The How's and Why's of Science

SERP

Summer 2018

Task

What numbers and letters are on the covered side of the block?

What process did you use to solve this problem?

Process to solve Mystery Blocks

- More than “scientific method”
- Begin by making assumptions – are these explicit?
- Involves identifying multiple alternative hypotheses
- Collaborative
- Perhaps competitive
- Involves peer review
- Iterative
- Each “answer” elicits new questions
- Others?

Task

How do we talk about “science?”

Venn Diagrams – compare the following pairs of words

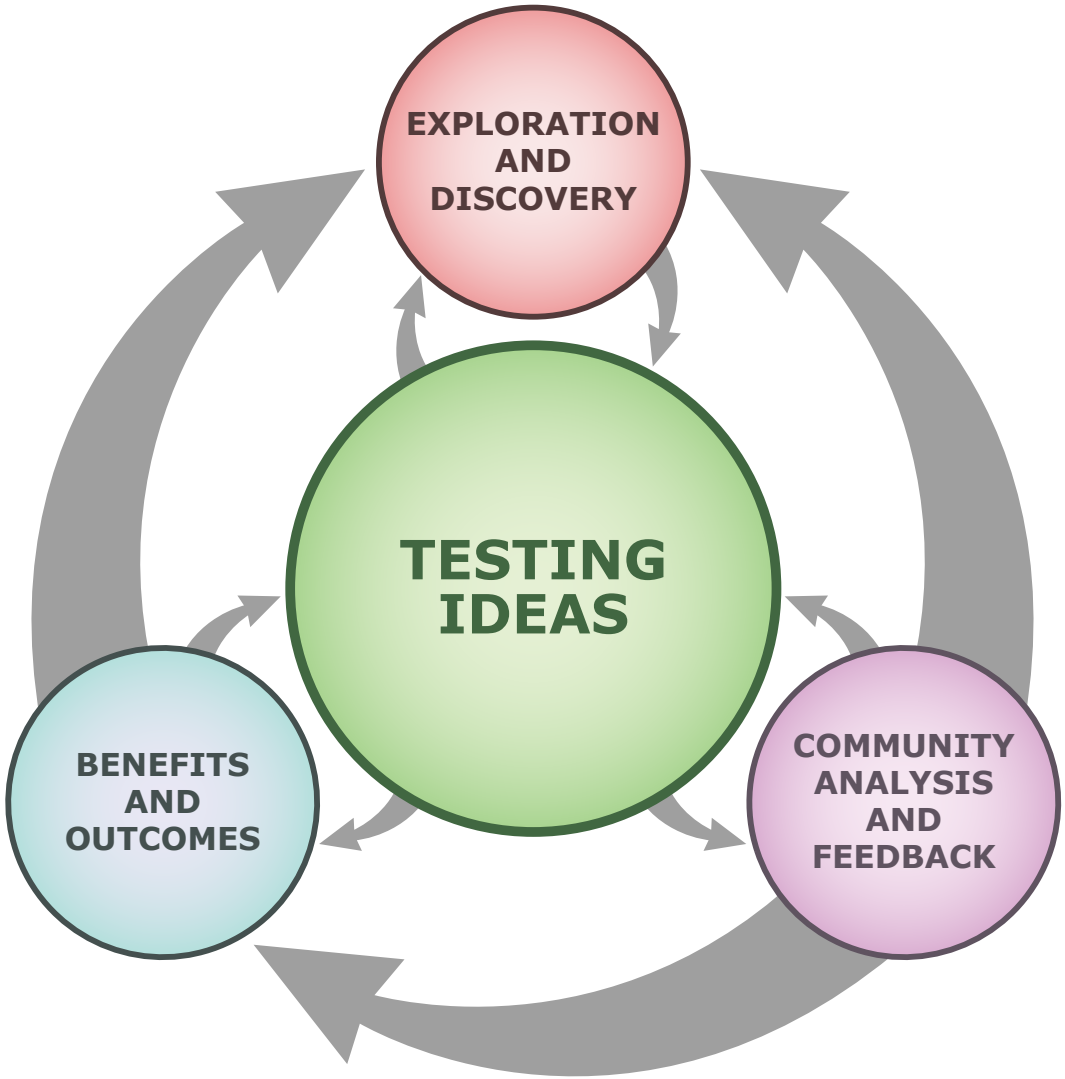
Hard Science vs **Soft Science**

Natural Science vs **Social Science**

"The" Scientific Method?

