Name: _____ **Date/Lab time:**_____

Lab 1: Scientific Investigations

LAB SYNOPSIS:

We will use the "scientific method" to study observations made about yawning. We will examine two hypotheses purposed to explain why people yawn.

- People yawn to get more oxygen to their brain.
- Yawning is contagious.

As a group, you will design and conduct an experiment testing if yawning is contagious.

OBJECTIVES:

- Use and understand how the scientific method allows scientists to investigate questions.
- Understand the vocabulary associated with the scientific method and experiments
- Understand and construct an experiment, determining experimental variables and control groups.
- Explain the importance of good experimental design in scientific experiments.
- Understand the role peer review plays in maintaining the integrity of science.
- Develop experiments to test hypotheses.

Overview:

Scientists observe the world around them, ask questions about these observations then purpose answers to these questions. They then conduct experiments to determine if their answers are correct.

The conclusions science makes to explain the natural world is done using a process called the **scientific method** (also known as the scientific process or scientific inquiry). There is nothing mysterious about scientific reasoning. In fact, most people use a scientific approach every day in solving problems and making decisions. You do not need special training to decide whether conclusions are reasonable from the results. You must simply follow the rules of logic. The basic features of the scientific method are:

1 2 3 4 5 6 7

Observation → Question (Problem) → Hypothesis → Test → Analyze Results → Conclusions → Document/Peer Review

We will examine the scientific method starting with observations about something you are probably already familiar with, yawning. Yawning is the involuntarily opening of one's mouth wide and inhaling deeply.

Exercise 1: The Scientific Method (on the yawning phenomenon)

Step 1 of the scientific method

OBSERVATIONS: Observation on yawning:

Good scientists are good observers of the world around them. How do you make good observations? Observations are <u>just the facts</u> (things that can be repeatedly measured or observed). Observations can be made using our senses (hearing, sight, touch, smell etc.) and/or aided by equipment (microscopes, Geiger counters, etc.).

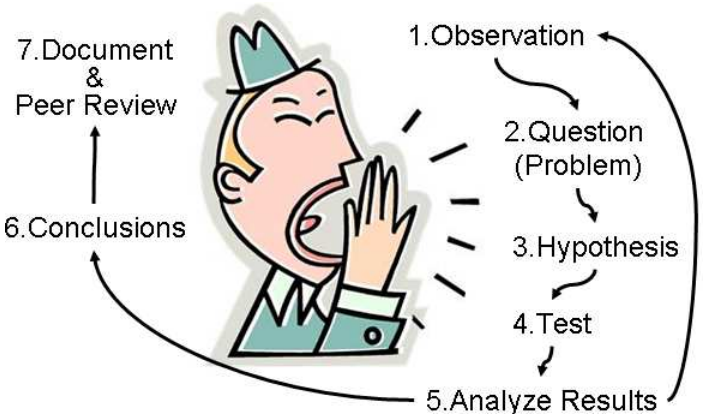

Figure 1. Scientific Method on why people yawn

Make observations on yawning below. Try to come up with good objective, unbiased observations, not those influence by preconceived ideas or conclusions. Avoid inferences and just record the facts of yawning.

Inference (A conclusion based on evidence and reasoning)	**Observation** (just the facts:)
Avoid -> People yawn when they are tired.	Better-> People who yawn often say they are tired.

In the table below, write down as many factual observations as you can about yawning.

Step 2 of the scientific method
QUESTION: Why do people yawn?

Scientists ask questions about observations. A basic question relative to yawning might be…
"Why do people yawn?"

Step 3 of the scientific method
HYPOTHESIS: (a tentative explanation of the phenomena of yawning)

All of your project research is done with the goal of posing a question, proposing an answer to it (the hypothesis), and testing your hypothesis. A hypothesis is just a testable educated guess as to the answer to your question. Educated, in that you use experiences from your past or logic to answer the question. Testable in that you can determine if it is or is not valid.

1. All by yourself, write down as many hypotheses as you can to answer the question, why do people yawn? **Circle** the one you think has the greatest impact on why people yawn.

What are the names of the people in the group you are working with?	

2. Compare your list with those of the others' in your group. Add any original hypotheses to your table.

a. How similar were your observations and hypotheses to others in your group? _____

b. Did everyone in your group choose the same greatest impact on yawning hypothesis? _____

d. How many different hypotheses did you and your group come up with/? _____

What is the difference between hypothesis and theory?

