Interpreting Evidence

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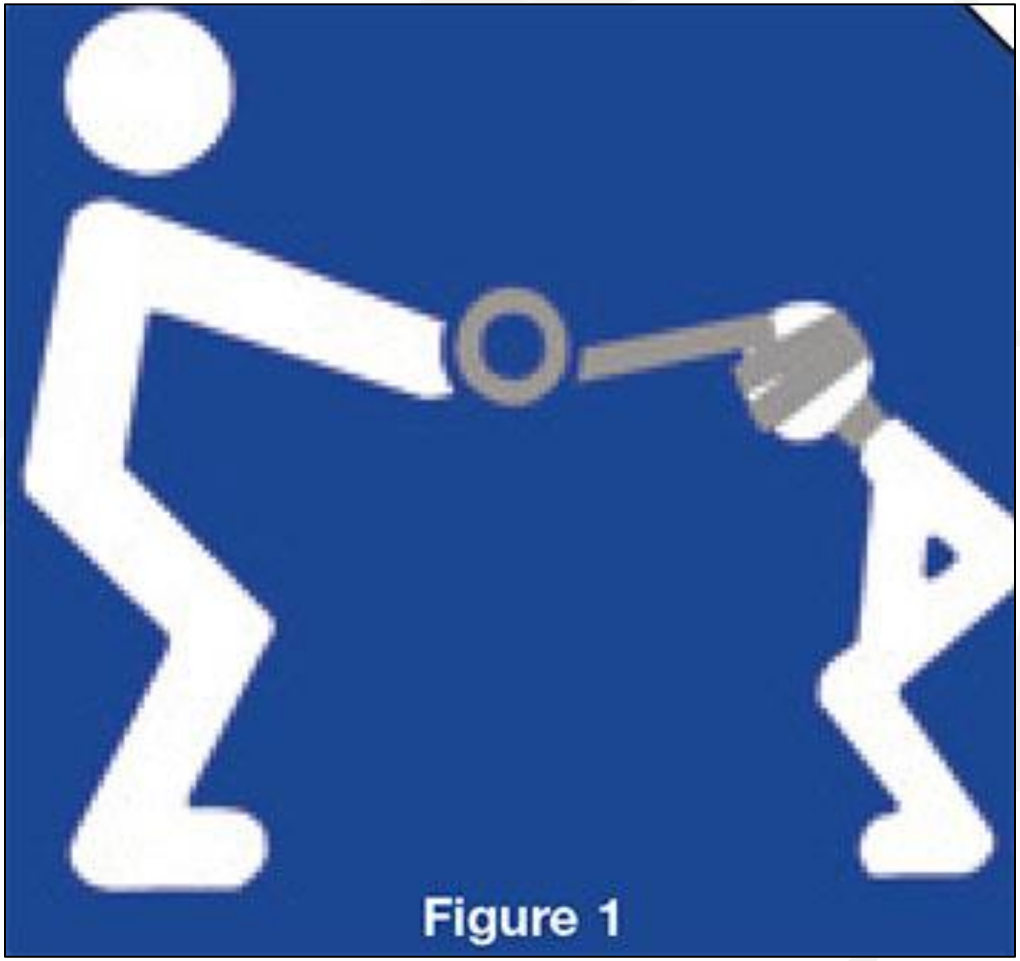
What does this mean?



Important Questions

- What is scientific evidence?
- How is evidence generated?
- How can evidence be used to test hypotheses?

What is science?

The systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts. The organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation.

Academic Press Dictionary of Science & Technology

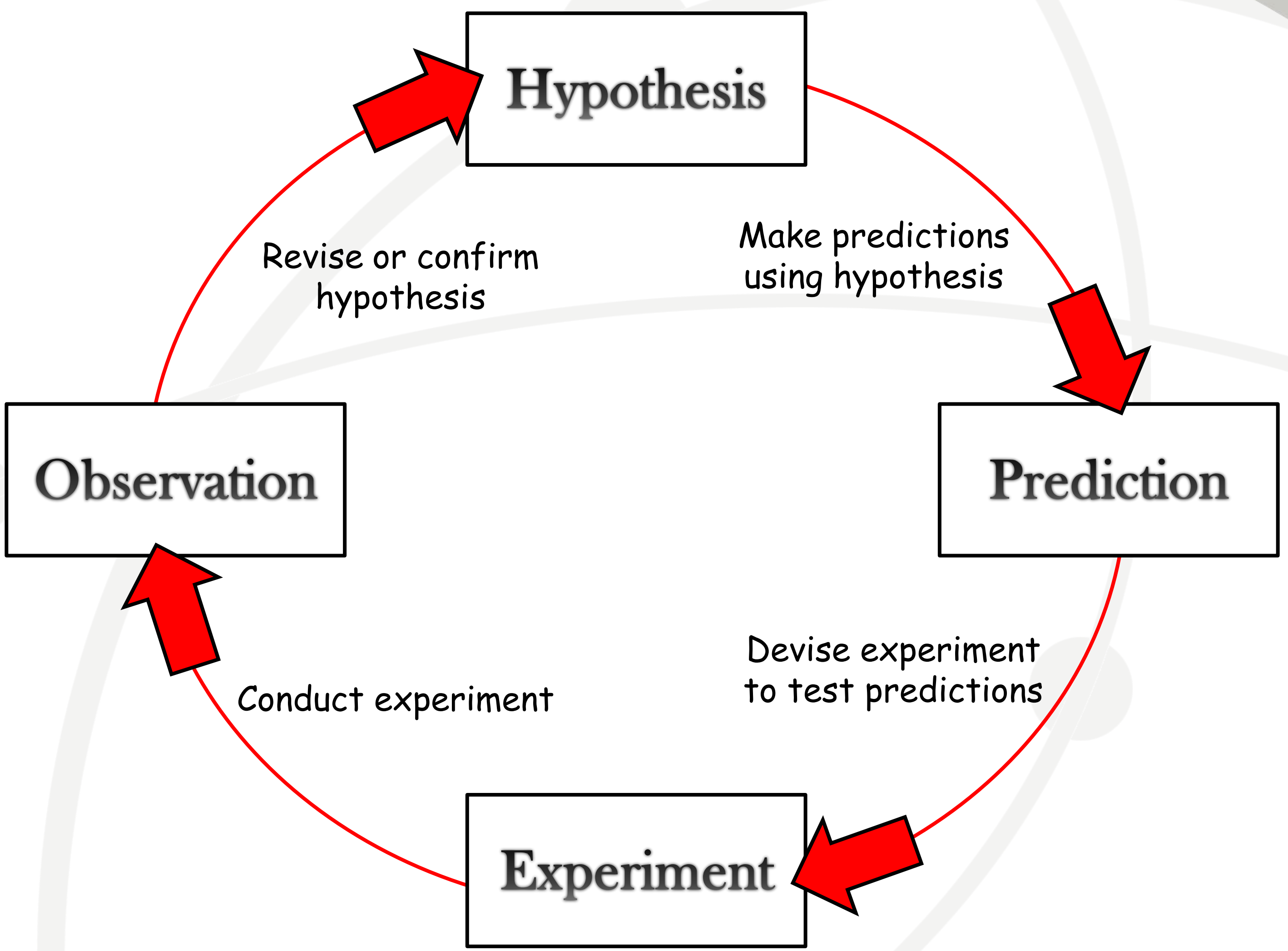
Science consists simply of the formulation and testing of hypotheses based on observational evidence; experiments are important where applicable, but their function is merely to simplify observation by imposing controlled conditions.

