



Being Critical in Science Education: Why knowing what's wrong matters as much as knowing what's right

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The Three Ironies of Science Education

- Training Not an Education
- Emphasis on the Intrinsic Value rather than Extrinsic Value
- The Absence of Critique

EXECUTIVE SUMMARY

RISING ABOVE THE GATHERING STORM

*Energizing and
Employing America
for a Brighter
Economic Future*

3
NATIONAL ACADEMY OF SCIENCES,
NATIONAL ACADEMY OF ENGINEERING, AND
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES



EUROPEAN
COMMISSION

Community research

*Europe
needs
more
scientists*

**Report by the High Level Group
on Increasing Human Resources for
Science and Technology in Europe
2004**





National Audit Office

**REPORT BY THE
COMPTROLLER AND
AUDITOR GENERAL**

**HC 492
SESSION 2010–2011
NOVEMBER 2010**

Department for Education

Educating the next generation of scientists

Beyond 2000
science education
for the future

1999
Beyond
2000
2001

a report with
ten recommendations

Science Education in Europe

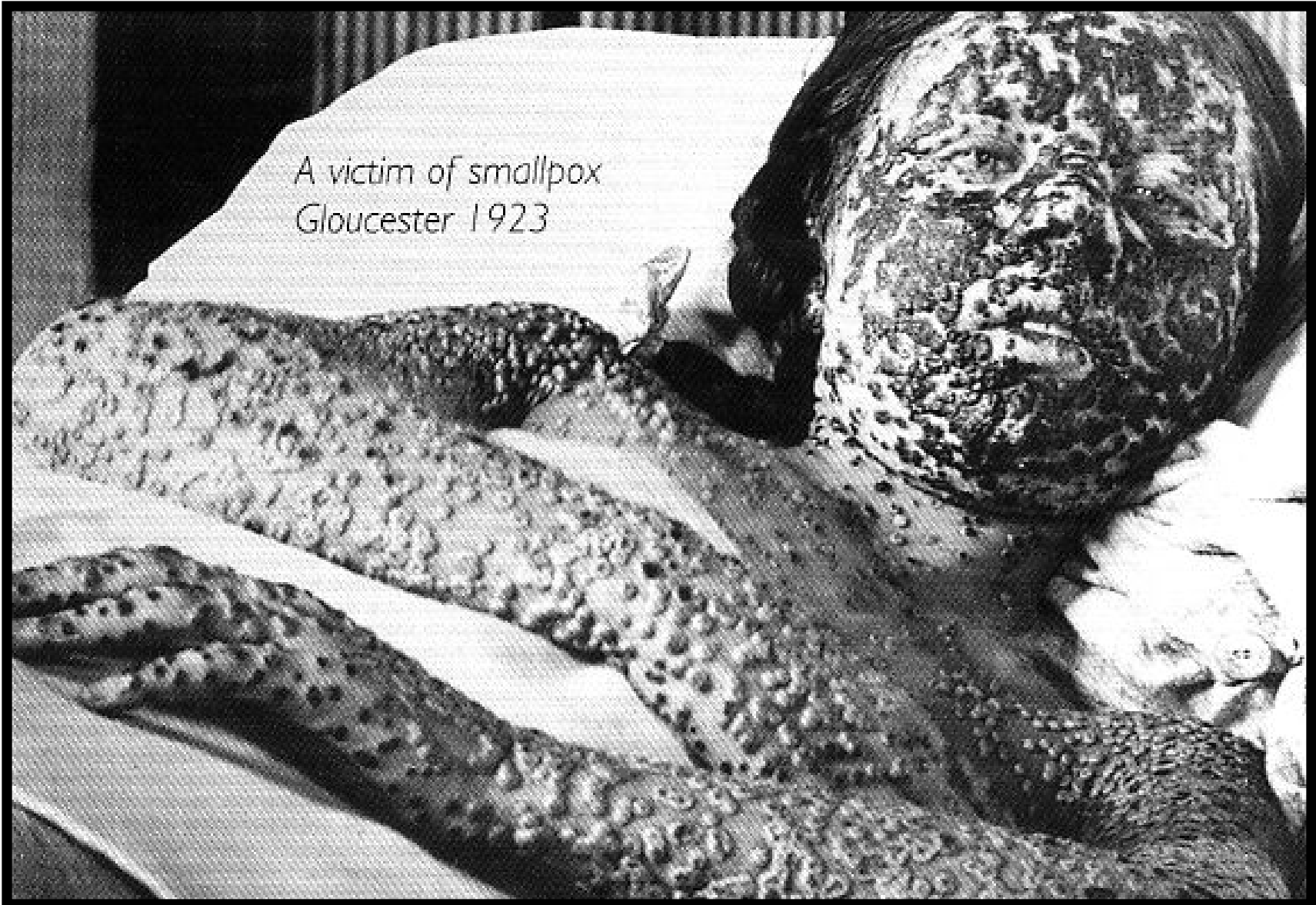
A Report to the Nuffield Foundation

Jonathan Osborne

Justin Dillon

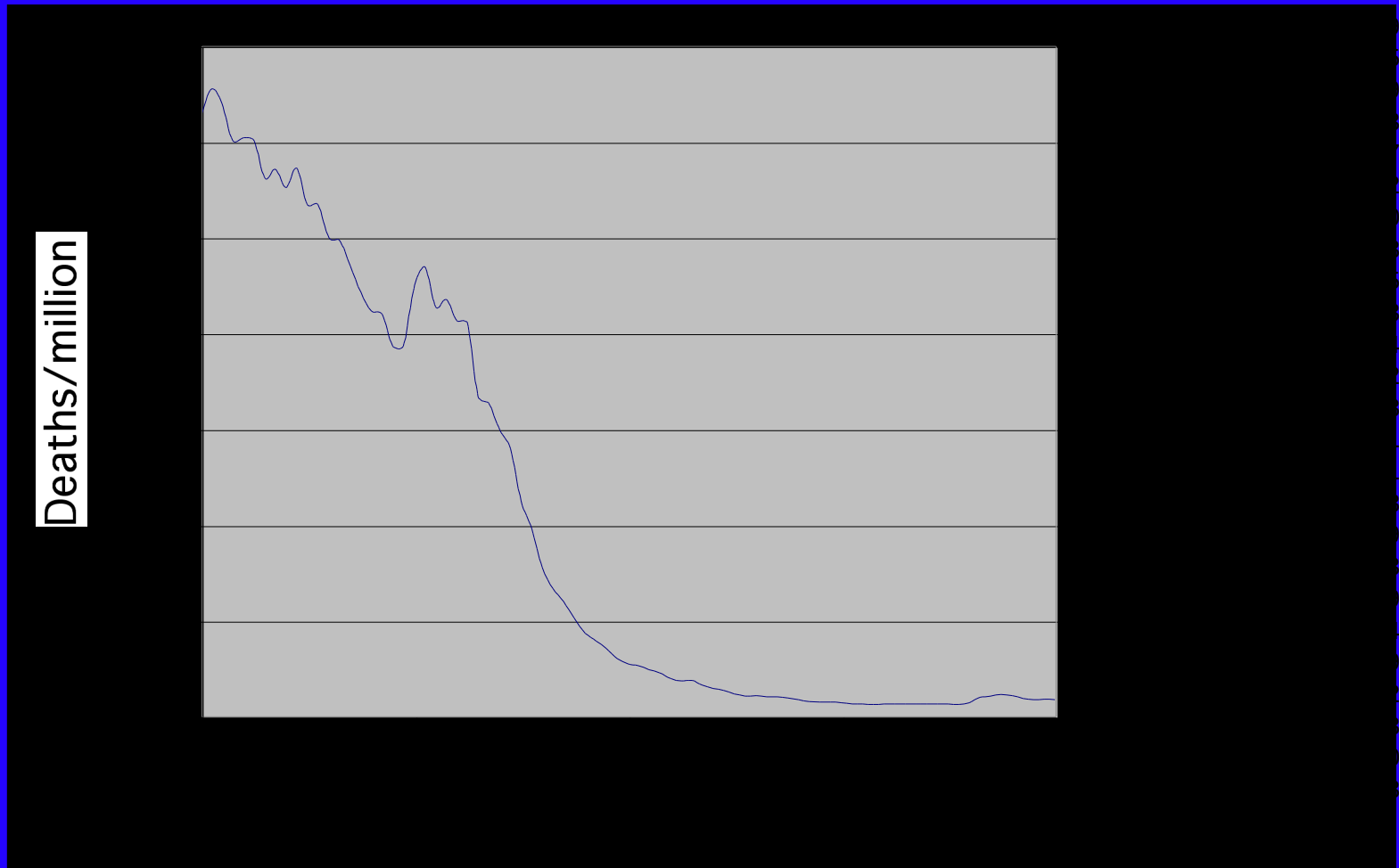
King's College London

August 2007



*A victim of smallpox
Gloucester 1923*

Deaths/million from Infectious & Respiratory Diseases 1920-2000 (UK)



“Grounds for accepting the models proposed by the scientist are often no different from the young African villager’s grounds for accepting the models propounded by one of his elders. In both cases the propounders are deferred to as the accredited agents of tradition.”

Second Irony

- Science teachers, science educators all are fascinated by the intrinsic value of science.
 - Low Use-Value

- Students value science for its Exchange Value.

Pupils' & Parents' Views of the School Science Curriculum

A study funded by the Wellcome Trust

Dr Jonathan Osborne & Dr Sue Collins

January 2000

Osborne, J. F., Simon, S., & Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *International Journal of Science Education*, 25(9), 1049-1079.

