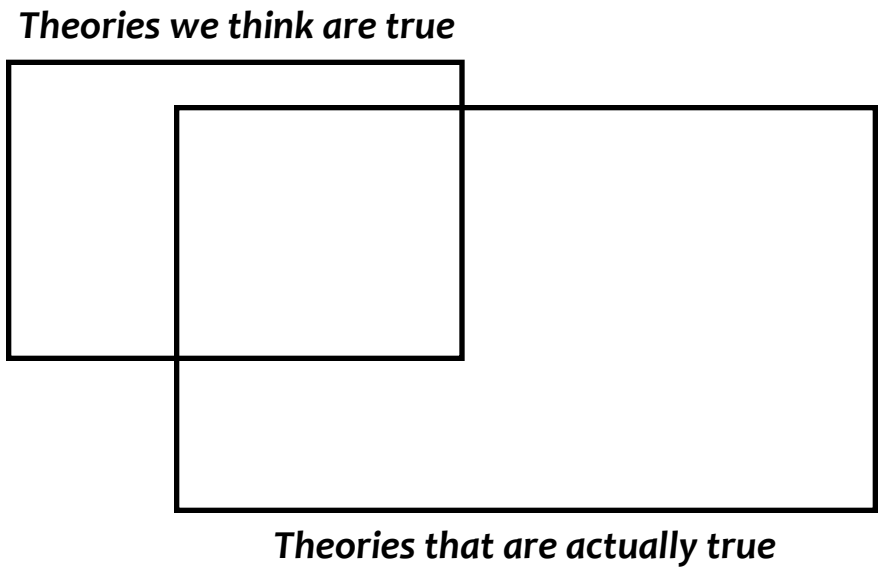
Why is science hard?

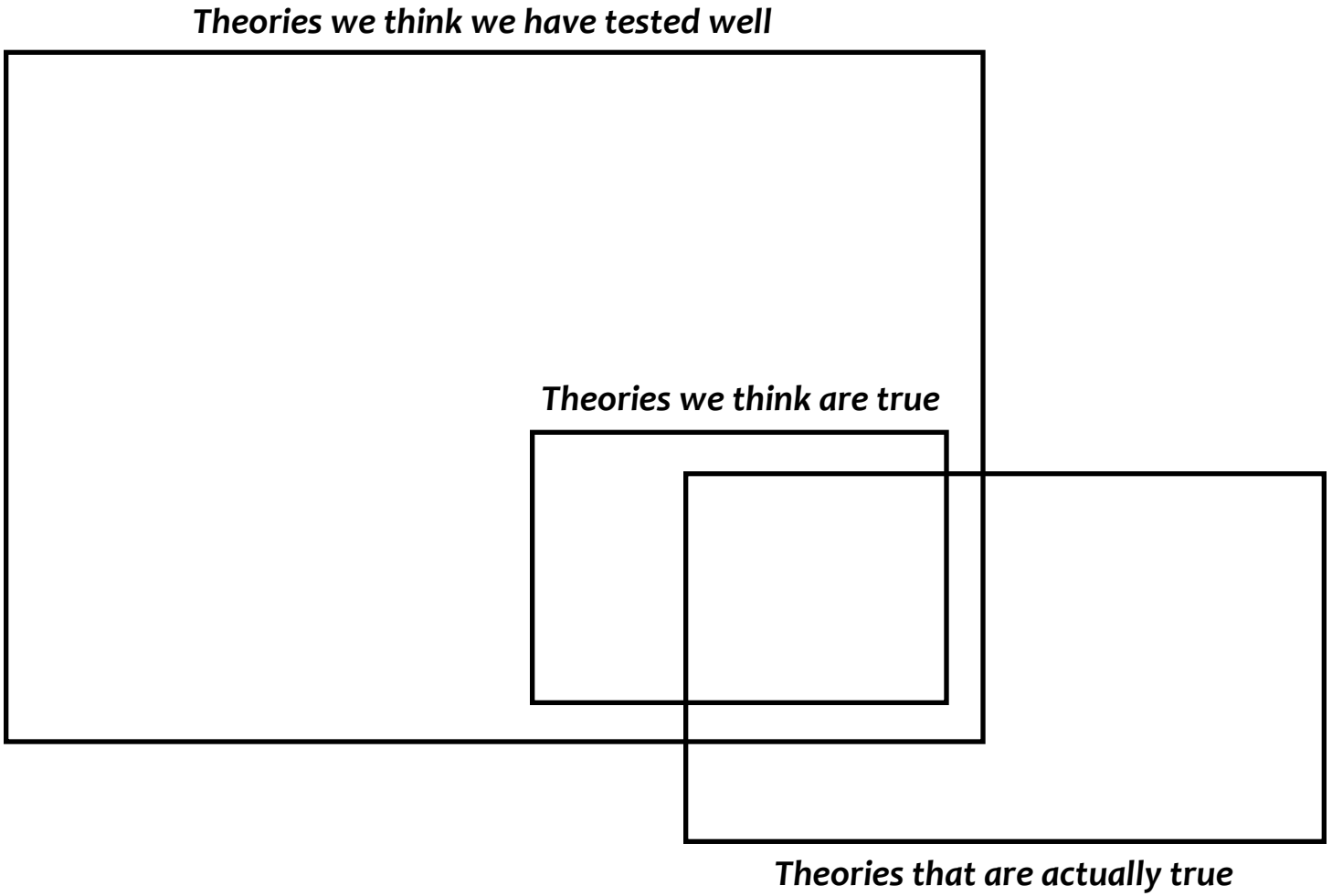
- **Intrinsic** — Our knowledge is imperfect in ways that makes it difficult to correct
- **Personal** — Individual scientists have biases and flaws in their approach
- **Community** — The way we organize ourselves can limit progress