Robert H. Dott, Jr., and Henry L. Batten, *Evolution of the Earth*

Science alone of all the subjects contains within itself the lesson of the danger of belief in the infallibility of the greatest teachers in the preceding generation . . .As a matter of fact, I can also define science another way: Science is the belief in the ignorance of experts.

Richard Feynman

The Scientific Method



Terms Used to Describe the "Nature of Science"

Fact: An observation that has been repeatedly confirmed and for all practical purposes is accepted as "true." Truth in science, however, is never final, and what is accepted as a fact today may be modified or even discarded tomorrow.

Hypothesis: A falsifiable statement about the natural world.

Law: A descriptive generalization about how some aspect of the natural world behaves under stated circumstances.

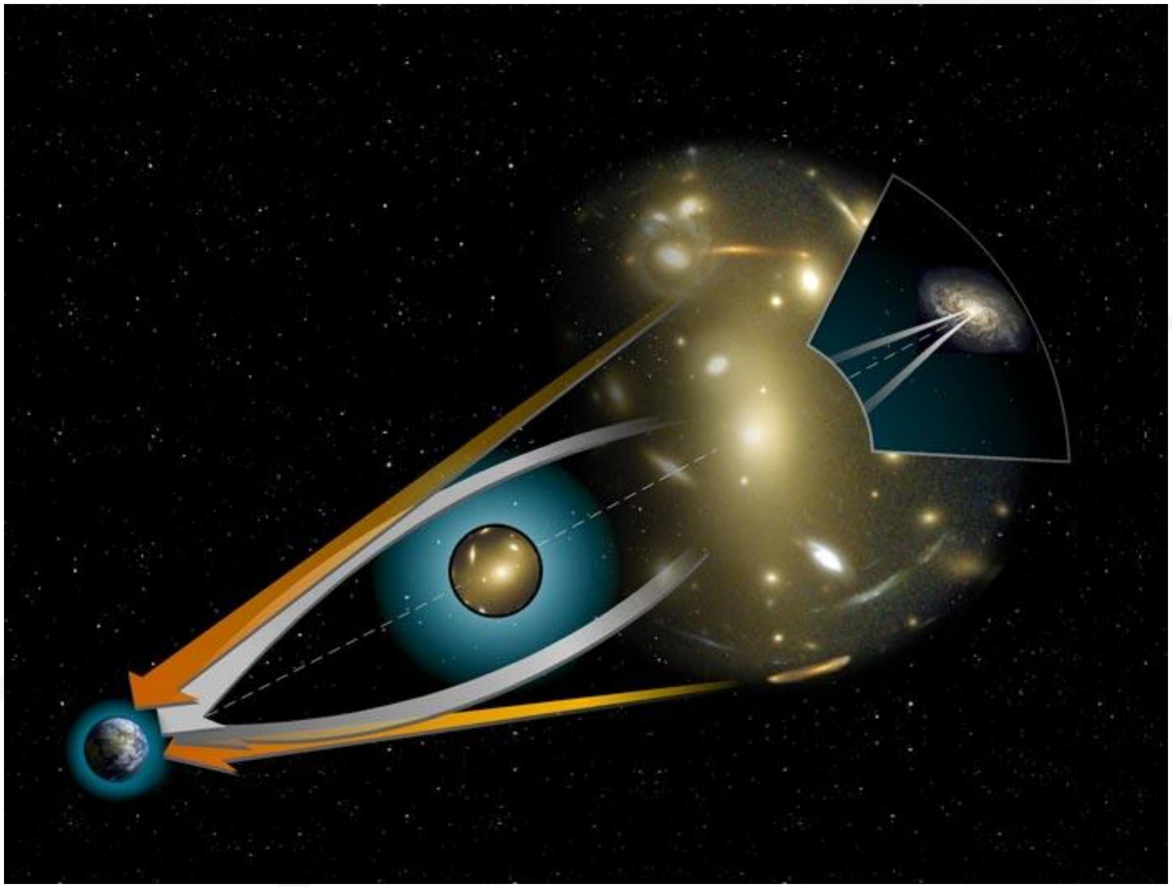
Theory: A well-substantiated explanation of some aspect of the natural world that can incorporate facts, laws, inferences, and tested hypotheses.

