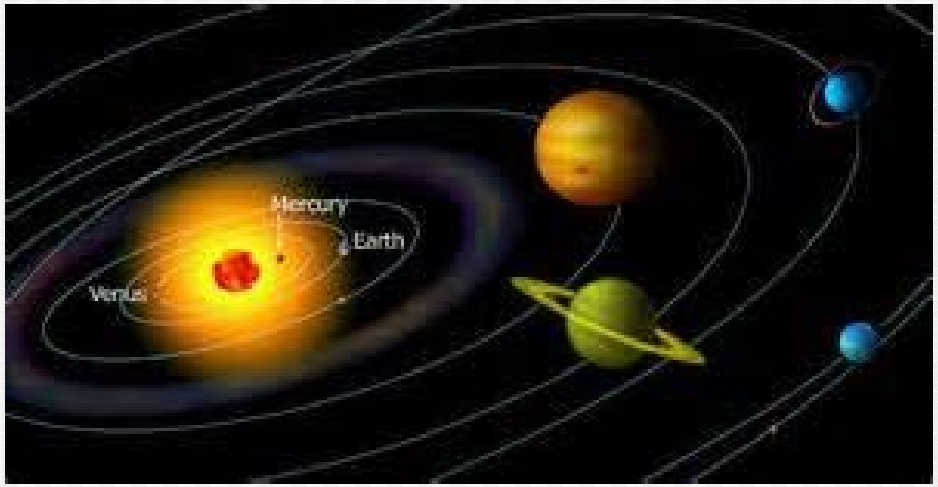
Demarcation of Science from other academic disciplines

- Demarcation of natural sciences from other academic disciplines
- Demarcation of science from technology, pure and applied science
- Demarcation of science from mathematics

- Literature: **Popper, Chalmers**, Ziman, Kitcher

Background - demarcation

- Aristotle and Plato – no distinction between science and philosophy
- Greeks to the Age of Enlightenment – mysticism, religion, ideology



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Background - demarcation

- Bacon and Descartes – scientific methodology, logic, mathematics
- Russell and Wittgenstein – demarcation between metaphysics and science; and between science and mathematics
- Popper – demarcation between natural and social sciences

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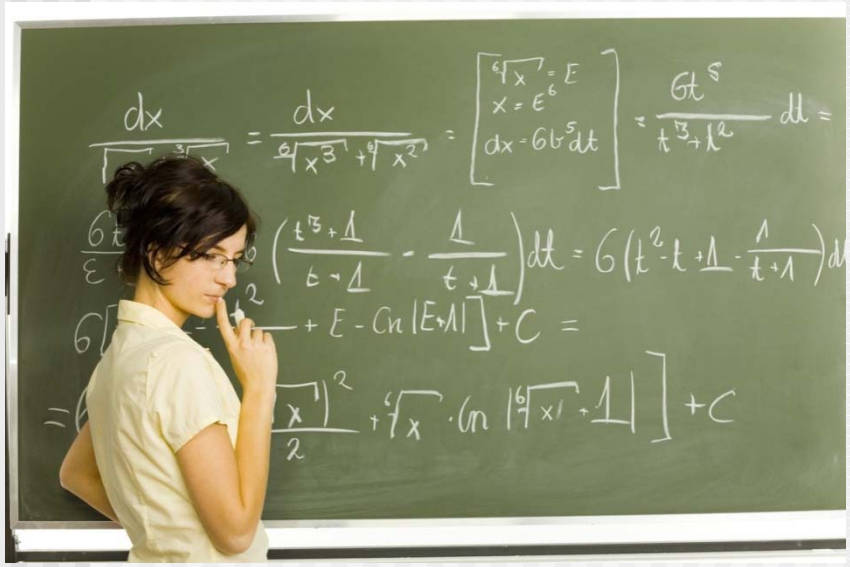
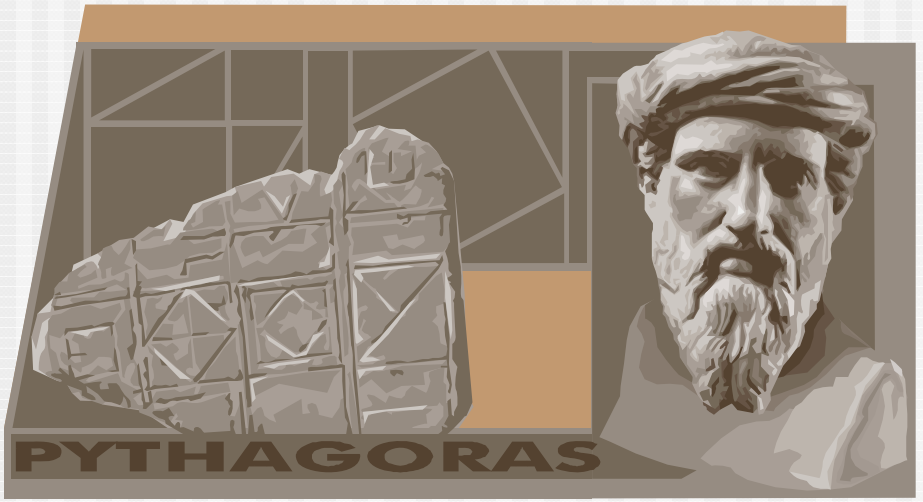
Science and Mathematics

