SCIENCE FAIR INQUIRY PROJECT


WHAT IS THE BEST WAY TO
GROW A PLANT?

PROJECT OVERVIEW

- Groups of 3-4 (you pick)
- Will design and carry out a single-variable controlled experiment over the course of several weeks
- Collect data and present your findings to your classmates

VOCABULARY

- Testable question
- Hypothesis
- Prediction
- Variables:
  - Control variable
  - Independent variable
  - Dependent variable
  - Confounding variable
- Control group
- Treatment/experimental group

WARM-UP DISCUSSION

1. What is science? Why is it important?
2. Describe the scientific method in your own words.
3. Distinguish between a scientific theory and an everyday "theory".

THE NEED FOR SCIENCE: CORRELATION VS CAUSATION

Module 1

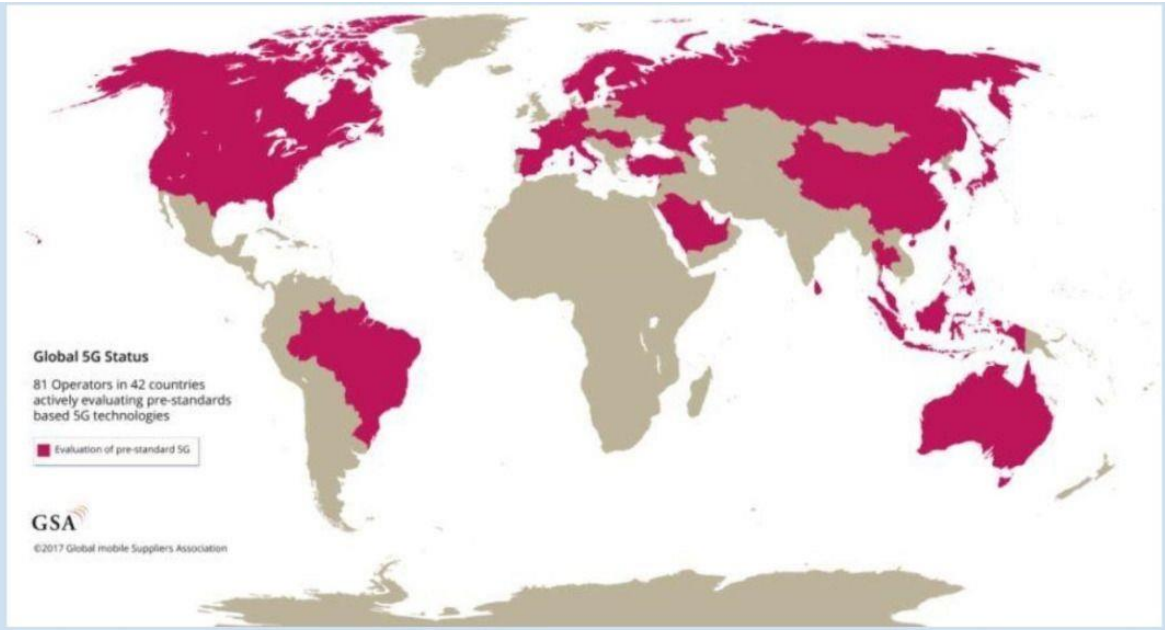
FACT: 5G CAUSED COVID-19

Source: The Science Page

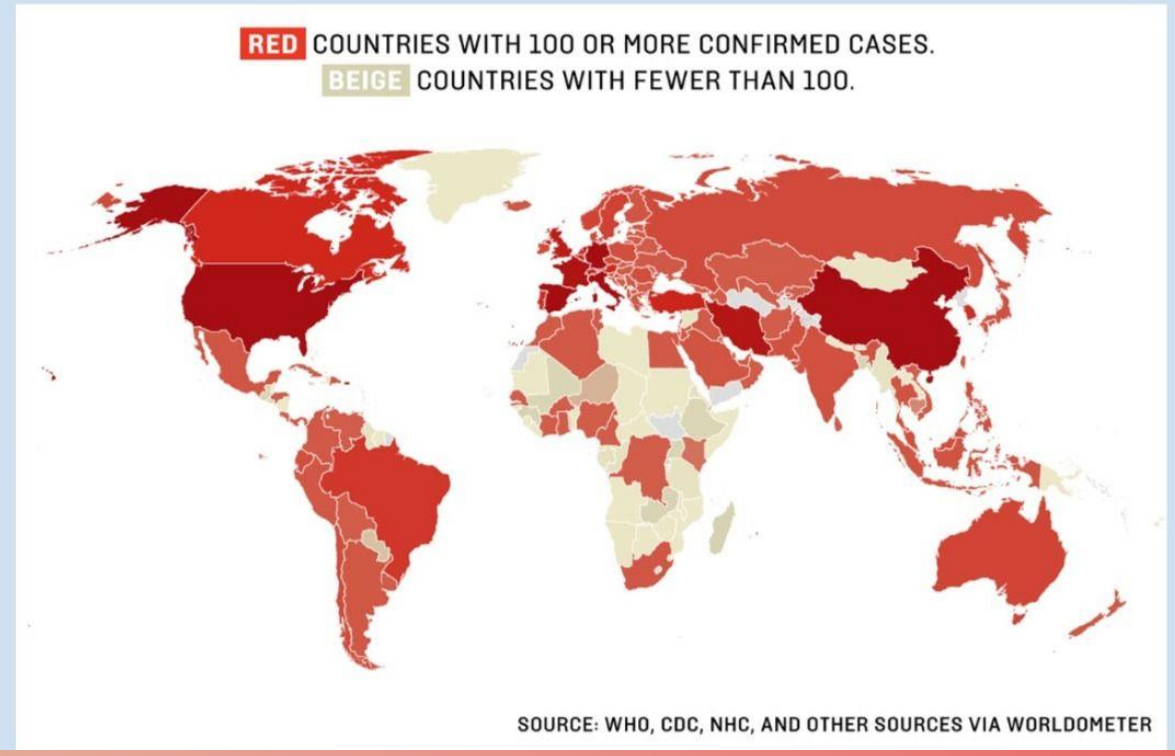
FACT: 5G CAUSED COVID-19

Source: iAfrikan.com

5G



Covid-19



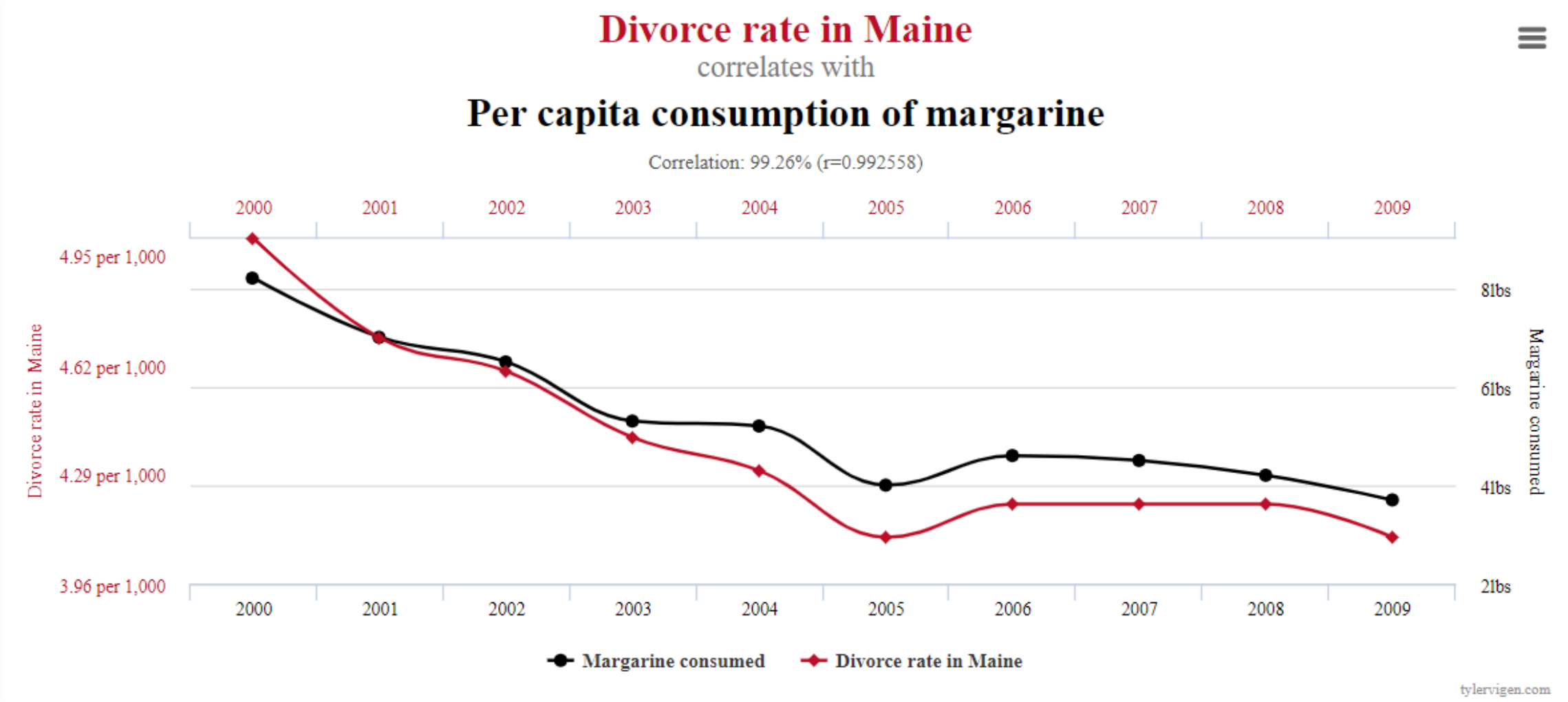
FACT: 5G CAUSED COVID-19

Source: Manchester Evening News

CORRELATION IS NOT CAUSATION

- **Correlation**: a mutual relationship or connection between two or more things (Oxford Dictionary)
- The maps show there is a correlation between 5G coverage and COVID-19 cases.
- What are some alternate explanations for this correlation?