Modified from National Academy of Sciences, 1999

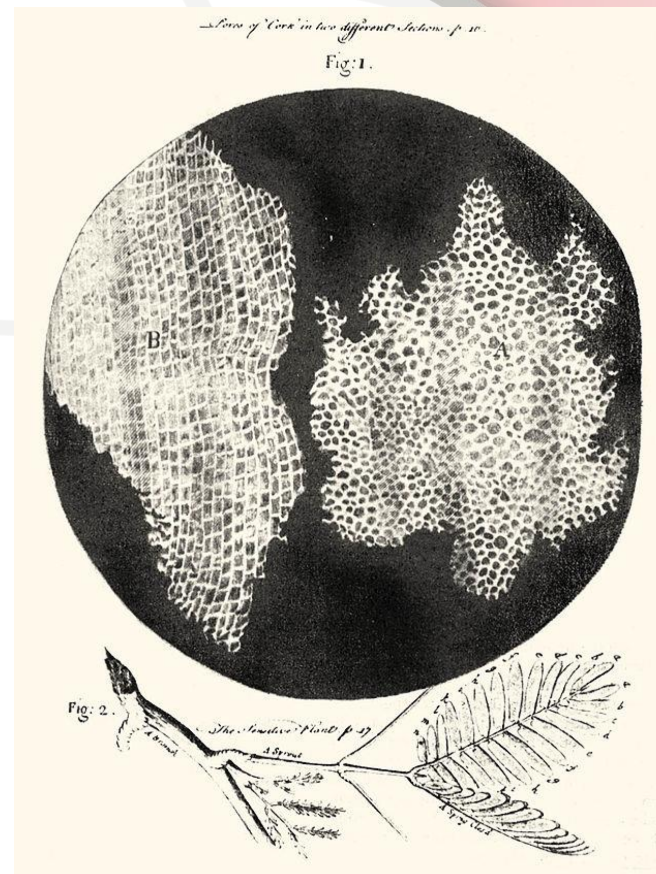
Scientific Theories

The contention that evolution should be taught as a "theory, not as a fact" confuses the common use of these words with the scientific use. In science, theories do not turn into facts through the accumulation of evidence. Rather, **theories are the end points of science**. They are understandings that develop from extensive observation, experimentation, and creative reflection. They incorporate a large body of scientific facts, laws, tested hypotheses, and logical inferences. In this sense, evolution is one of the strongest and most useful scientific theories we have.

Scientific Theories

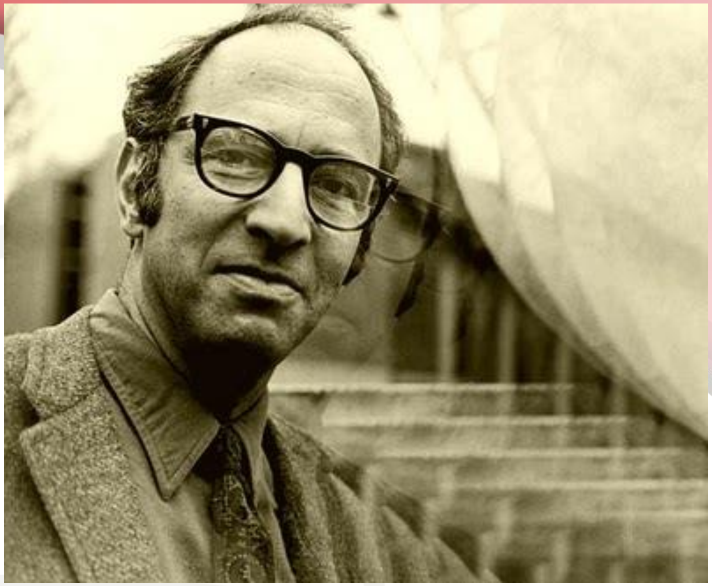


General Theory of Relativity



Cell Theory

Paradigms



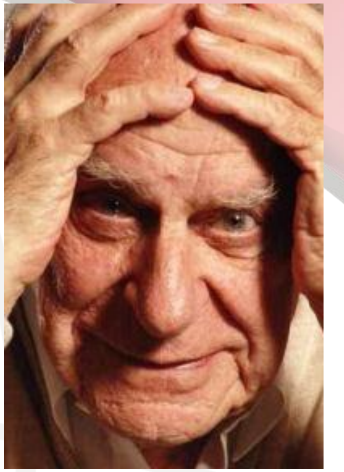
Thomas Kuhn (1922-1996)

The Structure of Scientific Revolutions

"Universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners."

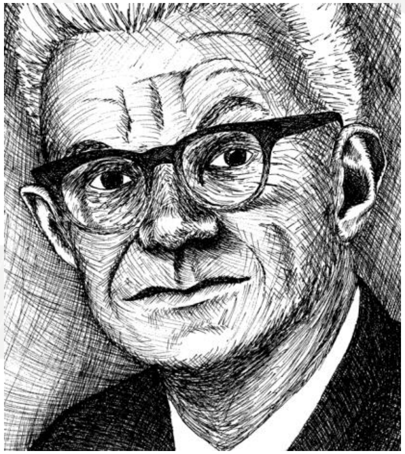
Wikipedia: The set of practices that define a scientific discipline at any particular period of time.

Types of Reasoning



Inductive logic: “bottom up”

- Inferring a general conclusion from individual observations



Deductive logic: “top down”

- Narrowing down general cases to a specific conclusion

Evidence of Causality

Necessity:

- If x is a necessary cause of y,
- Then the presence of y necessarily implies the presence of x.
- The presence of x, however, does not imply that y will occur.

Sufficiency:

- If x is a sufficient cause of y,
- Then the presence of x necessarily implies the presence of y.
- However, another cause z may alternatively cause y.
- Thus the presence of y does not imply the presence of x.

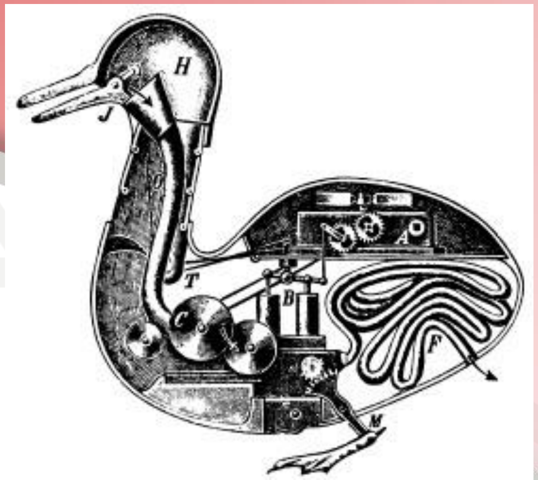
Forms of Argument

Modus ponens:

- If today is Tuesday, then John will go to work.
- Today is Tuesday.
- Therefore, John will go to work.

Modus tollens:

- If the watch-dog detects an intruder, the watch-dog will bark.
- The watch-dog did not bark
- Therefore, no intruder was detected by the watch-dog.