- Similarities: search for truth and proof
- Science relies on mathematics





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Science and Mathematics

- Differences:
  - Mathematics relies on logic rather than experiment and observation
  - Mathematics uses more sophisticated forms of proof: eg. Asserting a proposition by proving that its negation implies a contradiction

Philosophy of Mathematics

- Origins of mathematics in China, India, Arabia, Middle East, Greece
- Philosophical questions concerned with the nature of mathematical truth. Are numbers mental constructs, facets of an idealised reality, rules

Al-Kwarizimi (ca 830) : Source of words algebra and word alogarithm

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Philosophy of Mathematics

- Mathematics: Analytical statements: true by virtue of the meanings of words
- Science: Synthetic statements: true by virtue of the way things are

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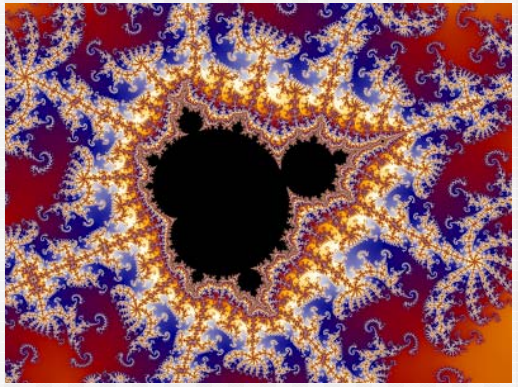
Milestones in the Philosophy of Mathematics

- Russell and Whitehead's *Principia Mathematica,* 1910
- Gödels Incompleteness Theorum proved that there will always be unanswerable questions in mathematics. No logic system is capable of providing the firm foundations that Russel had hoped for

Russell's Paradox: *Imagine there is a town with one barber, and where the law states that everyone who doesn't shave himself is shaved by the barber. Who shaves the barber?* (1901)

Milestones in the Philosophy of Mathematics

- Chaos Theory: Lorenz (1960) observations of effect of small varitations in weather models: Non-linear systems

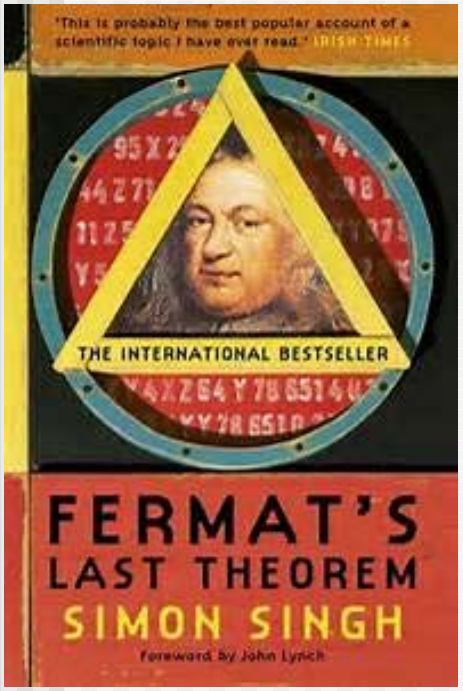


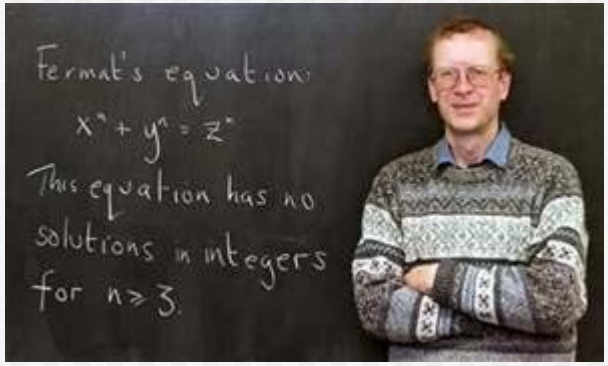
calepiopress.it/mandelbrot_large/

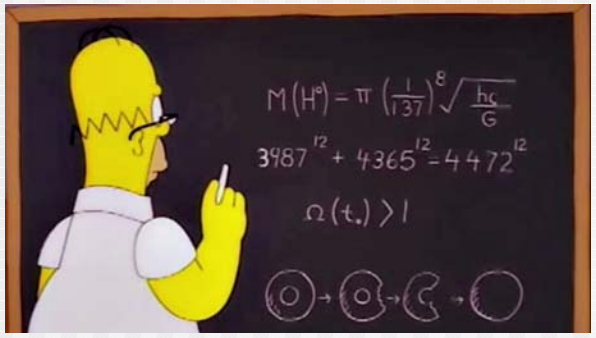
mikecane2008.wordpress.com/edward-lorenz

