Scientific Arguments

Berkeley: Understanding Science project

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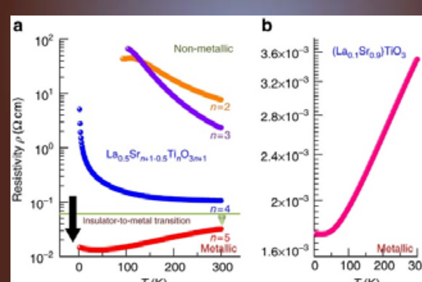
A scientific argument is not…
…a history of what you did and statement of your conclusion.

Equipment list:
1 lock-in amplifier
3 RG-58 cables
1 oscilloscope
1 function generator
1 sample



1. Connect amplifier, function generator, scope
2. Scan current, measure voltage, vary T

Conclusion: The insulator-metal transition is driven by dimensionality

Scientific Arguments

Assumptions
+ Evidence
+ Logic / Inferences

→ Thesis / Conclusion

6 people, 9 weapons,9 rooms
One of each not in players' hands

Mrs. Peacock with the rope in the library.

Unlike in Clue, you have to explain your argument so that it can be evaluated

1. It wasn't Professor Plum.

2. It wasn't the Revolver.

3. It wasn't the Ballroom.

4. It wasn't Colonel Mustard.

…

18. It wasn't the Kitchen.

19. One of Professor Plum, Colonel Mustard, Mrs. White, Mrs. Peacock, Reverend Green and Miss Scarlett has to be the murderer. (SP)

20. One of Candlestick, Dagger, Lead Piping, Revolver, Rope and Spanner has to be the murder weapon. (SP)

21. One of Ballroom, Kitchen, Conservatory, Dining Room, Billiard Room, Library, Hall, Lounge and Study has to be the murder room. (SP)

Ergo: It was Reverend Green with the Dagger in the Library. (From 1-21.)

You must connect all the steps for the reader or listener

Assertions are not arguments!

"The earth is flat."

"The earth is spherical."

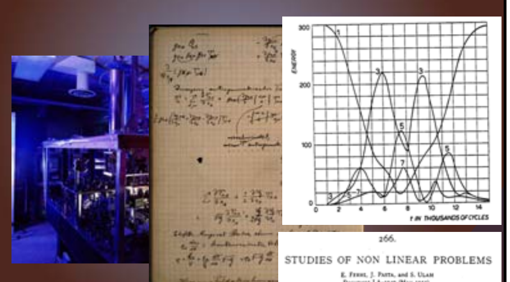
Assertions: conclusions
unsupported by evidence and inferences

The correct conclusion by assertion≠physics!

Evidence

Central to physics

Can be measurements,
pen & paper theory,
numerical simulations



Must be repeatable & reproducible
Techniques must be valid

Physics is an empirical science. Measurement is the ultimate test of theories of nature.

But …
Evidence is still subject to interpretation

The “Flat Earth”

- The sun and moon are spheres measuring 32 miles that move in circles 3,000 miles above the plane of the Earth.
- Stars move in a plane 3,100 miles up
- An invisible "antimoon" obscures the moon during lunar eclipses.
- The disc of Earth accelerates upward at 9.8 m/s^2 driven by dark energy.

https://www.livescience.com/24310-flat-earth-belief.html

Be skeptical of your evidence

Don’t get attached to your hypothesis

A valid hypothesis is **falsifiable***. Try to disprove your ideas!

Formulate more than one hypothesis

All possible explanations for an observation should be examined. Devise experiments to discriminate between several working models. Use Occam’s razor.

Quantify

Measure / compute whatever you can, even if you do not think it is important.

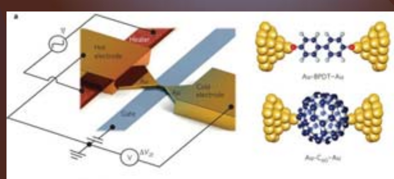
Do not cherry pick data

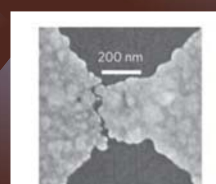
*see Karl Popper

Watch out for selection bias

In mesoscopic physics, for example, 2 out of 50 devices may show the anticipated effect.

