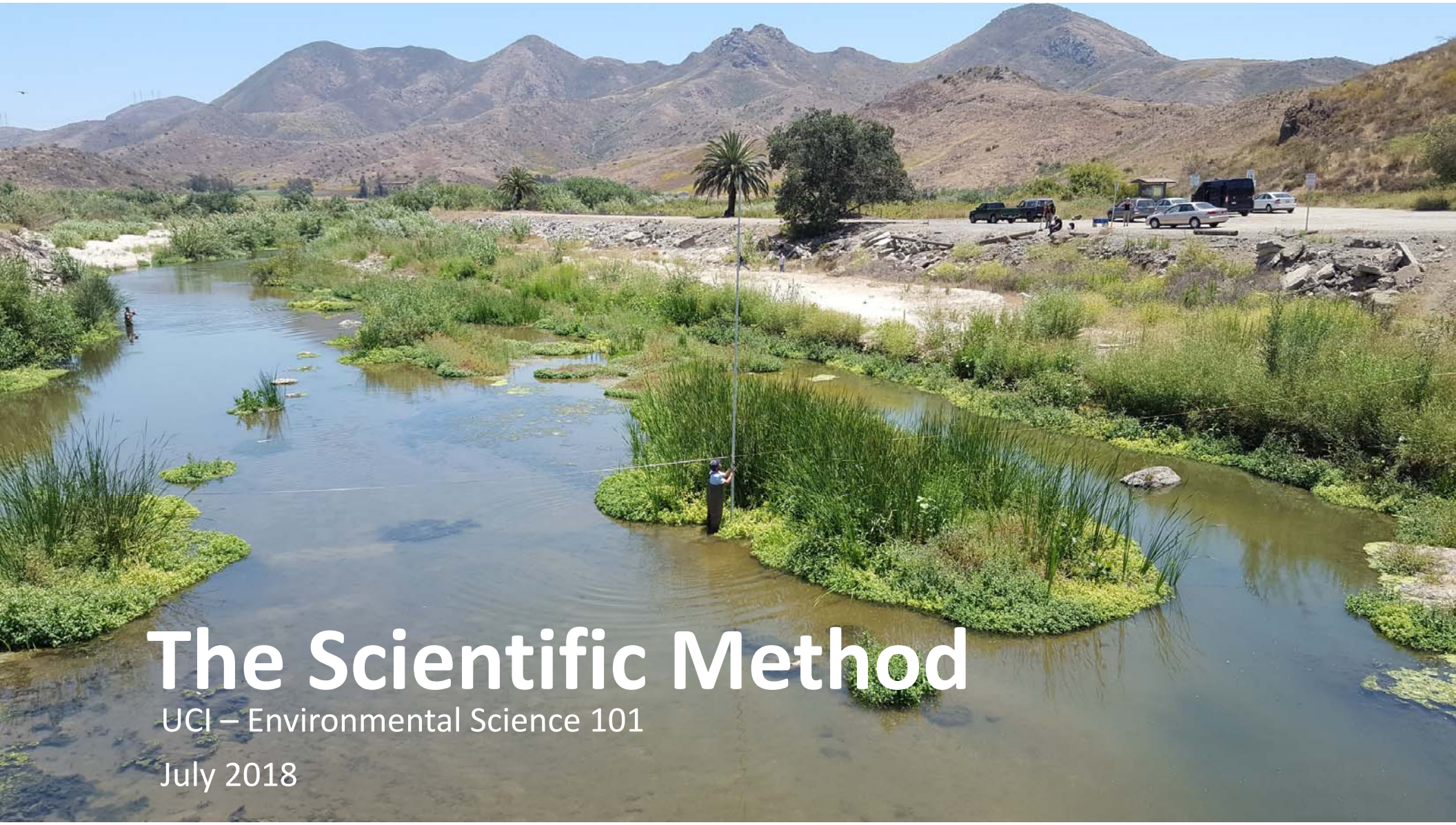
