SCIENCE AND THE SCIENTIFIC METHOD

What is Science

- A systematically organized **body of knowledge** on a subject.
  - ***Scientific Knowledge***
- The intellectual and practical ***activity*** encompassing the ***systematic study*** of the structure and behavior of the physical and natural world through ***observation and experiment.***
  - ***'Doing Science' via the Scientific Method***

Lets play a game

6 Steps of the Scientific Method

1. Ask a question based on observations (data)
2. Form a hypothesis
   - *Based on available data*
   - *Ensure falsifiability/refutability of the hypothesis*
3. Test the hypothesis
   - *Collect, Organize and Analyze the Data*
   - *Use statistical techniques to validate the data*
4. Draw Conclusions
   - *Does the results corroborate the hypothesis?*
   - *Does the hypothesis need to be refined?*
   - *Is there any unpredicted and emergent property observed*
5. Communicate the results
   - *Publish the results for peer review*

What is a law? How is it different from a theory?

Which one is better?

STEP 1: Ask a question

- Ask a question that can be answered scientifically
  - *It should be answered through observations and analysis*
- Some questions are beyond the reach of science
  - *Philosophers would handle that*

Step 2: Form A Hypothesis

- Based on your observation a Hypothesis is formed that tries to explain your observation or answer your question
  - ***A hypothesis tries to predict or determine the outcome of your experiment even before the experiment is done***
    - Predictions usually stated in an “if ….. Then” statement. Ex: If I drop a rock then it will fall down toward the ground
- Hypothesis must be **testable** and **falsifiable**/refutable

Testability and Falsifiability

- Testability means the capability of being tested scientifically.
  - An idea is testable when it logically generates a set of expectations about what we should observe in a particular situation.
- falsifiability or refutability is the capacity for a statement, theory or hypothesis to be contradicted by evidence.
  - *Karl poppers contribution*
  - *Lets mindstorm examples*


3sat

Bold Hypothesis that can be proven wrong easily is a better scientific hypothesis!

Scientists should design their experiments to disprove their hypothesis and *not to* prove it!

A proven or corroborated hypothesis *just* proves that the theory is not refuted *yet*!

There is no way to prove a theory, but only ways to refute it!

Step 3: Test the Hypothesis

- Collect more data
- Analyze the data
- See if it corroborates the hypothesis (see if we can refute it)
  - *If not, its wrong no matter who you are*


Vox
DARKROOM

Step 3.1: Data Collection

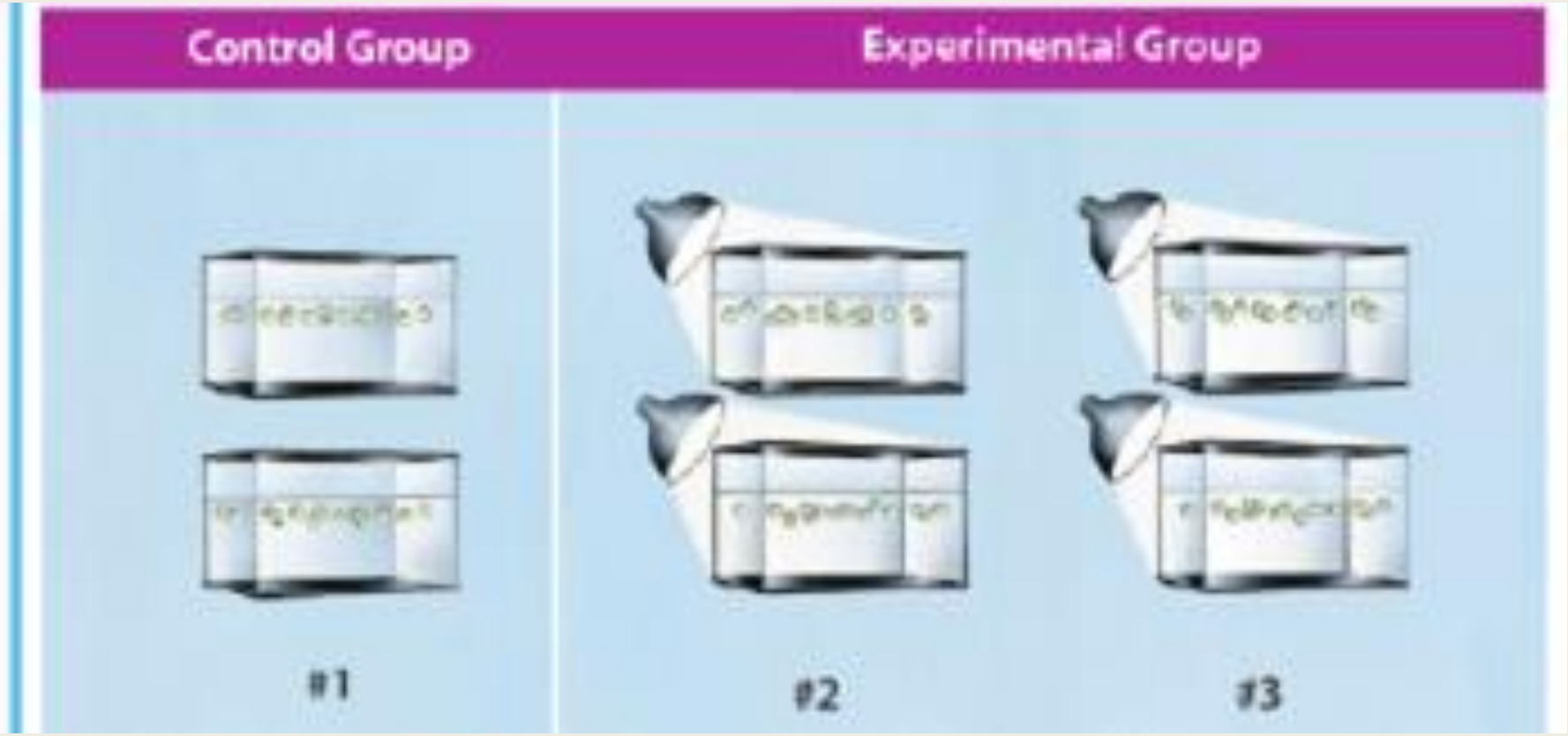
- Collect data via exploration or experimentation
  - *fossil hunting for Paleontologists*
  - *Scanning the sky using a Telescope for astronomers*
  - *Surveys for Social Scientists*
  - *The lucky ones get to do controlled experiments in the lab*
  - ***Even more lucky ones** can do **computational simulations***

