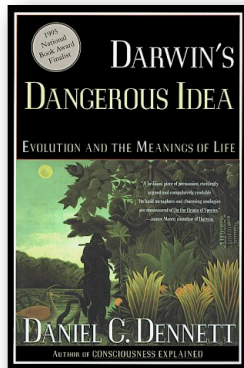


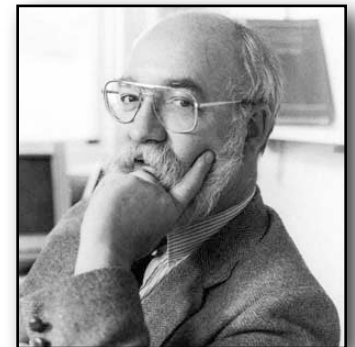
If I were to give an award for the single best idea  
anyone has ever had, I'd give it to...

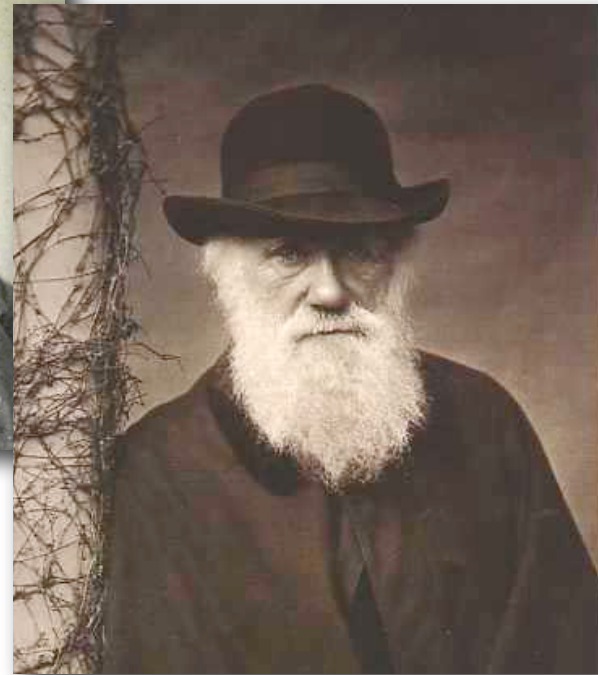
**Darwin**

ahead of Newton and Einstein  
and everyone else. In a single stroke,  
the idea of evolution by natural selection  
unifies the realm of life, meaning, and purpose  
with the realm of space and time, cause and effect,  
mechanism and physical law.



– Daniel Dennett  
*Darwin's Dangerous Idea*

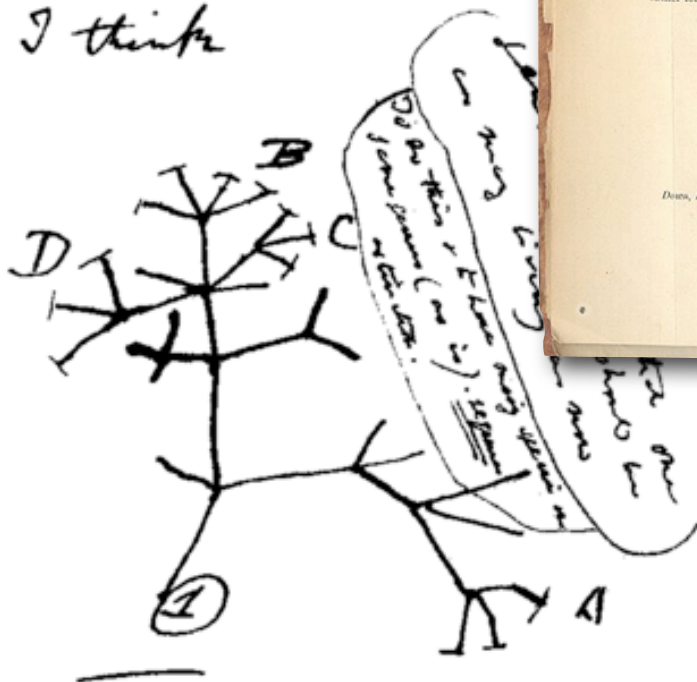




Charles Robert Darwin

(12 February 1809 – 19 April 1882)

I think



"But with regard to the material world, we can at least go so far as this—we can perceive that events are brought about not by insulated interpositions of Divine power, exerted in each particular case, but by the establishment of general laws."