https://www.tylervigen.com/spurious-correlations

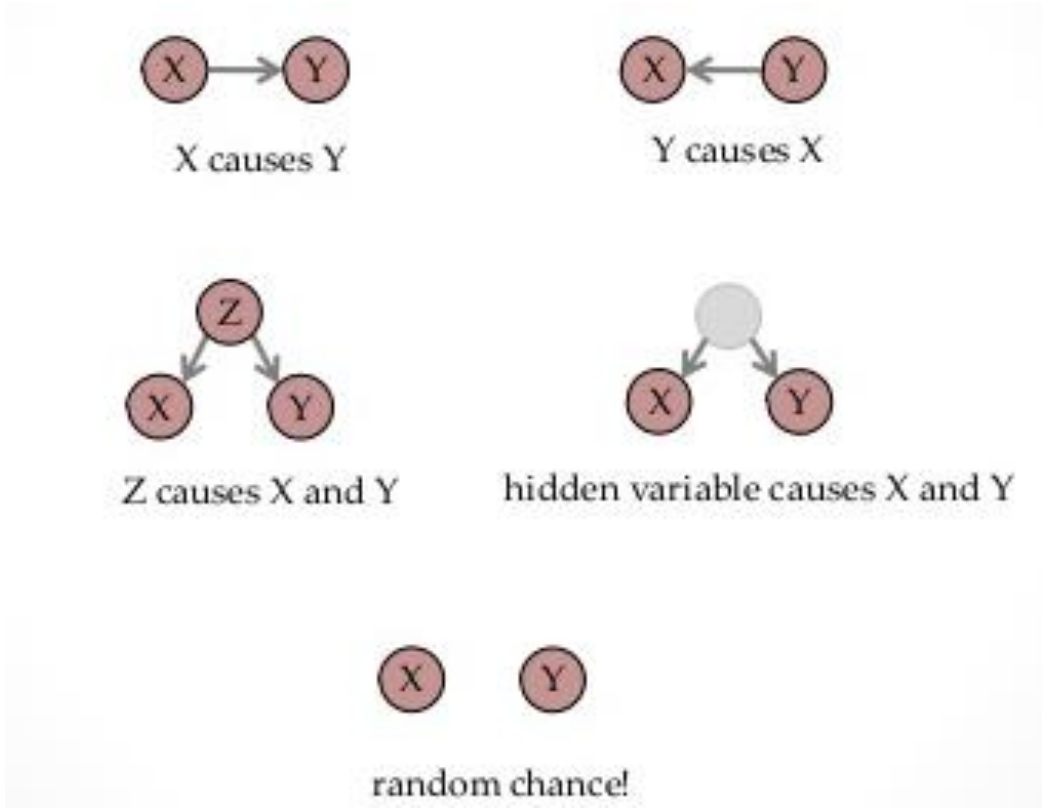


Data sources: National Vital Statistics Reports and U.S. Department of Agriculture

CORRELATION IS NOT CAUSATION

It is fairly straightforward to show that two variables are related.

But to show that x *causes* y, we need to conduct a controlled scientific experiment.



https://www.slideshare.net/JonathanStray/frontiers-of-computational-journalism-week-4-statistical-inference

VARIABLES

Module 2

THOUGHT EXPERIMENT

What factors will affect how a plant grows?

What are some different things we could observe or measure about a plant?

THOUGHT EXPERIMENT

What factors will affect how a plant grows?

- Watering (total amount),
- Atmospheric gas concentration
- Fertilizer/plant food
- Brightness or intensity of light
- Soil quality and quantity

THOUGHT EXPERIMENT

What are some different things we could observe or measure about a plant?

- Height
- Growth rate
- Total growth (e.g. maximum height)
- Colour
- Number of leaves/seeds/flowers
- Whether it germinates or not
- Health (how do its leaves appear? Has it caught any diseases?)
- Thickness of stem

VARIABLES

- An element of an experiment that changes or can be changed
- Is a "general category" which different observations or values could be assigned to

Variable	Qualitative & Quantitative Observations (Not Variables)
Temperature	5°C, 205°C, freezing, warm
Colour	Blue, white, pink, light with a 690nm wavelength
Growth Rate	Fast, 5 cm/day, 2 mm/hour
Gender	Male, female, transgender, two-spirit

VARIABLES

4 types:

- Dependent variable
- Independent variable
- Control variable
- Confounding variable

DEPENDENT VARIABLE(S)