(May be even ABM simulations)

Step 3.1: Data Collection via Experimentation

- Plan the experiment carefully
  - *What are the independent/input variables*
  - *What are the dependent/output variables*
  - *What are the constants/invariants*
  - *Document any and all assumptions clearly*
- The setup
  - ***Control condition:*** *The independent variable is left at 'default' and the output is monitored (aka the Placebo group)*
  - ***Experimental condition(s):*** *The independent variable is varied methodically and the output is monitored*

Sample Experiment: Does plants grow better when exposed to UV light?



Control condition
No UV light

Experimental-1
UV-15 days

Experimental-1
UV-30 days

Sample Experiment: Does plants grow better when exposed to UV light?

- Dependent variables: factors indicating plant growth
  - *No of new leaves/flowers*
  - *Height of the plant*
  - *Girth of the stem*
- Independent Variable: The amount of UV exposure measured in no of days
  - *It's always better if you have only one independent variable*
  - *Things can become convoluted otherwise*
- Constants/Invariants:
  - *Soil, Fertilizer, amount of water, amount of natural light source, etc.*

Step 3.2: Collect, Organize & Analyze Data

- Data collected from experiments
  - *Data is defined as: recorded observations or measurements (qualitative = description, quantitative = number data)*
    - How nice is the smell of flowers from plant exposed to UV light (qualitative)
      - *Bad smelling, OK smelling, Better smelling, Great Smelling*
    - The height of the plant from root to the tallest point (quantitative)
- Data is organized in tables, charts and graphs so that it can be more easily analyzed

Step 3.3: Hypothesis Testing

- To tell whether our data supports or rejects our ideas, we use statistical hypothesis testing.
- The problem is that we often get data that seem to support our ideas. The literature is full of papers that accept a pet idea uncritically. Statistical testing keeps scientists honest.
- If you read a paper that suggests some alternative hypothesis should be accepted, but there is no statistical test, don't believe it.
  - *We will dedicate another detour session (we might use some results that are from our models)*

Step 4: Draw Conclusions

- Scientists decide whether the results of the experiment support a hypothesis.
- When the hypothesis is not supported by the tests the scientist must find another explanation for what they have observed.
  - *There is **no meet in the middle** or compromise*
  - *Either your hypothesis is correct: it accounts for all observations (before and during experiment)*
  - *Or it is wrong*

Step 5: Communication and Peer review

- Results must be communicated in the form of a publication
  - *Remember the Cruel game of Nature*
- Communication helps other scientists performing the same experiments to see if the results of your experiment are the same as their results
  - *Helps people see if results are repeatable!*

Summary: The Scientific Method

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.....*The Father*.....