W. WHUWELL: *Bridgewater Treatise*.

"To conclude, therefore, let no man out of a weak conceit of sobriety, or an ill-applied moderation, think or maintain, that a man can search too far or be too well studied in the book of God's word, or in the book of God's works; divinity or philosophy; but rather let men endeavour an endless progress or proficience in both,"

Bacon: *Advancement of Learning*.

Down, Bransley, Kent,  
October 1st, 1850.

ON

# THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE  
FOR LIFE.

By CHARLES DARWIN, M.A.,

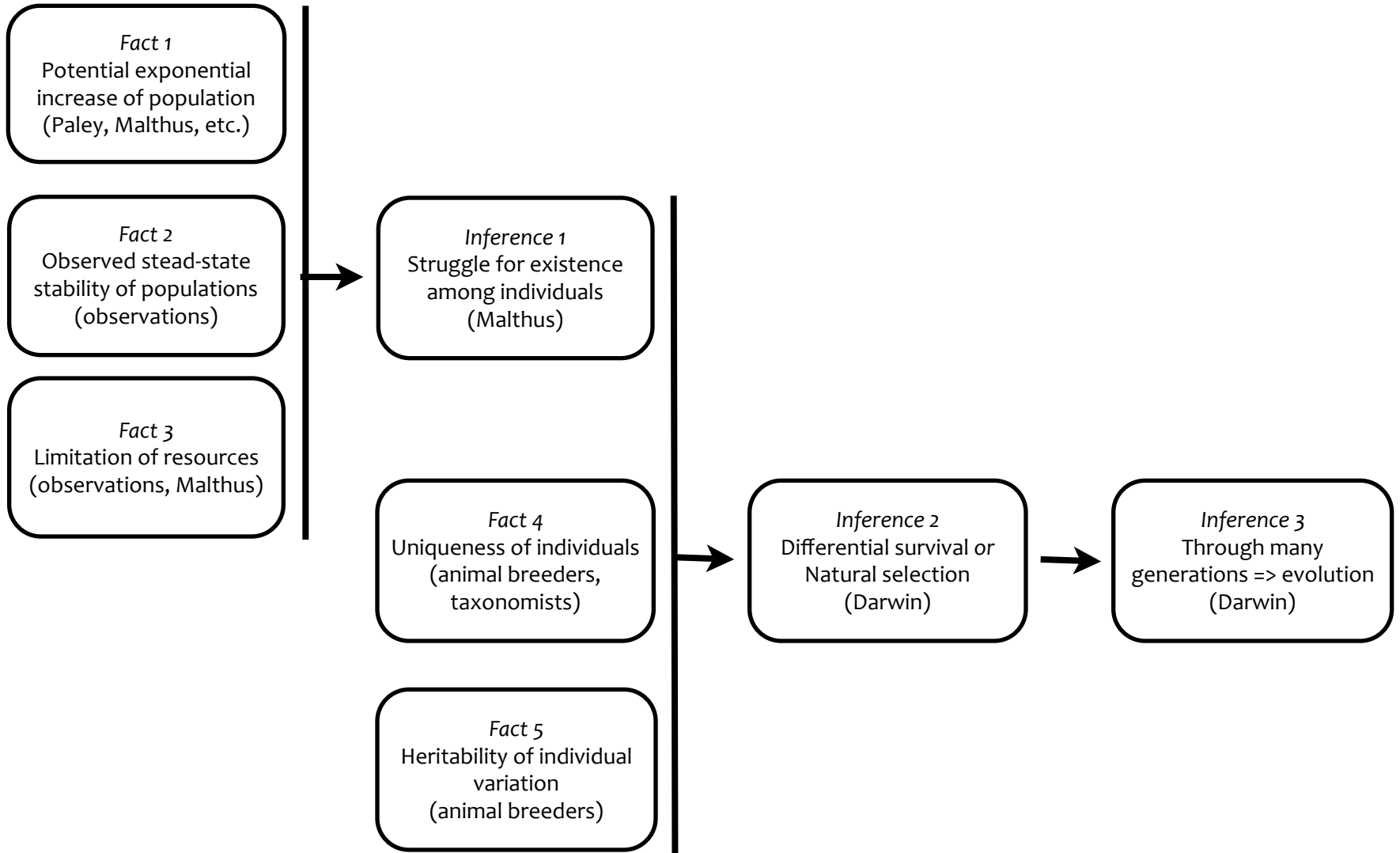
FELLOW OF THE ROYAL, GEOLOGICAL, LINNEAN, ETC., SOCIETIES;  
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE  
ROUND THE WORLD.'

LONDON:

JOHN MURRAY, ALBEMARLE STREET.