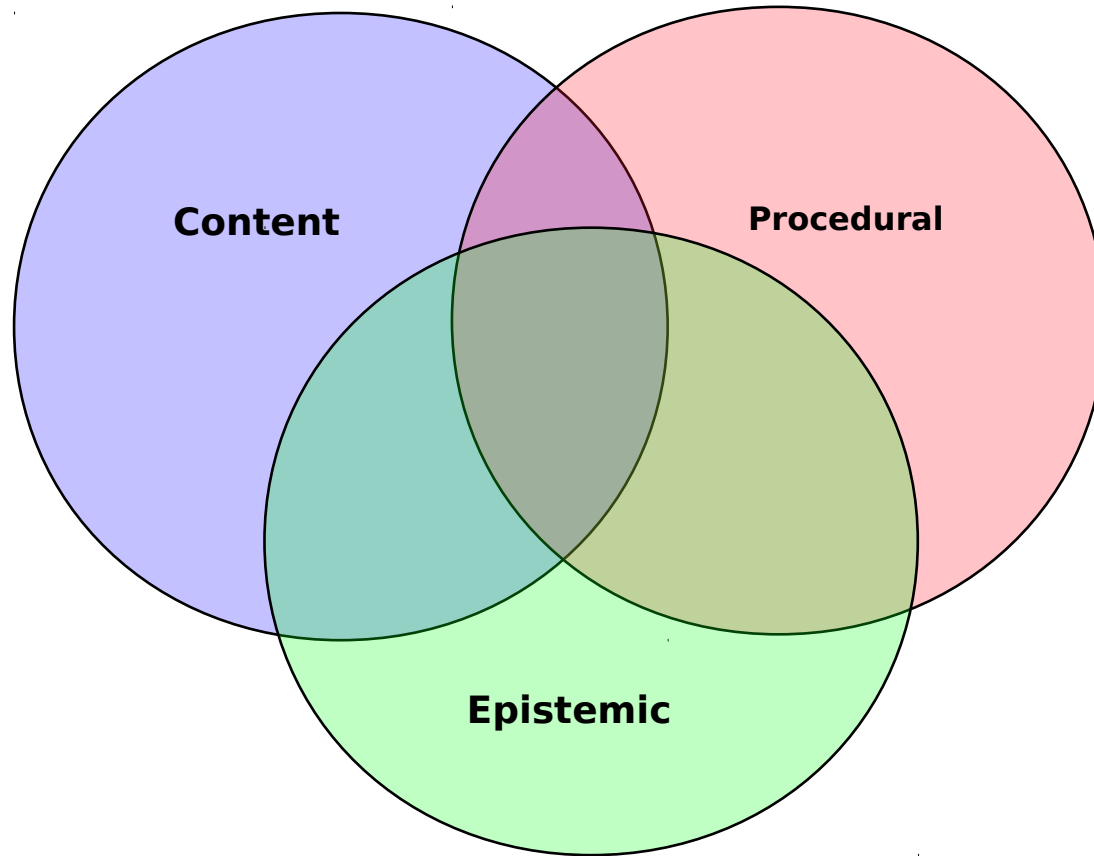
Third Irony: The Absence of Critique

Construction

v

Critique

Three Form of Knowledge in Science



