IF YOU WERE NOT HERE ON WEDNESDAY...

PLEASE COME TO THE FRONT OF THE CLASS AND SEE PROF. COTTON.

COMMENTS:

PAPERS: we will not accept the excuse “the drive ate my paper”

- backup to a thumb drive/flash drive
- send a copy to yourself in email as you write it
- use automatic cloud backup
- there is no such excuse in the modern age as “the computer ate my paper”

ELECTRONIC SUBMISSION: when you send homework, etc. by email, CC yourself and read the email that arrives. Make sure it contains a readable version of the CORRECT assignment.

"Everyone is entitled to his own opinion, but not his own facts."
-- Daniel Patrick Moynihan (1927-2003), United States Senator from New York

"Facts do not cease to exist because they are ignored."
--Aldous Huxley

"When the facts change, I change my mind. What do you do, sir?"
-- attributed to John Maynard Keynes

“I have a hypothesis, an idea I can test!”
-- Buddy the Tyrannosaurus Rex, “Dinosaur Train”, PBS Kids

The Scientific Method

Supplementary Material for CFB3333/PHY3333

Professors John Cotton and Stephen Sekula

January 20, 2012

Based on the following information on the web:

http://www.physics.smu.edu/pseudo/SciMeth/

Objectivism

Before we proceed, we must all agree that . . .

- There is an objective reality which is the same for everyone.
- There exist unchanging laws by which the Universe works and these laws can be discovered (not invented) through experimentation.

Objectivism (continued)

- This is a matter of belief; we can't prove it to you. But we can justify it.
- The rules above lead to progress. They put people on the Moon and robots on Mars and Titan; they predict solar eclipses centuries in advance; they cure diseases like smallpox and polio; they give you light at the flick of a switch and more computing power in the palm of your hand than in the Space Shuttle, and more computing power in the Space Shuttle than in all the eons before.