- How many devices/tests show the effect?
- What fraction of devices/tests show the effect?
- Do I understand when the effect does not appear?
- Can I justify why I choose certain data and not others?



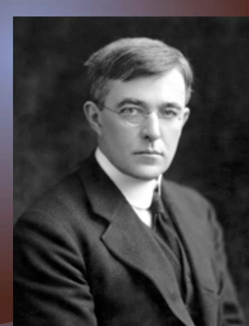


Example: Break junctions can show similar data when connected by molecule, water, or air gap

Beware of pathological science!

Research conducted according to scientific method, but tainted by bias or subjective effects

- The maximum effect is produced by a barely detectable cause, and the magnitude of the effect is substantially independent of the intensity of the cause.
- The magnitude of the effect remains close to the detection limit, or many measurements are necessary because of low statistical significance
- Claims of great accuracy
- Fantastic theories contrary to experience
- Criticisms met by ad hoc excuses



Langmuir, Colloquium on Pathological Science", Knolls Research Laboratory, December 18, 1953.

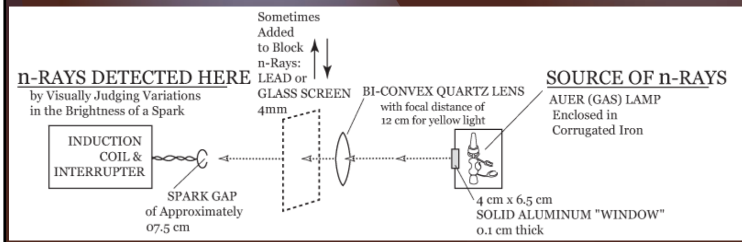
Modern problem: p-value hacking

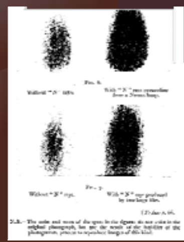
Case Study: N-Rays and René Blondlot

Distinguished French physicist at the University of Nancy

Claimed to discover a new type of visible radiation, N-rays (for "Nancy"), which was radiation given off by many materials, including humans….but not green wood and certain treated metals!

(1849-1930)





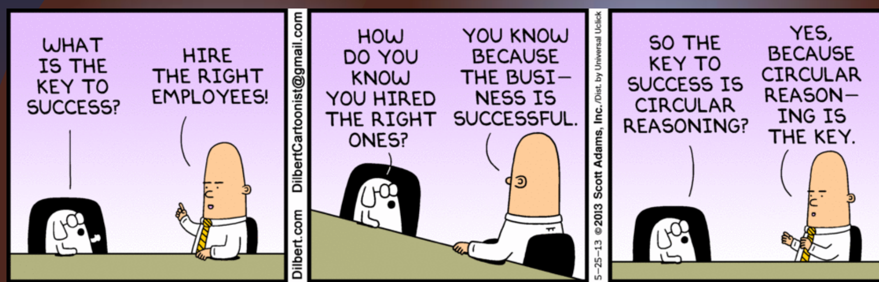
Skeptic's Toolbox for Pathological/Bad Science

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"

Warning #2: Blondlot's experiments were confirmed in some other laboratories (120 scientists in 300 articles, in France), but were also not confirmed in many others (mostly outside of France)

The scientific process worked: *Nature's* editors sent American physicist Robert Wood to check 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)

Inferences are equally important



Avoid logical fallacies

Identifying Logical Fallacies in Arguments

(1) ***ad hominem*** **argument**

Ad hominem means "to the man." Arguments that attack a person making an argument without addressing 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.

(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

"Free will must exist: if it didn't, we would all be machines."

(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 hypotheses

(5) Argument 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

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

(7) Begging the question

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

(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"

(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

After I coughed, my microwave exploded. Therefore, my coughing caused my microwave to explode.

(10) Straw Man Argument

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

Best case:

Assumptions + perfect evidence + pure deductive reasoning → rock solid conclusion

Real science is messy:
imperfect measurements, impossible to solve theories / computations, guesswork…

Your job: make the best argument, expose the weaknesses for everyone