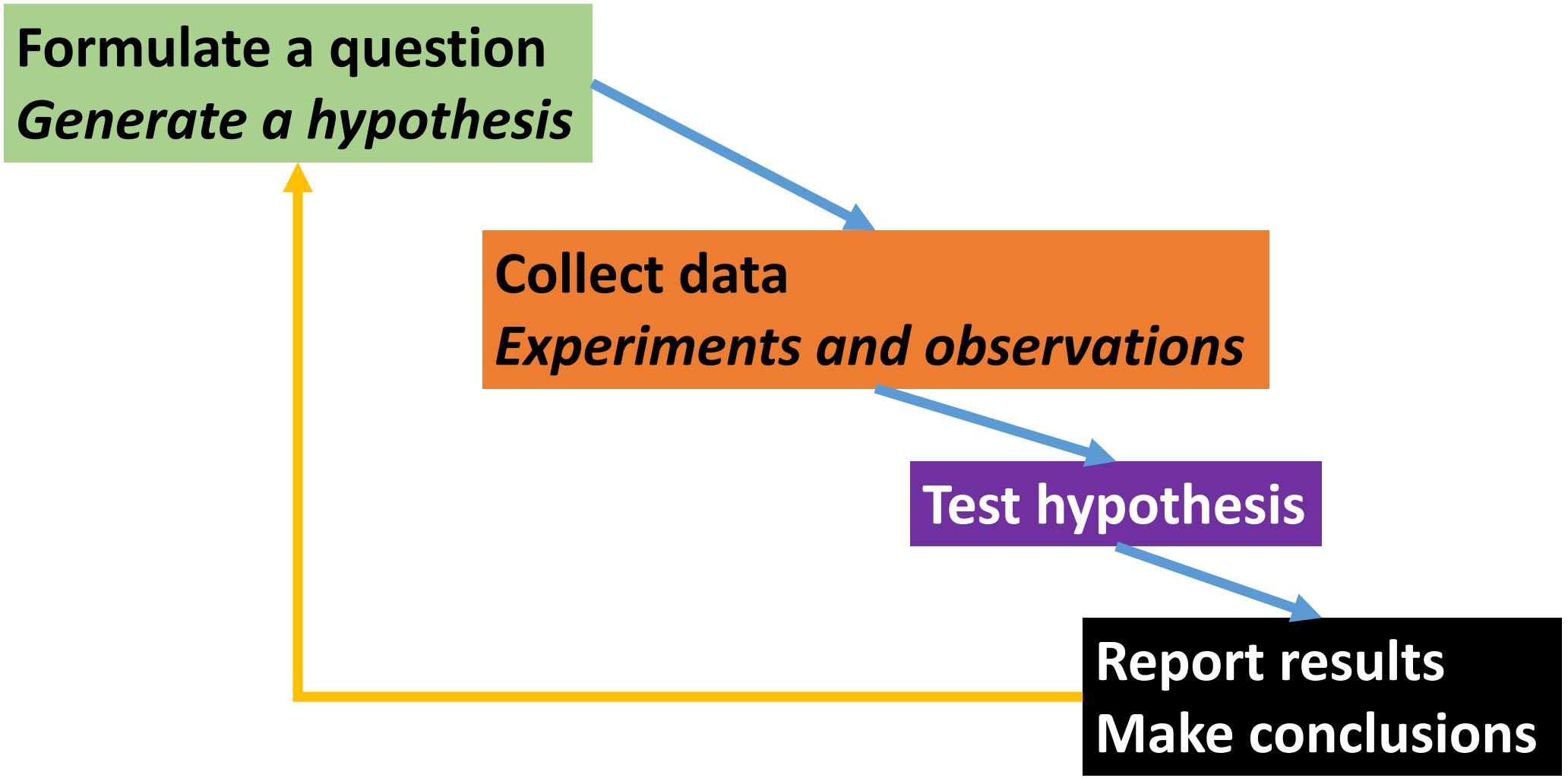