How do we Know?

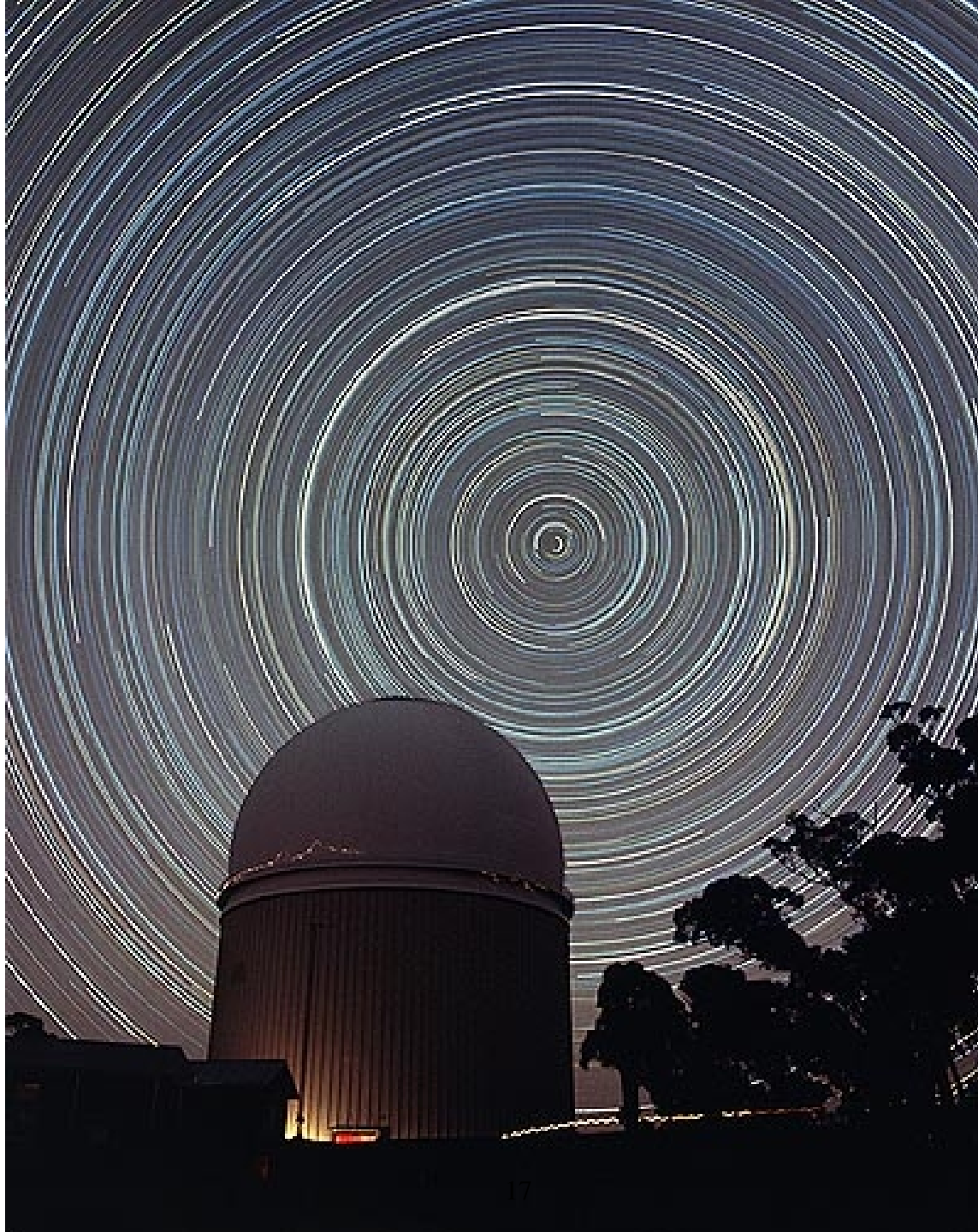
That Day and Night are caused by a spinning Earth?

