SCIENTIFIC METHOD + EXPERTIMENTS

1. THE SCIENTIFIC METHOD

Scientific Method = Systemic and Objective Investigation

1. Purpose/Question
Ask a question.

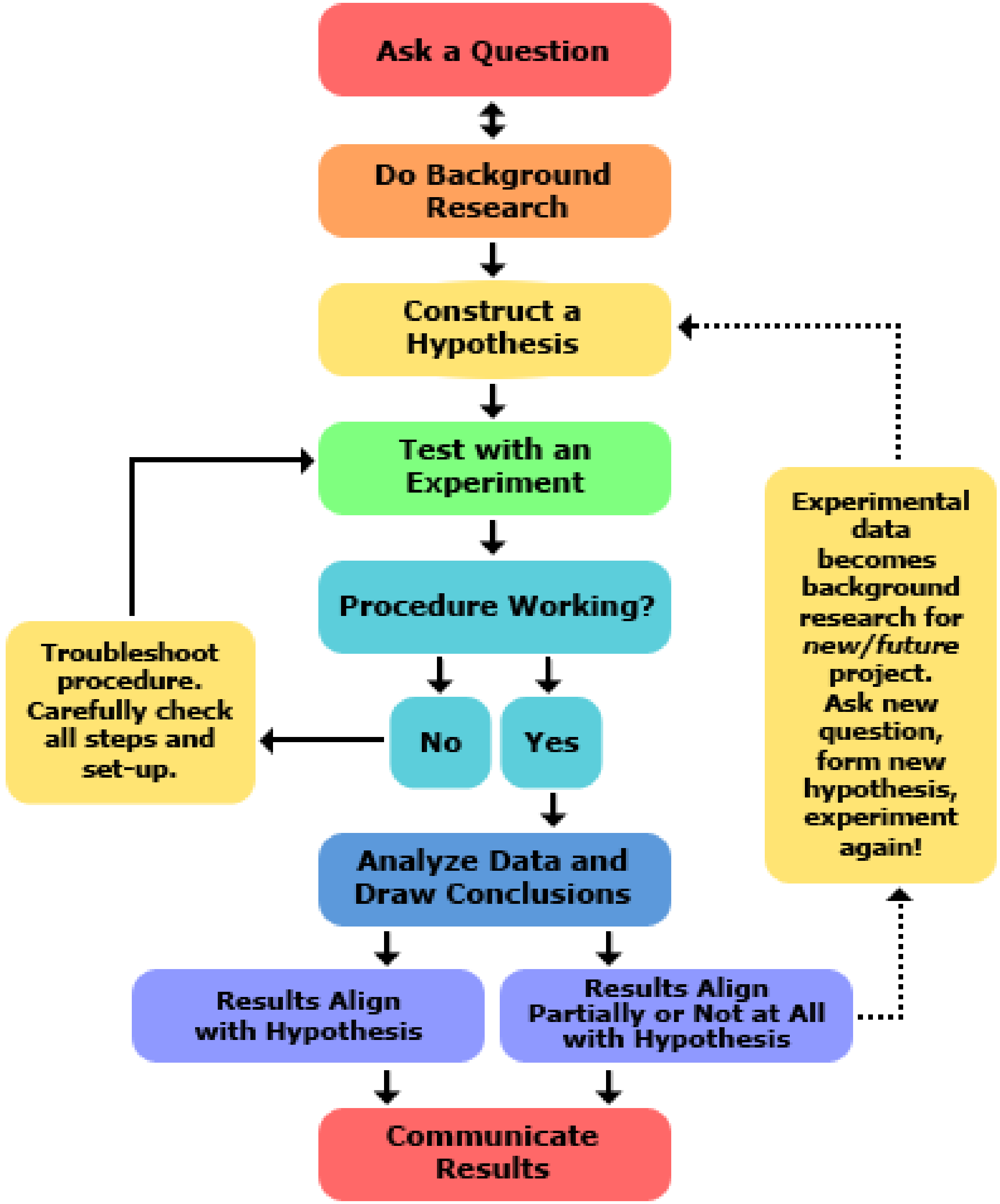
2. Framework
Conduct background research.
Write down your sources so you can cite your references.

3. Hypothesis
Propose a hypothesis.
This is a sort of educated guess about what you expect.

4. Experiment
Design and perform an experiment to test your hypothesis.
An experiment has an independent and dependent variable.
You change or control the independent variable and record the effect it has on the dependent variable.