ALTERNATIVES

OBJECTIVISM

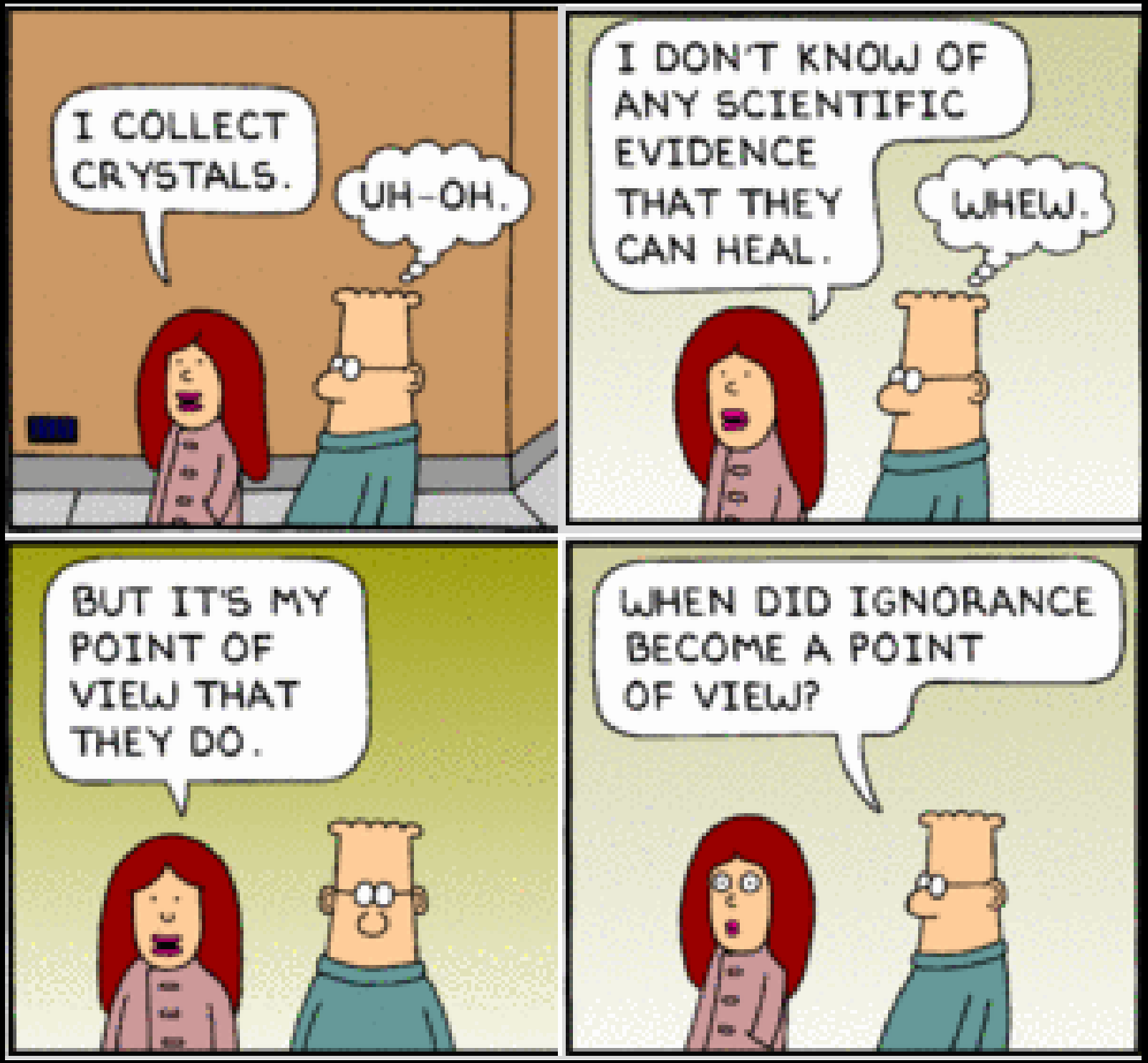
RELATIVISM

Relativism - Solipsism

Solipsism is the belief that everyone creates their own reality.

This approach does not produce any useful results. If your own private reality includes a law of gravity that is different from Newton's, any predictions you make with it are not going to match reality. The solipsistic approach yields nothing useful and does not improve the human condition.

If you think that you are creating your own reality right now, why don't you see if you can make yourself fly? Having trouble?


I COLLECT CRYSTALS.
UH-OH.
I DON'T KNOW OF ANY SCIENTIFIC EVIDENCE THAT THEY CAN HEAL.
WHEW.
BUT IT'S MY POINT OF VIEW THAT THEY DO.
WHEN DID IGNORANCE BECOME A POINT OF VIEW?

Relativism - "New-Age" or "Post-Modern" Thinking

There are people today who insist that all points of view are equally valid. Cotton and Sekula are NOT among them. You may think that we are being one-sided or biased because we ignore some "points of view." In science, you encounter the disturbing fact that, if your "point of view" does not agree with reality as determined by experiment through the scientific method, then your point of view is simply wrong. Our *view* of the universe may change as science uncovers more of its secrets, but that change of view will be driven by *evidence*.

Not only does the relativist viewpoint disagree with observations of the Universe, it is also logically inconsistent. It is self-refuting. See Schick and Vaughn, page 325:

“To say that everything is relative is to say that no unrestricted universal generalizations are true ... but the statement "No unrestricted universal generalizations are true" is itself an unrestricted universal generalization. So if relativism in any of its forms is true, it's false. As a result, it cannot possibly be true.”

The Scientific Method (in a nutshell)

- What is "The Scientific Method?"
  - Quite simple:
    - A way to ensure that you are not fooled by others and that you do not fool yourself.

The Scientific Method (in a nutshell)

- Observation and description of a phenomenon.
- Formulation of an hypothesis to explain the phenomenon.
  - The hypothesis often takes the form of a causal mechanism or a mathematical relation. This requires creative thinking.
  - The mechanism should be plausible.
- Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.
  - This requires critical thinking.
- Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.