Arguments Against:

1. The Sun moves
2. If you jumped up you would not land in the same spot
3. If the Earth was spinning at that rate, the speed at the equator is over a 1000 mph and you should be flung off.

The Foucault Pendulum





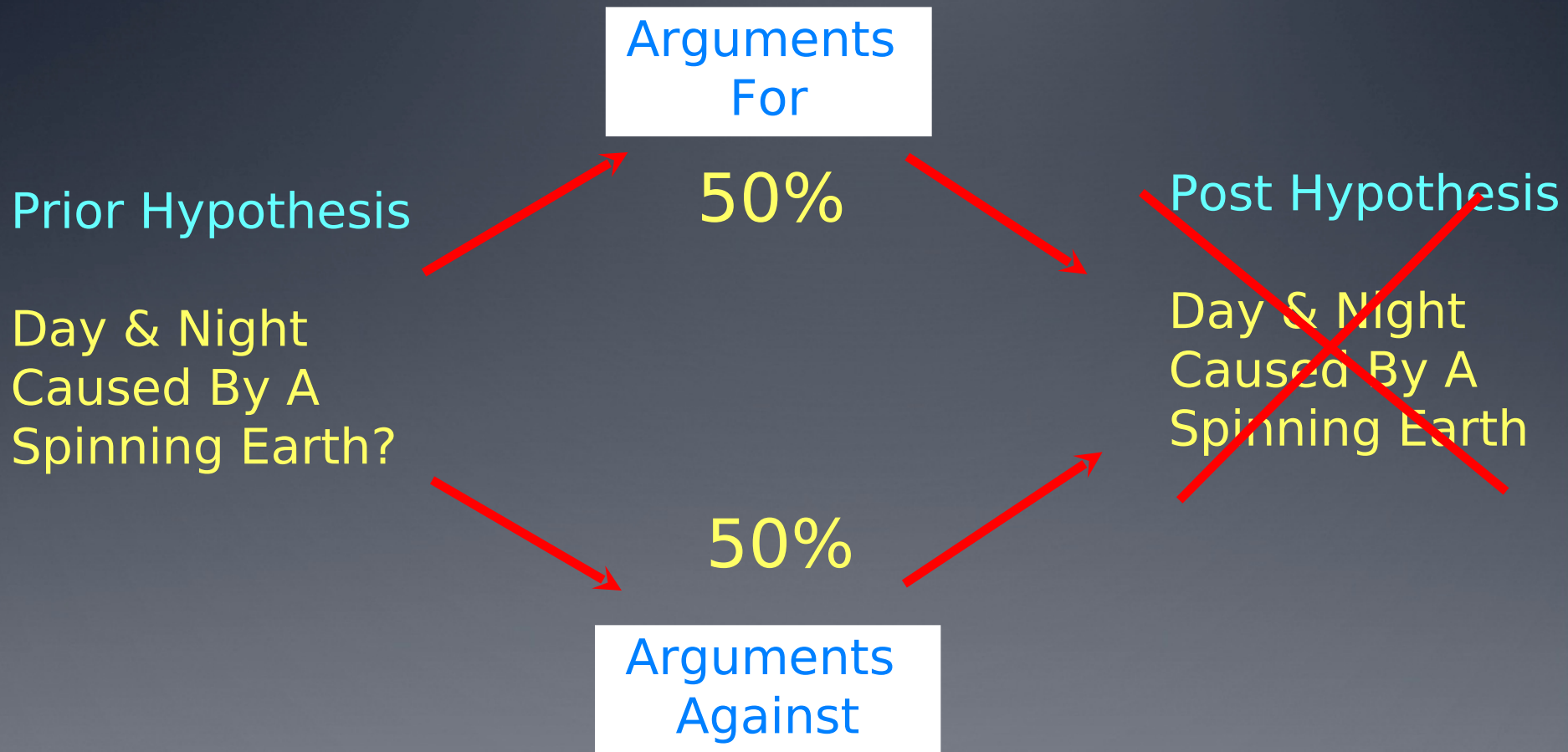
A Sample Question

Janet was asked to do an experiment to find how long it takes for some sugar to dissolve in water. What advice