5. Data/Analysis
Record observations and analyze what the data means.
Prepare tables or graphs of the data.

6. Conclusion
Conclude whether to accept or reject your hypothesis.
Communicate your results.


Ask a Question
Do Background Research
Construct a Hypothesis
Test with an Experiment
Procedure Working?
No
Yes
Troubleshoot procedure. Carefully check all steps and set-up.
Analyze Data and Draw Conclusions
Results Align with Hypothesis
Results Align Partially or Not at All with Hypothesis
Experimental data becomes background research for *new/future* project. Ask new question, form new hypothesis, experiment again!
Communicate Results

Scientific Method Step 1: Make Observations

A lot of people think that the scientific method starts with forming a hypothesis. The reason for this misconception may be because many observations are made informally. After all, when you are looking for a project idea, you think through all of the things you have experienced (observations you have made) and try to find one that would be suitable for an experiment.

Although the informal variation of Step 1 works, you will have a richer source of ideas if you pick a subject and write down observations until a test-able idea comes up. For example, let's say you want to do an experiment, but you need an idea. Take what is around you and start writing down observations. Write down everything! Include colors, timing, sounds, temperatures, light levels... you get the idea.

Scientific Method Step 2: Formulate a Hypothesis

A hypothesis is a **statement** that can be used to **predict the outcome of future observations**. The null hypothesis, or no-difference hypothesis, is a good type of hypothesis to test. This type of hypothesis assumes no difference between two states.
example of a null hypothesis: 'the rate at which grass grows is not dependent on the amount of light it receives'. Even if I think that light affects the rate at which my grass grows (probably not as much as rain, but that's a different hypothesis), it is easier to disprove that light has no effect than to get into complicated details about 'how much light', or 'wavelength of light', etc. However, these details can become their own hypotheses (stated in null form) for further experimentation.
It is **easiest to test separate variables in separate experiments**. In other words, don't test the effects of light and water at the same time until after you have tested each separately.

Scientific Method Step 3: Design an Experiment

There are many different ways to test a single hypothesis.
Example, ‘the rate of grass growth is not dependent on quantity of light’, I would have grass exposed to no light (a control group... identical in every way to the other experimental groups except for the variable being tested), and grass with light.
I could complicate the experiment by having differing levels of light, different types of grasses, etc.

IMPORTANT: the **control group can only differ** from any experimental groups **with respect to the one variable**.
For example, in all fairness I could not compare grass in my yard in the shade and grass in the sun... there are other variables between the two groups besides light, such as moisture and probably pH of the soil.

Keep your experiment simple.

Scientific Method Step 4: Test the Hypothesis

Perform an experiment!
Your **data** might take the form of numbers, yes/no, present/absent, or other observations.
It is important to keep data that 'looks bad'. Many experiments have been sabotaged by researchers throwing out data that didn't agree with preconceptions. **Keep all of the data!**
Make notes if something exceptional occurred when a particular data point was taken.
Also, it is a good idea to **write down observations related to your experiment that aren't directly related to the hypothesis**.
These observations could **include variables over which you have no control**, such as humidity, temperature, vibrations, etc., or any noteworthy happenings.

Step 5: Accept or Reject the Hypothesis

For many experiments, conclusions are formed based on informal analysis of the data. Simply asking, '**Does the data fit the hypothesis**', is one way to **accept or reject a hypothesis**. However, it is better to **apply a statistical analysis to data, to establish a degree of 'acceptance' or 'rejection'**. Mathematics is also useful in assessing the effects of measurement errors and other uncertainties in an experiment.