The Role of the Hypothesis

- Observation: your hypothesis passes the proposed test. What does that imply?
  - Notice that you have NOT PROVED that the hypothesis is correct. You merely have more confidence in your hypothesis after the test. It still might be wrong.
  - Indeed, you can NEVER PROVE the hypothesis correct. But if your hypothesis passes test after test after test, you can be more certain of the hypothesis.
  - A result that contradicts the hypothesis DISPROVES it. You can then try another hypothesis and repeat steps 2,3,4.
  - Hypotheses that are not, in principle, DISPROVABLE are not in the purview of science.

A Good Hypothesis

- Conclusion:
  - A GOOD HYPOTHESIS (a SCIENTIFIC HYPOTHESIS) is one which is, in principle, DISPROVABLE.
  - No hypothesis, no matter how good, can ever be completely PROVEN – it can only survive test after test and over time become elevated.

HYPOTHESIS -> MODEL -> THEORY* -> LAW -> FACT

*** NOTE! “Theory” is short for “Scientific Theory,” which doesn't have the same meaning as when casual people use the word “theory.” When casual people say “I have a theory,” what they mean in a scientific sense is “I have an hypothesis.”**

The Scientific Method: A Simple Example

- Observation

The Scientific Method: A Simple Example

- Observation
  - I turn on my desk lamp, but nothing happened

The Scientific Method: A Simple Example

- Observation
- Formulation of a hypothesis
  - takes the form of a causal mechanism ("The light did not come on because..."
  - this requires creative thinking [*]
  - the mechanism should be plausible