Reductionism

The whole is just the sum of the parts.

"The universe can be understood by abstracting and breaking down each system into component parts that are ever more basic and fundamental. Reductionism exposes the nature of a system whereas scientific hypothesis testing allows for the synthesis of scientific truth."

Is this always the case?

- Larger scale organization can influence smaller scales .
- Feedback loops create structure at a given level, independently of details at a lower level of organization.

Controls Make The World Go Round

Controls are “anti-experiments”:

- They represent a null hypothesis.
- The answer should already be known.
- Nothing is being tested. It’s either going to ‘work’ (positive control) or it’s going to have no effect (negative control).

Activity

Discuss the examples on the handout

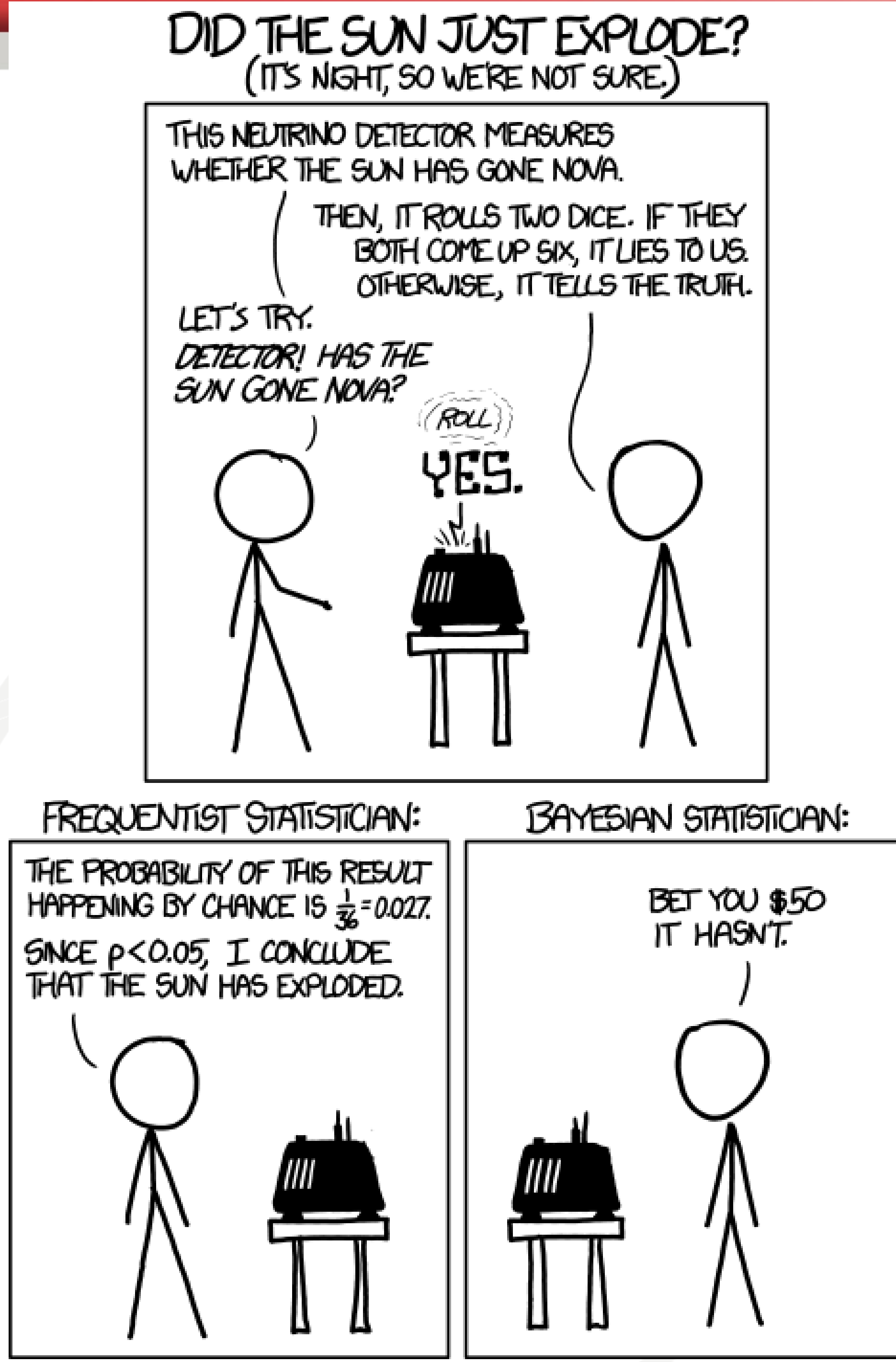
Think about types of reasoning and causality