The Scientific Method

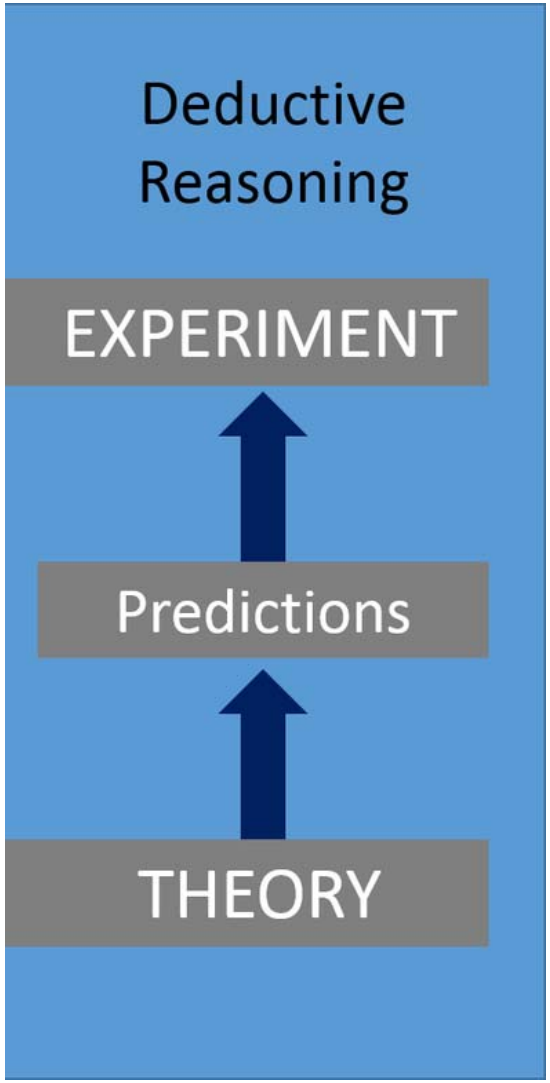
UCI – Environmental Science 101

July 2018


Formulate a question
Generate a hypothesis
Collect data
Experiments and observations
Test hypothesis
Report results
Make conclusions

Formulate a question

Generate a hypothesis



Formulate a question

- Should be specific (to allow formation of a hypothesis)
- Must be answerable
- Use what we know (previous work) and deductive reasoning

1. Every X has the characteristic Y.
2. This thing in my hand is X.
3. Therefore, this thing has the characteristic Y.

Generate a hypothesis

A **hypothesis** is a **tentative explanation** for an observed phenomenon

- Null hypothesis (what you seek to reject)
- Alternative hypothesis or hypotheses

Example questions and hypotheses

Question: Does fertilizer increase the amount of tomatoes produced by a plant?

Null Hypothesis: Adding nitrogen fertilizer does not change the number of tomatoes produced.

Alternative hypothesis: Adding nitrogen fertilizer increases the number of tomatoes produced.

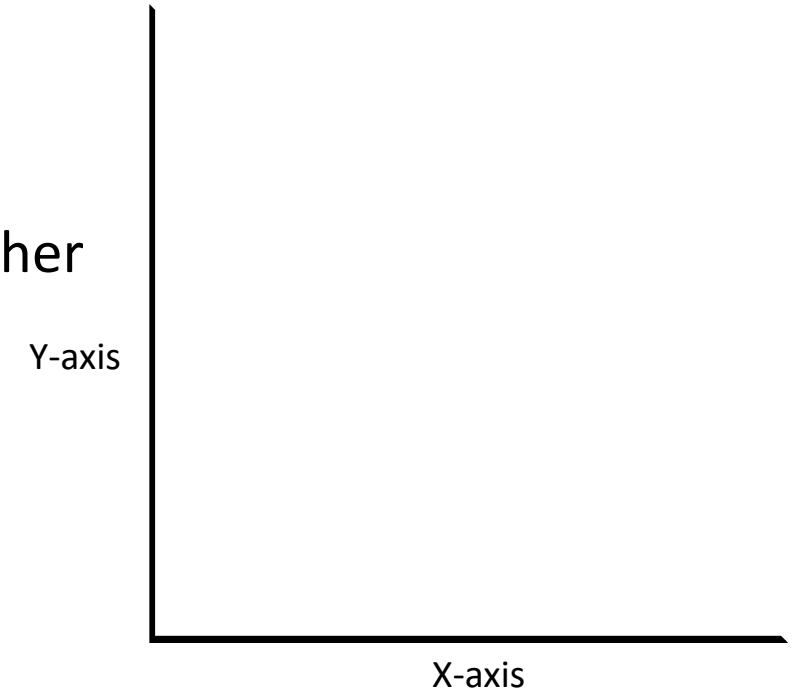
Collecting data

- Observations
- Experiments

Types of variables

2 categories:

- **Dependent/Response variable (Y)**: not controlled by the researcher—i.e., the answer!
- **Independent/Predictor variable (X)**:
  - Factor: Controlled by the researcher
  - Covariate: Not controlled by the researcher



Testing hypotheses

- **Null hypothesis**:
  - What you hope to reject
  - No effect, no relationship amongst your variables
- **Alternative hypothesis:**
  - Everything not consistent with the null
  - Is there a difference between your groups?

Source: https://xkcd.com/892/

Testing hypotheses

You are not “proving” either hypothesis!

