Scientific Reasoning
Lecture-Seminar 1
‘Observation and Theory’

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Course Introduction

What is this course about?

- **Aim**: To cultivate a general understanding of science and, in particular, scientific reasoning.

  Focus: Some key methodological ideas and tools in science.

- A great deal of the material in this course is typically found in a philosophy of science course.

- As always, please consult the corresponding Moodle page where you will find the syllabus and various readings.

Topics

week 01: observation and theory
week 02: induction and falsification
week 03: explanation and confirmation
week 04: thought experiments
week 05: the social science and humanities context
week 06: methods in psychology
week 07: READING WEEK
week 08: evidential standards in medicine
week 09: data science (part I)
week 10: data science (part II)
week 11: REVISION
week 12: EXAM

Today's lecture

- The aim of this lecture is threefold:

  * What is a theory?

  * What is an observation?

  * How are the two related?

Theories

What is a theory?

- Arguably, the main aims of science are to describe, predict and explain the world. To do that, scientists utilise theories.

- As a first approximation, a theory can be thought of as a set of general claims about some domain of 'phenomena'.

Examples:
* Maxwell's theory of electromagnetism
* Lavoisier's caloric theory of heat
* Darwin's theory of evolution
* Neoclassical theory of economics
* Freud's theory of the subconscious
* Marx's theory of historical materialism
* Velikovsky's theory of worlds in collision
* …

Theories vs. hypotheses

- In scientific discussions they are often treated as distinct concepts. Hypotheses are thought of as (more) tentative.
- Should we call non-scientific, e.g. common-sense or religious, general claims about some domain of 'phenomena' theories?
- Following the above rationale, so long as they are not (so) tentative, they deserve to be classified as theories.
- We here take a more liberal approach and, unless otherwise noted, use the two concepts interchangeably.
- The question then becomes whether they're *good* or *bad* at representing, predicting and explaining their phenomena.

What's in a theory?

- A theory may be *said* to consist of or at least to be associated with one or more of the following:

  laws, principles, (statistical) regularities, models, axioms, invariances, symmetries, etc.

- **Examples**:

  * Law of diminishing returns (Production theory).

  * Law of gravitation (Newtonian physics).

  * The Hardy–Weinberg principle (Population genetics).

What accompanies a theory?

- A theory is useless unless it's also accompanied by some conditions of application:

  initial, boundary or idealising conditions

- For convenience, and unless otherwise stated, we shall stick to the umbrella term 'auxiliary assumptions' to cover all of these.

- Examples of auxiliary assumptions:

  * the density of the universe at the Big Bang is ρ_c
  * the motion of membrane-embedded molecules is 2D.
  * market *m* is in a state of perfect competition.

Theories and mathematics

- In the natural sciences at least, the more mature a theory is the more likely it will be mathematically formulated.

  Galileo: "... this grand book [of the universe]... is written in the language of mathematics" (quoted in Drake 1990, pp. 237-8).

- Why is mathematics so important?

  Because it allows us to formulate more precise (and thus more easily refutable) claims.

- *Compare*:
  Electrons have mass.
  Electrons have a mass of $9.10938291(40) \times 10^{-31}$ kg.

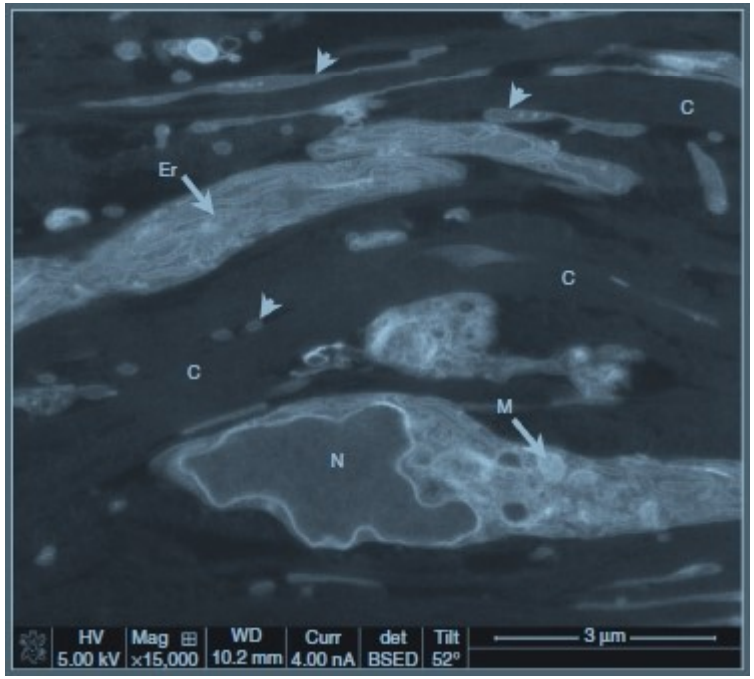
Can you think of some other examples of theories?

