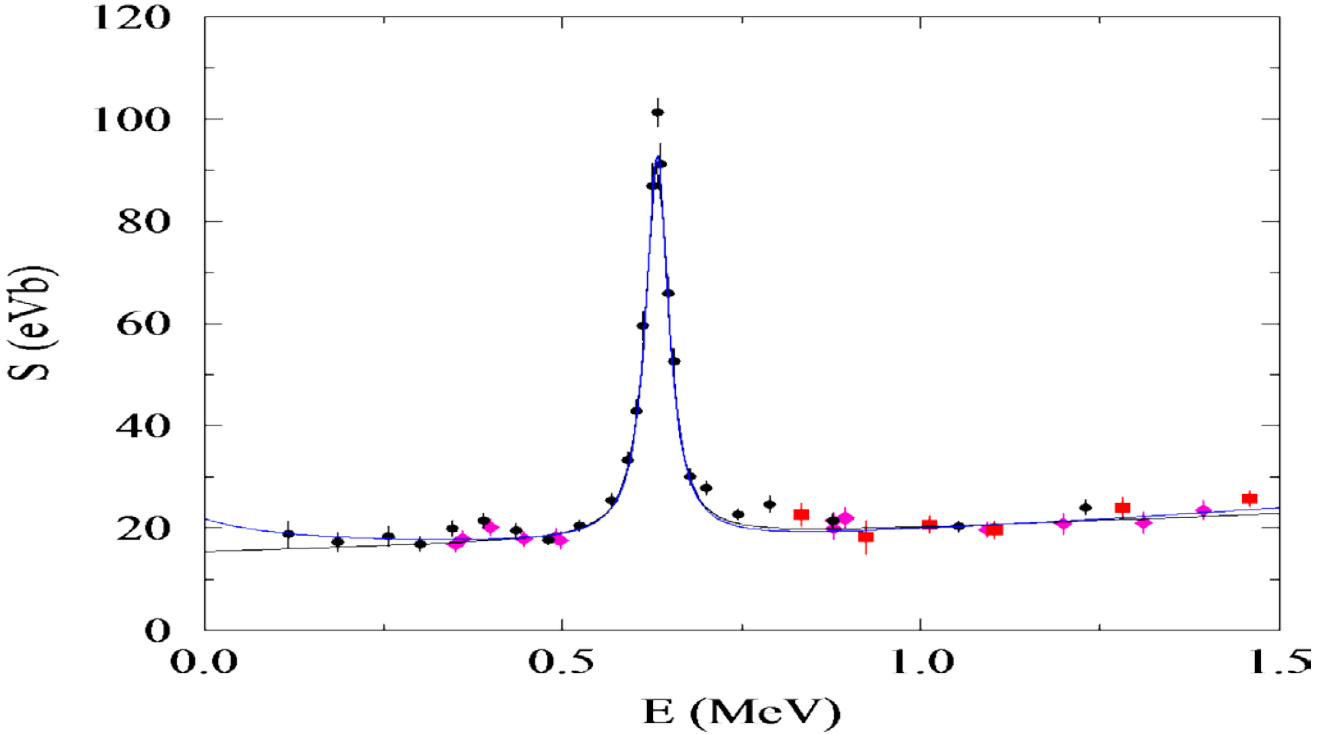
- William of Ockham (1285 – 1349)
  - **Occam's razor:** The razor asserts that one should proceed to simpler theories until simplicity can be traded for greater explanatory power.
- Simplicity absolutely necessary.
  - An arbitrary number of curves can be drawn through any set of points.
  - Separates the standard model from its extensions.
  - Simplicity frequently trumps accuracy but in the end it fails.


120
100
80
60
40
20
0
S (eVb)
0.0
0.5
1.0
1.5
E (McV)

- But, as many skeptics pointed out, rival theories are always indefinitely many and therefore the **proving** power of experiment vanishes. One cannot learn from experience about the truth of any scientific theory, only at best about it falsehood: **confirming instances have no epistemic value whatsoever** (emphasis in the original). Imre Lakatos (1922 – 1974),
- What about the confirming instance that got P. Higgs and F. Englert a Nobel prize?

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- What about the confirming instance that got P. Higgs and F. Englert a Nobel prize?

- is a measure of the minimum computational resources needed to specify the data object.
- is not a computable function.
- 690927210797509302955321165344987202755960236480665499119881834797753566369807

Deep Breath

- If simplicity in the sense of Kolmogorov complexity is needed to define a scientific model, you cannot get from experimental data to a scientific model algorithmically. (Gregory Chaitin defined a theory as a minimal computer program.)