Intrinsic

All possible theories

Theories that are actually true


Theories we think are true
Theories that are actually true

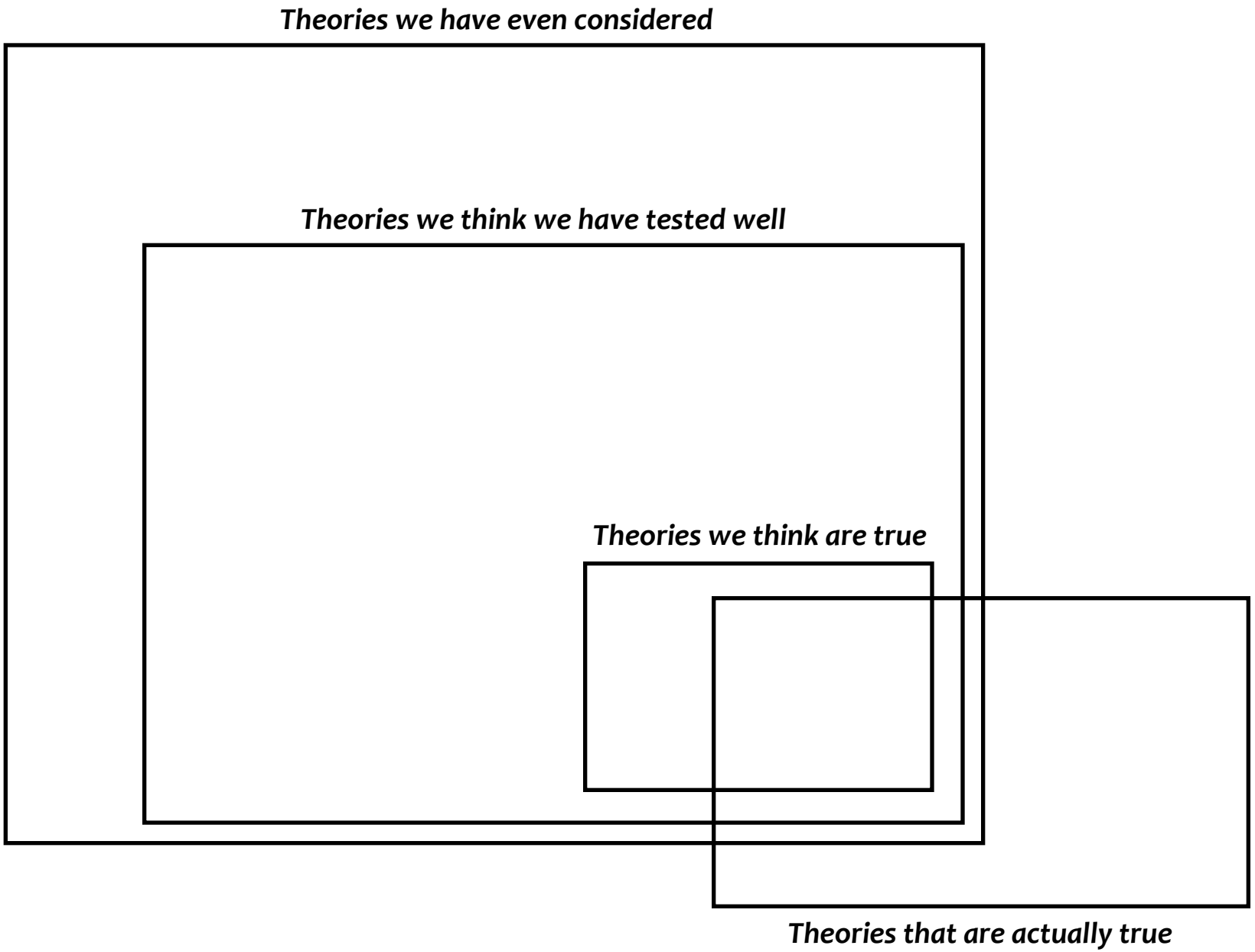

Theories we think we have tested well
Theories we think are true
Theories that are actually true

Facts are deceptively simple *in retrospect*

Somebody once observed to the eminent philosopher Wittgenstein how stupid medieval Europeans living before the time of Copernicus must have been that they could have looked at the sky and thought that the sun was circling the earth. Surely a modicum of astronomical good sense would have told them that the reverse was true.

Wittgenstein is said to have replied:
"I agree. But I wonder what it would have looked like if the sun had been circling the earth."

Source: J. Burke. The Day the Universe Changed


Theories we have even considered
Theories we think we have tested well
Theories we think are true
Theories that are actually true

Personal

Why do we need help doing this?

- Isn't science just "advanced common sense"?
  - Yes, but it is *advanced* common sense
- Both lay observers and experts tend to...
  - See patterns in random data
  - Generalize from incomplete samples
  - See confirmation for favored ideas in ambiguous data
- We tend to believe...
  - What we already think we know
  - What we hear second-hand
  - What our community believes

Source: T. Gilovich. *How We Know What Isn't So*. 1991.

Personal failings

- **Slop** — Doing research in such a way that it is impossible to know for certain what was done or observed; Confused or unclear procedures and data-recording techniques; Imprecise theorizing, unexpressed assumptions, and informal derivation of predictions.
- **Sloth** — Doing too little; Laziness such that important potential data are not obtained or recorded; Partial or incomplete analysis of data.

Drawn from: Donald D. Jensen (circa 1995), Unpublished lecture notes. University of Nebraska - Lincoln.

Personal failings