1. **Aristotelian Method**
   - Inductive and deductive reasoning
2. **Hypothetico-Deductive Model**
   - Make Observations
   - Develop and test hypothesis
   - Collect Data
   - Analyze data and evaluate hypothesis
3. **Pragmatic Model**
   - *Abduction* (logical inference from observation)
   - *Deduction* (explanation and demonstration; logical reasoning from one or more premises to reach a definitive conclusion)
   - *Induction* (logical reasoning for which premises are evidence to support a probable conclusion)

How science works

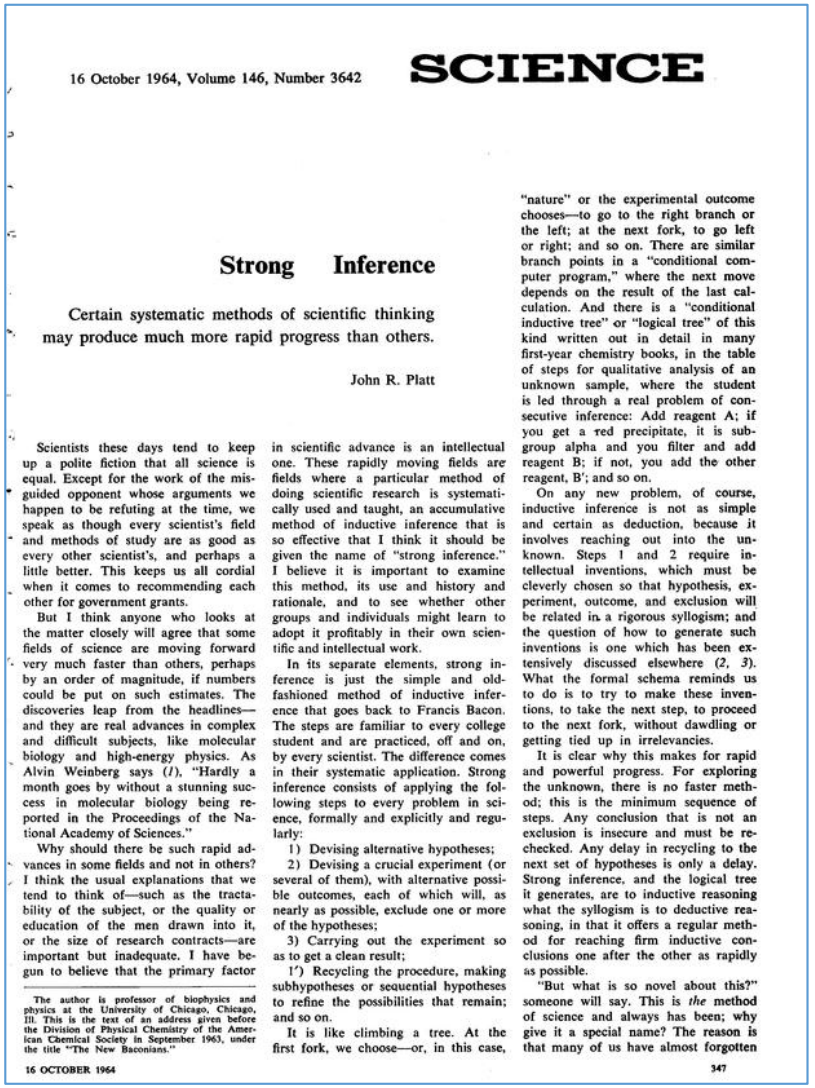


"Nature of Science" (NOS) is more than the simplistic "scientific method"

http://undsci.berkeley.edu/teaching/allgoals.php

Strong Inference

1) Devising multiple, alternative hypotheses
2) Devising crucial experiments to test hypotheses with the goal of exclusion
3) Carry out experiments to get results
4) Cyclical application of process in order to revise scientific understanding



16 October 1964, Volume 146, Number 3642

SCIENCE

Strong Inference

Certain systematic methods of scientific thinking may produce much more rapid progress than others.

John R. Platt

Scientists these days tend to keep up a polite fiction that all science is equal. Except for the work of the misguided opponent whose arguments we happen to be refuting at the time, we speak as though every scientist's field and methods of study are as good as every other scientist's, and perhaps a little better. This keeps us all cordial when it comes to recommending each other for government grants.