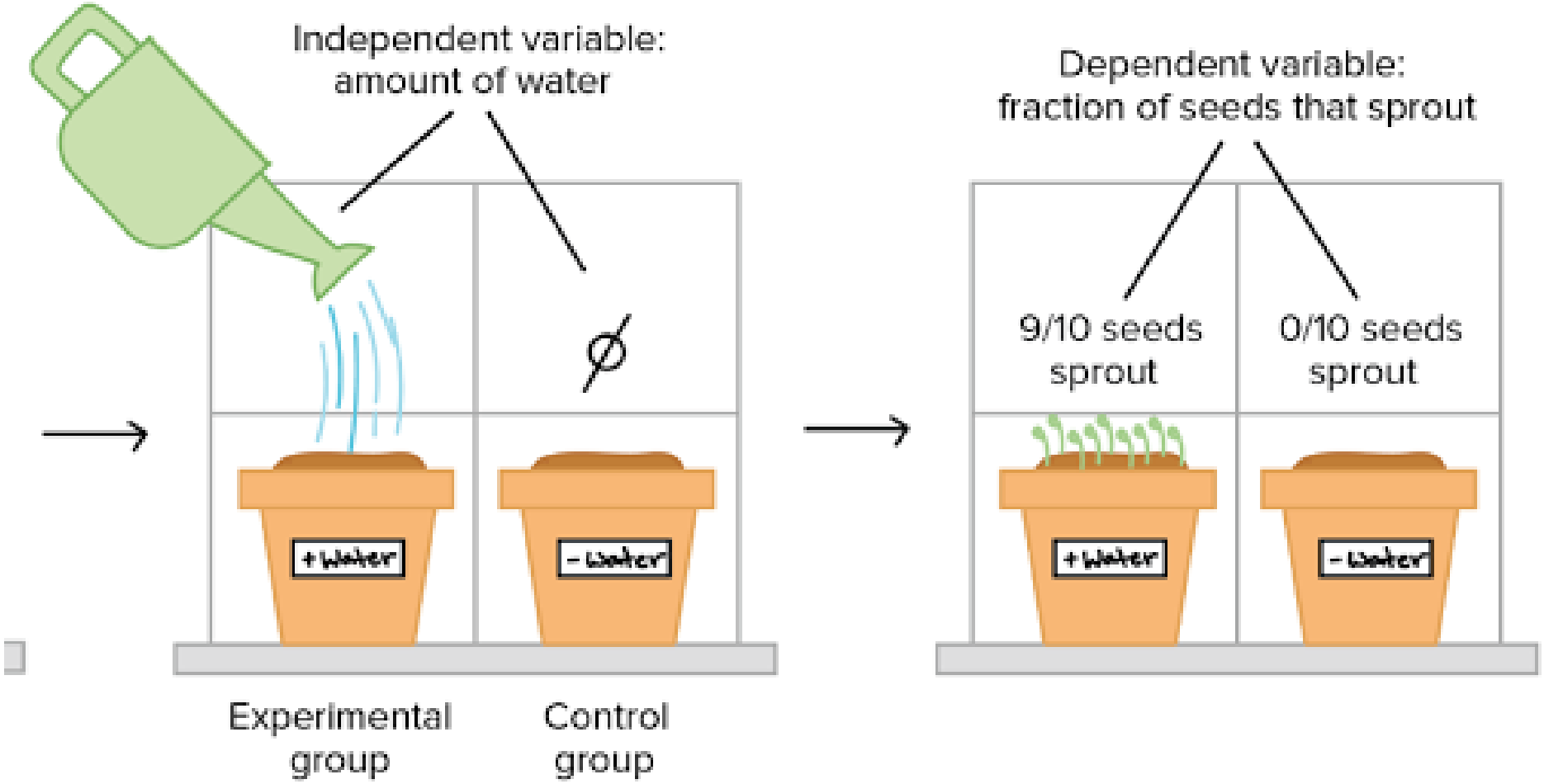
- The **dependent variable** is “y”: the variable whose value you are most interested in **measuring or observing**
- You think it will *depend* upon another variable (“x”), and that it will change when you manipulate the value of x.

DEPENDENT VARIABLE(S)

- In this experiment, your ***dependent variable*** will be something relating to ***plant growth***.
- Often, scientists will measure more than one dependent variable in an experiment.
  - You are welcome to if you wish, especially if you think it will strengthen your project. E.g. perhaps you measure "growth" in more than one way. However, you are advised to focus on one main dependent variable.

INDEPENDENT VARIABLE

- After selecting your dependent variable, brainstorm all the different factors that *could* affect your dependent variable. Pick one to be your **independent variable**: this is what you will be **manipulating or changing on purpose**.