Observations

Observing (broadly construed)

- Observation, as it is understood in this context, is not restricted to seeing, but refers also to the other forms of sensing.

- Moreover, our senses have been 'extended' by various instruments. These act to amplify certain signals.



Examples:
* a cell's structure through an electron microscope.

* cognitive process complexity via response times.

* solar neutrinos through particle detectors.

Direct vs. indirect observation

- **Direct**: When our observations track the object we are targeting.

  Example: Observations of the Sikhote Alin meteorite.

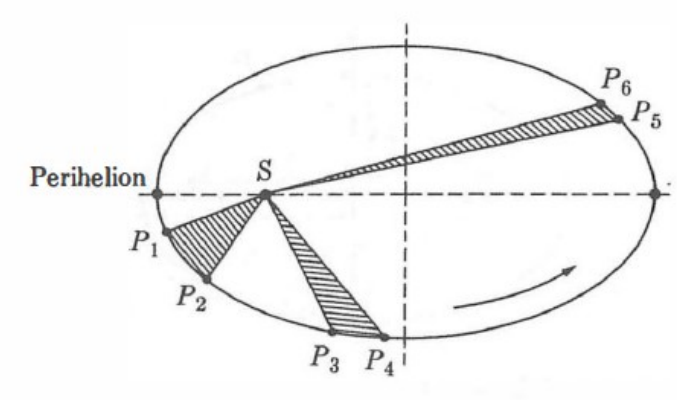
- **Indirect**: When we observe something else that allows us to *infer* the existence and properties of the target object.

Example: Meteorite inferences via observations of the Barringer crater.

The significance of observations

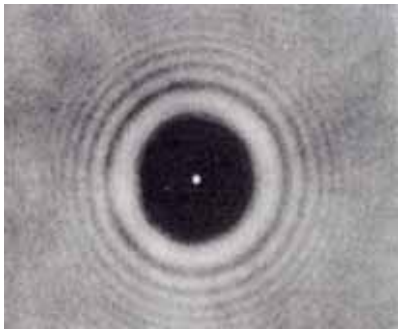
- Observation can help the construction/alteration of theories.

Example: Tycho Brahe's meticulous observations helped Kepler postulate his three laws of planetary motion.



- Perhaps more importantly, observation seems to be the ultimate arbiter of disagreement between theories.

Example: The unexpected Poisson spot and other observations favoured Fresnel's wave theory of light over the corpuscular theory.



Theories go beyond observations

- Theories have much more content than actual observations. After all, to generalise is to go beyond particular observations.

  Compare (Case 1):
  * When dropped, *this* object will move towards the ground with constant acceleration.

  * When dropped, *all* objects will move towards the ground with constant acceleration.

  Compare (Case 2):
  * John and Jill are economists and have clear and ordered preferences when investing.

  * All economists have clear and ordered preferences when investing.

Theories go beyond the observable

- Theories do not only generalise but sometimes go beyond what is directly observable and even beyond what is observable.

  * Positing entities that are only *indirectly observable*.

  Example:
  Higgs bosons produced in a particle accelerator.

  * Positing entities that are *not observable at all*.

  Example:
  Branching worlds (whose existence is presumably effected by the measurement of microscopic states).

Give an example of a thing that is only indirectly observed.

Theory-Ladenness of Observation

Theory-ladenness of observations

- Keeping in mind that theories go beyond actual observations, we should be cautious about this extra content.

- Indeed, there are reasons to be cautious about observations themselves. That's because of the risk of theory-ladenness.

- Though the rough idea is arguably quite old, the modern conception owes much to N. R. Hanson (1958), among others.

Central Idea: 'Theoretical' factors influence and potentially distort perceptions, perceptual beliefs and observation reports.

- Why the inverted commas? Because many of these factors are not strictly speaking theoretical in character.