Preferably work in pairs or groups of 3

Statistical Inference

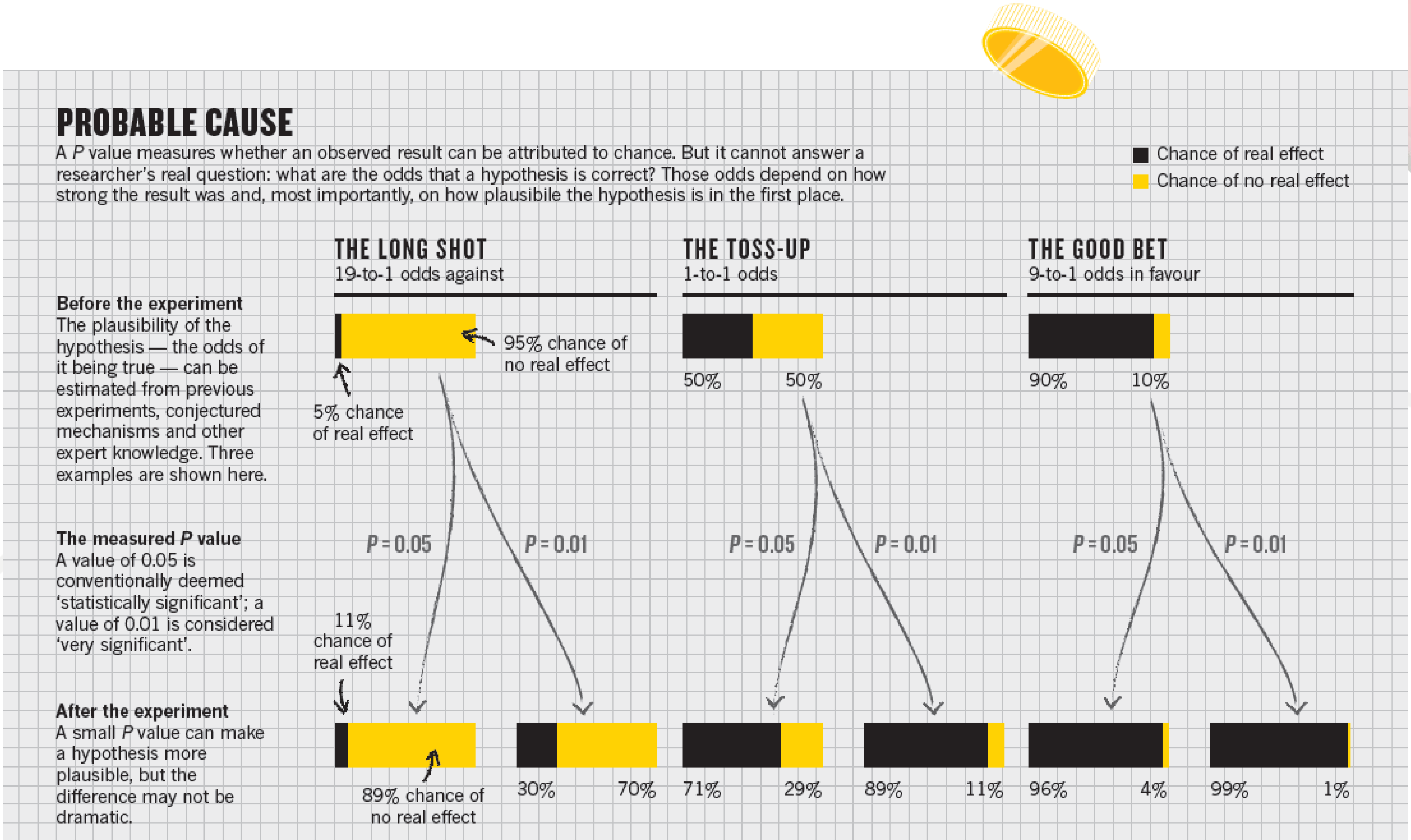
The process of drawing conclusions from data that are subject to random variation.

- Central to inductive arguments.
- Paradigms:
    - Frequentist: sharp decision rules for propositions
    - Bayesian: degrees of belief in a proposition


DID THE SUN JUST EXPLODE?
(IT'S NIGHT, SO WE'RE NOT SURE.)
THIS NEUTRINO DETECTOR MEASURES WHETHER THE SUN HAS GONE NOVA.
THEN, IT ROLLS TWO DICE. IF THEY BOTH COME UP SIX, IT LIES TO US. OTHERWISE, IT TELLS THE TRUTH.
LET'S TRY.
DETECTOR! HAS THE SUN GONE NOVA?
(ROLL)
YES.
FREQUENTIST STATISTICIAN:
THE PROBABILITY OF THIS RESULT HAPPENING BY CHANCE IS $\frac{1}{36}$=0.027.
SINCE $p<0.05$, I CONCLUDE THAT THE SUN HAS EXPLODED.
BAYESIAN STATISTICIAN:
BET YOU $50 IT HASN'T.