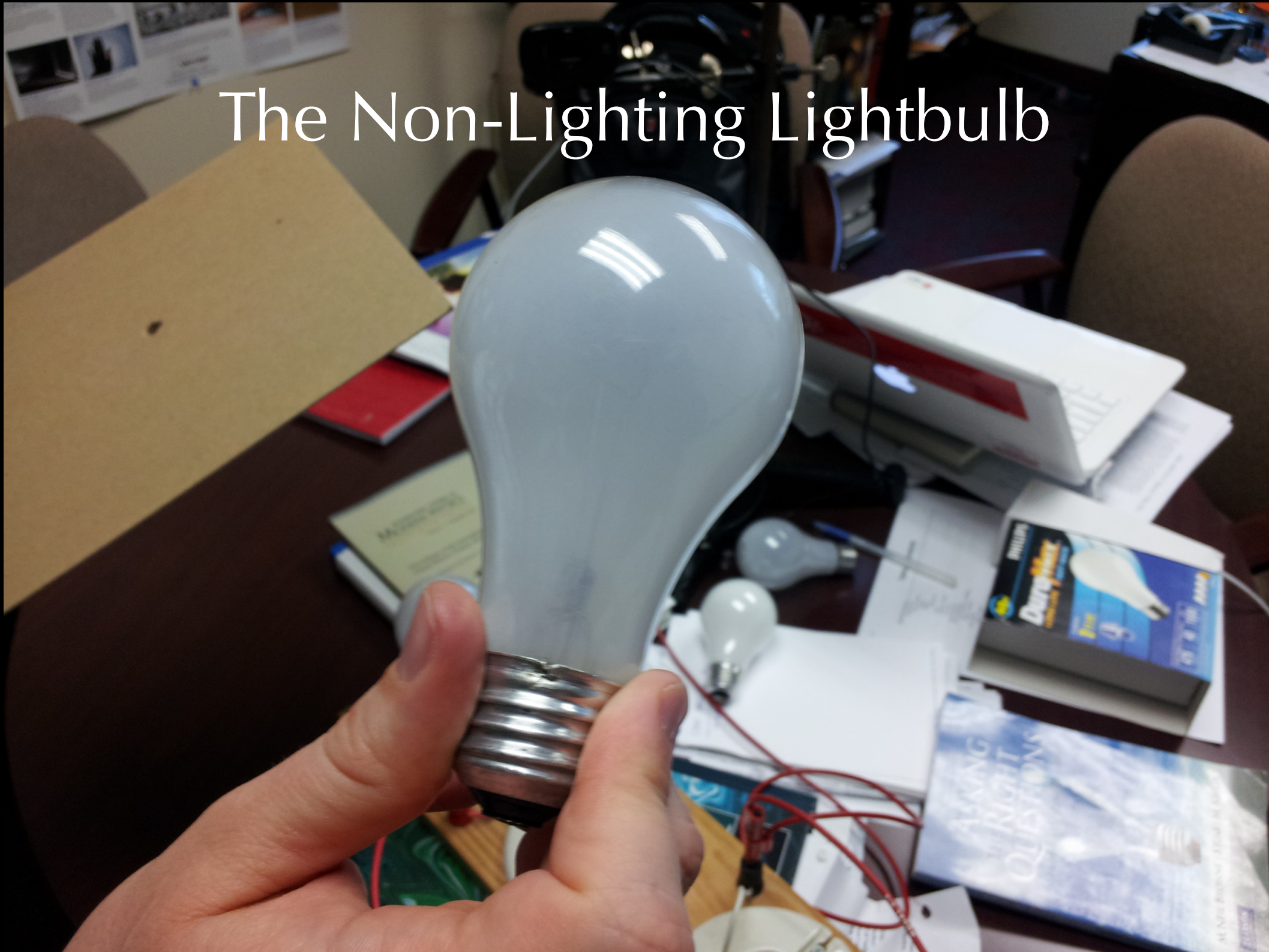
The Scientific Method: A Simple Example

- Observation
- Formulation of a hypothesis
- Use of hypothesis to predict other phenomena
  - test using properly formed experiments, conducted by independent experimenters

The Scientific Method: A Simple Example

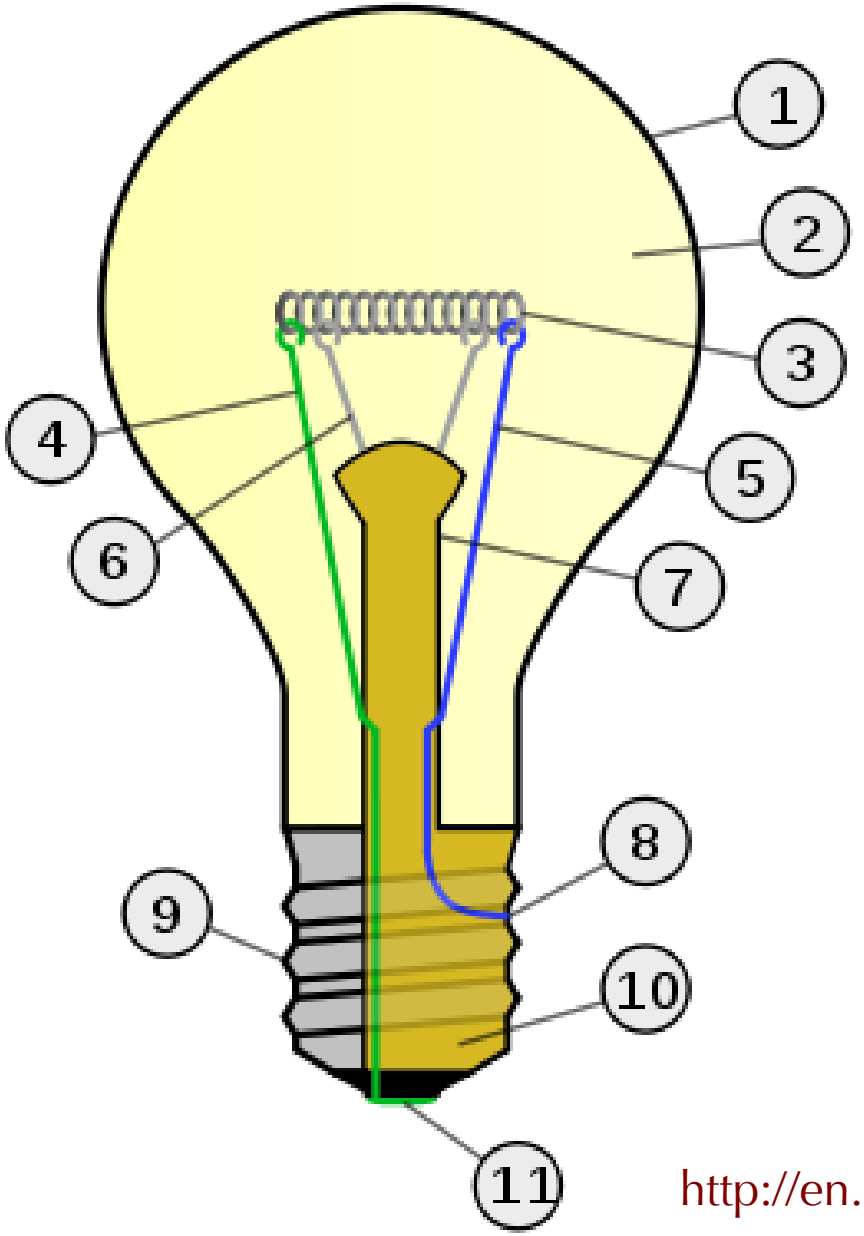
- Observation
- Formulation of a hypothesis
- Use of hypothesis to predict other phenomena
  - test using properly formed experiments, conducted by independent experimenters
  - note that just because your hypothesis passed a test doesn't mean the hypothesis is correct! You have MORE CONFIDENCE in the hypothesis. It might still be wrong.