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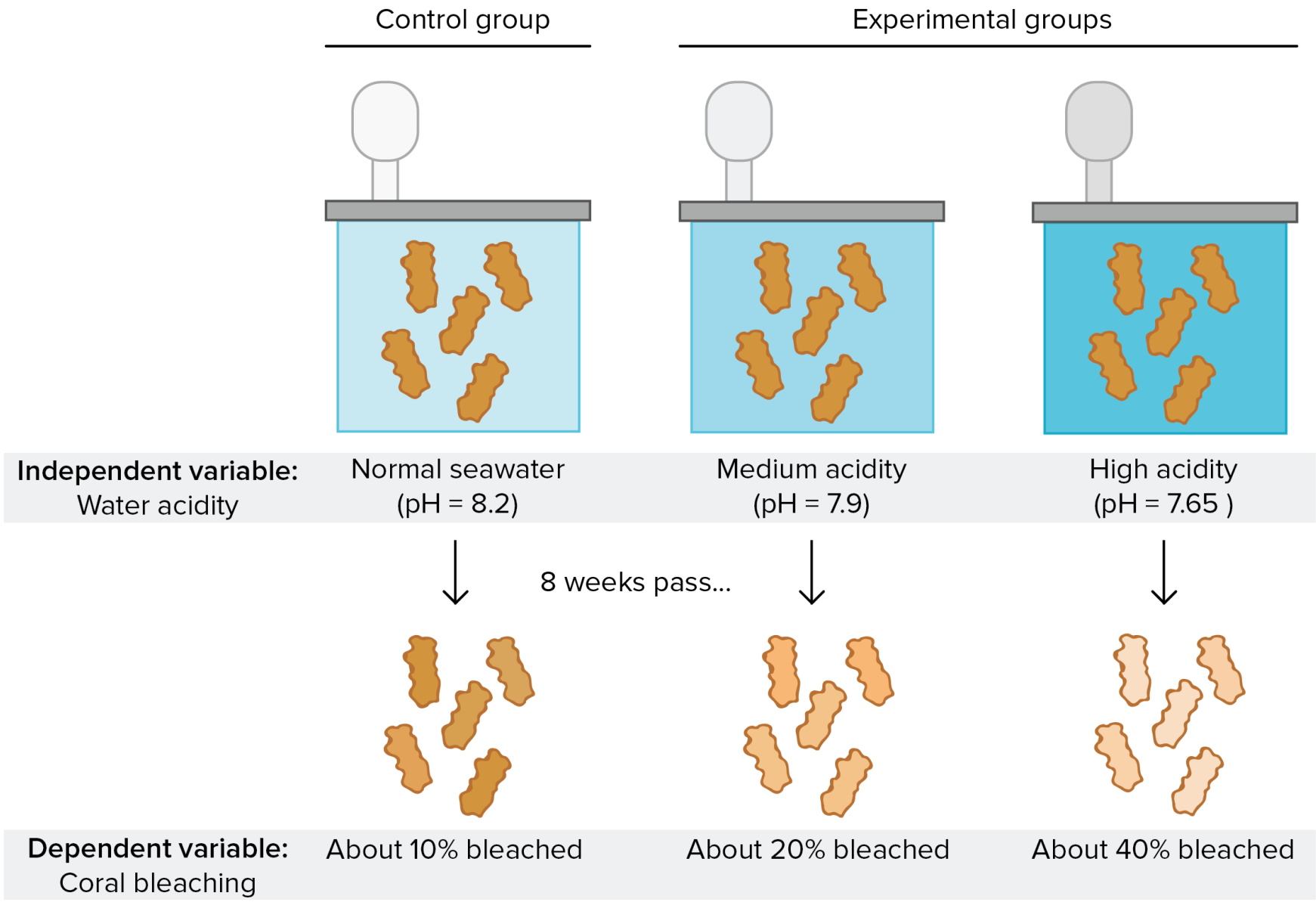

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CONTROL VARIABLES AND CONFOUNDS

- Every other "factor that could affect your dependent variable" must be controlled for and made the same across your experiment. It must be a **control variable**.
    - You must control for every relevant variable. If not, you will have **confounding variables**: they affect your experiment and now you have no idea whether the effect you observe in "y" is because of the change you made to the independent variable, or because of one of your confounds.

MATH TEST EXAMPLE

Suppose we are investigating students' scores on a math test. This is our dependent variable.

What factors might affect this?

- How much they study
- How they study
- When they study
- How much sleep they get
- Whether they have coffee
- Class attendance
- IQ
- Whether they like math or not
- The teacher they have
- Whether they did their homework
- How long they take on the test

MATH TEST EXAMPLE #1

Select 30 students who take Kumon after school, and have them take it online for a month. At the end of the month, each student takes a test on fractions. These scores are compared to those of students who continued to receive in-person instruction.

1. Identify the independent, dependent and control variables.
2. Identify confounding variables, if any.
3. Critique this experiment. What is done well? What would you do differently? What information is missing?

MATH TEST EXAMPLE #2

Select 100 B-level students who are all in Mr. Wilton's Gr. 7 class.

All of them are asked to take a survey before participating in the study. Students are excluded from the study if they: had any tea or coffee in the morning; had outside of 7-9 hours of sleep that night, or have ever learned about algebra before.

All of them attend a 2-hour class on algebra. Then, they have an hour to do practice questions. Half the students work alone; the other half work in pairs. After, they have 30 minutes to write the same algebra test.

Their scores at the end of the test are compared.

1. Identify the independent, dependent and control variables.
2. Identify confounding variables, if any.
3. Critique this experiment. What is done well? What would you do differently? What information is missing?

COMMON MISTAKES

- Your variable should be a general category, which can have different values. “temperature” and “height” and “colour” are variables; “cold”, “hot”, “cold vs hot”, “50 cm” are not variables…these are values or observations.
    - Sometimes it will be difficult to reword your variable…ask for help or a second opinion.
- Make sure you know very clearly what ‘control variable’ refers to. The word ‘control’ will come up again in a later context.

USING VARIABLES TO WRITE A TESTABLE QUESTION

Once you have your independent and dependent variables, you can write your **testable question** using one of the following formats to guide you:

- What is the effect of [i.v.] on [d.v.]?
- How is [d.v.] affected by [i.v.]?

Examples:

- What is the effect of after-school tutoring on university admission rates?
- How is the height of a marigold (*Tagetes* spp.) plant affected by the quality of sunlight it receives?

USING VARIABLES TO WRITE A TESTABLE QUESTION

Consider:

- Is your variable specific enough? E.g. “height” is too vague…”height” of what?
- If your variables don’t slot nicely into the sentence examples on the previous slide, you may need to take another look at how they are worded. Ask for help if unsure.