would you give Janet to tell her how many repeated measurements to take?

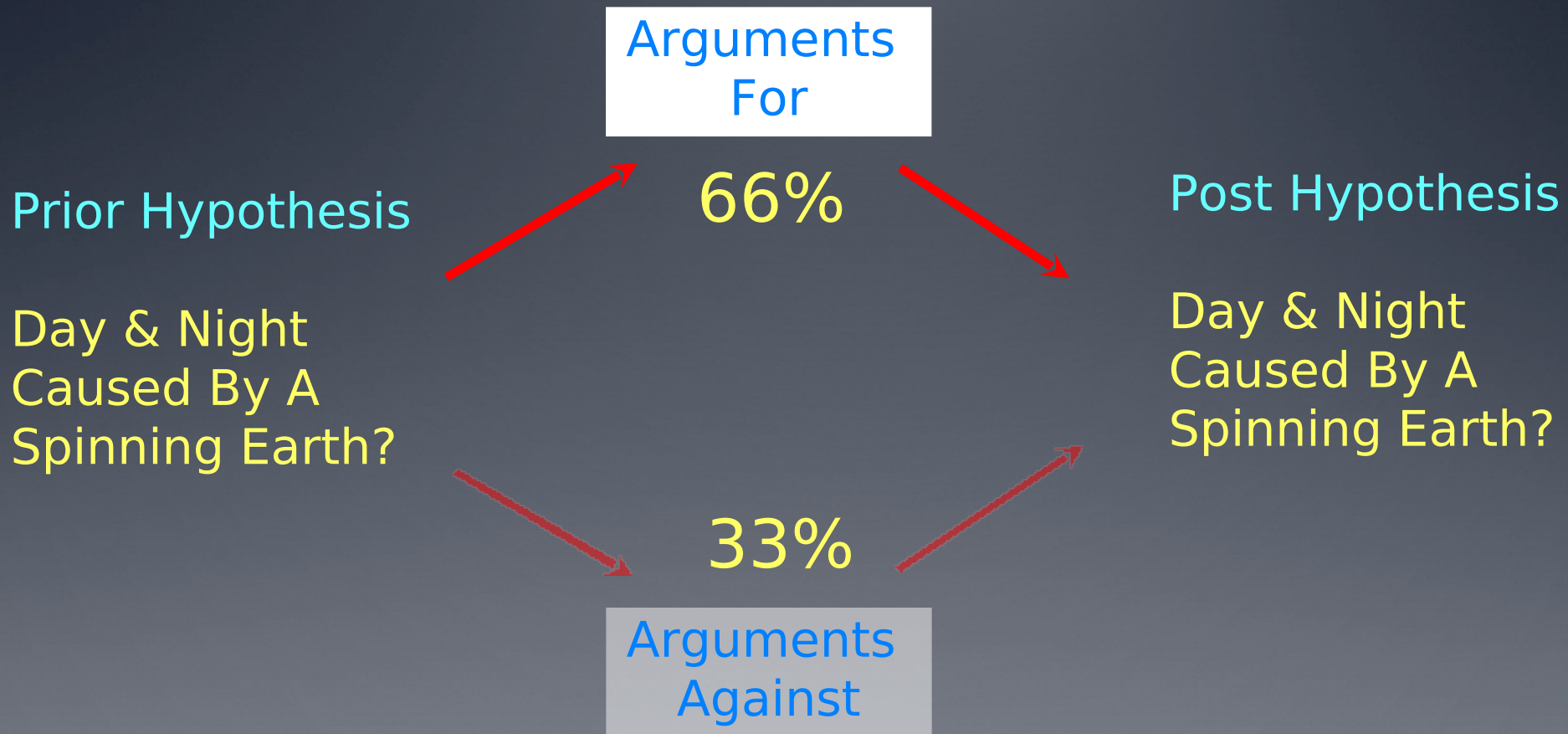
- A. Two or three measurements are always enough
- B. She should take 5 measurements
- C. If she is accurate she only needs to measure once
- D. She should go on taking measurements until she knows how much they vary
- E. She should go on taking measurements until she gets two or more the same