The Non-Lighting Lightbulb



The Filament of a Working Bulb


Filament of non-working bulb



1. Outline of Glass bulb
2. Low pressure inert gas (argon, neon, nitrogen)
3. Tungsten filament
4. Contact wire (goes out of stem)
5. Contact wire (goes into stem)
6. Support wires
7. Stem (glass mount)
8. Contact wire (goes out of stem)
9. Cap (sleeve)
10. Insulation (vitrite)
11. Electrical contact

http://en.wikipedia.org/wiki/Incandescent_light_bulb

ALTERNATIVES

HYPOTHESIS

CONSTRUCT

A Construct vs. an Hypothesis

- CONSTRUCT
  - A statement that cannot be disproved
- Why are constructs bad?
  - They make worthless hypotheses because they cannot be disproved by a test
  - They teach us nothing about the natural world

The Purpose of the Scientific Method

- Purpose of the Scientific Method
  - ***to construct an accurate, reliable, self-consistent, non-arbitrary representation of the world.***
- The procedures are standardized to minimize any prejudice ("bias") the experimenter might have when testing the hypothesis.
- The Scientific Method is carried out collectively by all researchers.
  - Individual experiments or experimenters can be wrong, but Science is self-correcting.
  - The Scientific Method is the ideal toward which scientists work.

GLOSSARY OF CRITICAL DEFINITIONS

FACT

- The National Academy of Sciences definition of fact:
  - ***An observation that has been repeatedly confirmed and for all practical purposes is accepted as true.***

"In science, 'fact' can only mean 'confirmed to such a degree that it would be perverse to withhold provisional assent.' I suppose that apples might start to rise tomorrow, but the possibility does not merit equal time in physics classrooms."
--Stephen Jay Gould

EXAMPLE: At Standard Temperature and Pressure, lead is more dense than water.

THEORY

- The National Academy of Sciences definition of fact:
  - ***A well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.***

Theories are not easily discarded; new discoveries are first assumed to fit into the existing theoretical framework. It is only when, after repeated experimental tests, the new phenomenon cannot be accommodated that scientists seriously question the theory and attempt to modify it.

EXAMPLE: Einstein's Special Theory of Relativity, which assumes that the speed of light is the same for all observers and all observers observe the same events, even if they disagree on why they occurred; it predicts that time slows down for observers in motion, space contracts according to observers in motion, the speed of light is the fastest that anything can travel, and that mass is another form of energy. These predictions have all been confirmed, repeatedly, by every test applied so far.

CONSTRUCT

A construct is "a non-testable statement to account for a set of observations. The living organisms on Earth may be accounted for by the statement 'God made them' or the statement 'They evolved.' The first statement is a construct, the second a theory. Most biologists would even call evolution a fact."
--Michael Shermer, Why People Believe Weird Things, pg. 20

OCCAM'S RAZOR

Occam's razor is a logical principle attributed to the mediaeval philosopher William of Occam (or Ockham) [1285-1349]. ***The principle states that one should not make more assumptions than the minimum needed.*** This principle is often called the principle of parsimony. It underlies all scientific modeling and theory building. It admonishes us to choose from a set of otherwise equivalent models of a given phenomenon the simplest one. In any given model, Occam's razor helps us to "shave off" those concepts, variables or constructs that are not really needed to explain the phenomenon. By doing that, developing the model will become much easier, and there is less chance of introducing inconsistencies, ambiguities and redundancies.