USING VARIABLES TO WRITE A HYPOTHESIS

Hypothesis:

- The expected relationship between the independent and dependent variables
- Should be an educated guess supported by observations and/or research

If … [independent variable] …
then … [dependent variable] …
because …

e.g. **If** a Gr 9 student's attendance improves, **then** their exam scores will improve, **because** increased exposure to in-class material and learning opportunities should lead to increased understanding and better retention.

Note: this is not the only way you can state your hypothesis. You can rearrange and reword as necessary, but the same basic elements should be there.

https://www.scribbr.com/research-process/hypotheses/#:~:text=Phrase%20your%20hypothesis%20in%20three,part%20states%20the%20dependent%20variable.

EXPERIMENTAL DESIGN

Module 3

INDEPENDENT VARIABLE

- Your independent variable should be a general category of something that you can manipulate or change about the experiment.
- Now it is time to determine the 'levels' of your independent variable. Suppose your independent variable is "amount of water". Then your levels could be:
  - 50 mL water per day
  - 100 mL water per day
  - 150 mL water per day
- But wait! Are we forgetting something?

INDEPENDENT VARIABLE

Often, we should have some idea of what is 'normal' for an independent variable. Examples for plants:

- Water amount → research how much that plant is supposed to receive per day
- Soil type → research the best type of soil to grow that plant

Examples for other studies:

- Calorie intake → research how many calories are recommended for an adult of that size and build

Build this 'normal' into our experiment…so we know what to expect.

CONTROL GROUP VS TREATMENT GROUPS

Our independent variable is “amount of water”. Research tells us:

- Keep soil evenly moist at all times. (https://www.gardenmanage.com/statuses/1000264091.html)
- Water to a depth of 4-6 inches. (https://garden.org/learn/articles/view/454/) (https://homeguides.sfgate.com/much-should-bean-plants-watered-32642.html#:~:text=Water%20Needs,system%20during%20the%20development%20period.)
- Use sprinkler or drip irrigation.