A hypothesis can be **refuted** (proven wrong, or **falsified**), but it *never can be proven to be true*.

Either:

Insufficient evidence to reject null hypothesis

OR

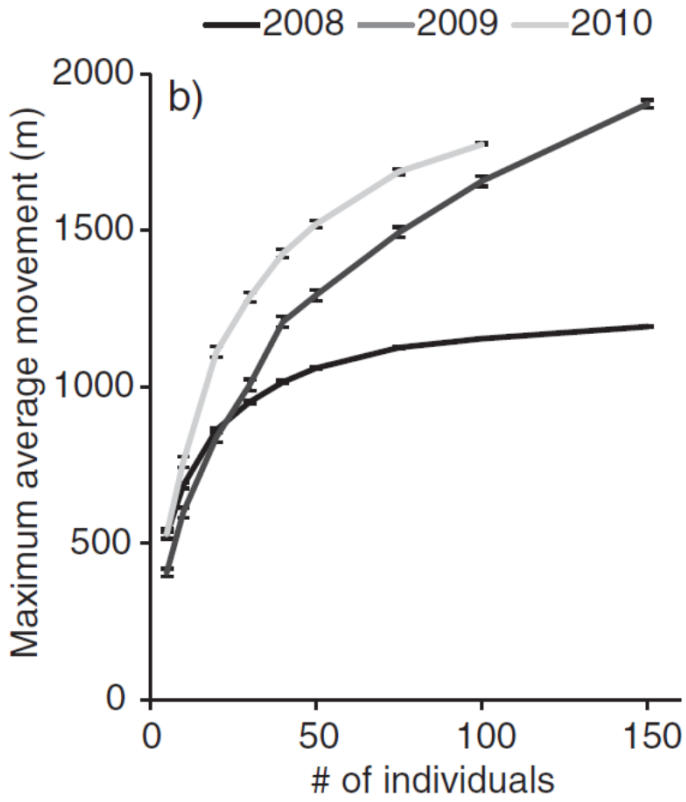
Evidence to reject null hypothesis, consistent with alternative hypothesis

Activity: Predation and camouflage

Replication

A single *datum* is inadequate to judge how reliably a characteristic has

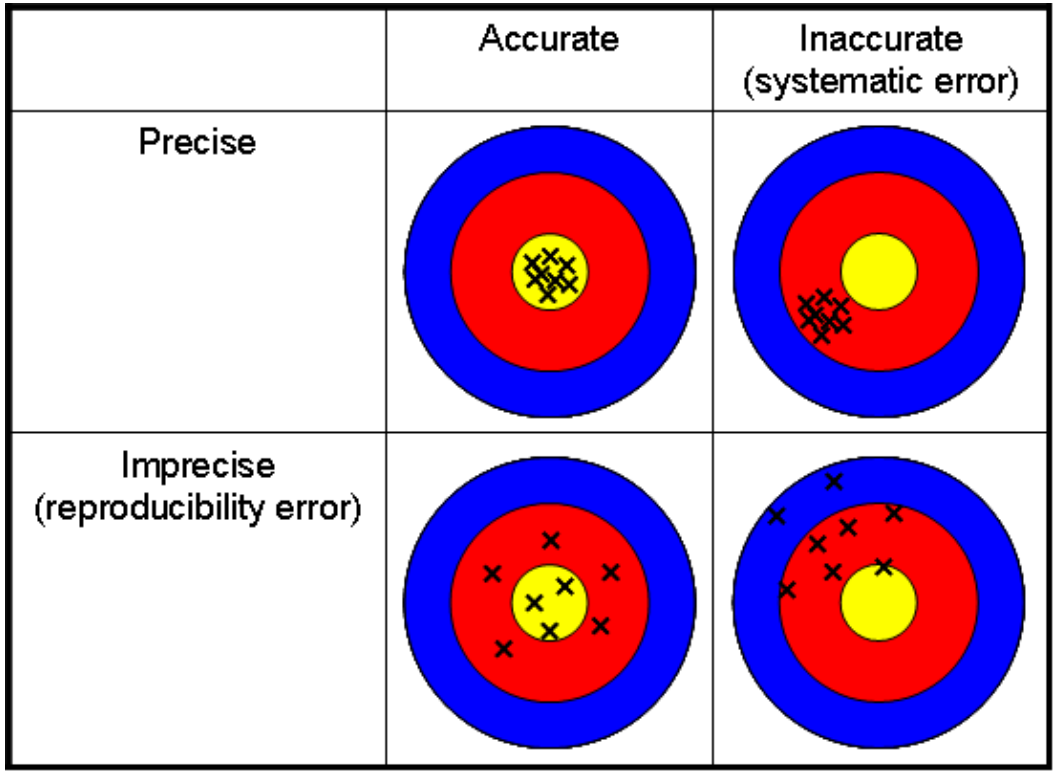
- Species-sample curves
- Performance curve
- Statistical power



