Physics 496
Introduction to Research

Lecture 2.0: Tools for the Scientific Skeptic

(Based on a talk by Lance Cooper)

Critical Evaluation

- Scientific papers and research presentations, when well done, are very convincing. How do you know if they are correct? How do you know if your own research is correct?
  - Answer: Apply logic. Critique the arguments made to arrive at the conclusions.

"Science is simply common-sense at its best; that is, rigidly accurate in observation and merciless to fallacy in logic." (The Crayfish, 1880).

"Darwin's Bulldog"

Thomas Henry Huxley, biologist
1825-1895

Aside: Oxford Evolution Debate

Held at the Oxford University Museum seven months after the 1859 publication of The Origin of Species.

Bishop Samuel Wilberforce to Huxley: “On which side do you claim your descent from a monkey, your grandmother or your grandfather?”

Huxley: “I would not be ashamed to be descended from a monkey. But I would be ashamed to be descended from a man who uses his great gifts to obscure the truth!”

The Scientific Method

1. Observe and describe a phenomenon or group of phenomena.

2. Formulate an hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.

3. Use the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.

4. Perform experimental tests of the predictions.

Read The Origin of Species to see steps 1-4 in action!

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- *Observe*
- *Guess/Predict*
- *Test/criticize*
- *Repeat*

The Skeptics Toolkit* for Evaluating Scientific Arguments

"It is the mark of an educated mind to be able to entertain a thought without accepting it."

- Aristotle (384 – 322 B.C.)

***These "tools" are simply an elaboration and extension of the more familiar Scientific Method**

Tools for Skeptical Thinking*
(Key requirements of the scientific process)

(1). Independent confirmation of the "facts"

In science, observations must be repeatable, and repeated by independent observers.

(2). Substantive debate by knowledgeable proponents of all points of view

It is inappropriate for an authority to silence substantive debate on an issue, or to ignore alternative hypotheses.

*** For great discussions of this, see *The Demon-Haunted World*, Carl Sagan (Ballantine Books, 1996) or *Why People Believe Weird Things*, Michael Shermer (Holt & Co, 1997)**

Tools for Skeptical Thinking (cont.)

(3). There are no true authority figures

Scientific discourse should take place on a level playing field in which ideas are judged by their merits, not by the credentials of the individuals promoting different ideas.

Tools for Skeptical Thinking (cont.)

(4). Formulate more than one hypothesis

All possible explanations for an observation should be examined. Have several "working hypotheses," and devise follow-up experiments to distinguish among these hypotheses.

-- it's good to make a "model" and present it as such

(5). Don't get too attached to your hypothesis

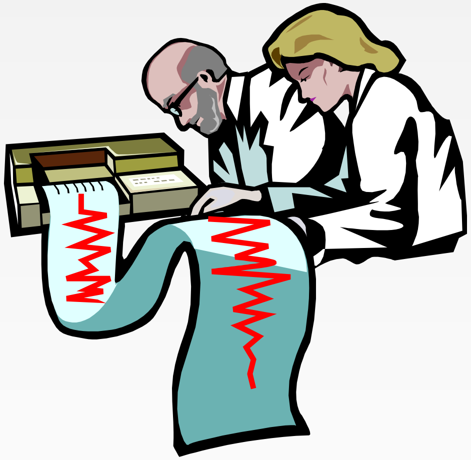
The whole point of testing a hypothesis is to try to falsify it. If you don't try to do this seriously, you're not doing science.

Tools for Skeptical Thinking (cont.)

(6). Quantify

If your explanation has something that can be measured, then make that measurement. This will allow you to discriminate among competing hypotheses.

Often statistical tests can be applied to your data to help distinguish between hypotheses.



(7). Avoid logical 'weak-links'

If your argument requires a "chain" of logical steps, every link in that chain must be valid (including the premise), not just most of them.

Tools for Skeptical Thinking (cont.)

(8). Occam's Razor

When confronted with multiple hypotheses that explain the data equally well, choose the simpler.

William of Ockham
1288 - 1348

alt: one should not increase, beyond what is necessary, the number of entities required to explain anything.

It is not obvious why this should work, but it *usually* does.

(9). Falsifiability

Scientific hypotheses must be testable, at least in principle. Propositions that are not falsifiable are not worth much scientifically.