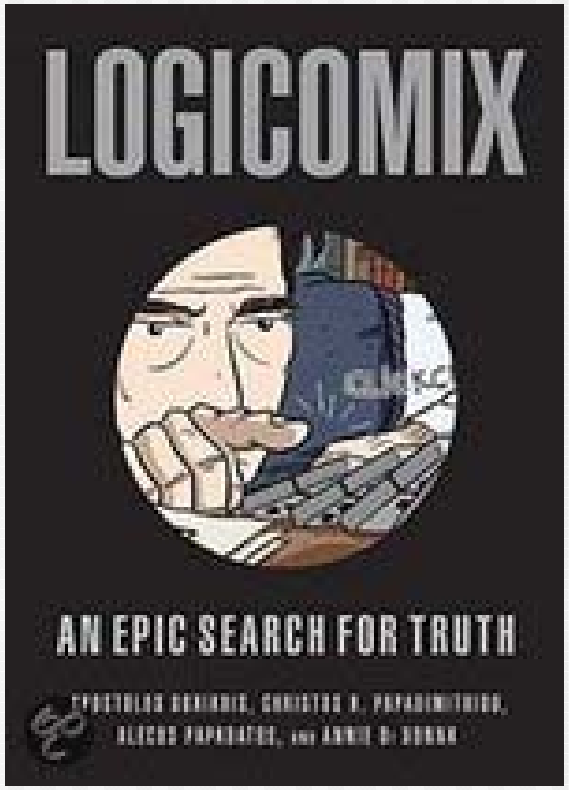
J. Gleick. Chaos (1987)

Other Popular Science









Simon Singh: Fermat's Last Theorum,
A. Doxiadis and C.H Papadatos: Logicomix; Uncle Petros

Science and Technology

- Arguments for a difference
  - Scientific thought has only one genesis (Greece-Europe)
  - Technology developed all over the world
  - The understanding of the world acquired through science is different than that obtained from technology

Thales (600-585 BC)

(Wolpert, 1992)

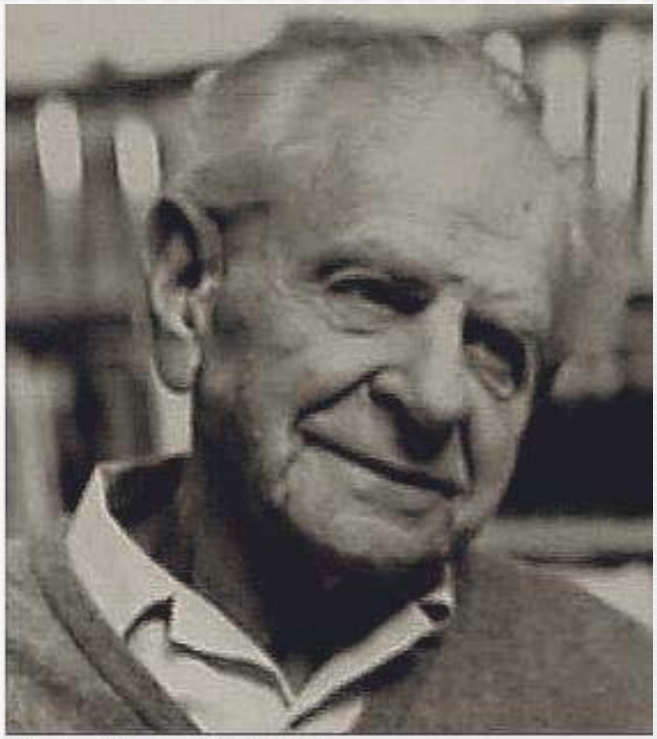
Counter-arguments

Counter-arguments

- Requires a theory of what science is
- The distinction between science and technology seems blurred in modern research
- The pragmatist/instrumentalist claims that science is only science when it is of practical use

Karl Popper

- Aim: To compare and contrast the following contemporary Twentieth century theories
  - Einstein's theory of relativity
  - Freud's theory of psychoanalysis
  - Alder's theory of psychology
  - Marx's theory of economics



Sir Karl Popper (1902-1994)

What made Einstein's theory special?

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Popper – Falsification

- Observation is guided by theory
- Theories are intellectually constructed conjectures
- Theories can be conclusively falsified in the light of suitable evidence, whereas they can never be established as true or even probably true whatever the evidence
- Scientific hypothesis need to be falsifiable
- Scientific knowledge grows, there is progress in science

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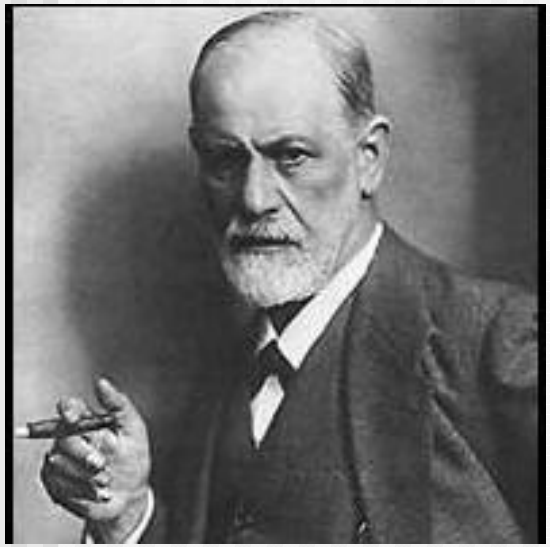
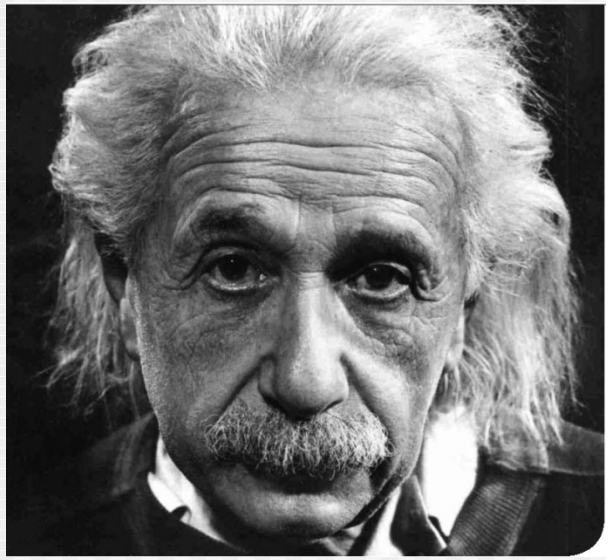
Falsifiability ?