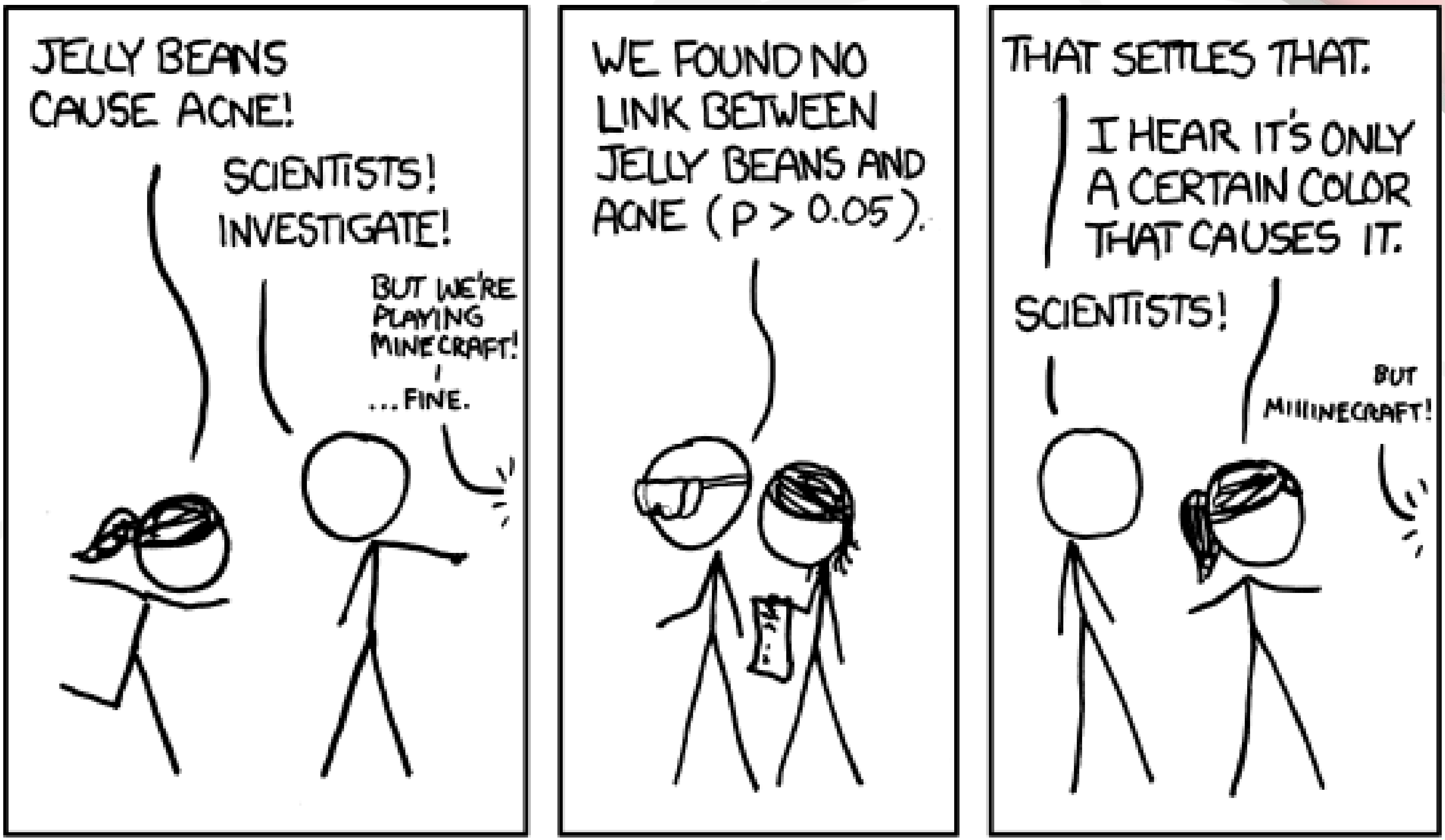
www.xkcd.com

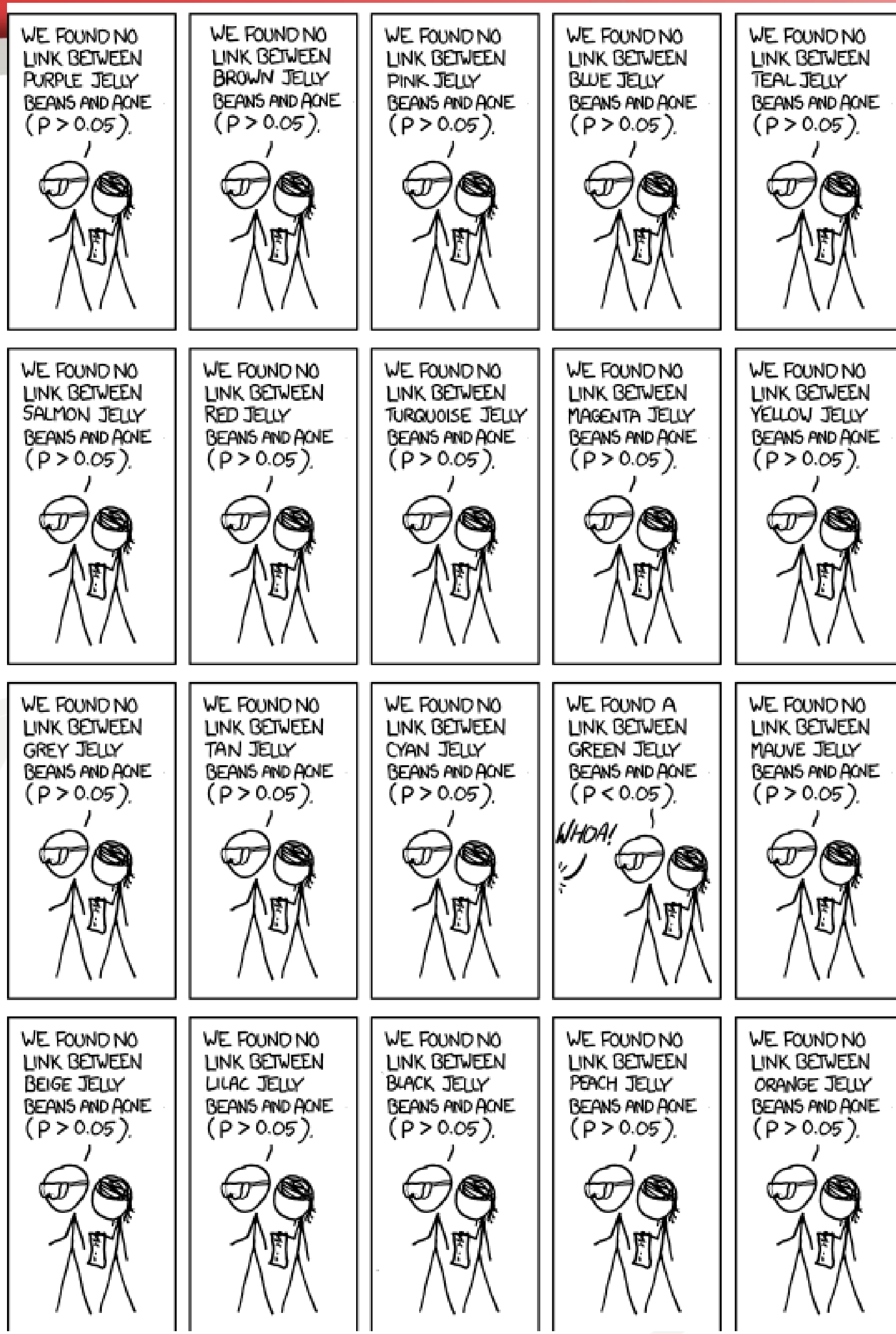
Statistical vs. Practical Significance

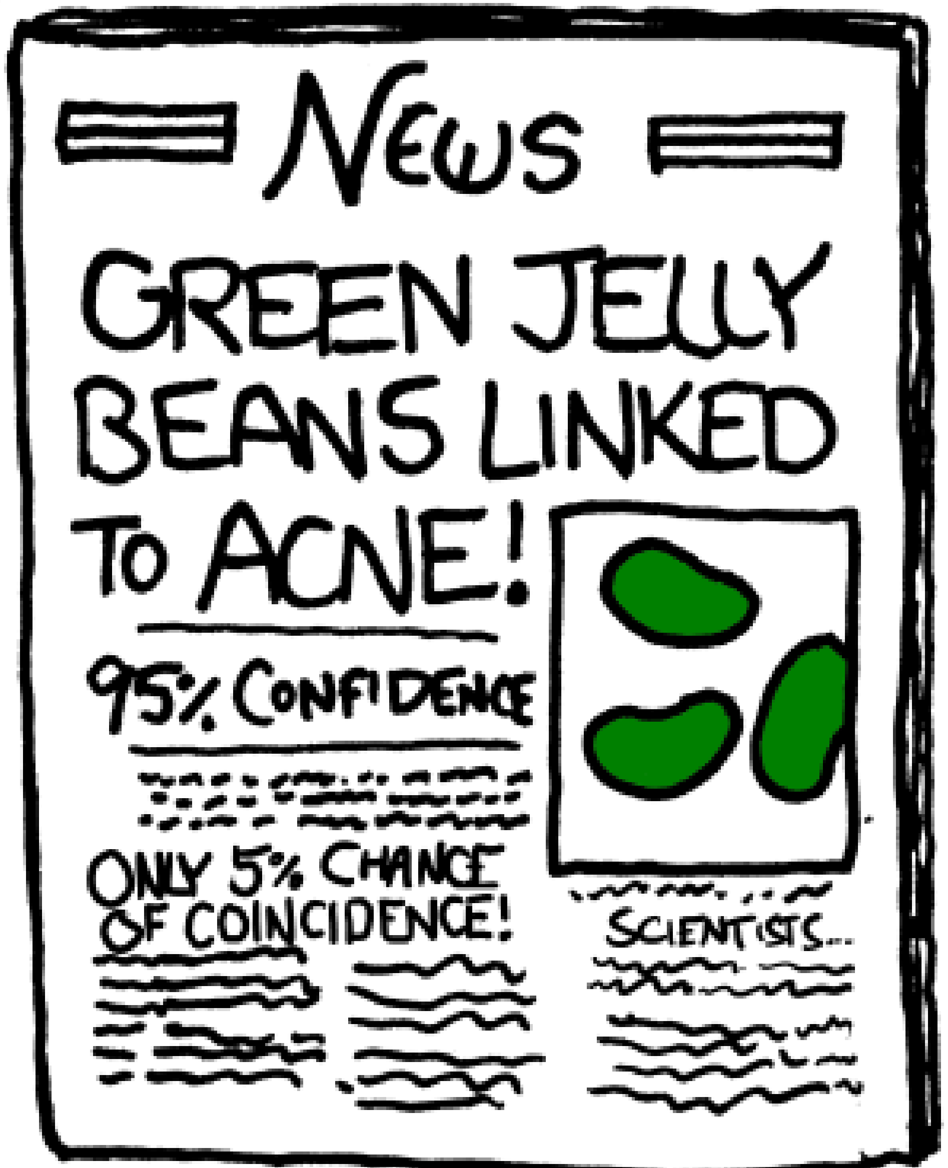


Nature, 506, 150–152 (13 February 2014)

Illustrating A "Long Shot"




WE FOUND NO LINK BETWEEN PURPLE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BROWN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PINK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLUE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TEAL JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN SALMON JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN RED JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TURQUOISE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN MAGENTA JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN YELLOW JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN GREY JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN TAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN CYAN JELLY BEANS AND ACNE (P > 0.05).
WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE (P < 0.05).
WHOA!
WE FOUND NO LINK BETWEEN MAUVE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BEIGE JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN LILAC JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN BLACK JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN PEACH JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN ORANGE JELLY BEANS AND ACNE (P > 0.05).



NEWS
GREEN JELLY BEANS LINKED TO ACNE!
95% CONFIDENCE
ONLY 5% CHANCE OF COINCIDENCE!
SCIENTISTS...

Common Types of Effect Size

Index	Description[b]	Effect Size	Comments
Between groups			