But I think anyone who looks at the matter closely will agree that some fields of science are moving forward very much faster than others, perhaps by an order of magnitude, if numbers could be put on such estimates. The discoveries leap from the headlines—and they are real advances in complex and difficult subjects, like molecular biology and high-energy physics. As Alvin Weinberg says (*1*), "Hardly a month goes by without a stunning success in molecular biology being reported in the Proceedings of the National Academy of Sciences."

Why should there be such rapid advances in some fields and not in others? I think the usual explanations that we tend to think of—such as the tractability of the subject, or the quality or education of the men drawn into it, or the size of research contracts—are important but inadequate. I have begun to believe that the primary factor in scientific advance is an intellectual one. These rapidly moving fields are fields where a particular method of doing scientific research is systematically used and taught, an accumulative method of inductive inference that is so effective that I think it should be given the name of "strong inference." I believe it is important to examine this method, its use and history and rationale, and to see whether other groups and individuals might learn to adopt it profitably in their own scientific and intellectual work.

In its separate elements, strong inference is just the simple and old-fashioned method of inductive inference that goes back to Francis Bacon. The steps are familiar to every college student and are practiced, off and on, by every scientist. The difference comes in their systematic application. Strong inference consists of applying the following steps to every problem in science, formally and explicitly and regularly:

1) Devising alternative hypotheses;

2) Devising a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses;

3) Carrying out the experiment so as to get a clean result;

1′) Recycling the procedure, making subhypotheses or sequential hypotheses to refine the possibilities that remain; and so on.

It is like climbing a tree. At the first fork, we choose—or, in this case, "nature" or the experimental outcome chooses—to go to the right branch or the left; at the next fork, to go left or right; and so on. There are similar branch points in a "conditional computer program," where the next move depends on the result of the last calculation. And there is a "conditional inductive tree" or "logical tree" of this kind written out in detail in many first-year chemistry books, in the table of steps for qualitative analysis of an unknown sample, where the student is led through a real problem of consecutive inference: Add reagent A; if you get a red precipitate, it is subgroup alpha and you filter and add reagent B; if not, you add the other reagent, B′; and so on.

On any new problem, of course, inductive inference is not as simple and certain as deduction, because it involves reaching out into the unknown. Steps 1 and 2 require intellectual inventions, which must be cleverly chosen so that hypothesis, experiment, outcome, and exclusion will be related in a rigorous syllogism; and the question of how to generate such inventions is one which has been extensively discussed elsewhere (*2*, *3*). What the formal schema reminds us to do is to try to make these inventions, to take the next step, to proceed to the next fork, without dawdling or getting tied up in irrelevancies.

It is clear why this makes for rapid and powerful progress. For exploring the unknown, there is no faster method; this is the minimum sequence of steps. Any conclusion that is not an exclusion is insecure and must be rechecked. Any delay in recycling to the next set of hypotheses is only a delay. Strong inference, and the logical tree it generates, are to inductive reasoning what the syllogism is to deductive reasoning, in that it offers a regular method for reaching firm inductive conclusions one after the other as rapidly as possible.

"But what is so novel about this?" someone will say. This is *the* method of science and always has been; why give it a special name? The reason is that many of us have almost forgotten

The author is professor of biophysics and physics at the University of Chicago, Chicago, Ill. This is the text of an address given before the Division of Physical Chemistry of the American Chemical Society in September 1963, under the title "The New Baconians."

Platt, J.R. 1964. Strong Inference. Science 146: 347-353.

Does language limit our understanding of science

Or

Does our understanding of science limit our language?