OCCAM'S RAZOR - EXAMPLE

The structure of the Solar System is a good example of the application of Occam's Razor. The geocentric (“Earth-centered”) system requires planets circling about empty points, with epicycles added to account for the non-uniform motions. Copernicus' heliocentric (“Sun-centered”) model solved the problems without need for epicycles and the associated assumptions.

"Adding epicycles" is now modern jargon for complicating an explanation beyond the point of confidence; it may be time to stop trying to make the old explanation work and start looking for a new hypothesis. Occam's Razor is a "heuristic", which means that it does not have a theoretical base. It is something that is usually good to do. Important to be aware that heuristics can fail; theoretically derived rules normally don't.

HAS OCCAM'S RAZOR EVER FAILED?

Sure! Almost every time.

The Universe is complicated and the simplest explanation is probably not correct.

Then why use Occam's Razor? Because one should only add new assumptions when forced to do so by the evidence, not on a whim.

Occam's Razor keeps Science on track by not allowing it to wander too far afield.

ASSUMPTIONS

- An ASSUMPTION is something taken to be true without proof.
  - Assumptions are necessary because nobody knows everything.
  - An assumption is not necessarily a guess - sometimes an assumption is made based on some knowledge of the situation. You might call it an educated guess.
- This is in contrast to what is known as a WAG (wild-ass guess) in which the guesser really knows nothing and is making random propositions.

SKEPTIC

- A skeptic asks for evidence before accepting a claim.
  - Anecdotes and "everyone knows it" aren't enough.
  - Skeptics are open-minded enough to look at evidence and decide whether to accept the claim, but not so open-minded that their brains fall out.
- Take careful note of the phrase "Extraordinary claims require extraordinary evidence." It's from Carl Sagan.
  - Whenever someone makes a really far-out claim, DON'T just take it at face value. Ask for some real evidence in support of the claim.

DENIER

- A “Denier” is often confused with a “Skeptic”
  - THEY ARE NOT THE SAME THING
- A DENIER is . . .
  - . . . someone for whom there is never enough evidence.
  - There are many, many, many kinds of deniers
    - Holocaust Deniers
    - AIDS/HIV Deniers
    - Global Climate Change Deniers
    - Evolution Deniers
    - 9/11 Deniers
    - Presidential Birth Certificate Deniers

CYNIC

- A cynic questions everybody's motives, figuring all actions are self-interested and/or self-serving.
  - A real cynic is annoying.
  - There are, however, some times when a cynical approach is useful - even helpful. We mean simply that there are some times that a cynical approach will get you the answers you need.

CYNIC – AN EXAMPLE

- The old saying "If it seems too good to be true, it probably is" is still valid.
  - Take, for example, Facebook. It's offered as a “free service” to connect with friends and family. In exchange for your personal information and access to your private life (photos, lists of friends, media habits, etc.) you get to connect endlessly for free.
  - Wait, is it really for free? What's the trade-off? How is Facebook, a for-profit company, benefiting from offering a free service?
    - Personal information means targeted advertising, and ways of developing strategies for selling off your personal information to third-parties so they can better target you and your interests.
    - You are trading personal information for access, and Facebook is making money from your personal information

Do Research on Lightbulbs!

- http://science.discovery.com/videos/how-its-made-light-bulb.html
- “Incandescent Light Bulb.” Wikipedia.
  http://en.wikipedia.org/wiki/Incandescent_light_bulb
  - Wikipedia is not a “primary source” - look at the sources of the Wikipedia article and track back through them. Primary sources of information (first-hand research, rather than reports of somebody else's work) are best.
- If you cannot think of failure modes for lightbulbs on your own, RESEARCH can help stimulate new ideas.