Source: Booth et al 2014 Transactions of the American Fisheries Society

Accuracy and precision

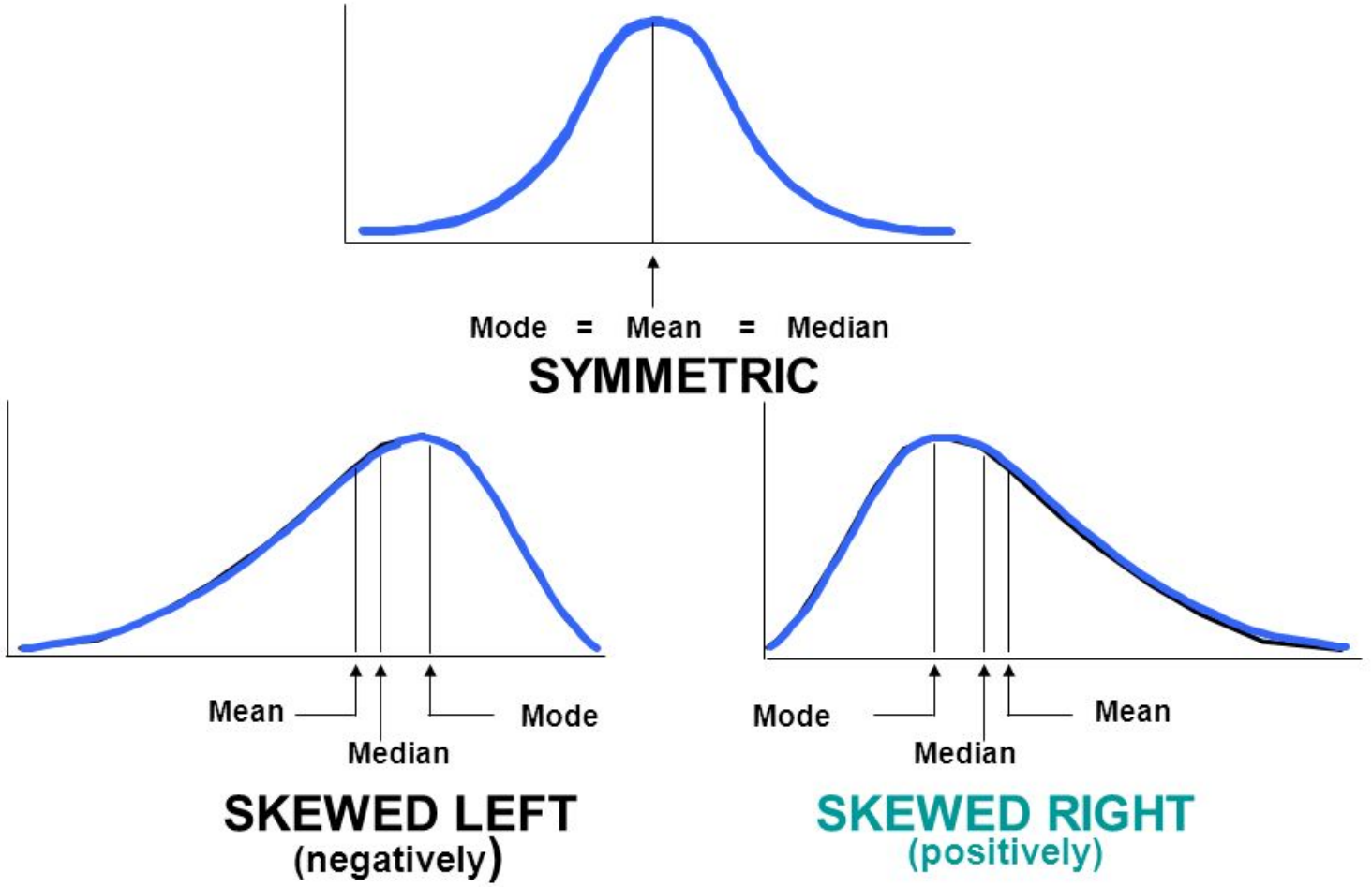
- Bias
- Accuracy (difference from true value)
- Precision (standard error)
- Confidence intervals (probability)