The multi-faceted nature of theory-ladenness

- That at least some **differences** in :
  - sensory physiology
  - linguistic choices
  - conceptual schemes
  - prior beliefs
  - theories
  - and/or environmental cues

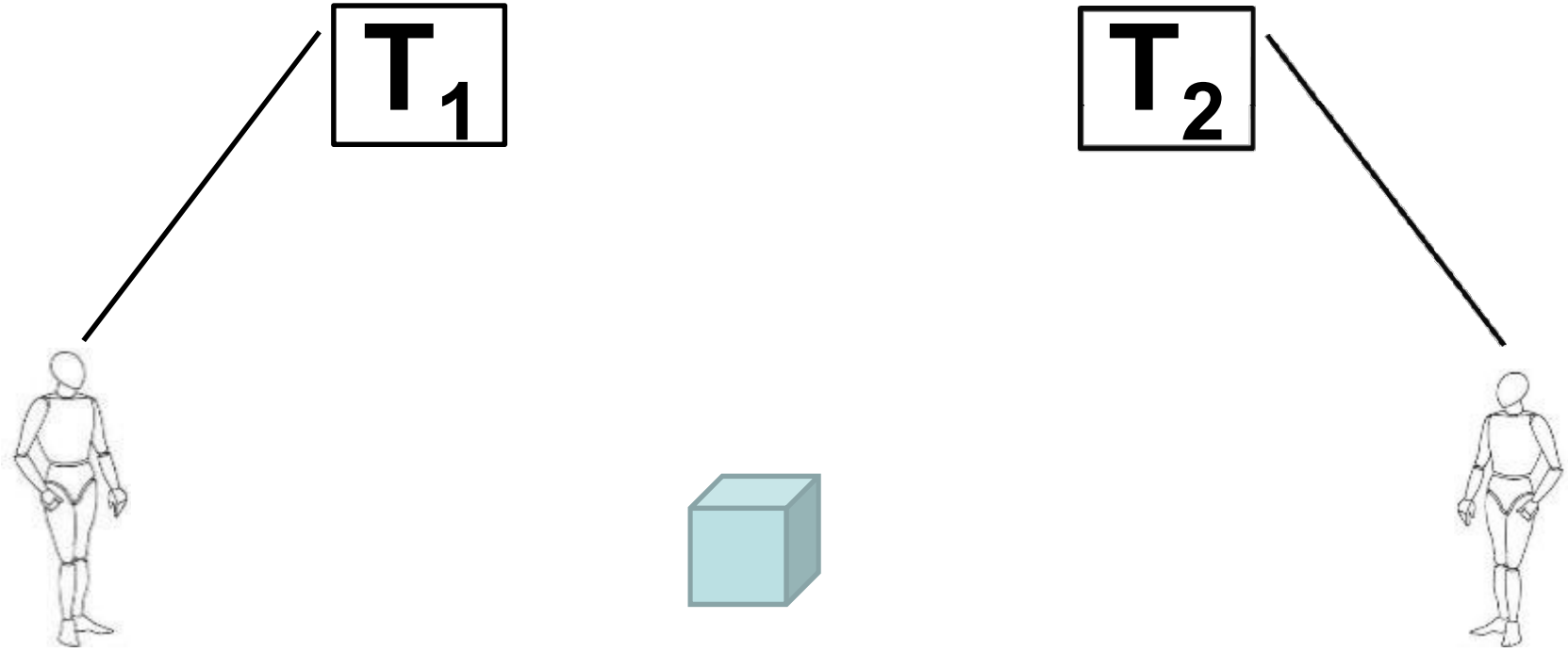
  affect and potentially distort what we perceive, believe and report.

Why care about theory-ladenness?

- **Problem**: If individuals sponsoring rival hypotheses perceive and/or report the world in a genuinely rival manner, then those perceptions /reports cannot be neutral adjudicators between the said hypotheses.

No neutral adjudication?

- Implicit in this claim is that distinct theories distort the content of observation reports in distinct ways.
- On this view, the reports of observers w/distinct theories cannot form a neutral adjudication basis.



