SCIENTIFIC METHOD

SCIENCE 8

OVERVIEW

- Scientific method overview of steps
- Observation types: qualitative and quantitative
- What is a variable?
- Experimental design examples
- Types of variables
- How to design your own experiment

INTRO TO THE SCIENTIFIC METHOD

Module 1

SCIENTIFIC METHOD

The scientific method is a* systematic and logical way of discovering the truth of ***how*** and ***why*** things work.

*It is ***not*** the only way. But it is widely used in science research because it is relatively immune to biases and distortions.

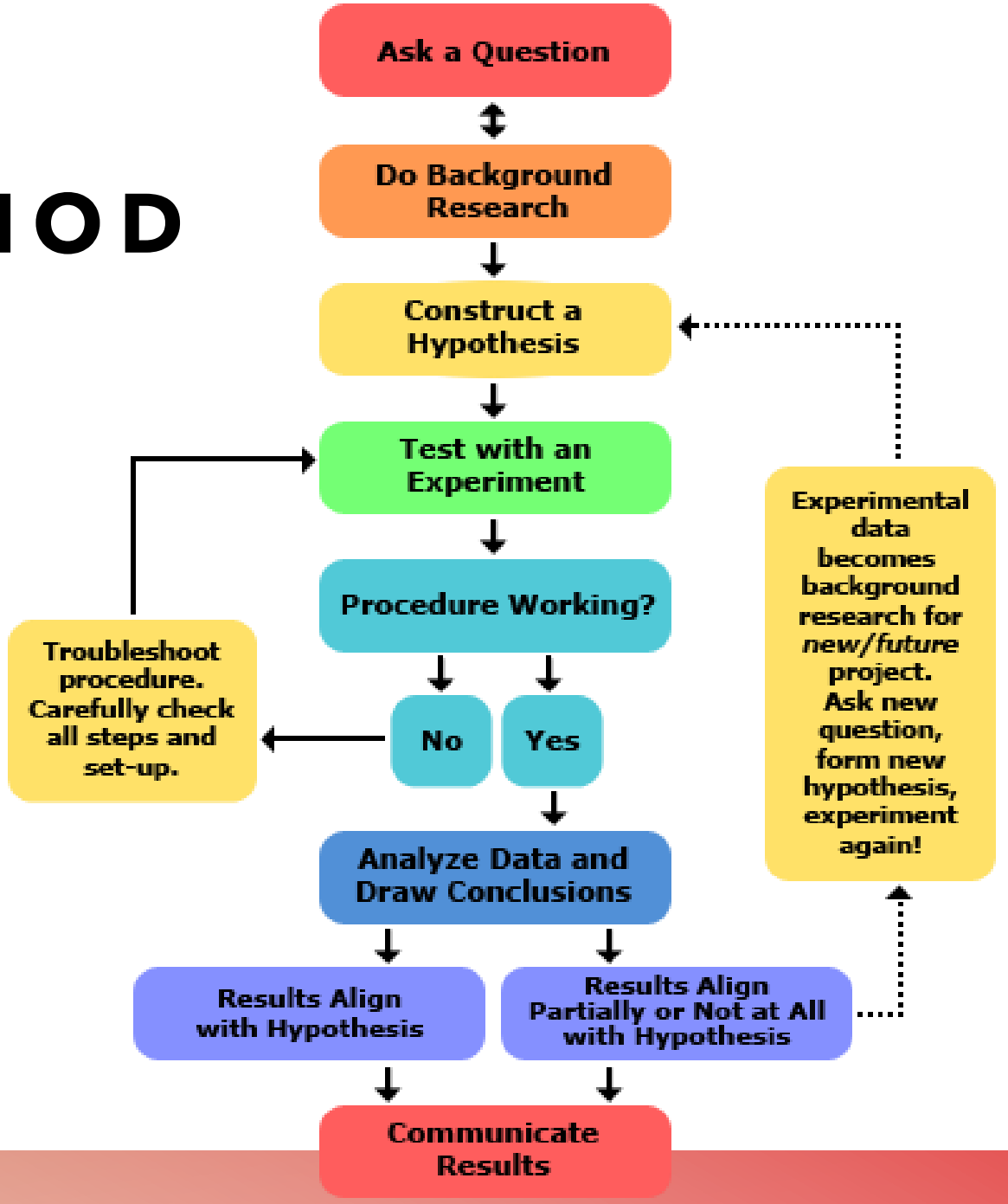
Discuss: What are some of the limitations of science and the scientific method? Are there any questions that science cannot answer?

SCIENTIFIC METHOD

Science never ends.

The search for the truth is ongoing; new findings influence future research.

Conclusions and findings are frequently altered as new techniques and facts are discovered.



SCIENTIFIC METHOD

https://www.youtube.com/watch?v=SMGRe824kak&ab_channel=Teacher%27sPet

SCIENTIFIC METHOD

https://www.youtube.com/watch?v=yi0hwFDQTSQ&ab_channel=Sprouts

SCIENTIFIC METHOD

Observation: all that can be observed with the 5 senses

Question: ask a question you would like to answer with your research

Research: use reliable sources to learn background information (avoid conducting experiments that have already been done)

Hypothesis:

- Specific prediction of what you believe will occur
- "If…then…" structure (e.g. "If gummy bears are placed in water for 24 hours then they will swell to over twice their original size.")