Bayesian Inference

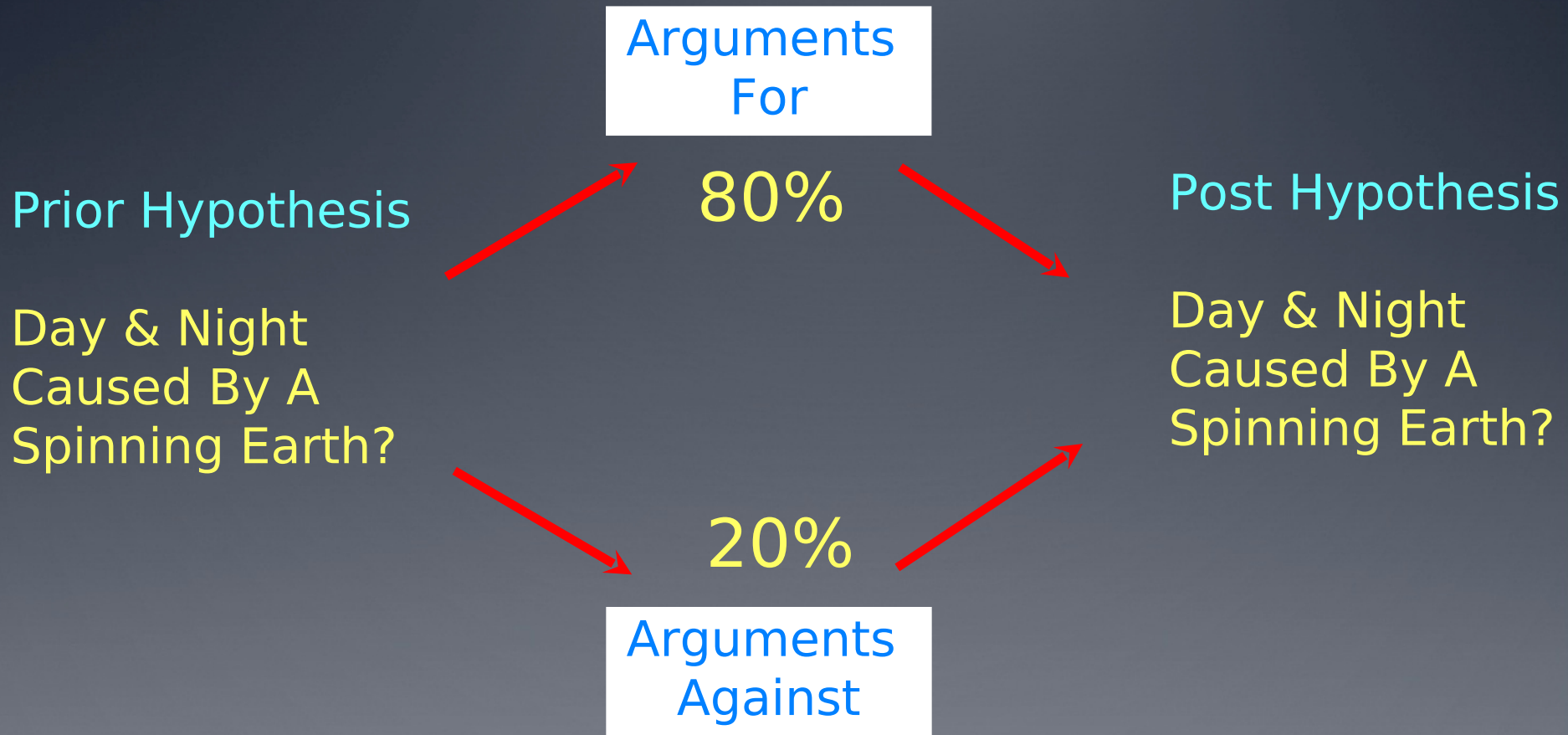
$$P(h | e) = \frac{P(e | h) P(h)}{P(e)}$$