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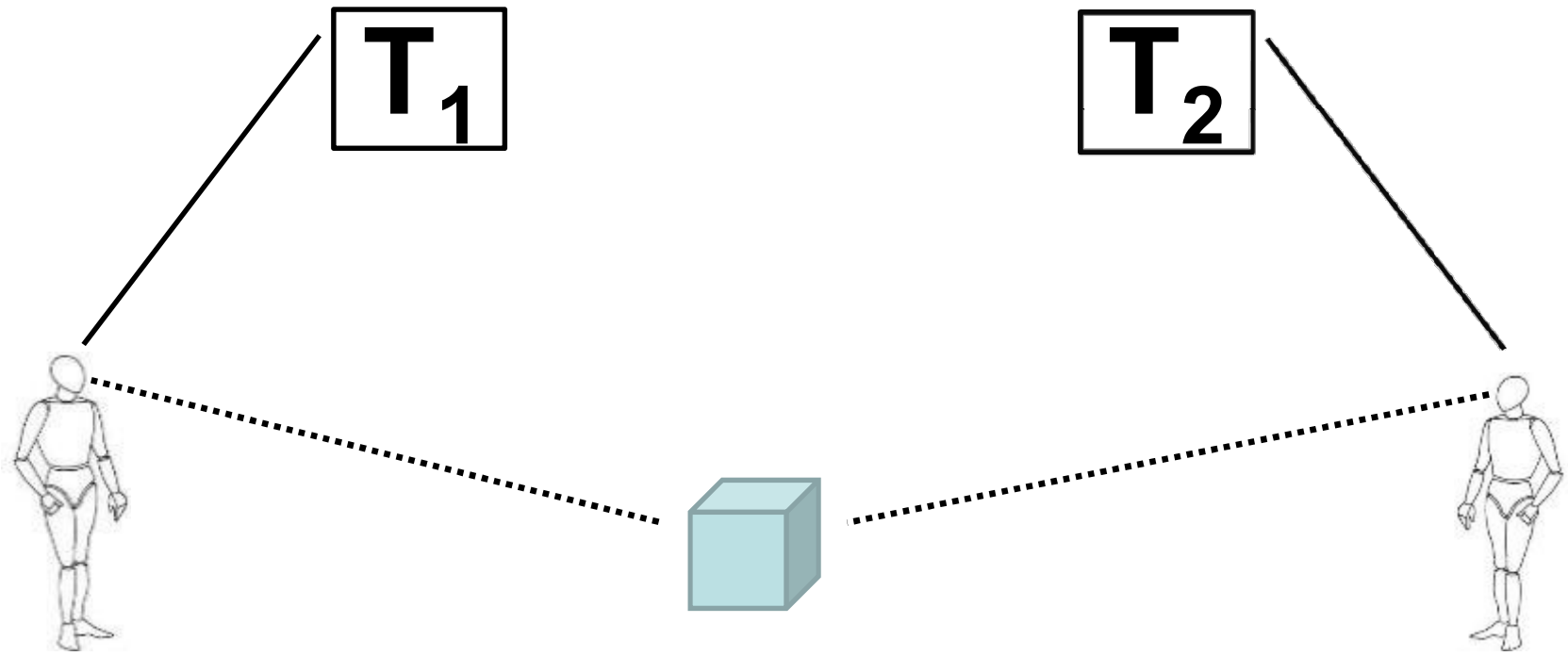

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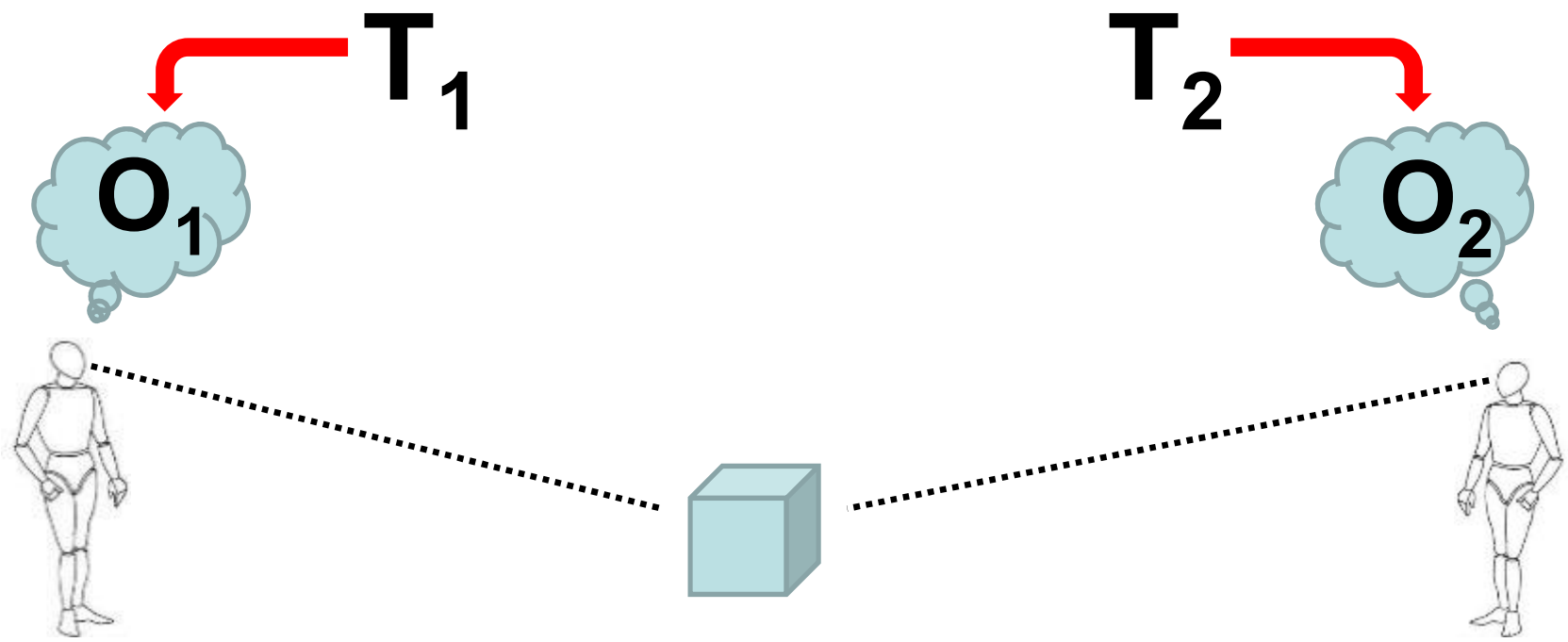