Freud

Marx



Einstein

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Falsifiable Hypotheses

- Metals contract when heated
- Planets circle the sun in ellipses
- Large gravitational fields will bend light
- Diseases are transmitted by germs

Broad Street Pump

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Non-falsifiable hypothesis

- All ferric compounds contain iron
- You might meet a tall handsome man this evening
- Animals have evolved so as to best fulfil the function for what they were intended
- Human emotions are motivated by feelings of inferiority

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Bold Conjectures and Experimental Hypothesis

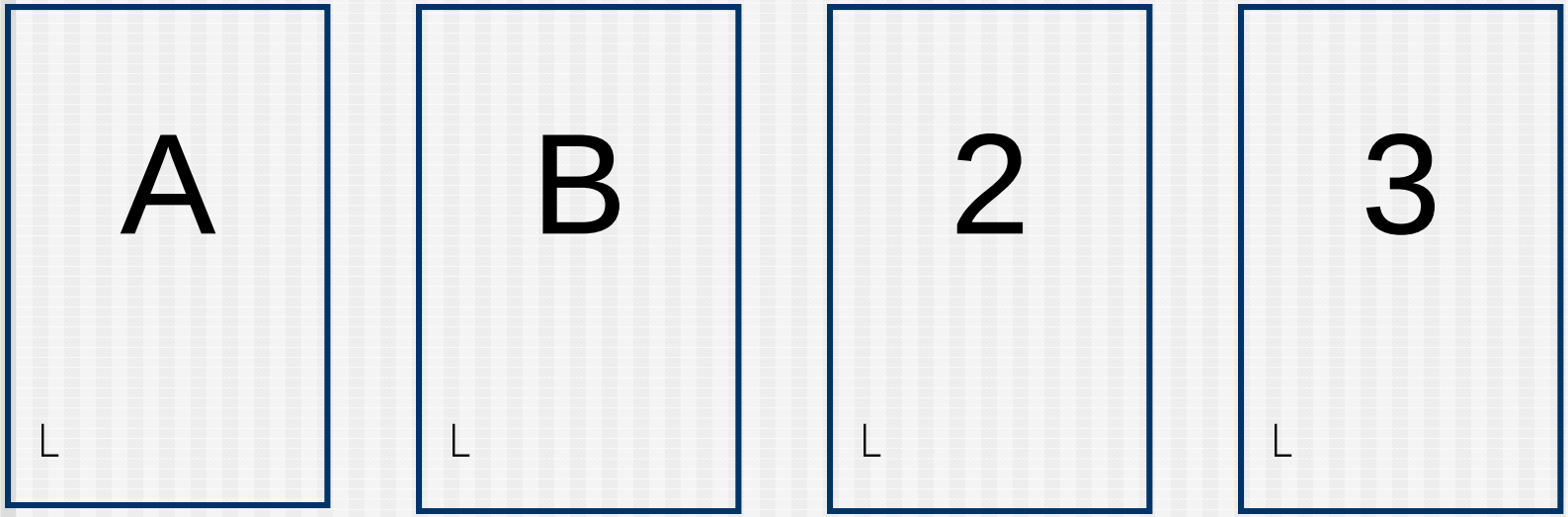
- ”Best” hypothesis: bold, falsifiable, testable
- ”Best” experimental scientists: really try to test their hypothesis (not to verify them)

See also Nelson Goodman on simplicity, strength and safety of hypotheses

Testing whether or not animals “kiss”

Hypothesis: ”Bats use ultrasound, not their eyes, to navigate”

Hypothesis: ”All vowel cards have an even number on their back”



- Which two cards should one turn to test the theory?

Goldacre, 2006

Case study: Dancing bees

- Karl von Firsch
- Hypothesis: after finding a source of nectar, bees returning to the hive use a complex ”dance” to communicate the location of the source to other bees

