

Science v. Pseudoscience

Critical thinking and the scientific approach



Science v. Pseudoscience

- Science: deals with things that can be tested by observation, or which can be disproved by evidence
- Pseudoscience: untestable or unrefutable

Assumptions of Science

- Events follow patterns or result from causes that can be understood
- Rules of nature are the same throughout the Universe, and always have been
- Scientific reasoning is inductive: it begins with specific observations and extends to generalizations
- Generalizations can be tested and disproved if untrue. If no test is possible, the generalization is unscientific
- New evidence can disprove theories, but absolute proof is impossible (e.g. will the sun come up tomorrow? Are you sure?)

Scientific reasoning is used everywhere...

- Police work, criminal investigation
- Medicine
- Law
- Engineering
- "Classic" sciences (chemistry, physics, biology, geology, etc.)
- Simply a formal way of describing the methods of rational thought

Error and Uncertainty

- Every measurement is an approximation... but some are better than others
- The degree of error in a measurement is always more than zero, but can be minimized, estimated through replicate analyses, use of standards, etc.
 - Ex. Age of rocks...
 - Earth is 4.6 billion years old, ± 0.1 billion years (~2% error)
- Measurements are always fuzzy... but within limits!
 - Age of Earth is **NOT**...
 - 4.6 billion years \pm 19.0 billion years!

It's *only* a theory...

- **Hypothesis** - a testable or disprovable inference or assertion... an idea that hasn't yet been tested
- **Theory** - a model based on verifiable hypotheses, shown to be consistent with available data and observations, and accepted as an explanation for some natural process
- Examples:
 - **Helio-centric Theory** (Big News: Earth orbits Sun!)
 - **Germ Theory of Disease** (Microbes, not demons, cause disease)
 - **Theory of Gravity** (Things fall, right?)
 - **Theory of Biological Evolution** (Get over yourself)

Skeptical thinking... "Does it follow?"

- Does the conclusion follow from the evidence?
- Skeptical thinking is NOT stubborn refusal to accept anything, or mistrust of everything
- It is rational thinking, free of bias, accepting the implications of hard evidence
- Extraordinary claims demand extraordinary evidence!
- Don't be gullible!

Critical thinking tools

- Look for independent confirmation of observations
 - Can you do it again?
 - Is your discovery reproducible or repeatable?
- Is open debate encouraged, or is free exchange of information stifled?
 - Privately-funded corporate "research"
 - Proprietary information
- Is there an easier way of explaining the data?
 - Occam's Razor - don't make a complicated hypothesis when a simpler one will do.
 - Face on Mars? Or just a funny rock formation?

Critical thinking tools (cont'd)

- Is there bias?
 - Financial - conflict of profit interest (e.g. drug research)
 - Religious - conflict with established dogma
- Quantify!
 - Measure, measure, measure!
 - It's easy to be fooled, if you can't put a number on something
 - EX: The Clean Air Act is bankrupting US businesses! Really?
 - 1997 USEPA study: costs of US CAA, \$523 billion, benefits were from \$6 to 50 **trillion**
 - EX: Acid rain is a hoax! Rain is acidic anyway! Really?
 - Natural rainfall has a pH of ~5.6 (from atmospheric CO₂)
 - Polluted rainfall can drop to a pH of ~2 (battery acid)

Critical thinking tools Carl Sagan's "Baloney Detection"

- Look for independent confirmation of observations
 - Can you do it again?
 - Is a discovery reproducible or repeatable?
 - E.g. Pans & Fleischman's cold fusion experiment
- Is open debate encouraged, or is free exchange of information stifled?
 - Privately-funded corporate "research"
 - Proprietary information
 - "National security" secrets
 - E.g. Secret ingredients in cigarettes made it more difficult to refute claims that smoking was neither harmful nor addictive
- Is there an easier way of explaining the data?
 - **Occam's Razor** - don't make a complicated hypothesis when a simpler one will do. Choose the simpler of 2 possible explanations for an observation.
 - Face on Mars? Or just a funny rock formation?

Critical thinking tools (cont'd)

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 - (By the way, pH of rainfall in SW MI last year averaged 4.7)

Faulty Reasoning Traps

- Appeal to Ignorance (Whatever has not been proved false must be true)
 - "We don't have direct evidence of life on other planets, so we're alone in the Universe!"
 - "There is nothing proving that UFO's don't exist, therefore they do."
- Ad Hominem, or Straw Man (attacking the advocate, not the argument)
 - Don't trust anything he says! He's a *liberal* and a tree hugger!
 - Tobacco company CEO's are pure evil. You can't believe anything they say!
- Unknown = Unknowable (Here be dragons...)
 - "God of the gaps" argument: Whatever we don't yet understand as of today right now... is unknowable and supernaturally caused.

Faulty Reasoning Traps

- Begging the Question (assuming the answer)
 - We can't end the death penalty, because crime would grow out of control! Tacit assumption: executions deter crime. Do they?
 - Switching to alternative energy would destroy the economy! Tacit assumption: GDP correlates with fossil fuel usage. Does it? Must it?
- Selective observation (counting hits & forgetting misses)
 - It always rains on Sundays! And how often does it rain on Mondays?

Faulty Reasoning Traps

- Inconsistency
 - Declining life expectancy in the former USSR was because of communism! Is high infant mortality in the US because of capitalism?
 - Massive military spending on *potential* enemy threats is ok, but spending on *potential* environmental threats is not?
- Statistics of small samples
 - They say one in five people is Chinese. I know dozens of people, and none are Chinese! Left your hometown yet? Are your acquaintances a representative sampling of the whole planet?
- Confusing correlation with causation
 - Before women could vote, there were no nuclear weapons!
 - Short hems mean a bull market!

Faulty Reasoning Traps

- False dichotomy (exclusion of the middle)
 - Anyone who opposes deregulation is a Communist!
- Argument from authority
 - Trust us, we know what we're doing. You don't need to know.
- Argument from adverse consequences
 - Do what you're told, or terrorists will get you.
- Mishandling of statistics
 - Our education system is failing! Fully half of our students score below average!

Recommendations: Books and Media

- *The Demon-Haunted World*, by Carl Sagan
- *Why People Believe Weird Things*, by Michael Shermer
- *Skeptic* magazine, published by the Skeptics Society
<http://www.skeptic.com>
- *Bullshit* television series on Showtime
- *The Skeptic's Guide to the Universe* podcast
<http://www.theskepticsguide.org/>