Cohen's d[a]	$d = M_1 - M_2 / s$ $M_1 - M_2$ is the difference between the group means (M); s is the standard deviation of either group	Small 0.2 Medium 0.5 Large 0.8 Very large 1.3	Can be used at planning stage to find the sample size required for sufficient power for your study
Odds ratio (OR)	$\frac{\text{Group 1 odds of outcome}}{\text{Group 2 odds of outcome}}$ If OR = 1, the odds of outcome are equally likely in both groups	Small 1.5 Medium 2 Large 3	For binary outcome variables Compares odds of outcome occurring from one intervention vs another
Relative risk or risk ratio (RR)	Ratio of probability of outcome in group 1 vs group 2; If RR = 1, the outcome is equally probable in both groups	Small 2 Medium 3 Large 4	Compares probabilities of outcome occurring from one intervention to another
Measures of association			
Pearson's r correlation	Range, −1 to 1	Small ±0.2 Medium ±0.5 Large ± 0.8	Measures the degree of linear relationship between two quantitative variables
r^2 coefficient of determination	Range, 0 to 1; Usually expressed as percent	Small 0.04 Medium 0.25 Large 0.64	Proportion of variance in one variable explained by the other

J Grad Med Educ. Sep 2012; 4(3): 279–282.

Error Bars

Table I. **Common error bars**

Error bar	Type	Description	Formula
Range	Descriptive	Amount of spread between the extremes of the data	Highest data point minus the lowest
Standard deviation (SD)	Descriptive	Typical or (roughly speaking) average difference between the data points and their mean	$SD = \sqrt{\frac{\sum (X - M)^2}{n-1}}$
Standard error (SE)	Inferential	A measure of how variable the mean will be, if you repeat the whole study many times	$SE = SD/\sqrt{n}$
Confidence interval (CI), usually 95% CI	Inferential	A range of values you can be 95% confident contains the true mean	$M \pm t_{(n-1)} \times SE$, where $t_{(n-1)}$ is a critical value of t. If n is 10 or more, the 95% CI is approximately $M \pm 2 \times SE$.