Hypothesis Accepted? Things to Keep in Mind

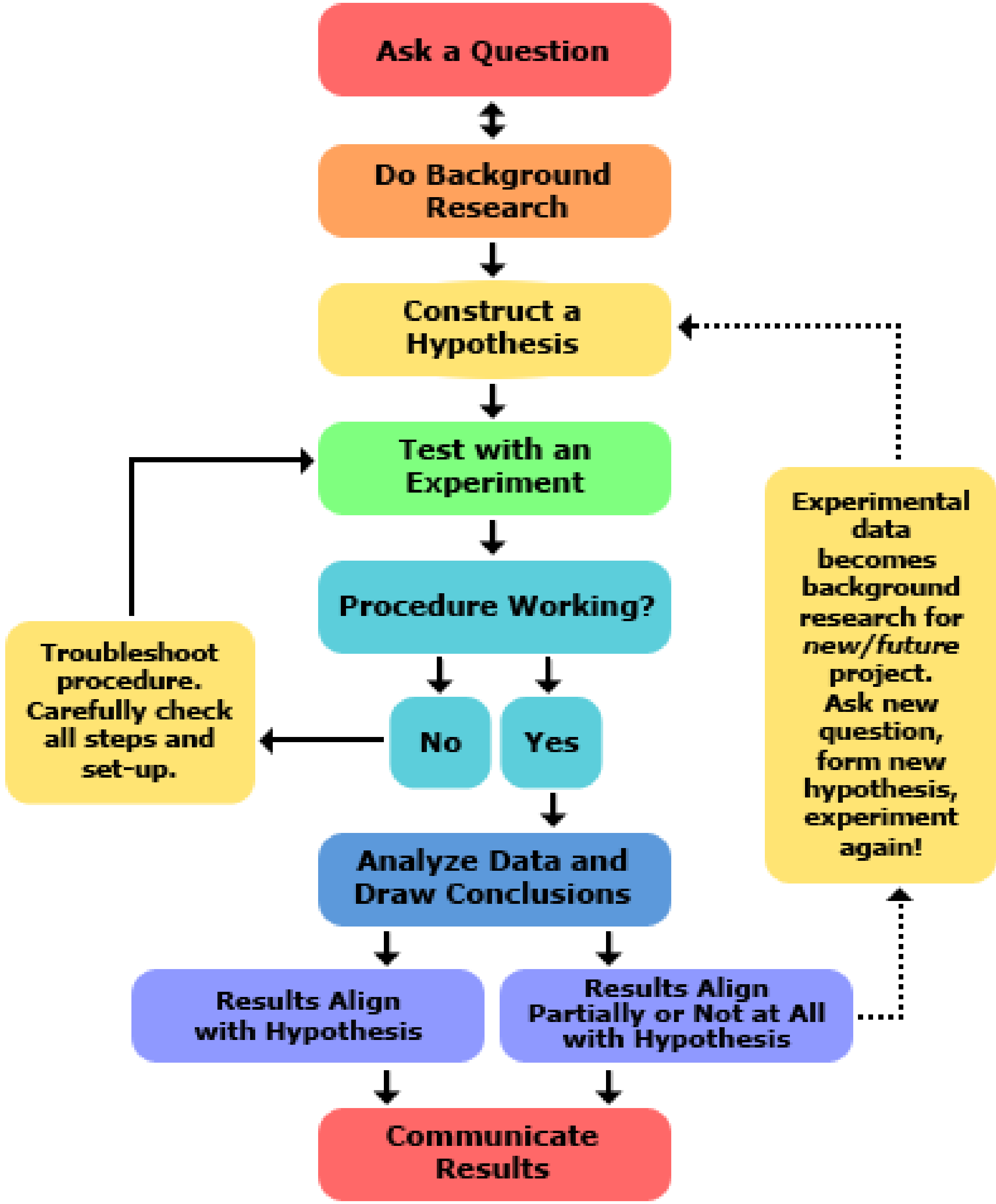
Accepting a hypothesis does not guarantee that it is the correct hypothesis!
This only means that the results of your experiment support the hypothesis.
It is still possible to duplicate the experiment and get different results next time. It is also possible to have a hypothesis that explains the observations, yet is the incorrect explanation.
Remember, a hypothesis can be disproven, but never proven!

Hypothesis Rejected? back to constructing a hypothesis!!!

If the null hypothesis was rejected, that may be as far as your experiment needs to go.

If any other hypothesis was rejected, then it is time to reconsider your explanation for your observations.

At least you won't be starting from scratch... you have more observations and data than ever before!



2. WHAT IS AN EXPERIMENT?

Natural Experiments

A natural experiment also is called a **quasi-experiment**.

A natural experiment involves making a prediction or forming a hypothesis and then gathering data by observing a system.

The variables are not controlled in a natural experiment.

Controlled Experiments

Lab experiments are controlled experiments, although you can perform a controlled experiment outside of a lab setting!

In a controlled experiment, you **compare an experimental group with a control group**.
Ideally, these two groups are **identical except for one variable**, the ***independent variable***.

Field Experiments

A field experiment may be **either a natural experiment or a controlled experiment**.

It takes place in a **real-world setting**, rather than under lab conditions.

For example, an experiment involving an animal in its natural habitat would be a field experiment.

A **variable** is anything you can **change or control** in an experiment.

Common examples of variables include temperature, duration of the experiment, composition of a material, amount of light, etc.

There are three kinds of variables in an experiment:
1. controlled variables,
2. independent variables,
3. dependent variables.

Controlled variables, sometimes called **constant variables** are variables that are kept **constant or unchanging**.