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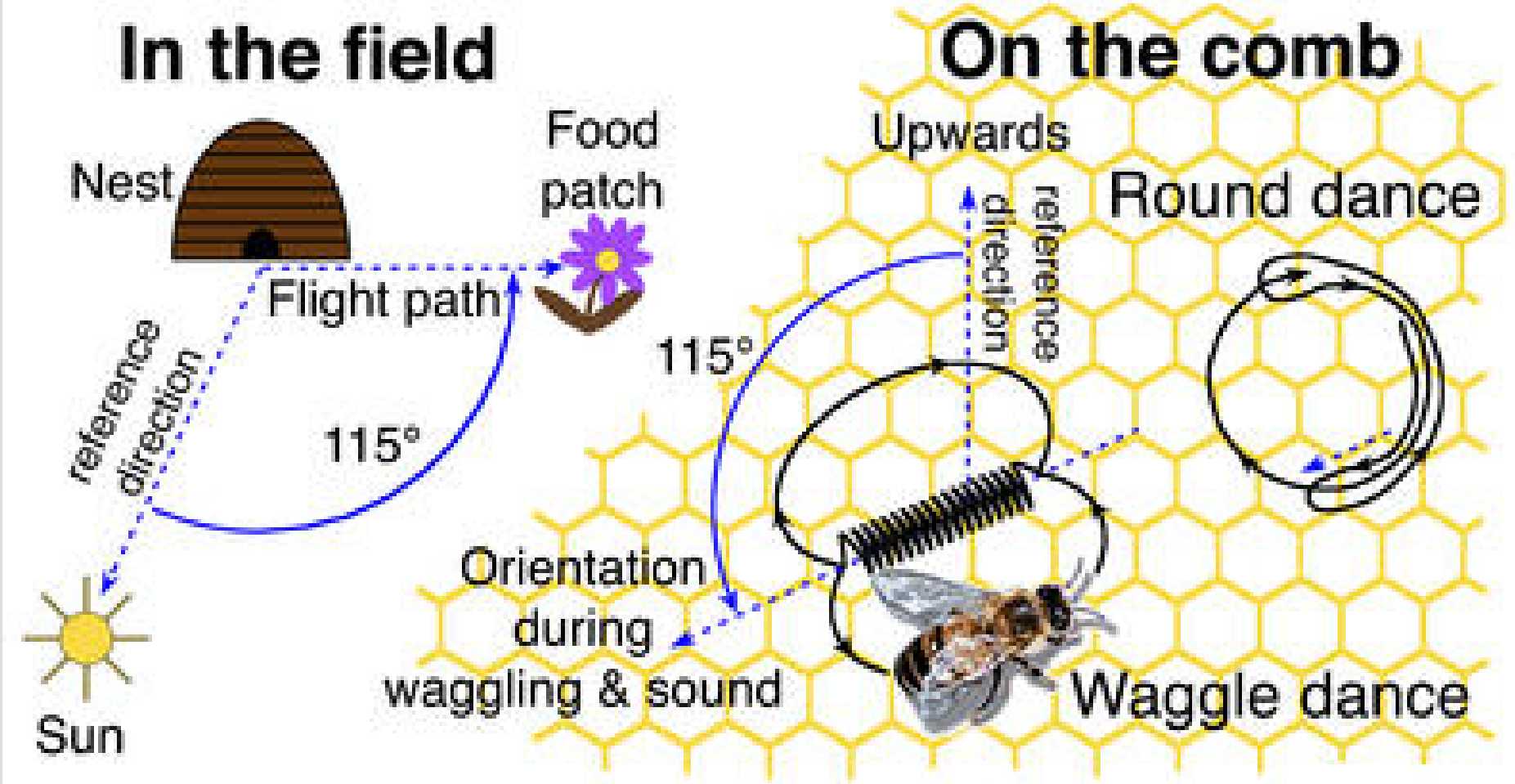
The ”waggle dance”



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Wenner's challenge

- No proof that the other bees understand the dance?
- Many other ways for the bees to find food – including odour-search. No proof of cause and effect.

- What kind of experiment would really test the hypothesis?

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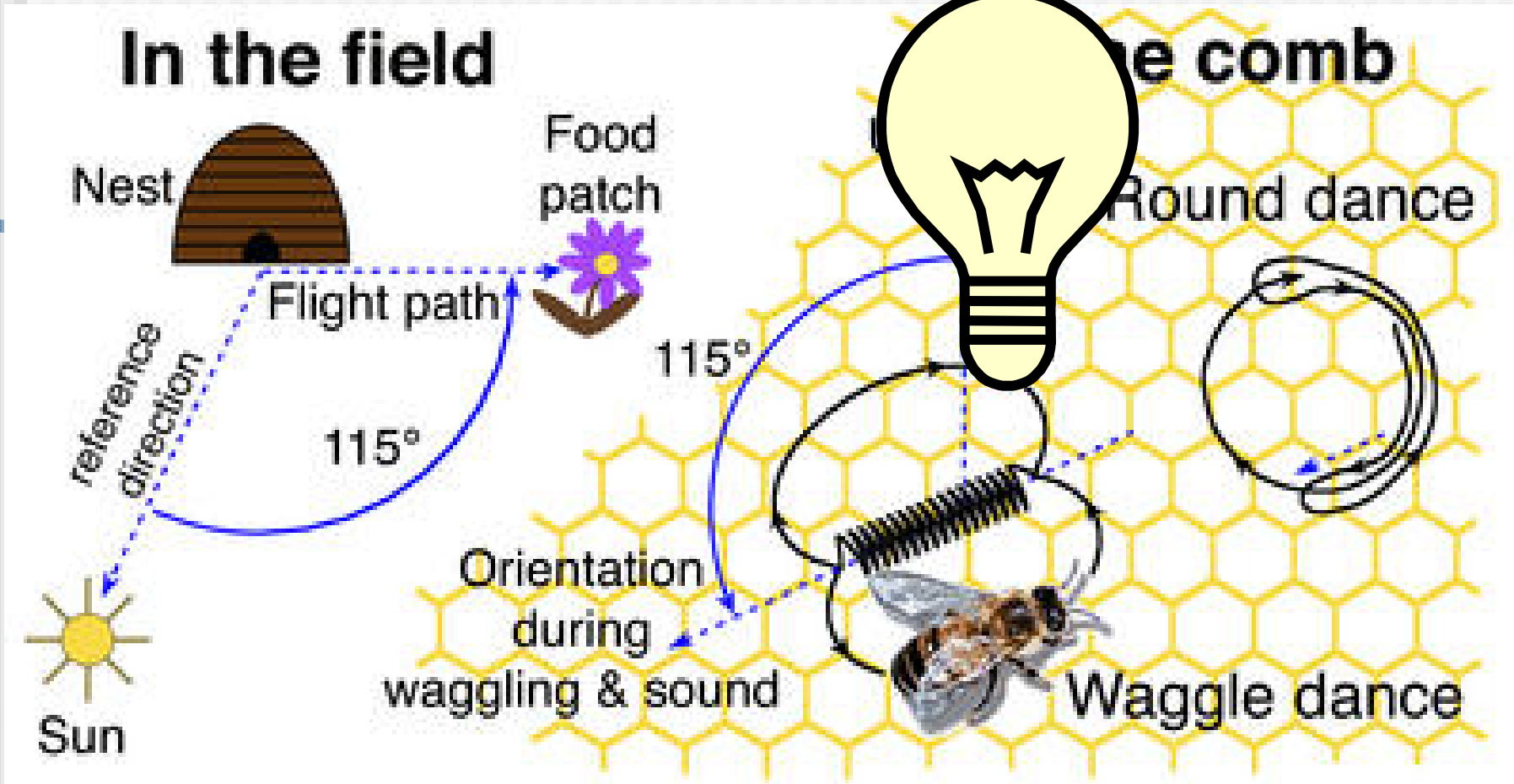