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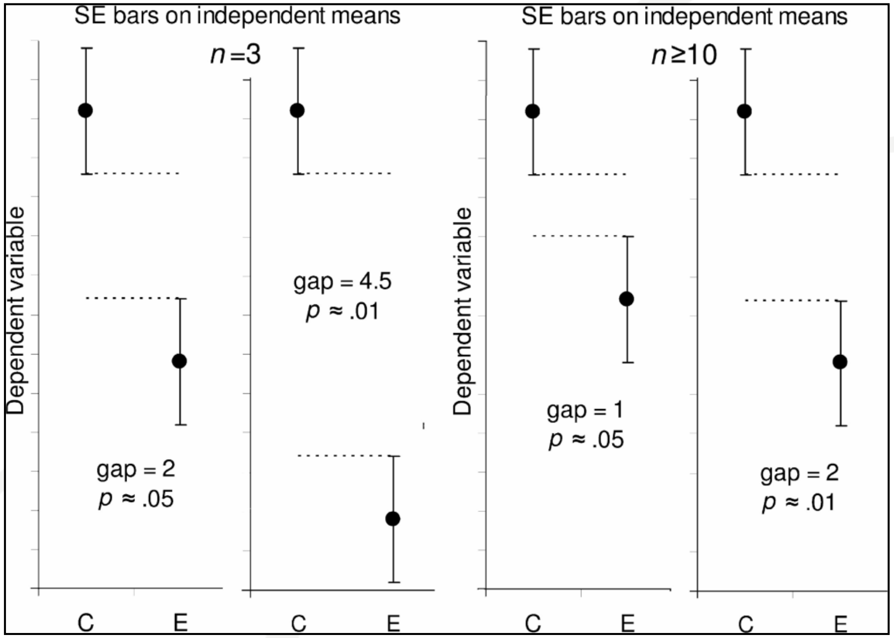
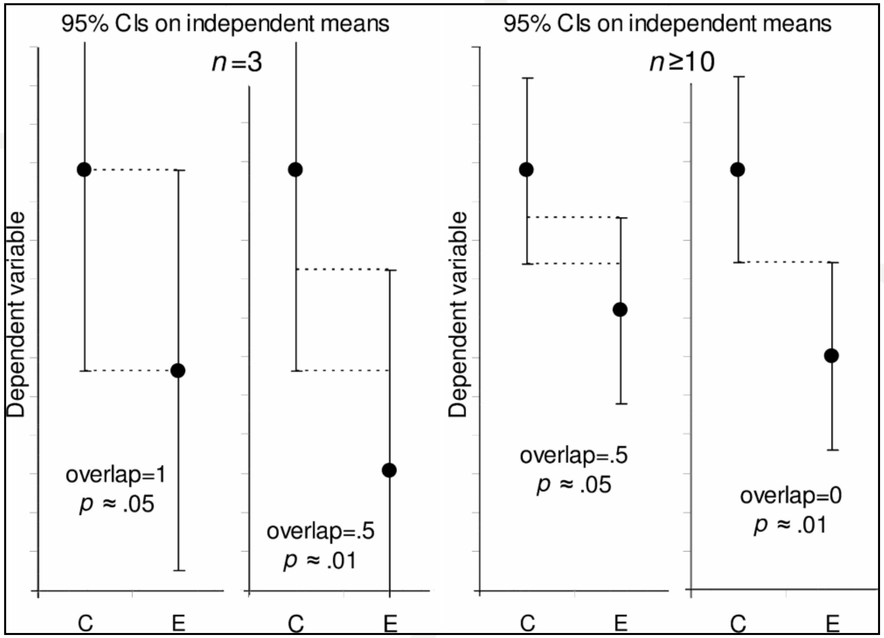
The Overlap Rule





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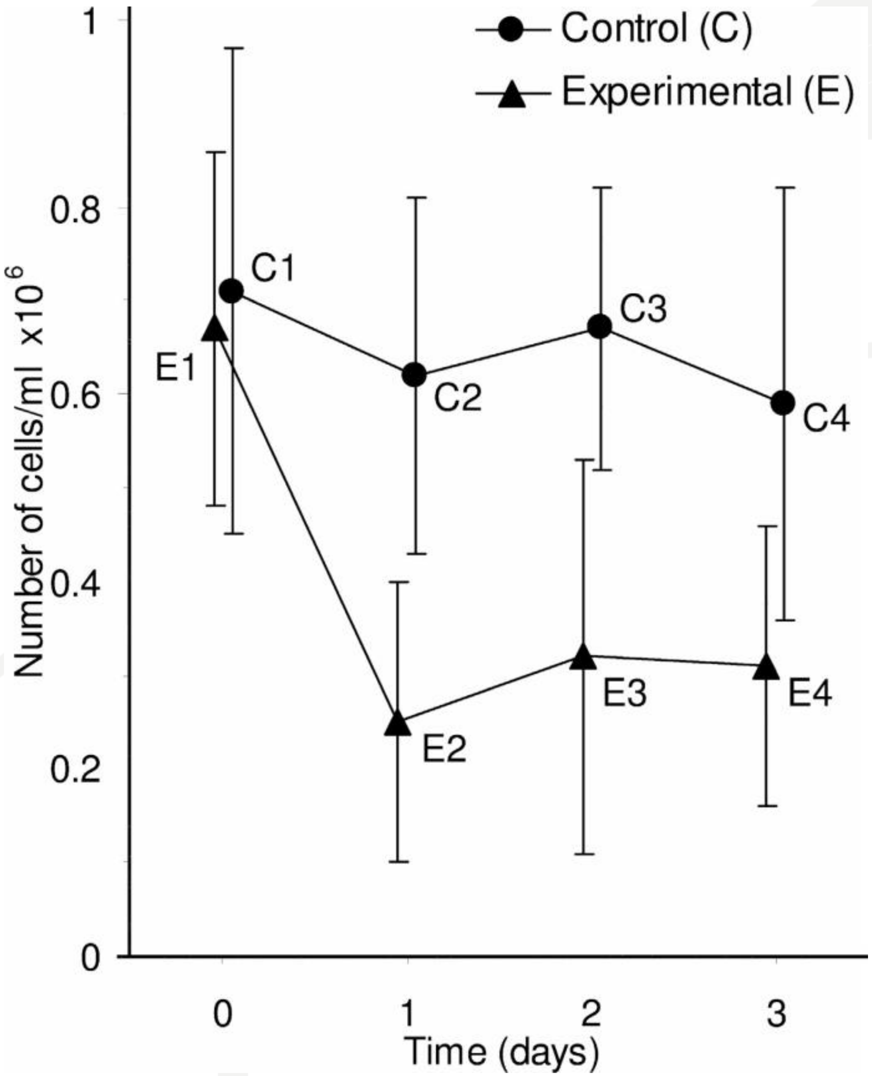
Try out the overlap rule



Means w/ SE bars

n = 3

Can you estimate *p*-values?

- Between groups?
- Within groups?

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Important Questions

- What is scientific evidence?
  - There are multiple levels, it depends on the questions and context of interpretation.
- How is evidence generated?
  - Understanding the “nature of science”.
  - Applying the scientific method.
- How can hypotheses be tested?
  - Building support (induction)
  - Ruling things out (deduction)
  - Statistical inference

Download Locations

ejsbio.weebly.com

labs.mcdb.ucsb.edu/smith/william/members/spina