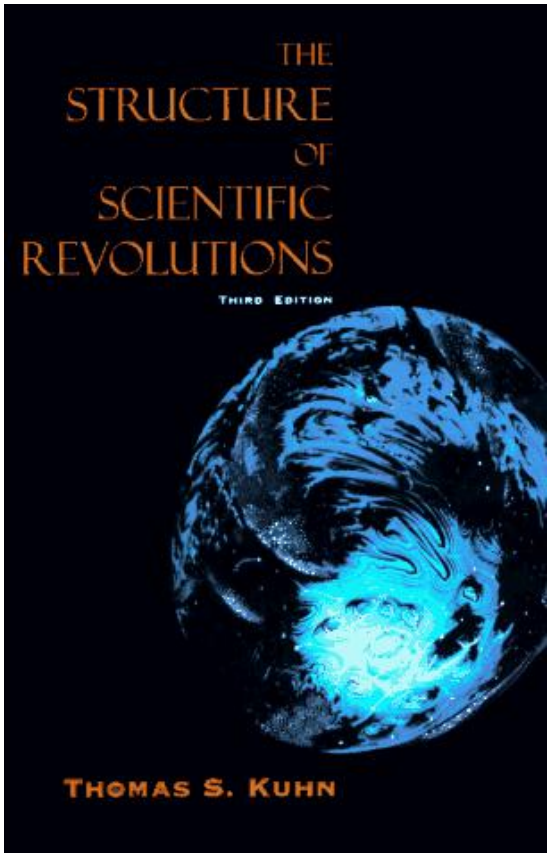
"The limits of my language mean the limits of my world." (Wittgenstein, 1922)

What is (Western Modern) Science?
WMS

- Noun
  - Facts (knowledge generated from scientific studies)
  - Theories (explanations of natural phenomena)
  - Laws (descriptions of natural phenomena)
- Verb
  - Descriptive/Observational studies
  - Experimental/Manipulative studies
  - Comparative studies
  - Theoretical studies

Science is embedded in Social Systems

- Testing theories, extending theories, building theories
- Science is influenced by social and cultural norms
  - Funding
  - Current events
  - Cultural context
- Paradigm shifts
  - Slow accumulation of evidence (from hypothesis testing of theories)
  - Massive shift in understanding (Interdisciplinary approaches → generation of novel ideas)



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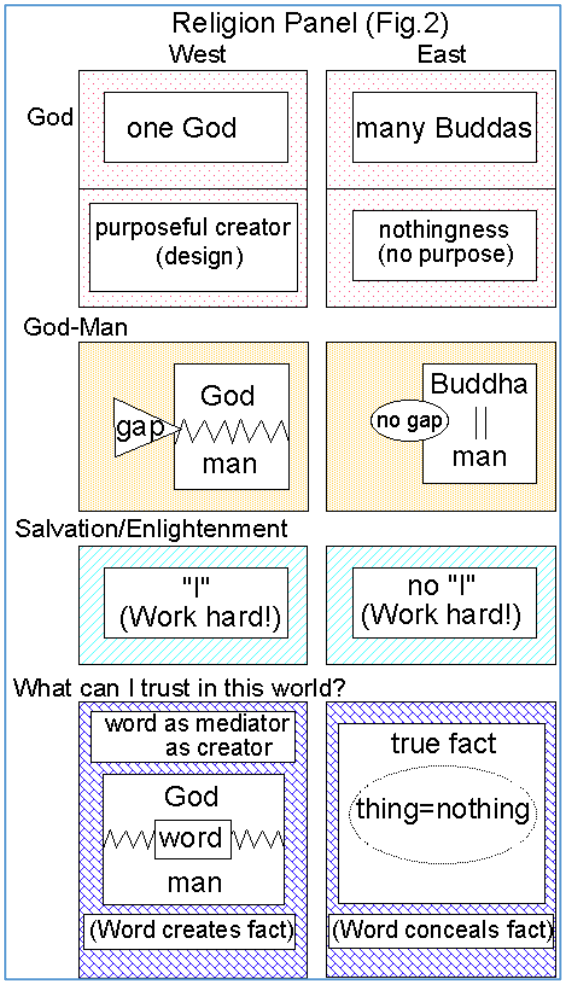
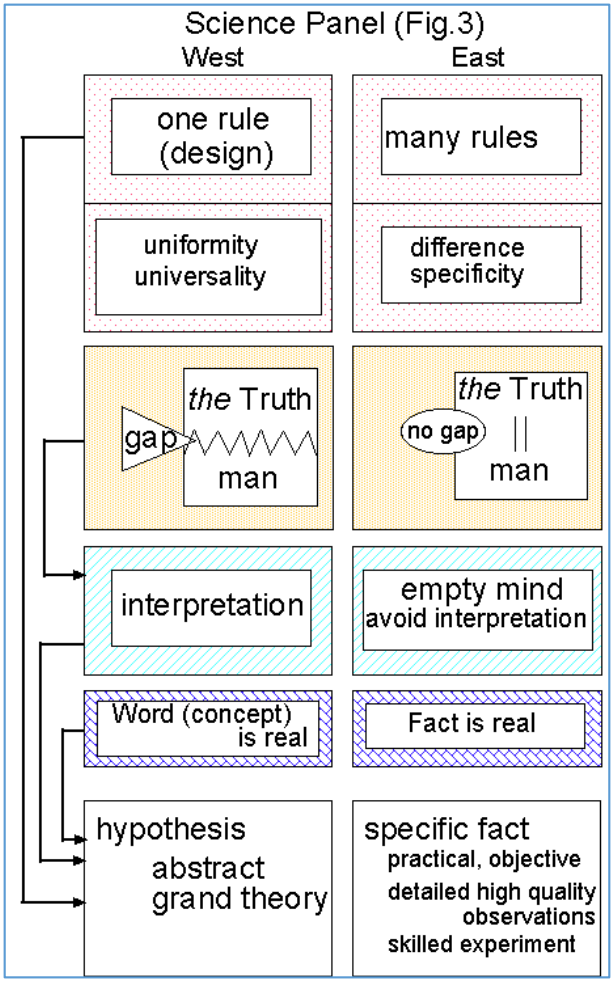
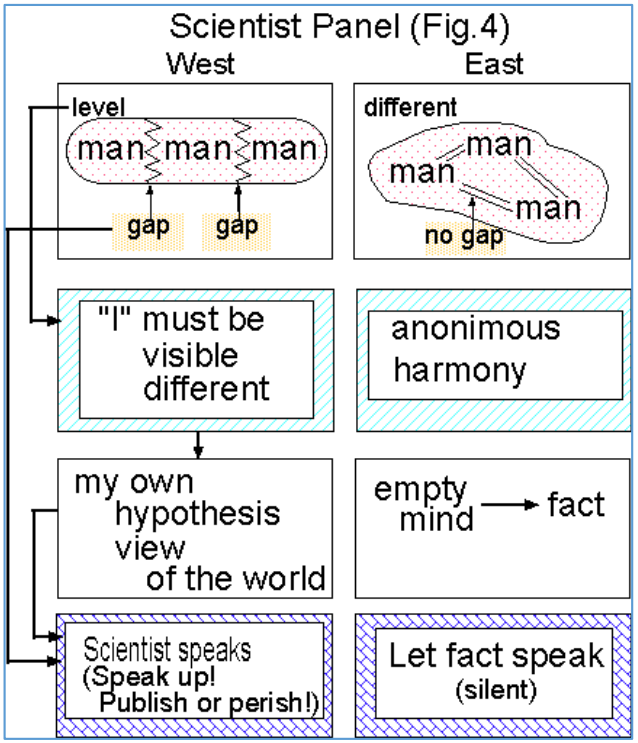
Cultural context of scientific inquiry