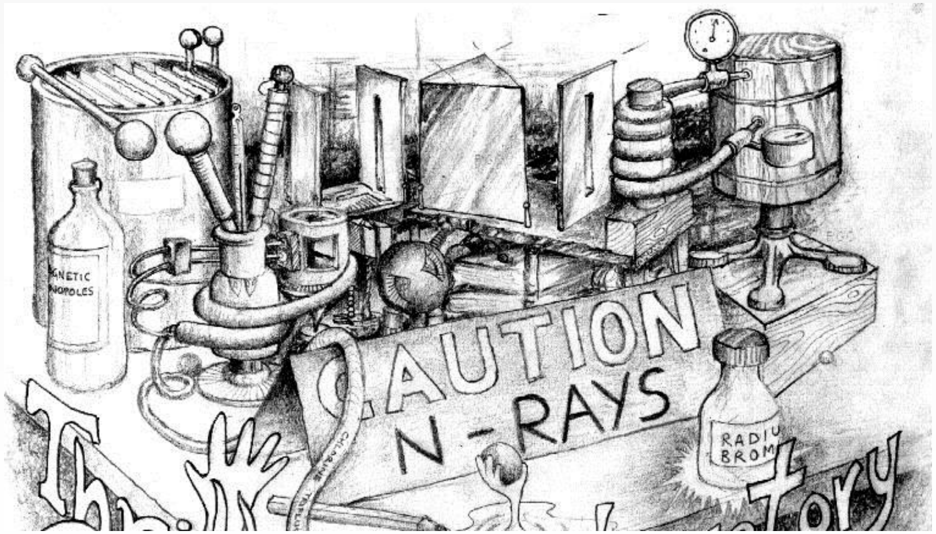
This is why theories must make predictions, not just fit existing data.

Case Study: N-Rays and René Blondlot

René Prosper Blondlot (1849-1930) was a distinguished French physicist at the University of Nancy

- Member of the French Academy of Sciences
- Winner of numerous scientific awards (i.e., a prominent "authority figure")

Following the discovery of x-rays by Roentgen, Blondlot claimed to discover a new type of visible radiation, N-rays (for "Nancy"), which was radiation purportedly given off by numerous items (including humans)….but not green wood!



Case Study: N-Rays and René Blondlot

What were the Skeptic's Toolbox warning signs?

Warning #1 - N-rays were extremely difficult to detect: it had to be dark to see them, and the rays were best observed "out of the corner of your eye"

Failure to quantify; falsifiability; Occam's razor
The "smell test" – "This result doesn't smell right"

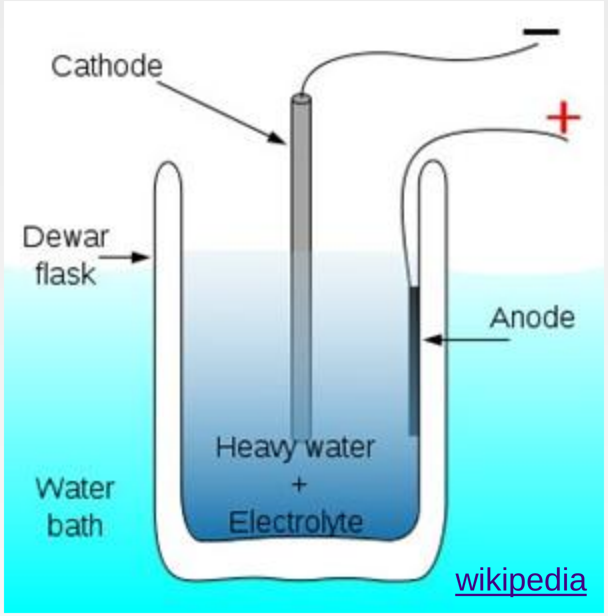
Warning #2 – Blondlot's experiments were confirmed in some other laboratories (in France), but were also not confirmed in many others (mostly outside of France)

Independent confirmation; argument from authority; attachment to hypothesis; group think.

But the scientific process worked – Nature's editors sent Wood to check out the claims since some labs could not reproduce the N rays. Wood make a simple (and unseen) alteration of the experiment and Blondlot and assistants still "saw" the N rays. When it was reversed, they thought he had removed the key prism, and now they "did not see" the N rays (but the expt. was unaltered)

Case Study 2: Cold Fusion

In 1989 two chemists at University of Utah, Pons and Fleischmann made an extraordinary claim: The claimed to have created nuclear fusion at room temperature in a simple tabletop device. A current through palladium rods in Li-enriched water put out more energy (in the form of heat) than was put in. Or so they said.



Skeptical physicists immediately said that if they were creating fusion, the neutron flux would have killed them.

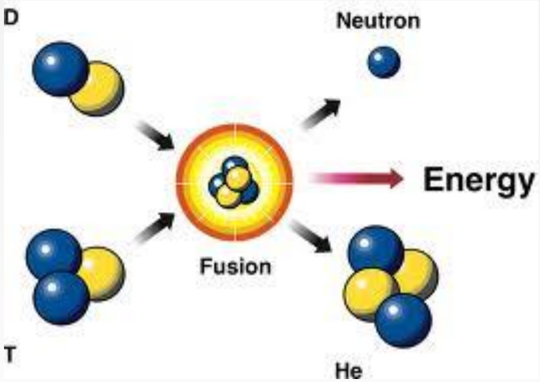
Palladium futures went through the roof while many scientists geared up to repeat the experiment.