SCIENTIFIC METHOD

Experiment:

- Determine what types of data you will collect: qualitative or quantitative
- Manipulate the independent variable to observe the effects on the dependent variable
  - Experimental group: has one independent variable altered
  - Control group: all other groups are compared to this (normal)

QUANTITATIVE AND QUALITATIVE DATA

Module 2

WARM-UP ACTIVITY

Describe characteristics that your classmate (or best friend) has. Be creative and use as many different types of words and phrases as possible.

Now, describe the same person in the way you think a scientist would. How do the descriptions differ?

SCIENTIFIC OBSERVATIONS

- Making observations is central to science. It is how we come up with research questions. It is how we measure the results of our experiments.
- Scientific Observations: qualities about our experiment that we observe with our 5 senses or through measurement

QUALITATIVE OBSERVATIONS

- Using five senses to make observations using descriptive language
- Focuses on qualities or characteristics, is subjective and dependent on the observer
- Examples:
  - My hair is black
  - Her skin is warm
  - The sandwich is spicy

QUANTITATIVE OBSERVATIONS

- Using measurement tools to make observations
- Focus is on numerical values, is objective and reliable
- Examples:
  - The tea is 80°C
  - There are 20 people in this science 8 class
  - The hamster weighs 15.2 grams

NOTE

The same characteristic (or *variable*) can often be described qualitatively and quantitatively. Your only limitation is your creativity and the equipment available to you.

Example: temperature

- Thermometer (quantitative)
- How long it takes to melt an ice cube (quantitative)
- How hot it feels to your hand (qualitative)
- How loudly your sister screams when she touches it (qualitative)

NOTE

The same characteristic (or *variable*) can often be described qualitatively and quantitatively. Your only limitation is your creativity and the equipment available to you.

Example: colour

- What it looks like, e.g. red or blue (qualitative)
- The colour code using hexadecimal code (quantitative)
- Wavelength of light (quantitative)

ACTIVITY

How many ways can you think of to make observations about:

- Height of a person
- Growth rate of a plant
- Speed of an airplane
- Difficulty of a test

Go back and categorize your examples as qualitative or quantitative. If you have few of one type, try and come up with more of that type.

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
- Germination Rate
- Health (how do its leaves appear? Has it caught any diseases?)
- Thickness of stem

VARIABLES

- An aspect of an experiment that can have different values
- Is a general, non-specific category that many observations could fall under

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

VARIABLES

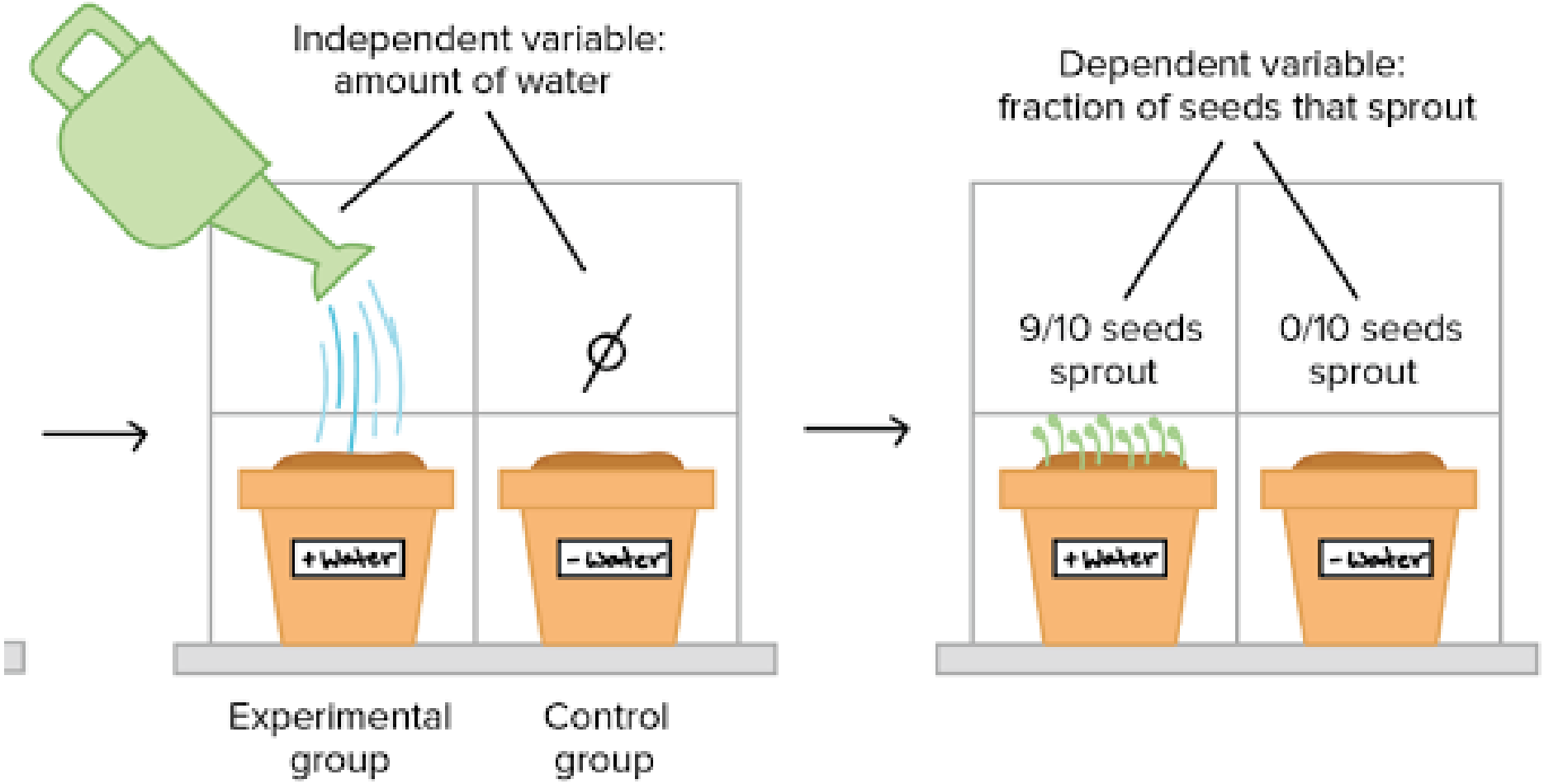
3 main types:

- Dependent variable
- Independent variable
- Control variable

INDEPENDENT AND DEPENDENT VARIABLES

Dependent variable: the variable you are most interested in ***measuring or observing***

Independent variable: the variable that is ***manipulated or changed by the experimenter***, to see the effect on the dependent variable



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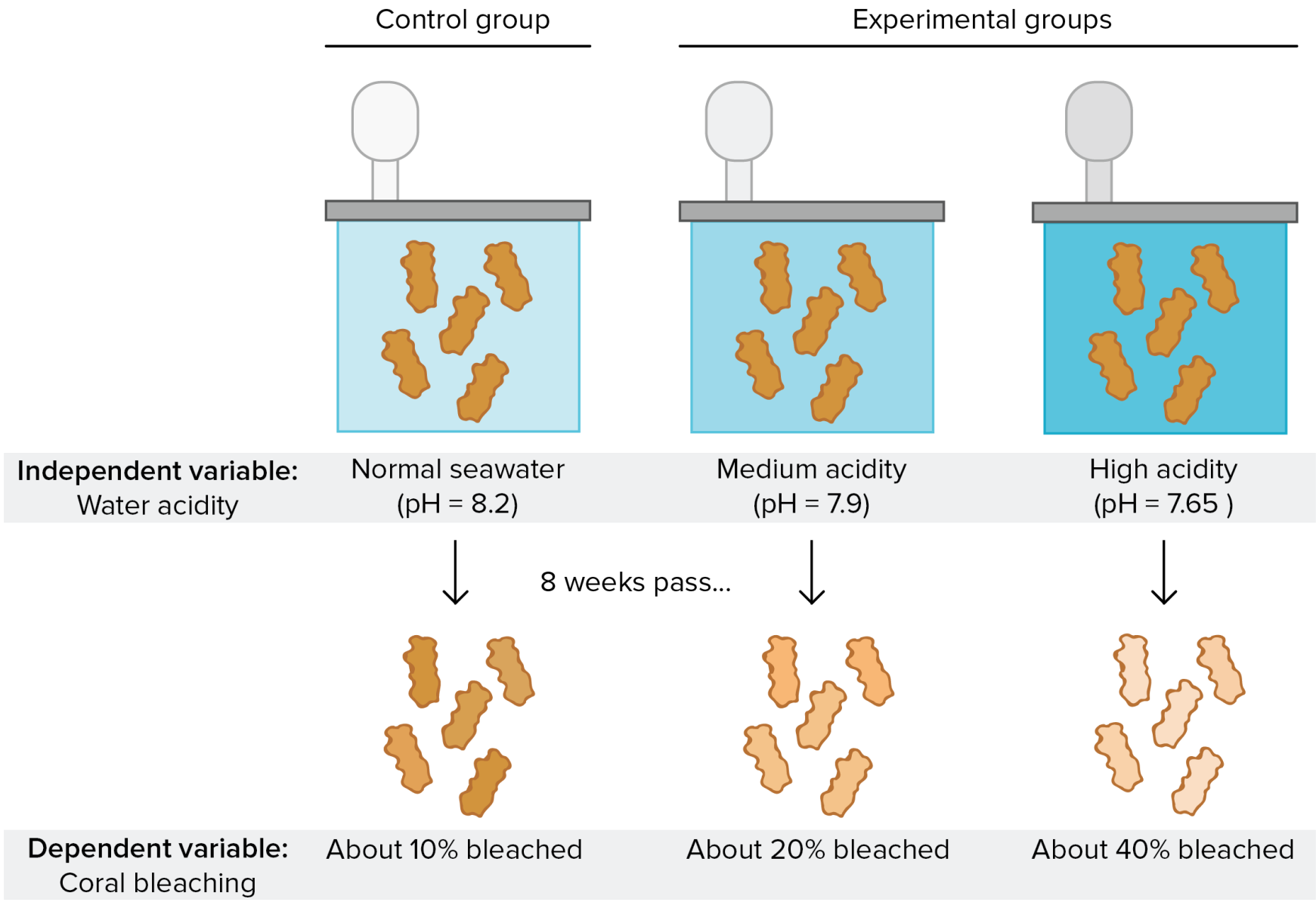


https://www.khanacademy.org/science/high-school-biology/hs-biology-foundations/hs-biology-and-the-scientific-method/a/experiments-and-observations