Source: https://www.quora.com/What-is-accuracy-and-how-does-it-differ-from-precision

Descriptive statistics

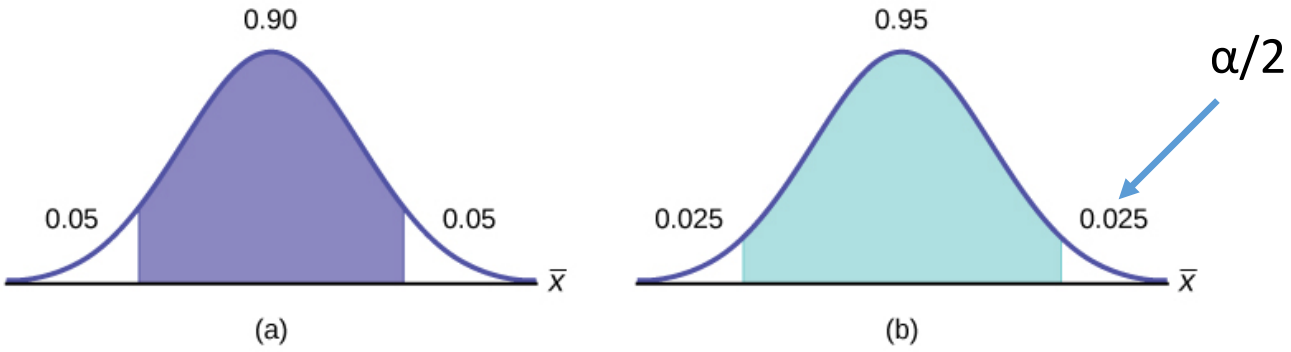
- Mean
- Median
- Mode
- Range



Hypothesis testing

A hypothesis is a statement about Θ (Greek letter theta), the population parameter of interest (usually the mean)

- **Null Hypothesis**, H_0:
  - What you hope to reject
  - No effect, no relationship among your variables
- **Alternative Hypothesis**, H_{alt}:
  - Everything/anything not consistent with H_0
  - Basically, is there a difference between the groups?



Source: https://cnx.org/contents/e7d9fbfa-04b4-4aad-aaf9-a9715015147b@2/A-Single-Population-Mean-using

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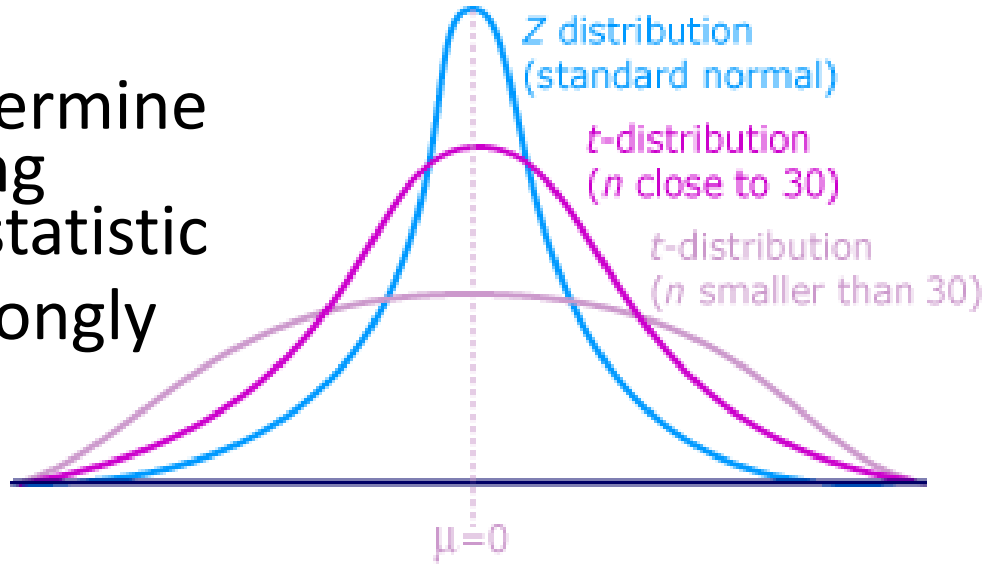
		Null hypothesis (H_0) is	
		True	False
Decision About Null Hypothesis (H_0)	Reject	Type I error (False Positive)	Correct inference (True Positive)
	Fail to reject	Correct inference (True Negative)	Type II error (False Negative)