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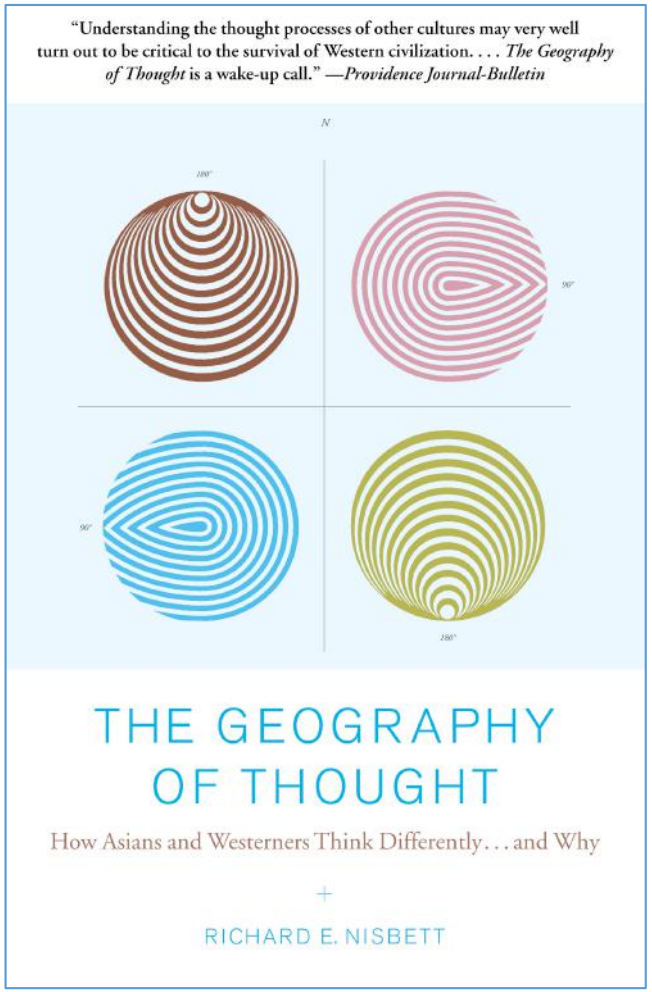
Cultural context of scientific inquiry