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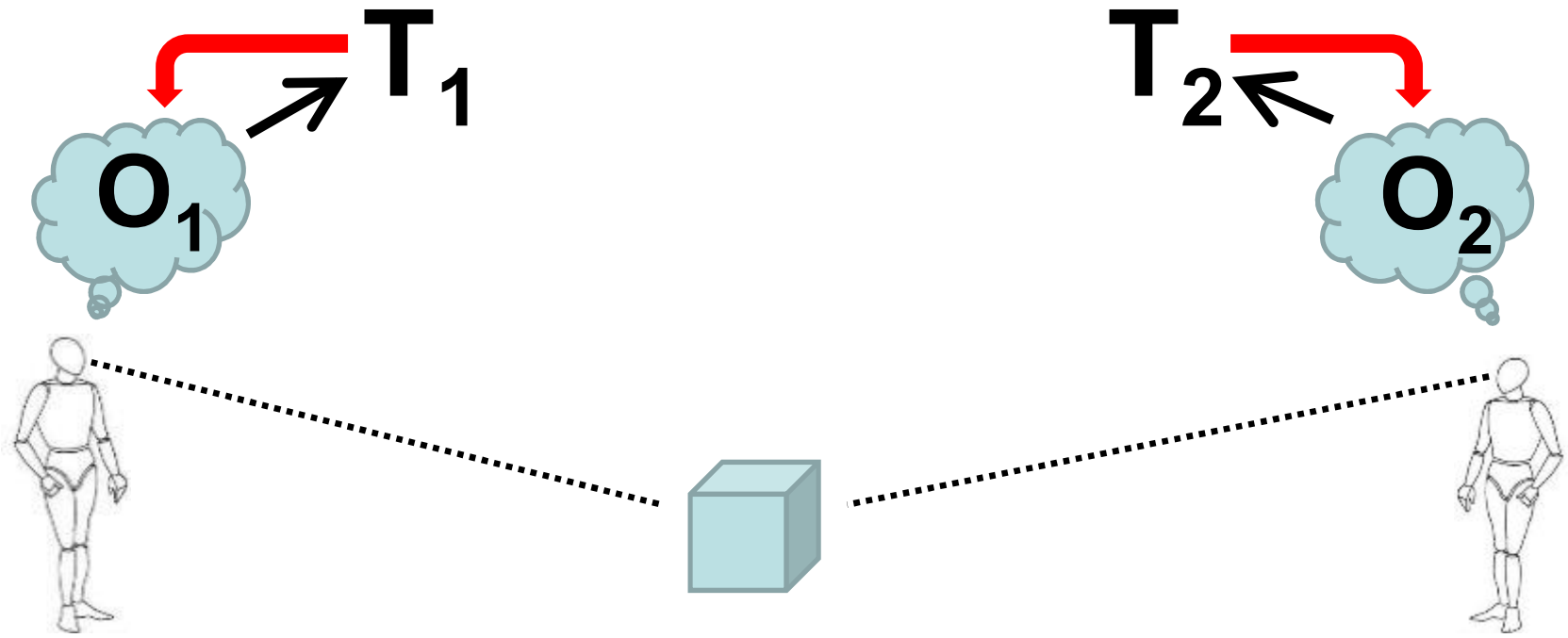