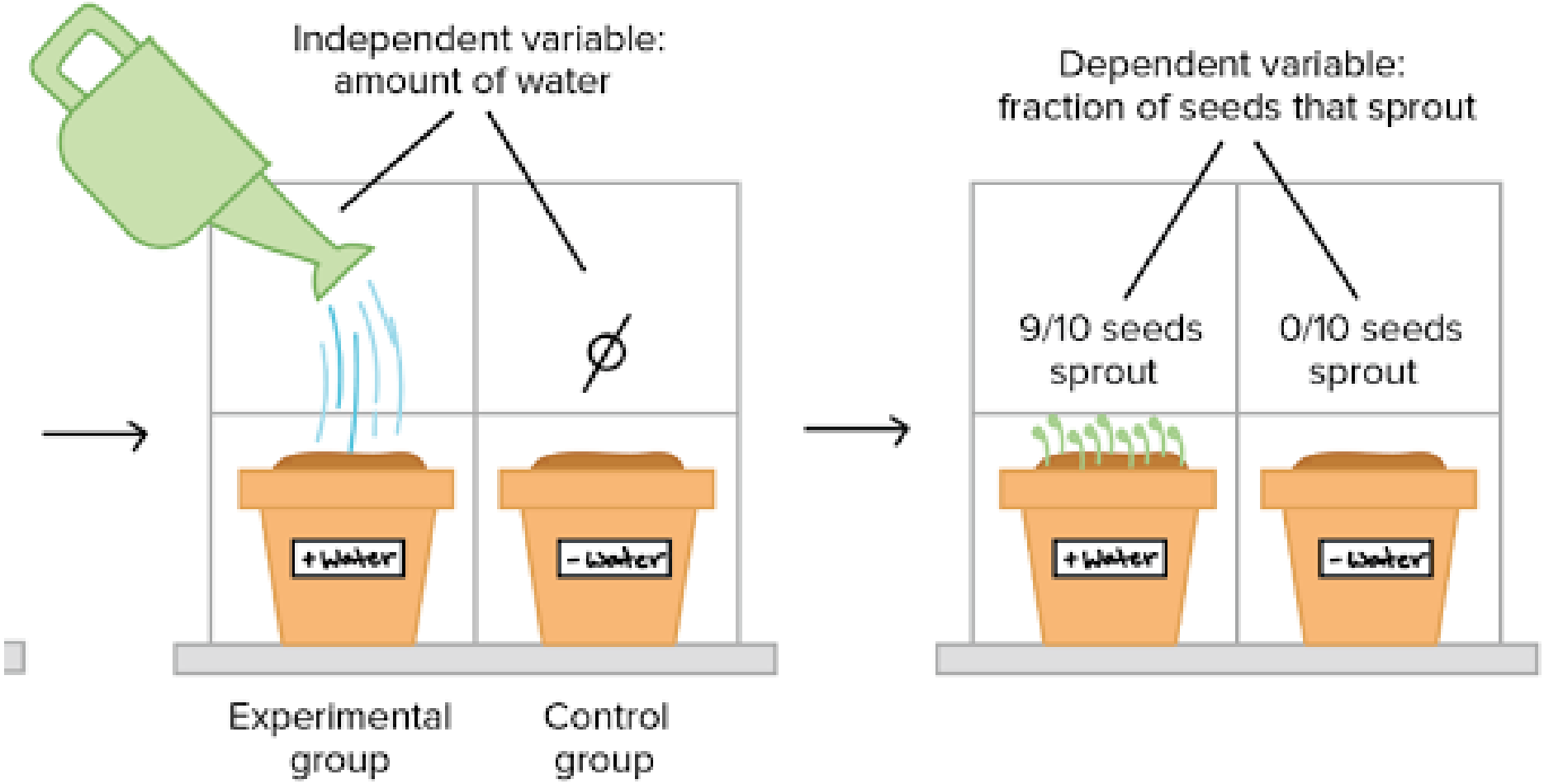
CONTROL GROUP VS TREATMENT GROUPS

- After playing around a bit with the materials we have, we determine that to meet these requirements, 15 mL of water per day per container, using a spritz bottle (because we don't have a sprinkler or irrigation system), will be our control group.
- We *expect* that in our **control group**, our plants will grow at a 'normal' rate, because we have followed growing advice from our research.

CONTROL GROUP VS TREATMENT GROUPS

Treatment group(s) are where we manipulate the independent variable, and are testing the [unknown] effect on the dependent variable. We will compare these groups to our control.

- 30 mL a day
- 45 mL a day



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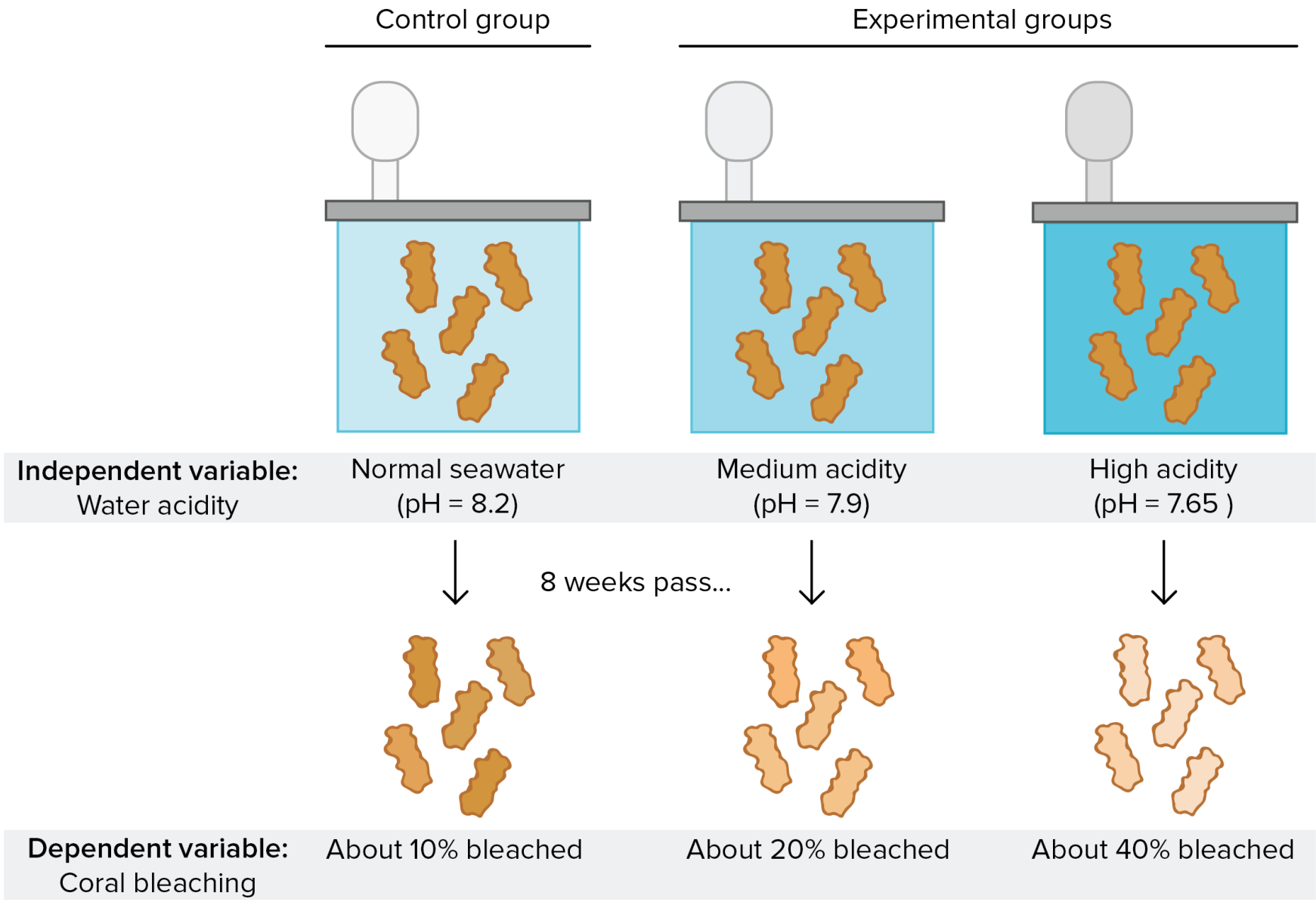

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EXERCISE

Suppose your dependent variable is each of the following. How would you measure it? Brainstorm all the ways you can think of.