For example, if you are doing an experiment measuring the fizz released from different types of soda, you might control the size of the container so that all brands of soda would be in the same sized cans.
Or
If you are performing an experiment on the effect of spraying plants with different chemicals, you would try to maintain the same pressure and maybe the same volume when spraying your plants.

The **independent variable** is **the one factor that you are changing**.

NB: Usually in an experiment you try to **change one thing at a time**. This makes **measurements and interpretation of the data much easier**.

Example: If you are trying to determine whether heating water allows you to dissolve more sugar in the water then your independent variable is the temperature of the water.
This is the variable you are purposely controlling.

The **dependent variable** is the **variable you observe**, to see whether it **is affected by your independent variable**.

Example: you are heating water to see if this affects the amount of sugar you can dissolve, the mass or volume of sugar (whichever you choose to measure) would be your dependent variable.

3. SIMPLE EXPERIMENT VS CONTROLLED EXPERIMENT

A Simple Experiment is not a synonim for Easy Experiment, it is a type of experiment.

Usually, a simple experiment answers a “What would happen if...?” cause-and-effect type of question.

Example: You wonder whether a plant grows better if you mist it with water. You get a sense of how the plant is growing without being misted and then compare this with growth after you start misting it.

Why Conduct a Simple Experiment?

Simple experiments usually **provide quick answers**.
They **can be used to design more complex experiments**, typically requiring fewer resources.
Sometimes simple experiments are the only type of experiment available, especially if only one sample exists.

Example: We conduct simple experiments all the time. We ask and answers questions like, “Will this shampoo work better than the one I use?”, “Is it okay to use margarine instead of butter in this recipe?”, “If I mix these two colors, what will I get?”

Controlled experiments have **two groups of subjects**.
One group is the **experimental group** and it is **exposed to your test**.
The other group is the **control group**, which is **not exposed to the test**.

There are several methods of conducting controlled experiments, but a simple controlled experiment is the most common.
The **simple controlled experiment** has **just the two groups**: one exposed to the experimental condition and one not-exposed to it.

Example: You want to know whether a plant grows better if you mist it with water. You grow two plants. One you mist with water (your experimental group) and the other you don't mist with water (your control group).

4. RECAP SCIENTIFIC EXPERIMENT

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> State a Problem

> Propose a Testable Hypothesis

> Identify the Independent, Dependent, and Control Variable

> Perform Enough Tests

> Gather the Right Data

> Tabulate or Graph the Results

> Test the Hypothesis

> Draw a Conclusion

A **hypothesis** is a **prediction of what you expect** will happen in an experiment. It's easier to analyze your data and draw a conclusion if you phrase the hypothesis as an **If-Then or cause and effect statement**.

For example, a hypothesis might be, "Watering plants with cold coffee will make them grow faster." or "Drinking cola after eating Mentos will cause your stomach to explode."
You can test either of these hypotheses and gather conclusive data to support or discard a hypothesis.

The **null hypothesis or no-difference hypothesis is especially useful** because it **can be used to disprove a hypothesis**.

For example, if your hypothesis states, "Watering plants with coffee will have no effect on plant growth" yet if your plants die, experience stunted growth, or grow better, you can apply statistics to prove your hypothesis incorrect and imply a relationship between the coffee and plant growth does exist.

Every experiment has variables. The **key variables** are the **independent and dependent variables**.

The **independent variable** is the one you **control or change to test its effect on the dependent variable**.
The dependent variable depends on the independent variable.

Example: In an experiment to test whether cats prefer one color of cat food over another, you might state the null hypothesis, "Food color does not affect cat food intake." The color of the cat food (e.g., brown, neon pink, blue) would be your independent variable. The amount of cat food eaten would be the dependent variable.

Hopefully you can see how experimental design comes into play. If you offer 10 cats one color of cat food each day and measure how much is eaten by each cat you might get different results than if you put out three bowls of cat food and let the cats choose which bowl to use or you mixed the colors together and looked to see which remained after the meal.

Data
The numbers or observations you collect during an experiment are your data. **Data are simply facts**.

Results
Results are your analysis of the data. Any calculations you perform are included in the results section of a lab report.

Conclusion
You conclude whether to accept or reject your hypothesis. Usually this is followed by an explanation of your reasons. Sometimes you may note other outcomes of the experiment, particularly those that warrant further study.

For example, if you are testing colors of cat food and you notice the white areas of all the cats in the study turned pink, you might note this and devise a follow-up experiment to determine whether eating the pink cat food affects coat color.