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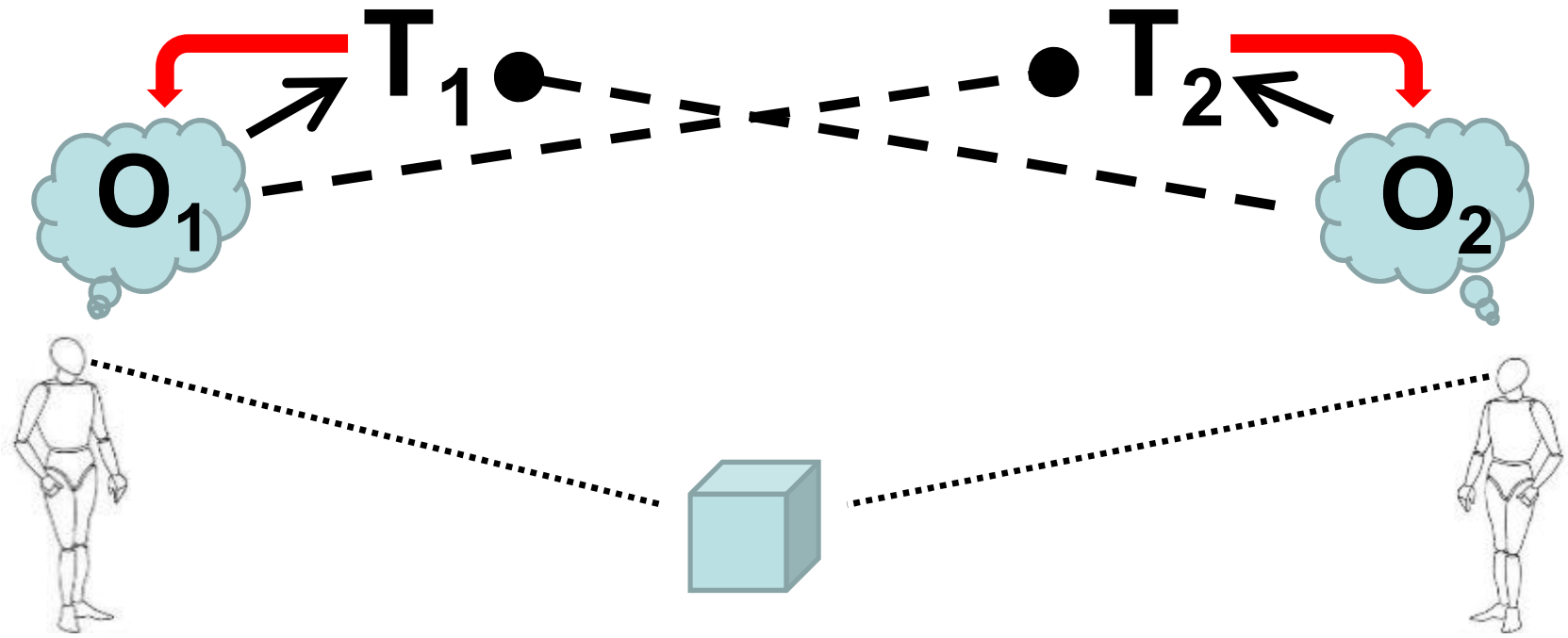
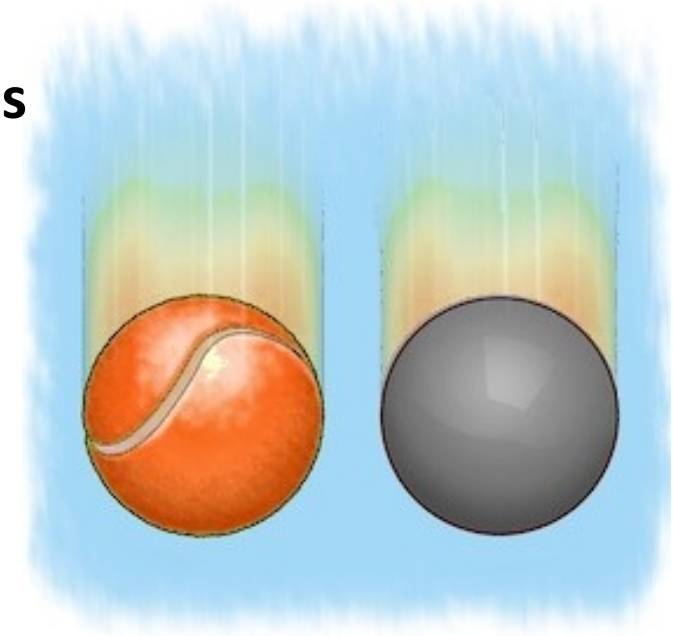


Example: Free falling objects

- Gunstone & White (1981): College students asked to perceptually judge falling speed of 2 balls (iron, plastic).