Hypothesis testing

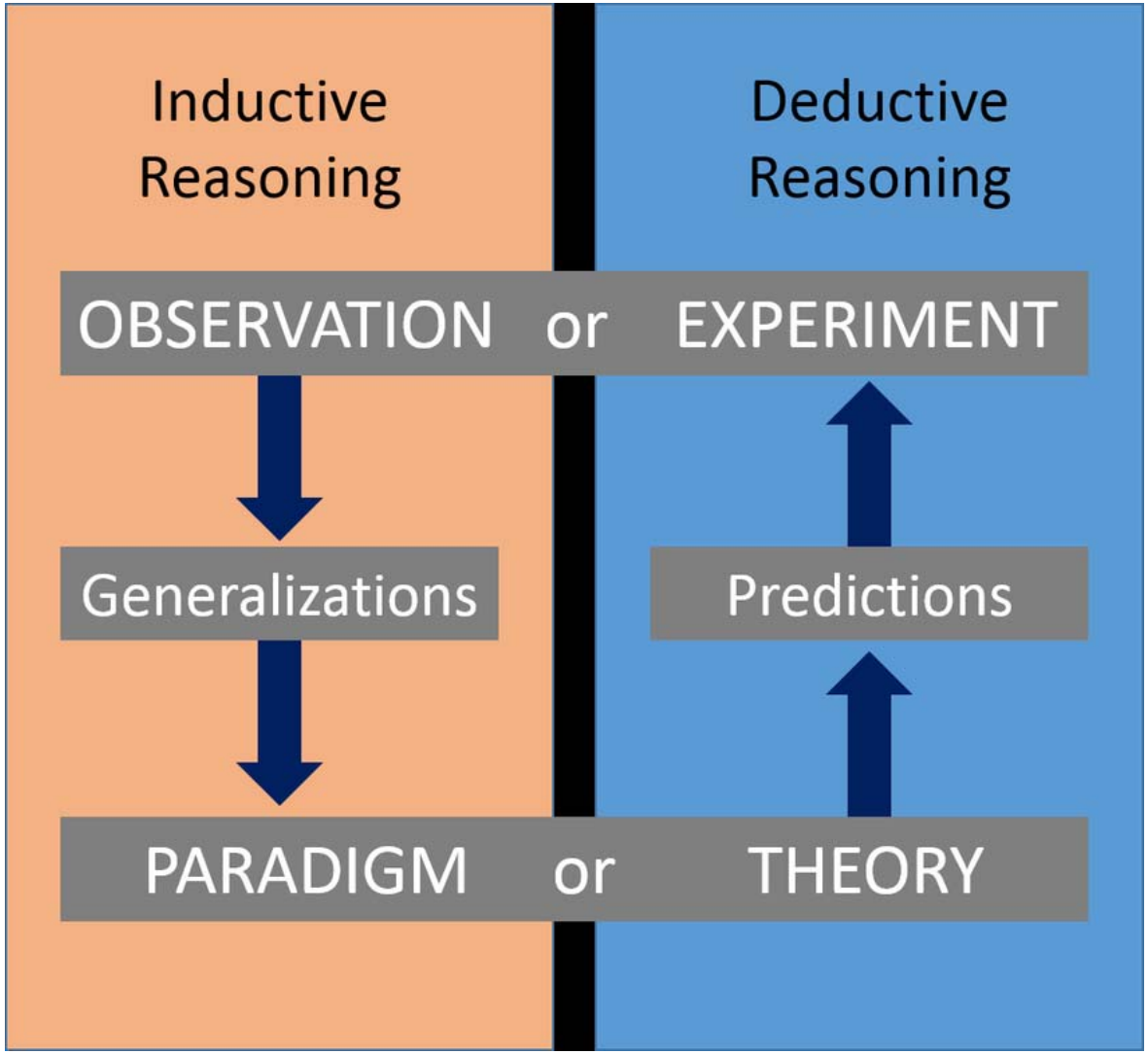
- **Test statistic:** difference between what was observed (the mean) and what is expected under H_0 – test statistic depends on the statistical test used (e.g., *t, F, Z,* X^2)
- **Null distribution:** used to determine what are the chances of having observed the calculated test statistic
- ***p*-value:** the probability of wrongly rejecting H_0