- Rate at which incense burns
- Intelligence (of teenager)
- Intelligence (of baby)
- Soil moisture preference (of earthworm)

DRAFT YOUR EXPERIMENTAL DESIGN

Dependent variable:

- How will you measure this? When will you measure it?
- Be specific.

Materials:

- What will you use to grow your plant? How will the plants be planted?
- Design a care regimen for your plant.

MODULE 4 SUMMARY

- Characteristics of a good experimental design
- Trials, replicates
- Experimental Setup:
  - Diagram
  - Procedure Write-up
- Critiquing experimental design

CHARACTERISTICS OF GOOD EXPERIMENTAL DESIGN

- Large sample size
- Has a control group
- Manipulates only the independent variable. Controls for everything else. Minimizes the number of confounding variables.
- Avoids bias
- Has a clear-cut methodology that is replicable
- Systematically records observations in an objective, well-defined, and replicable way. Observations are not subject to observer bias.

CASE STUDY: COUNT MY BEANS

Natasha and her three friends drink 250 mL of Starbucks medium roast coffee (no sugar, no cream) right before doing a practice math test. On a different day, they do a different (but same level difficulty) practice math test, but do not drink coffee. On average, they performed 25% better when they had had coffee.

Their conclusion: Drinking coffee before math tests increases performance.

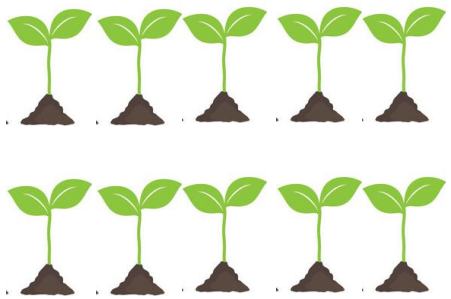
1. What was the testable question?
2. What could the group's hypothesis have been?
3. What was the independent variable?
4. What was the dependent variable?
5. What were some control variables? Are there any confounding variables that are not accounted for by this experimental design?
6. Which was the control group? Treatment group?
7. What questions do you have about the conclusion that they drew from this experiment?

SAMPLE SIZE

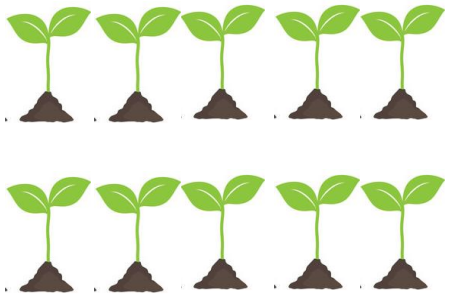
- The more times you repeat your experiment, the more likely your results are to be true (instead of the result of random chance, luck)
- Necessary for statistical analysis (calculating averages and standard deviation)

SAMPLE SIZE

- Goal: At *least* 10 subjects per treatment or control group. More if your experiment is easy/fast to conduct.
  - Subjects need to be alive! Err on the side of caution…have to account for germination rate → research!



Control group



Experimental group

SAMPLE SIZE: PRACTICAL CONSIDERATIONS

…But not so many subjects that they take up too much room. Each pod gets ~1 meter of windowsill.

CASE STUDY: SINGING + PLANTS

Timothy and Oscar are investigating whether singing to plants helps them grow faster. They plant bean plants into two plots: A and B. Each plot has 10 plants in it. They water the plants regularly and all the plants have the same exposure to sunlight. They sing to the plants in plot B only. Then, after three months, they record the growth rates of the plants. They conclude that singing to plants helps them grow faster.

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8. Given only the information from the experiment above, could you repeat this experiment? What information are you missing, that you would need?

CASE STUDY: SINGING + PLANTS

8. Given only the information from the experiment above, could you repeat this experiment? What information are you missing, that you would need?

- What bean species?
- How much water? What pH of water? What temperature of water? How frequently do they water?
- Where is this experiment conducted? What is the climate of the experiment?
- How do they sing? What song do they sing? How do they ensure the singing is the same every time? Is every plant getting the same musical experience? How is the music delivered: is there a confounding variable based on the fact that they have to walk around the vicinity of the plants?
- How are the plants protected from predation and other environmental factors?
- Is the soil the same in both plots? How do they know?
- How do they record growth rates?*
    - *What are some ways you could think of that they could have measured growth rate?

CASE STUDY: BEAN SCIENCE FAIR

- https://www.education.com/science-fair/article/making-plants-grow/

CLEAR-CUT METHODOLOGY

- A well-written Procedure means you have carefully thought through your experiment and all the variables that could affect your results.
- Detail, detail, detail! Examples of things that could affect your experiment:
  - Ambient temperature, climate, time of day, location
  - Identity of the experimenter
  - Size and material of apparatus (e.g. 500 mL glass beaker)
  - Species name (for biological experiments; no need for human experiments though)
  - Defining things precisely
    - E.g. Brown rabbits vs white rabbits. What if you had a white rabbit with two brown spots? What would this count as?
    - E.g. “added enough milk until the mixture turned cloudy” vs “added 150 mL of 2% Lucerne brand milk”
- Tip: Give your Procedure to someone else to read and see whether they have any questions about how you did something.