CONTROL VARIABLES

- **Control variable:** a variable that is kept the same between control and experimental groups

MILK EXPERIMENT

MATERIALS

- Petri dish bottom x1
- 25 mL graduated cylinder x1
- Blue food colouring bottle x1
- Scoopula
- Weighboat
- Electronic scale
- Wooden stick x1
- 15 mL tap water
- 3 g milk powder
- [Dish soap]

PRIOR OBSERVATIONS

Water:

- Quantitative observations (volume)

Milk powder:

- Quantitative observations (mass)
- Qualitative observations (colour, texture, appearance, smell)

Food colouring:

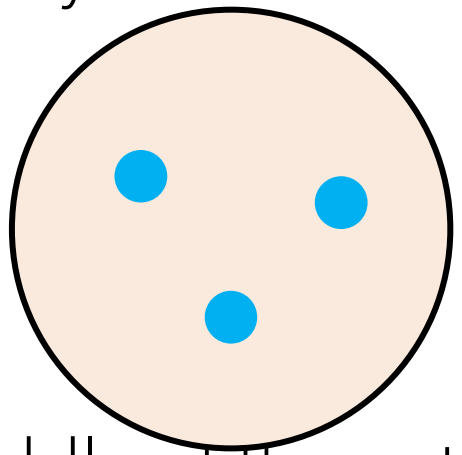
- Qualitative observations (colour)

Dish soap:

- Qualitative observations (colour, brand)

PROCEDURE

1. Add water and milk powder to petri dish. Stir gently with back of scoopula until powder is completely dissolved.
2. Add 3 drops of food colouring, evenly spaced out in the petri dish.
3. Dip the toothpick into the dish soap.
4. Touch the soaped end of the toothpick to the middle of the petri dish and leave it there for 0.5 seconds.
5. Make qualitative [and quantitative] observations about what you see.