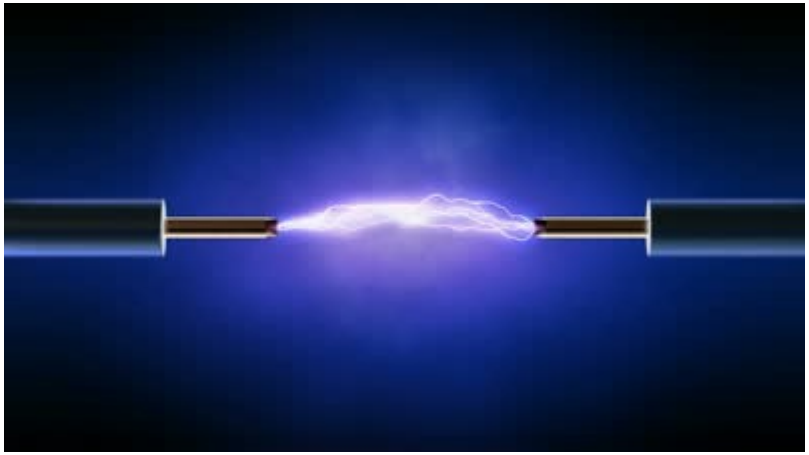
- For all intents and purposes, **the two balls reached the ground at the same time.**

- A number of students whose initial hypothesis was that the heavier balls fall faster maintained that view.



Example: N-rays

- In 1903, Prosper-René Blondot, a renowned French physicist, announced the discovery of N-rays.



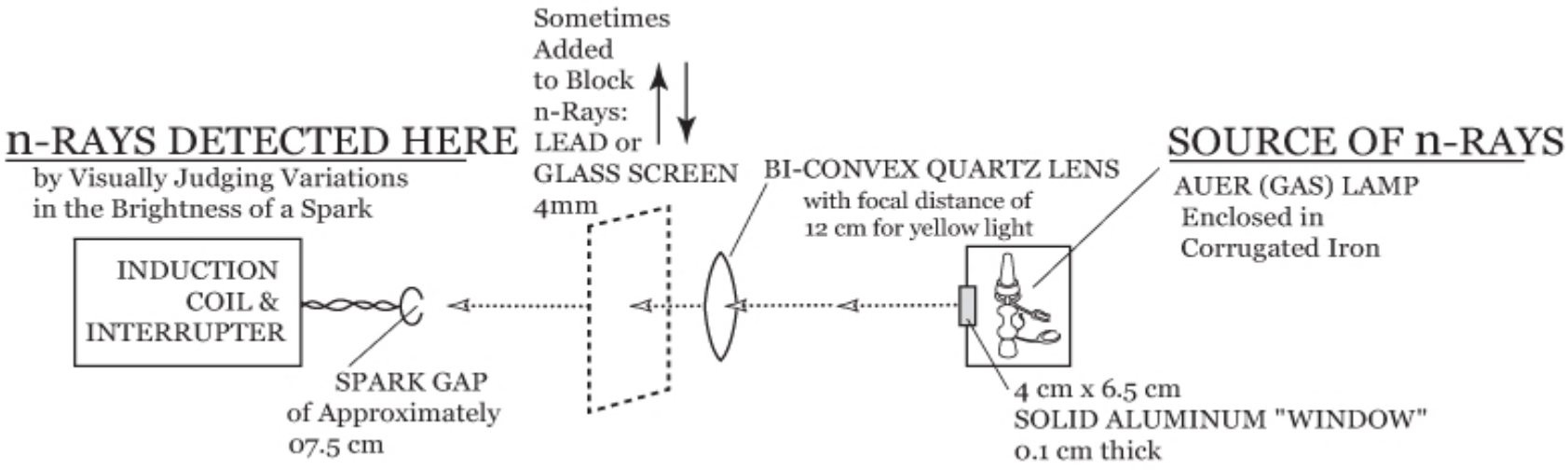
- Brewer & Lambert (2001: 180): "[s]oon over 300 papers by 100 different scientists were published on the properties of N-rays".