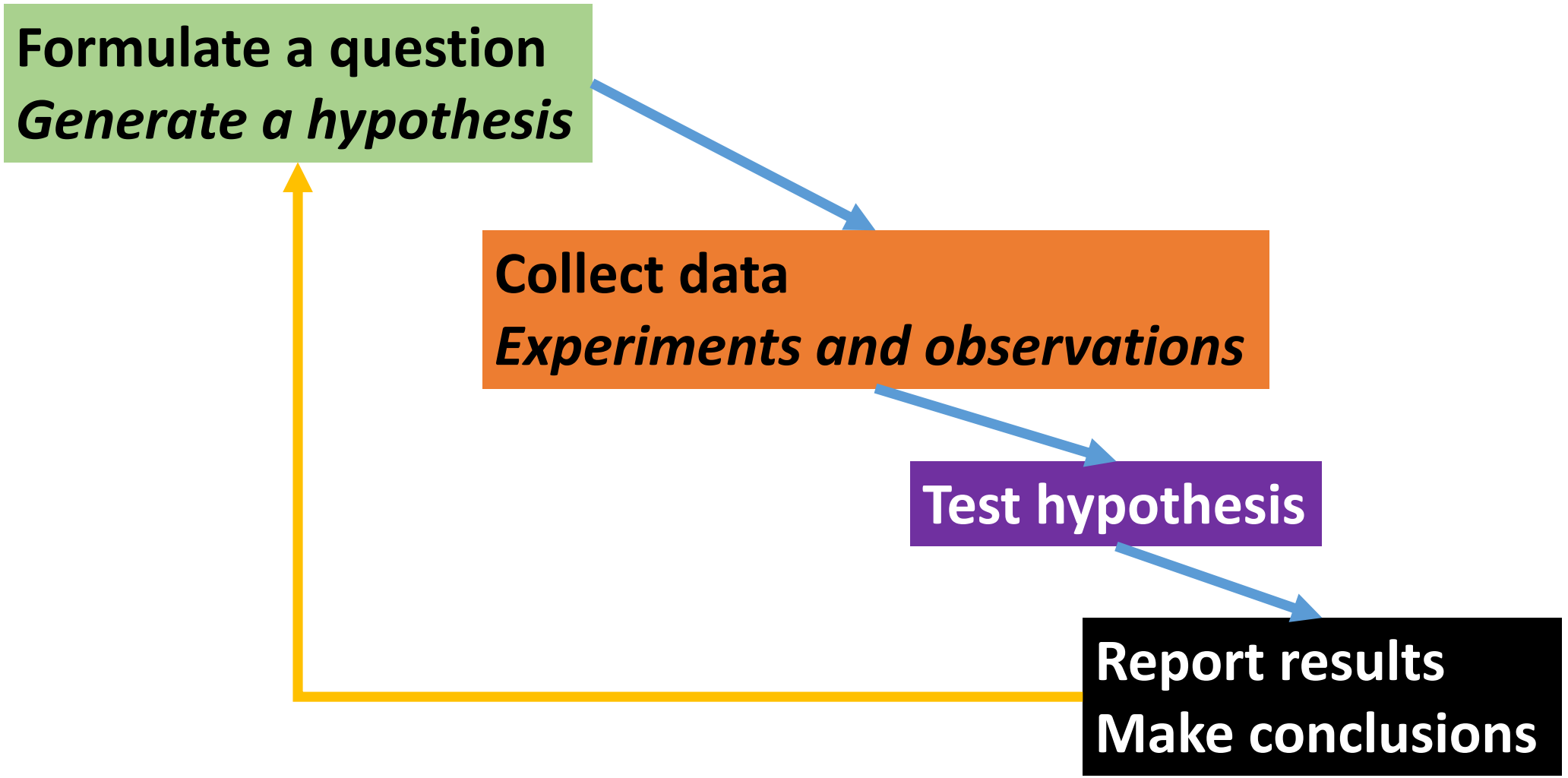


Source: http://ci.columbia.edu/ci/premba_test/c0331/s7/s7_4.html

Report results and conclusions

- Did you reject the null hypothesis?
- If not, is there another question or approach that would answer your overarching question?
- How confident are you in your results?


Inductive Reasoning
Deductive Reasoning
OBSERVATION or EXPERIMENT
Generalizations
Predictions
PARADIGM or THEORY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