How Likely? Ratio of 50:50



How Likely? Ratio of 66:33

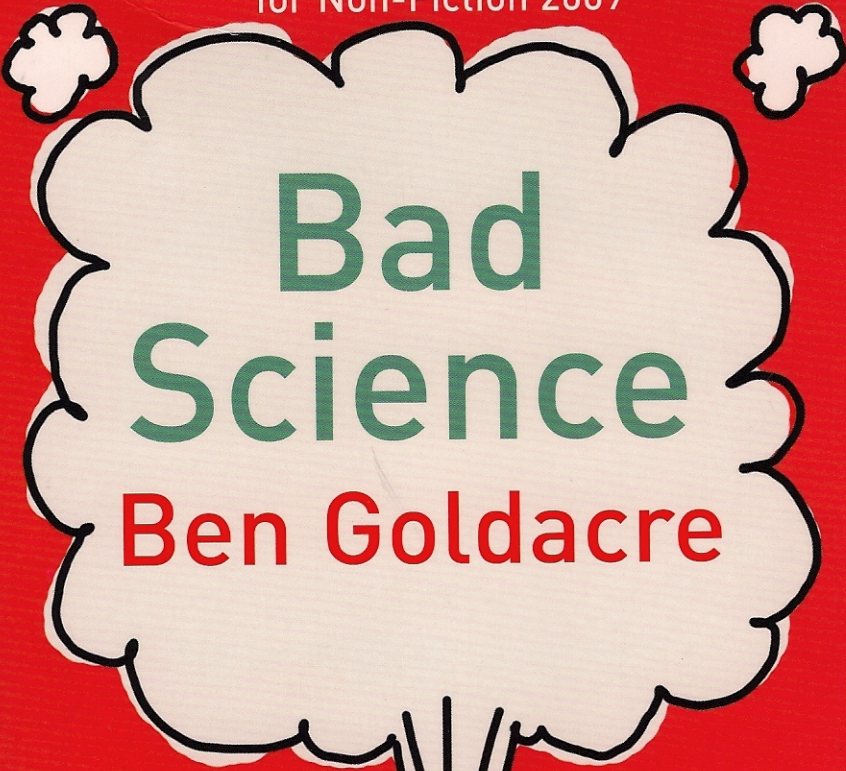


How Likely? Ratio of 80:20

Evidence for this View

- Hynd, C., & Alvermann, D. E. (1986). The Role of Refutation Text in Overcoming Difficulty with Science Concepts. *Journal of Reading*, 29(5), 440-446.
- Ogborn, J., Kress, G., Martins, I., & McGillicuddy, K. (1996). *Explaining Science in the Classroom*. Buckingham: Open University Press.
- Johnson, A. (2009). *Hitting the Brakes: Engineering Design and the Production of Knowledge*. Durham: Duke University Press.
- Koslowski, B. (1996). *Theory and Evidence: The Development of Scientific Reasoning*. Cambridge, MA: MIT Press.

Shortlisted for the BBC Samuel Johnson Prize
for Non-Fiction 2009



Bad Science

Ben Goldacre

'A fine lesson
in how to
skewer the
enemies of
reason and
the peddlers
of cant and
half-truths'
The Economist



'You'll laugh
your head off,
then throw
all those
expensive
health foods
in the bin'
Observer,
Book of the Year

The *Sunday Times* top ten bestseller