- But... within a few years, N-rays were rejected as unreal.

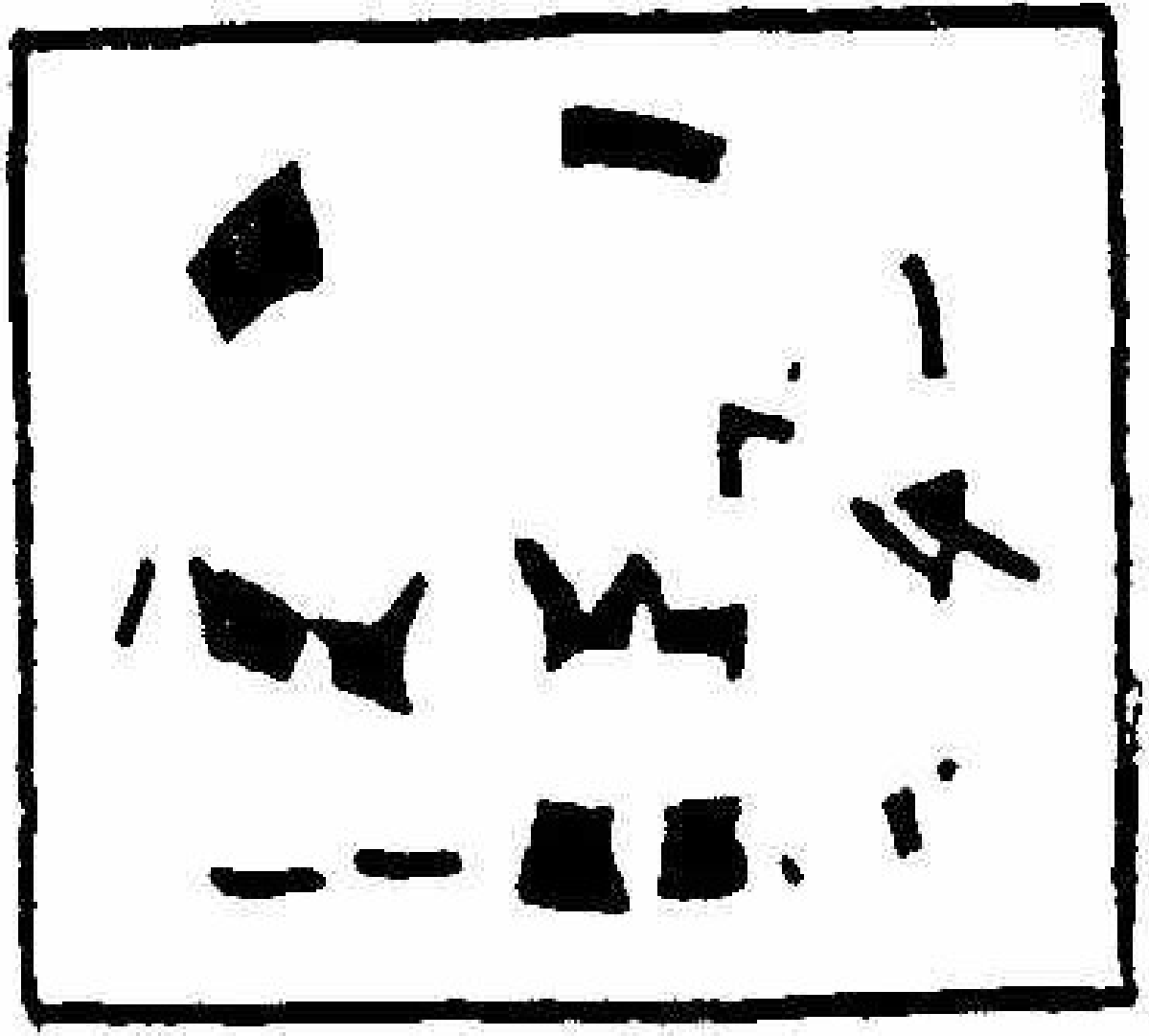
Fighting biased observations

- If the results cannot be reproduced (using the same or even different instruments) then the observations are suspicious.

- R.W. Wood visited Blondot's lab only after the inability of other labs to reproduce those results.



What do you see?



Reading

- Kukla, A. (2008) ‘Observation’, in M. Curd and S. Psillos (eds.), *The Routledge Companion to Philosophy of Science*, New York, NY: Routledge.

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