Case Study 2: Cold Fusion

Some experiments produced heat, others did not.
The predicted neutron flux was not seen.

Eventually several DOE panels have concluded that there is no evidence for cold nuclear fusion.

Warning #1 – Pons & Fleischmann were still alive.



Prediction: If fusion, find fusion byproducts.
This failed.

Warning #2 – Pons & Fleischmann's experiment was confirmed in some other laboratories (mostly in the State of Utah) but not confirmed in many others.

Independent confirmation; attachment to hypothesis; group think.

Constructing A Scientific Case: Arguments vs. Assertions

Assertion – A claim unsupported by an argument

You must avoid these in scientific writing!

Example of an assertion from a recent condmat submission:

"This dramatic result…suggests aspects of the data and ideas based on critical points inside the superconducting dome [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]."

Argument - We support the conclusions we draw in scientific papers using logical arguments. An argument is a connected series of statements to establish a definite proposition.

Deductive arguments have three stages:

(i) a premise - hypothesis or assumption

(ii) an inference - process of generating inferences from true statements (propositions)

(iii) a conclusion – the result you're trying to prove

We construct scientific arguments with propositions, i.e., true or false statements

Identifying Logical Fallacies in Arguments

(1). *ad hominem* argument

Ad hominem means “to the man." *Ad hominem* arguments are those that attack a person making an argument without touching the argument itself.

“The missile theory has no merit. It was proposed by Pierre Salinger, and he's been wrong about numerous previous incidents.”

(2). Appeal to ignorance

This argument claims that whatever has not been proved false, must be true, and vice versa.

“There is no compelling evidence that UFO’s haven’t visited earth, therefore UFO’s must exist.”

Identifying Logical Fallacies

(3). Argument from adverse consequences (similar to "slippery slope")

Argument that demands accepting a position, based upon the proposition that rejecting the position would result in negative consequences.

"The defendant must be found guilty, otherwise others will be encouraged to commit this crime"

(4). Observational selection

Presenting only the observations that tend to fit one's hypothesis, while ignoring those that either don't fit or that fit other hypothesis.

Identifying Logical Fallacies (cont.)

(5). *A*rgument from authority

The argument that we should adopt an idea because some respected person tells us to.

"The missile theory has expert witnesses. For example, just before Flight 800 broke into flames, private pilot Sven Faret reported that he saw 'a little pin flash on the ground.' In his view, that flash 'looked like a rocket launch.'"

(6). Bandwagon (group think)

The argument that because most other people believe a proposition, it must be true.

Identifying Logical Fallacies (cont.)

(7). Begging the question

An argument that assumes the answer to a question when posing it.

"We must institute the death penalty in order to discourage violent crime."

Aside: Begging the question does *not* mean that the question is begging to be asked! This is one of the most mis-used phrases in the English language.

(8). Confusion of correlation and causation

Assuming that because two things happen simultaneously, one must cause the other.

"The percentage of persons wearing glasses is higher for college graduates than for individuals with a lower educational background. Therefore, education must be detrimental to ones eyesight"

Identifying Logical Fallacies (cont.)

(9). Post hoc ergo propter hoc

“It came after so it was caused by..." A special case of the correlation = causation fallacy in which one event follows another, and so is claimed to have been caused by the earlier event.

That man is violent because he watched violent TV programs as a child

(10). Straw Man Argument

Presenting a weak substitute for an opposing position, then attacking the substitute.

Name That Fallacy

"Literacy rates have steadily declined since the advent of television. Clearly television viewing impedes learning."

Confusion of correlation and causation

"If we legalize marijuana, then more people would start to take crack and heroin, and we'd have to legalize those too."

Slippery slope

"You should disregard that company's argument because they are being funded by the logging industry."

Ad hominem

"Economist John Kenneth Galbraith argues that a tight money policy is the best cure for a recession."

Argument from authority

Name That Fallacy

"We should reinstate the draft. People don't want to enter the military because they find it an inconvenience. But they should realize that there are more important things than convenience."

Straw man

"Paranormal phenomena exist because I have had experiences that can only be described as paranormal."

Begging the question

"Four out of five dentists surveyed preferred Crest toothpaste."

Bandwagon

"No one has ever proved that backscatter x-rays from scanners are unsafe, so backscatter x-rays must be safe."

Appeal to ignorance