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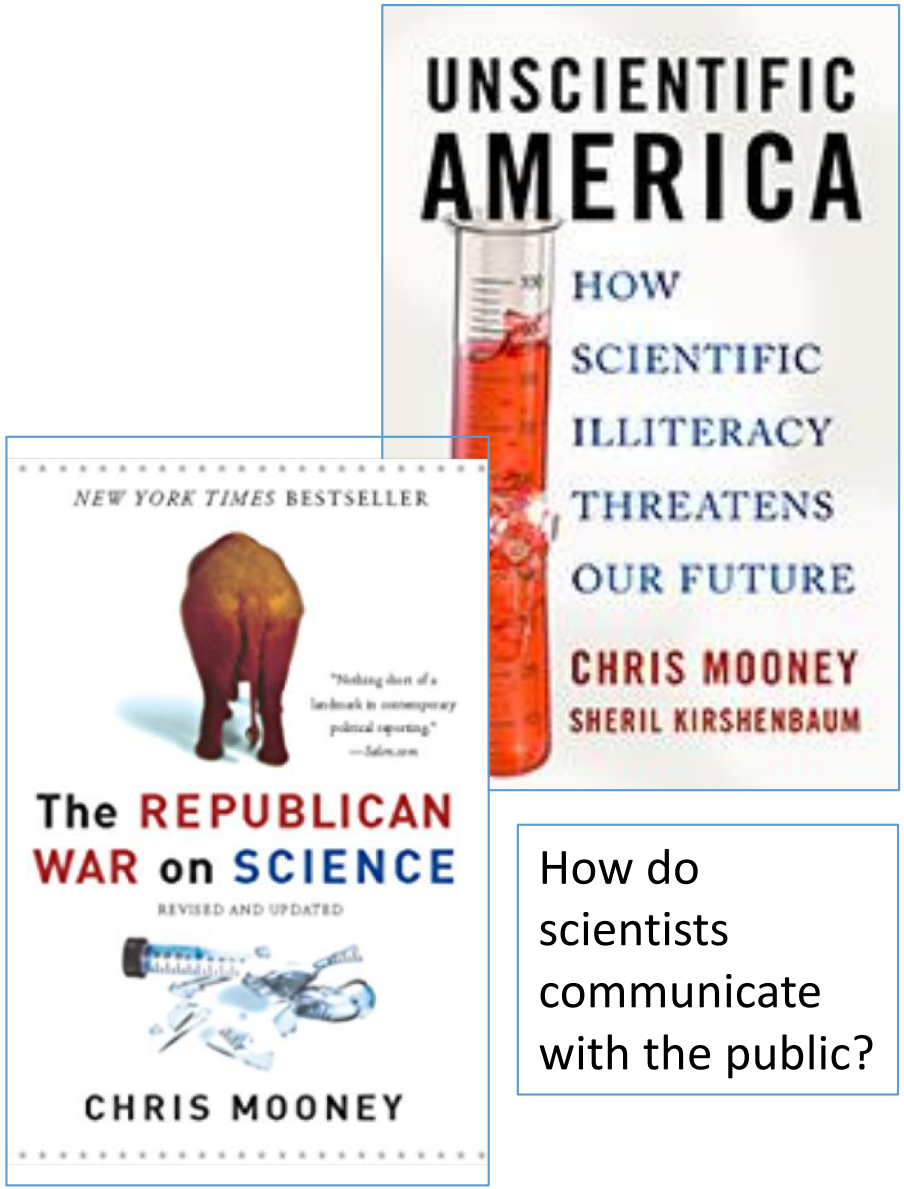
Why Science?

- Cultural norms/ perspectives
- Science for knowledge
- Science for society (advocacy and change)



How do scientists communicate with the public?