/END FOR SCIENCE 8 2021-2022


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

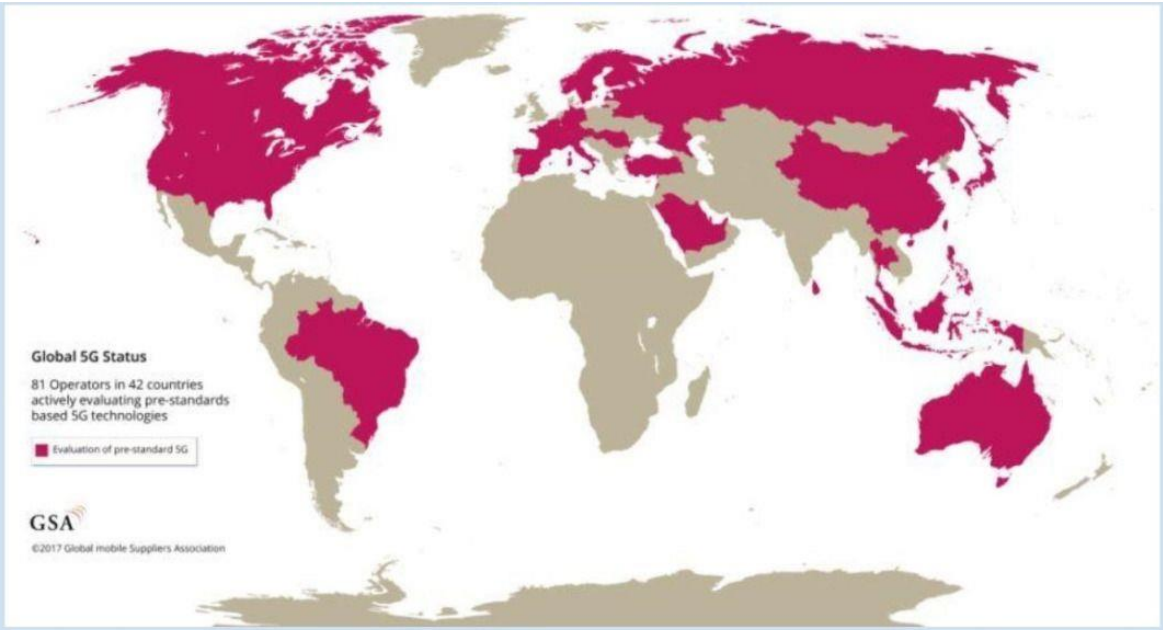
FACT: 5G CAUSED COVID-19

Source: The Science Page

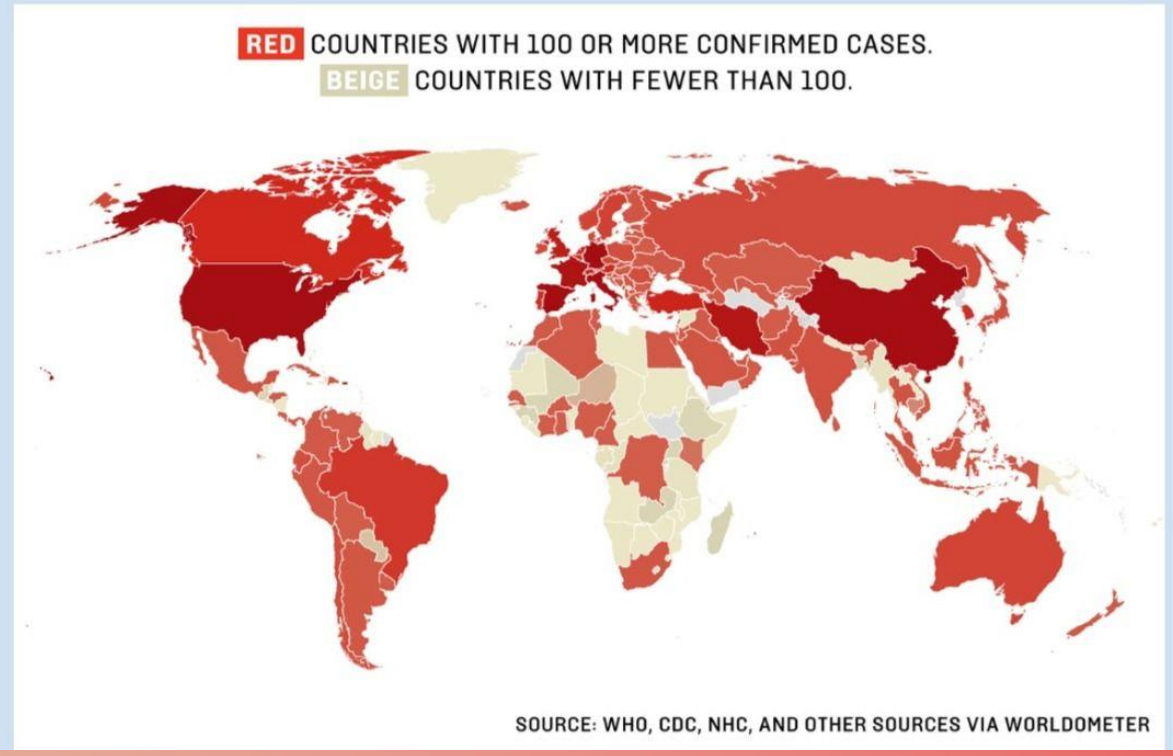
FACT: 5G CAUSED COVID-19

Source: iAfrikan.com

5G



Covid-19



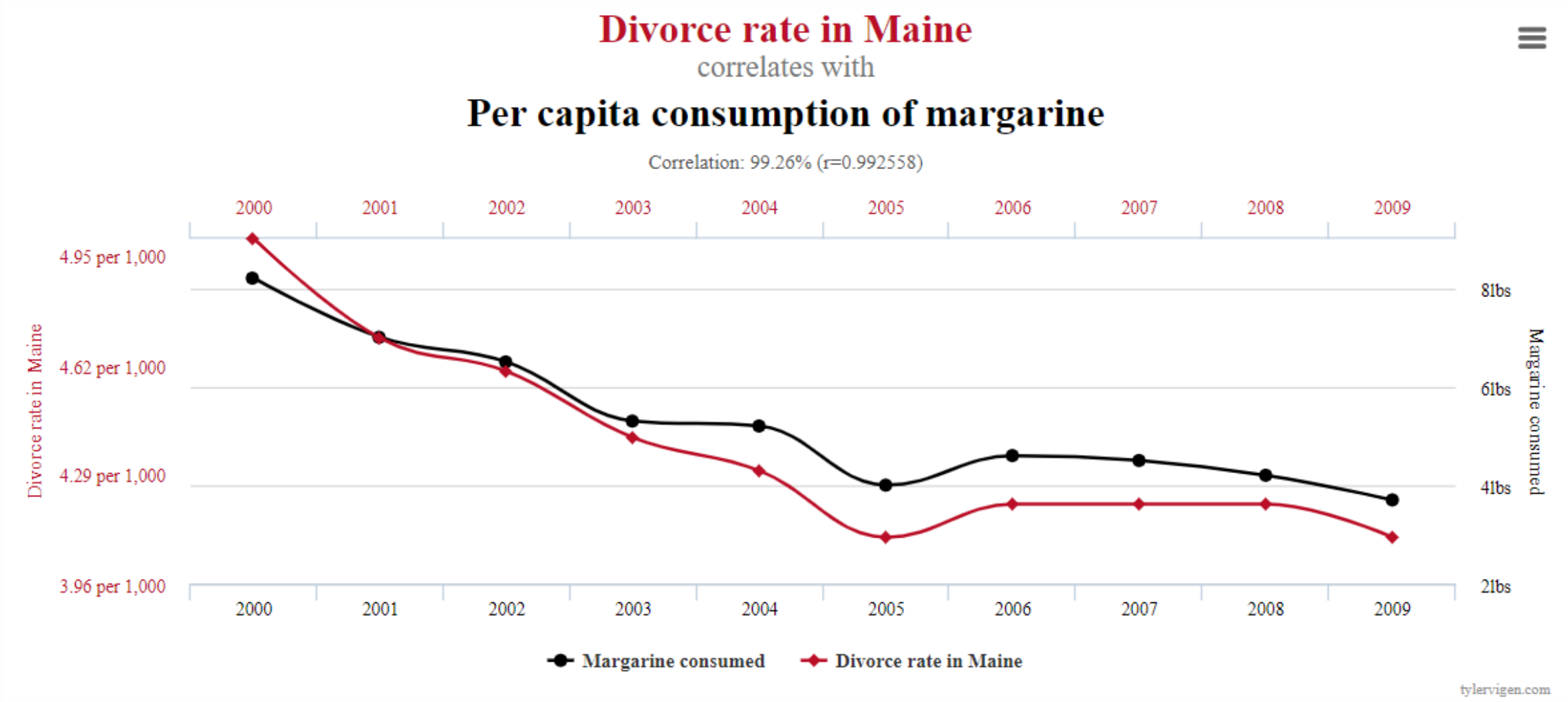
FACT: 5G CAUSED COVID-19

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

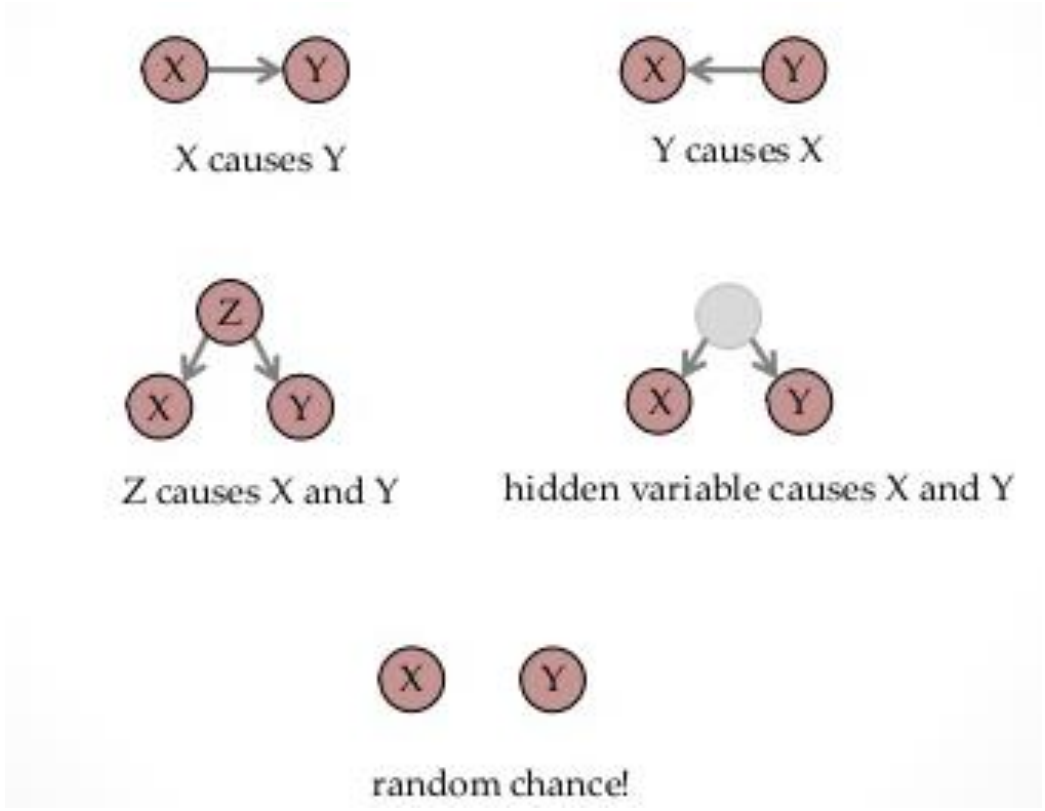


Data sources: National Vital Statistics Reports and U.S. Department of Agriculture

CORRELATION IS NOT CAUSATION

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

But to show ***causation*** (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

NOTE: DIFFERENT TYPES OF EXPERIMENTS

Observations: making observations in an unstructured way; is not a real experiment but can lead to formation of an experiment

- "What colour is ___?" "What does yeast mitosis look like?" "What happens if I do ___?"

Correlational Experiment: examines the correlation between two variables where manipulation is not possible; cannot claim causation

- "How does ethnicity affect salary?" "How does being dropped on the head at birth affect intelligence?"

Controlled Experiment: controls all variables except independent variable; can claim causative relationship between x and y

- "How does watering amount affect plant growth?" "Does the vaccine reduce the risk of catching COVID-19?"