1850.

The right of Translation is reserved.





# 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

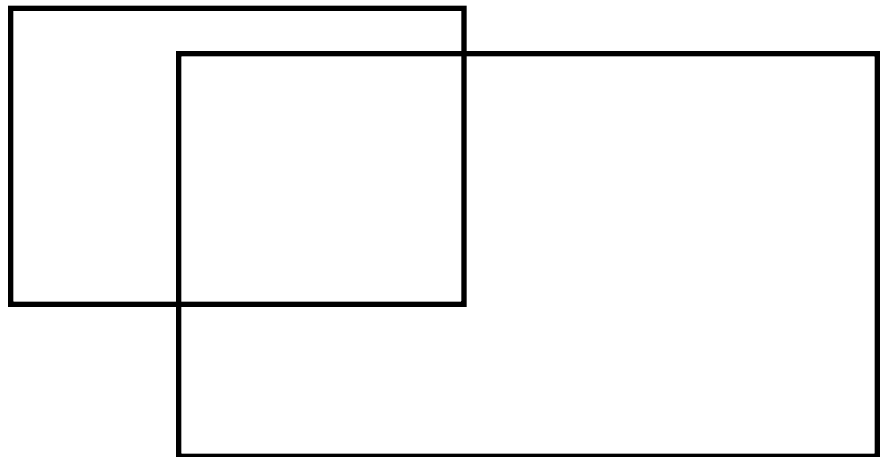
**Intrinsic**

*All possible theories*



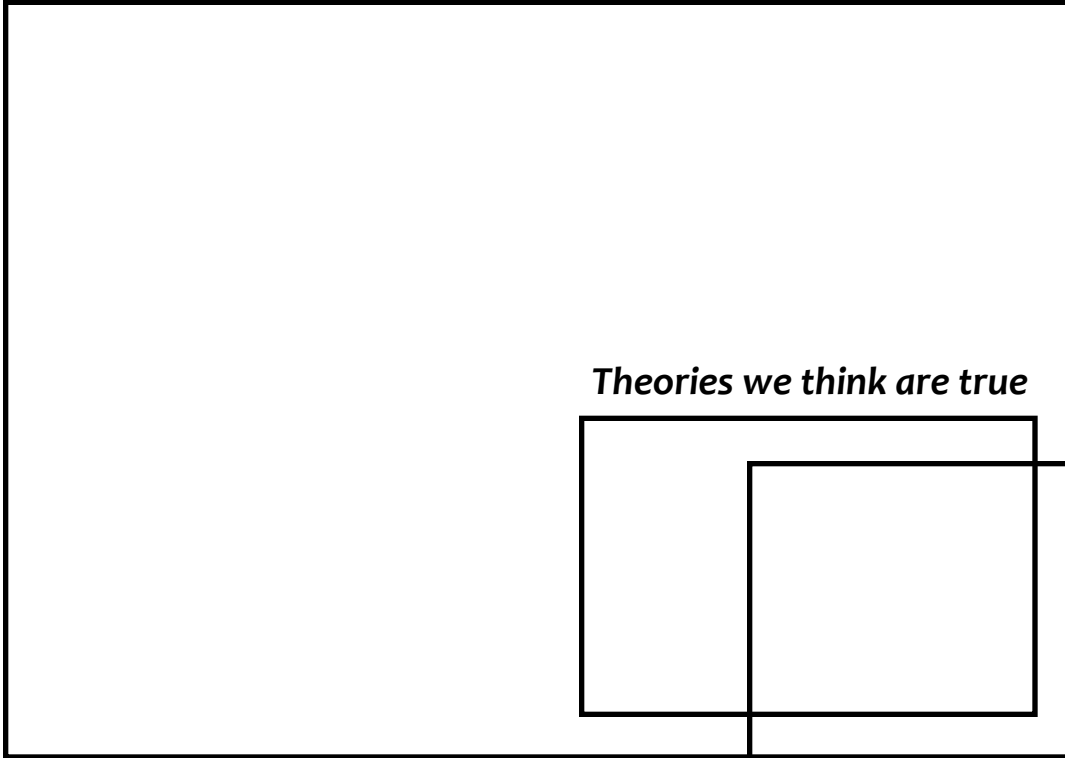
*Theories that are actually true*

*Theories we think are true*



*Theories that are actually true*

*Theories we think we have tested well*



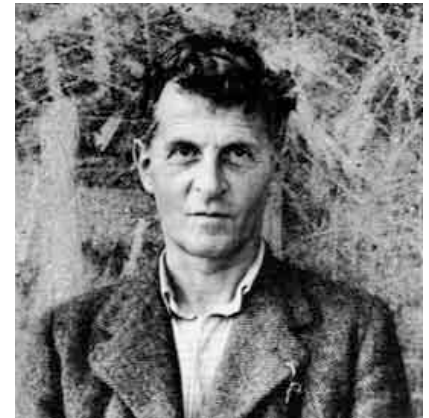
*Theories we think are true*