- To Err is human, to control error science.
  - Error control is a scientists day job.
- Very few tools
  - Care in doing the experiment
    - Blind analysis
    - Double bind medical tests
      - Uselessness of testimonials.
  - Independent checking
    - Peer review
      - Openness
      - Incompatible with intellectual property.
    - Independent repetition

- Improve the techniques
  - Lagrangian formulation of classical mechanics
- Error correction
  - The secular term in planetary orbits.
- Sideways expansion
  - Discovery of Uranus, neutrino mass
- Replace the foundation
  - Classical mechanics → quantum mechanics

Digression – Business Standards

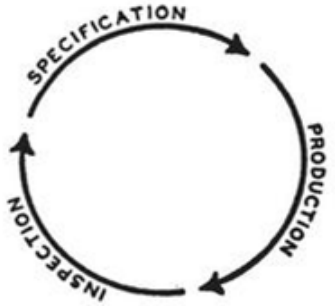
From 1939 book by Walter Shewhart

Became the foundation of ISO, ANSI, and CSA Management Standards.

Standards would be better implemented if this background understood.

The three steps in fig. 10 correspond to the three steps in a dynamic scientific process of acquiring knowledge

OLD

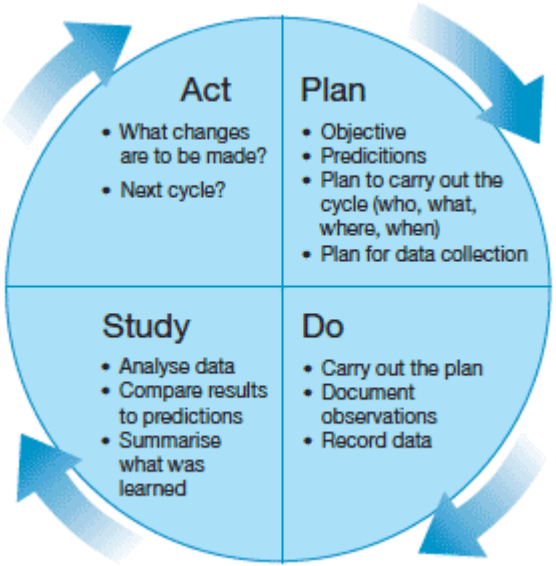


NEW

From Edwards Deming

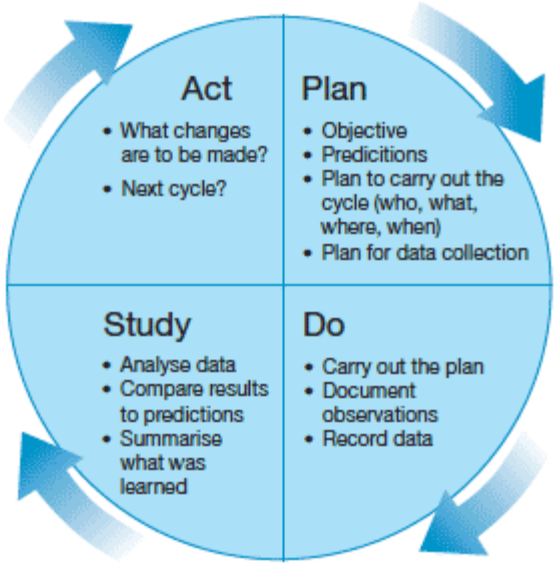
Became the foundation of ISO & ANSI Management Standards.

Useful in business, medical therapy and even testing your pet theory of nuclear structure.



Model/Theory

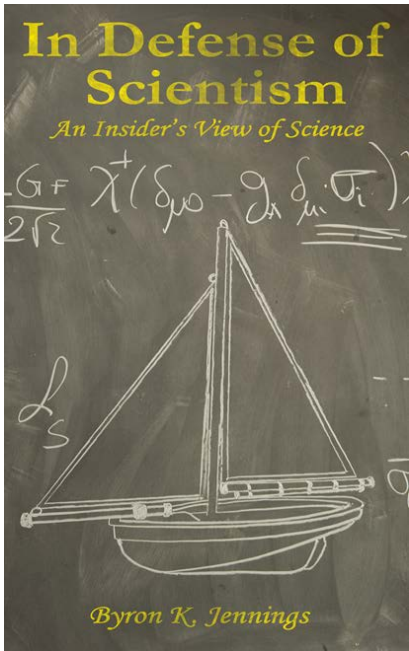
Publication



Predictions

Observations

- Henri Poincaré (1854 – 1912)
  - Science and Hypothesis, 1905
    - Chapters – IX, X
- C.I. Lewis (1883 – 1964)
  - The Mind and the World Order (1931)
- Willard V. O. Quine (1908 – 2000)
  - Two Dogmas of Empiricism (1951)
  - On What There Is (1961)
- B.K. Jennings
  - In Defense of Scientism (2015)



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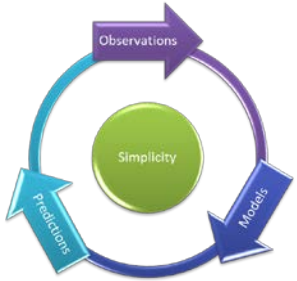

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Thank you!
Merci!

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