- James L. Gould – ”blindfolded” the dancing bee

Problems with Falsification

- Scientists don't reject their hypothesis
- Too restrictive
- All observation statements are fallible, including those purporting to reject a hypothesis

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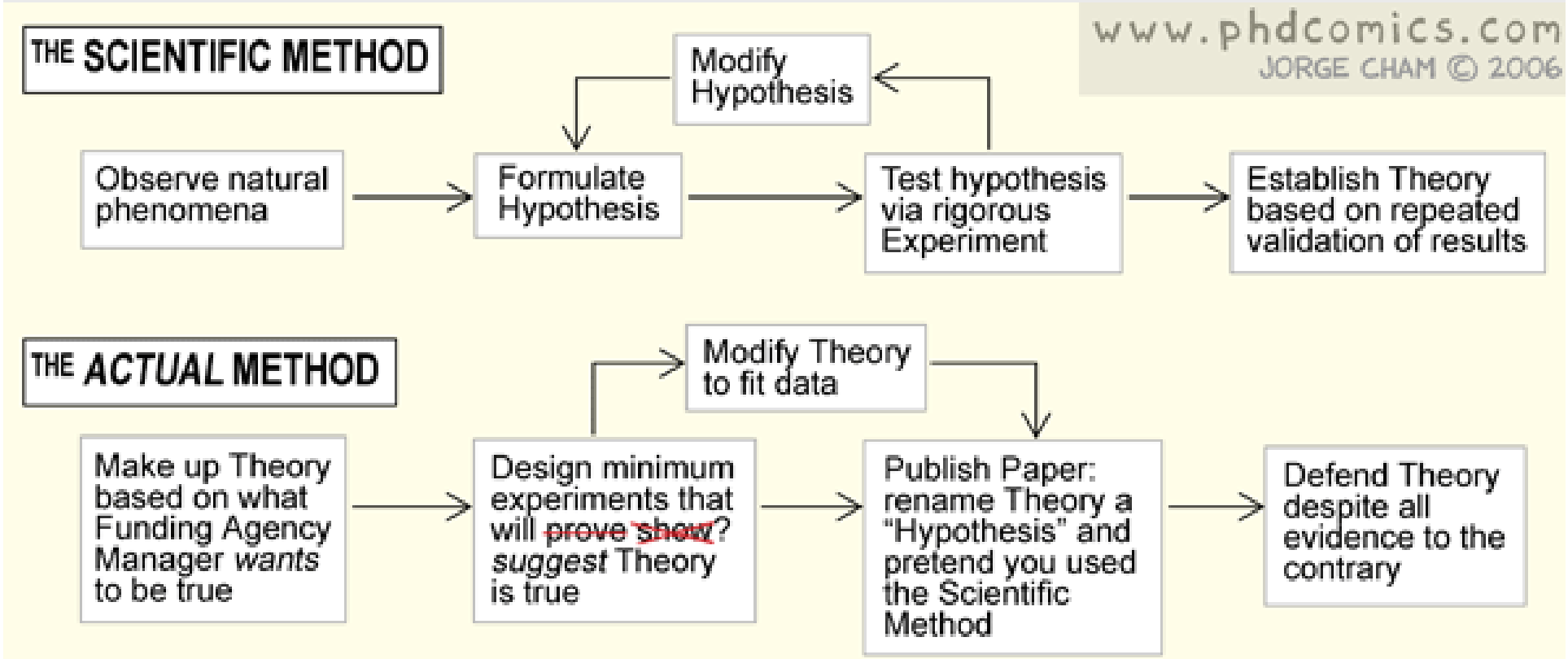

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Does Popper work for you?