*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.”*



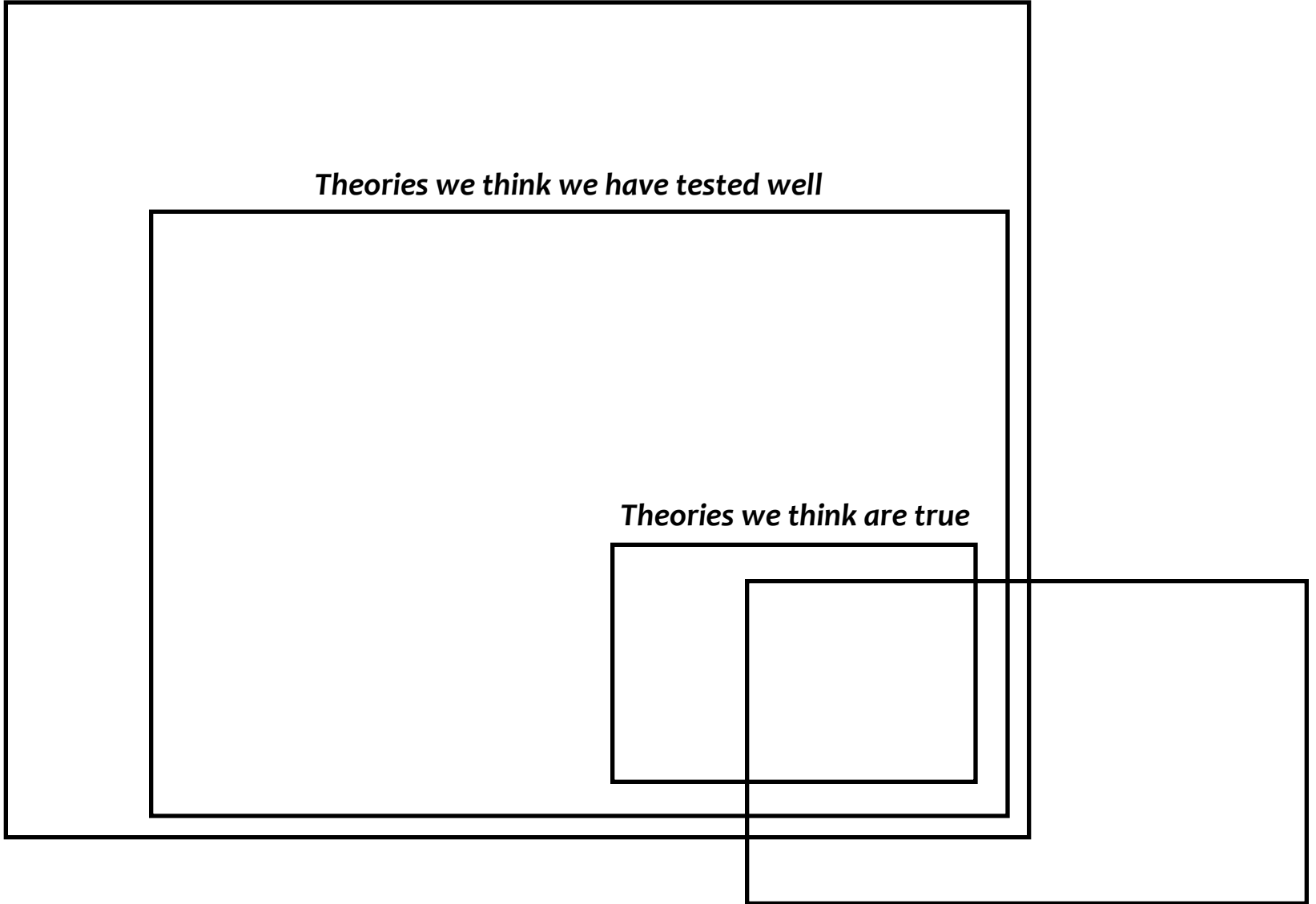


*Theories we have even considered*

*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

# 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.

# 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.

# 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



# 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