- **Precipitance** — Jumping to a conclusion; Premature decision on an issue; Accepting as established something that deserves further investigation.
- **Propaganda** — Biased presentation of a theory or data; Also called "special pleading"; Acting as a proponent rather than an disinterested presenter of facts and interpretation; Salesmanship rather than science.
- **Prejudice** — Biased evaluation of theory and data; expecting more of other theories than of one's own; "Tilting the playing field" in favor of one's own theory.
- **Perseveration** — Holding to a theory despite clear evidence that it is false.

Drawn from: Donald D. Jensen (circa 1995), Unpublished lecture notes. University of Nebraska - Lincoln.

Personal failings

- **Finagle** — "Adjusting" data so that it fits a favored theory. Minor fraud.
- **Filch** — Stealing ideas or data without giving appropriate credit; Plagiarism or other unauthorized use of the work of others.
- **Fraud** — Falsifying data and investigation

Drawn from: Donald D. Jensen (circa 1995), Unpublished lecture notes. University of Nebraska - Lincoln.

Good research methods help you…

- Identify interesting new questions you hadn't thought of
  (Exploratory data analysis)
- Ask questions that are scientifically meaningful
  (Falsifiable hypotheses)
- Avoid fixating on one favored hypothesis
  (Multiple working hypotheses)
- Devise evaluations that maximize what you can learn
  (Experimental design)
- Avoid seeing patterns in randomness
  (Hypothesis tests)
- Understand when you have collected sufficient evidence
  (Statistical power)
- Formulate broader theories
  (Modeling)

Community

Community failings

- Science is a human community
- Like any other community, we have...
  - Fads and fashions
  - Structures and traditions that interfere with progress because they don't change with changing needs
  - Disagreements over goals and direction that consume time and resources
  - Outsize personalities that seek personal success in ways that conflict with the goals of the community
- Science progresses *in spite of* these problems and seeks to minimize their impact