- Yes, in my own research
- Not in my own research, but in my field of research
- Not in my own field, but I can see why it applies in other areas
- Not at all

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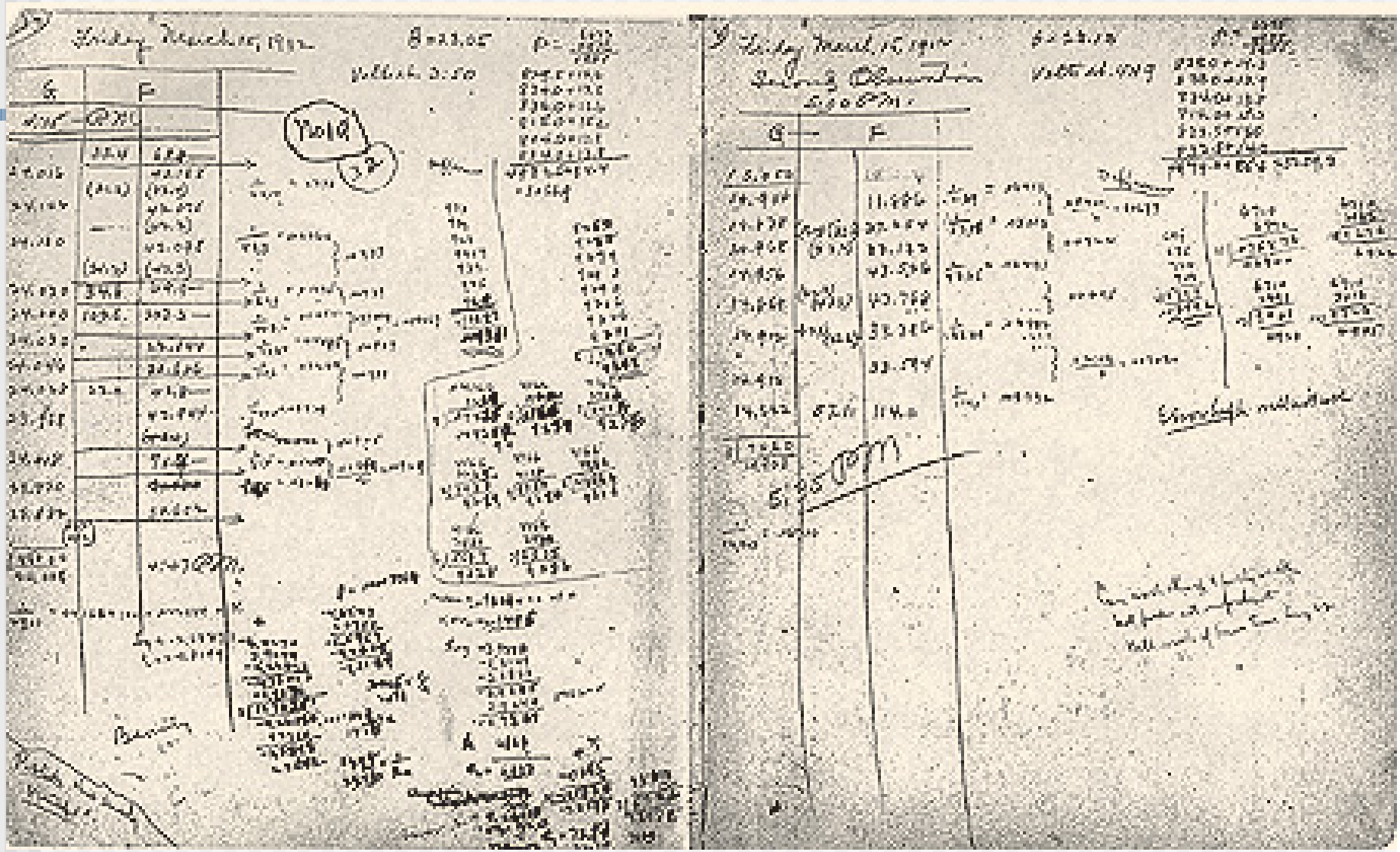
Milikan's Oil Drop Experiment (1916)