HOW TO SET UP AN EXPERIMENT

0. (Ask a question.)
1. Determine your dependent variable. What factor are you most interested in measuring or investigating?
2. Brainstorm all the variables that could affect your dependent variable. Select one to be your independent variable. The rest must be control variables.
3. ~~Do some research.~~ Determine different level(s) of your independent variable to investigate. ~~Assign one to be your control group.~~
4. Write a step-by-step procedure for your experiment. Ensure you have included enough detail that someone could replicate your experiment.

HOW TO SET UP AN EXPERIMENT

Goldfish

https://www.youtube.com/watch?v=_VdOB4JJE_8&ab_channel=BrainSTEM

Running a Race

https://www.youtube.com/watch?v=iaewZmc4TYQ&t=5s&ab_channel=HighSchoolScience101

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.

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?

Their scores at the end of the test are compared.

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.

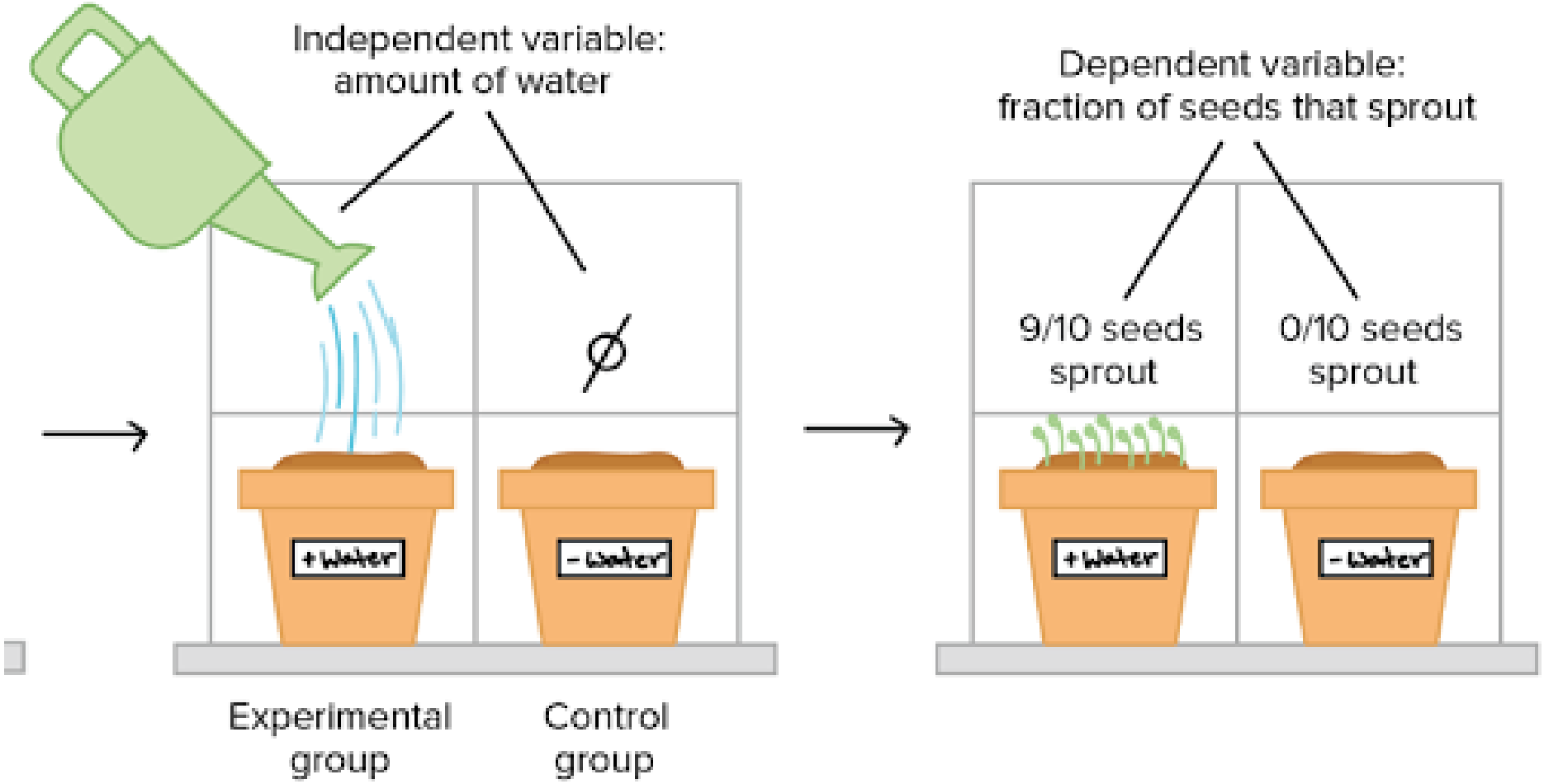
CONTROL GROUP VS TREATMENT GROUPS

- 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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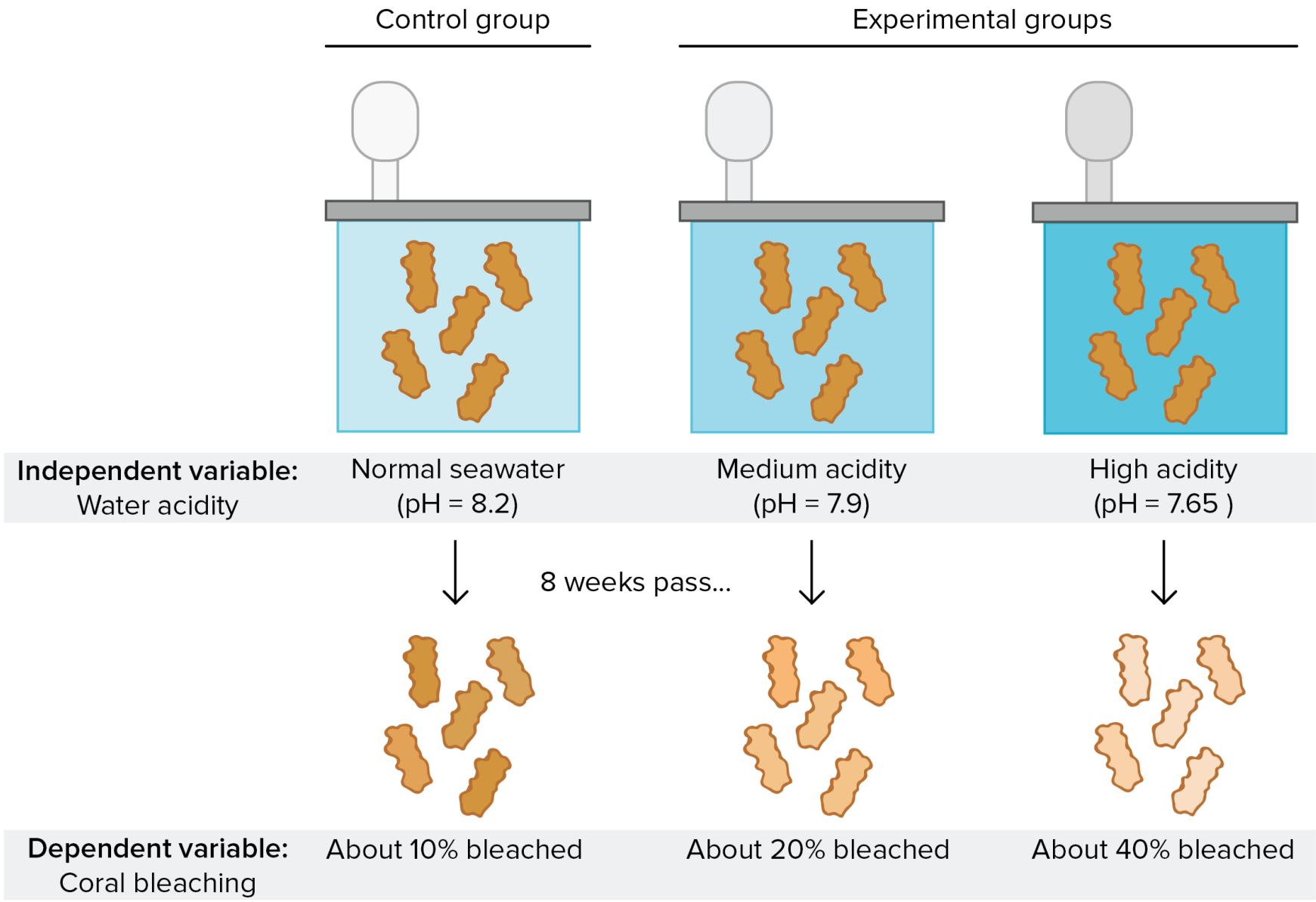

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EXERCISE

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.

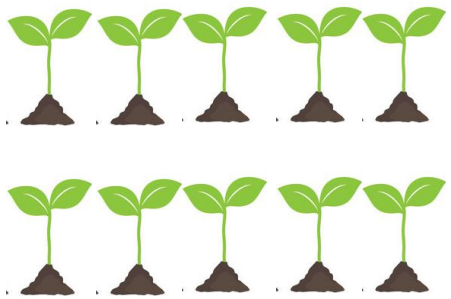
1. What was the testable question?
2. What could the group's hypothesis have been?
3. What was the independent variable?
4. What was the dependent variable?
5. What were some control variables? Are there any confounding variables that are not accounted for by this experimental design?
6. Which was the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

SAMPLE SIZE

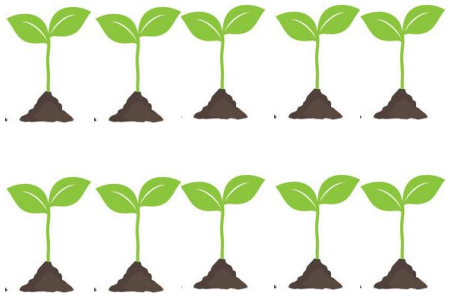
- The more times you repeat your experiment, the more likely your results are to be true (instead of the result of random chance, luck)
- Necessary for statistical analysis (calculating averages and standard deviation)

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.

1. What was the testable question?
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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.