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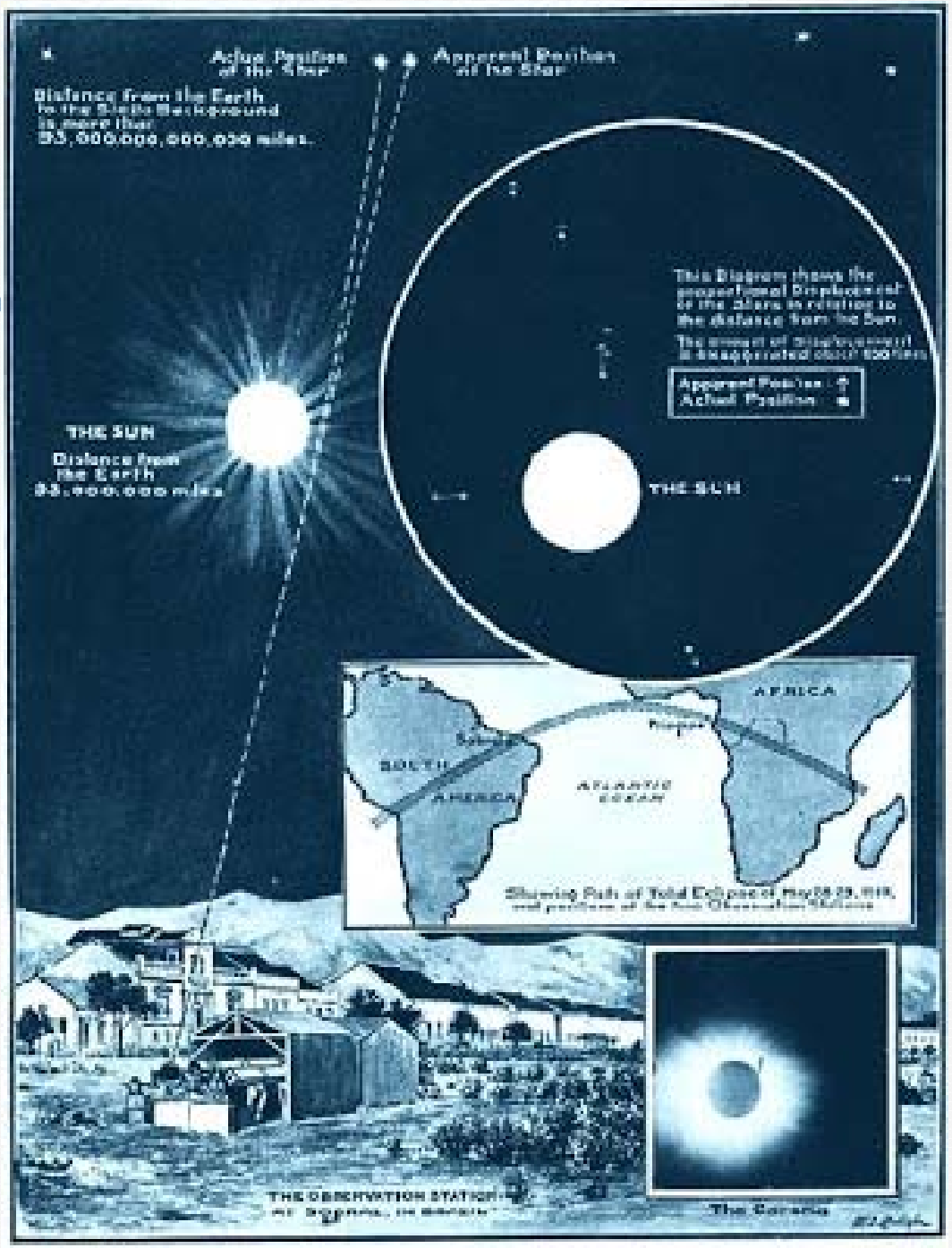
Eddington's Experiment



Auxiliary and *ad hoc* Hypothesis

- Scientists try to save their theories in the light of falsifying evidence
- Hypotheses are usually built on a host of auxiliary hypothesis and subsidiary assumptions

- Popper's reply
  - Distinguish between interpretations of evidence that bring forth new, independently testable hypothesis and those resorting to *ad hoc* hypothesis

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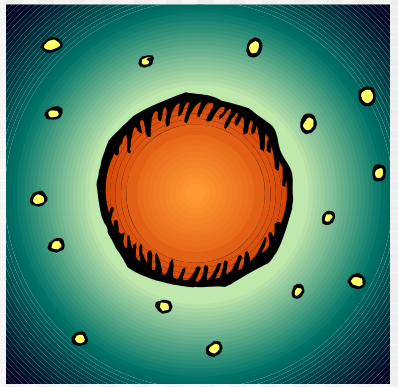
Correct use of auxiliary hypotheses

- Independently testable
- Science should be unified
- Fecundity – opens up new areas of research

- Ad hoc hypothesis – no change in testability
- Example: The prediction of Neptune from Uranus's movements



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Mode of discovery and mode of justification

- Difference between what scientists do as individuals (fallible) and what they do as a scientific community – critical rationalism
- Progress can be measured by the significance of observations and confirmations
- Problem: all observation statements are fallible, including those purporting to reject a hypothesis

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Popper's response

”The empirical basis of objective science has nothing ”absolute” about it. Science does not rest upon a bedrock. The bold structure of its theories rises, as it were above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or ”given” base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.”

K.R. Popper. *The Logic of Scientific Discovery* (London: Hutchinson, 1968)

Additional Literature

The Karl von Firsch dancing bees and James L. Gould's "blindfold" experiments are described in Richard Dawkins, *River out of Eden,* Phoenix, 1995. A more critical assessment of the dance hypothesis, with reference to philosophy of science, is given by the original critic, Andrew Wenner, "The elusive honey bee dance "language" hypothesis, *Journal of Insect Behaviour*, 15: 859-878 (2002); and Wells and Wenner (1973) Do bees have a language, *Nature*, 241:171-174. The Gould experiments are described in Gould et.al., 1970, "Communication of direction by the honey bee", *Science*, 169: 544-554. All easily available from the internett

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Essay Topics

- Which do you think is the most rational grounding for scientific facts: observation or theory?
- Identify some key hypotheses from your own branch of science. How well do they meet Popper's model?
- Do some areas have an inherently harder job in demonstrating this type of scientific validity as compared to physics?

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Tuesday 24th

- Svein Sjöberg (Kristian Nygaards Hus)
- Andreas Karlsson

Wednesday 25th

- Demarcation of science from pseudoscience
  - Recommended Literature : Feyerabend paper