A hypothesis should not be confused with a theory. Theories are general explanations based on a large amount of data. Theories explain facts and are what science is most confident about.

Diversity of people brings diversity of ideas

Science is a collaboration and is rarely done by a single person. Science thrives on the diversity of ideas and input from a broad range of people. Research shows, that the more diversity we see within the scientific community, the more unique ideas and progress is made to answering questions.

Notice that there are a number of possible hypotheses to answer the question, "Why do people yawn?" There will always be more than one possible hypothesis for any given question (if there is only one possible hypothesis, then it must be correct and would not be called a hypothesis anymore ☺!) but the most useful hypotheses provide a deeper understanding of the observations. For example, an explanation for why we yawn is that we yawn when we are bored. Yet this still leaves us with the question, why do we yawn when we are bored?

Hypothesis #1. People yawn to get more oxygen to their brain

Activity: Identify variables and controls within an experiment

Scientists have been thinking about yawning for a long time (maybe since some of their introductory science classes). Scientists have come up with several different hypotheses to explain why we yawn. One of these is that yawning allows more oxygen (O_2) to enter into our body so that we yawn in response to low oxygen levels, or to elevated carbon dioxide (CO_2). This hypothesis has already been research. We will examine this research below.

Prediction

It is often beneficial to reword a hypothesis as a prediction. A prediction defines cause and effect. It is an "if-then" statement that helps if forming a testable experiment. For example, a hypothesis might be that that people yawn when they are tired. A testable prediction would be- If yawning is related to being tired, if people are tired then they are more likely to yawn. The cause is being tired and the effect is yawning.

1. Make a prediction based on the hypothesis that "people yawn to get more oxygen to their brain".

⇨

Cause
↓
Effect

Step 4 of the scientific method
TEST: of the hypothesis

The goal of an experiment is to test if the hypothesis is or is not valid. Tests can include observation, literature review or experimentation. A good experiment should be laid out so that experimenters and readers clearly understand what is being done and what is being measured. We will consider **experimental variables** and the use of **experimental controls** as we review the following experiment published in 1987, "Yawning: No Effect of 3-5% CO_2, 100% O_2, and Exercise" (Provine et al. 1987)

Experiment layout (abbreviated and modified from actual experiment)

Each of the following 4 treatments were given to 18 separate college students (ages 17-21)

- 0.03% CO_2 21% O_2 (Normal air)
- 3% CO_2 21% O_2
- 5% CO_2 21% O_2
- 0% CO_2 100% O_2

Only one trial was done per day. Each trial lasted 30 minutes. The number of yawns and duration of yawns were measured over 30 minutes.

Experimental variables (independent, dependent & standardized variables)

The things that have an effect on an experiment are called "variables". Three kinds of variables should be identifiable within your experiments (independent, dependent, and standardized).

- **Independent variable:** This is the single variable that is being purposely changed or modified in the experiment.

Although there are many possible hypotheses for why people yawn, within an experiment only one factor should be tested at a time. For example, if we tried to test for two hypotheses (people yawn because they are tired and because they are cold) any results would be unclear as to which factor was actually effecting the yawning.

- **Dependent variable(s):** These are the variables that change depending on the independent variable, i.e. the variables that are being measured or observed. The data you collect is usually your dependent variable
- **Standardized variable(s):** These are variables that could have an effect on the outcome of the experiment. You try to keep standardized variables constant during the experiment. Standardized variables can also be possible independent variables, but you are not testing at this time.

⇨ **Table 1. Experimental variables**. Identify the experimental variables in the experiment determining the effect of CO_2 on yawning.

Independent variable The one thing you change	
Dependent variables All the things you will measure.	
Standardized variables Identified in the experiment.	
What are some standardized variables not outlined in the experiment?	

Experiment controls

The ideal experiment has two (or more) different groups with the only difference being a change in the independent variable.

One group, the **control group**, serves as a comparison for the **experimental group**. Since ideally the only difference between these groups is a change in the independent variable, any difference in the two tests should be due to the effect of the independent variable.

- **Experimental group:** You are exposing this trial to your independent variable.
- **Positive control(s):** This is a control where you know the outcome should show expected results.
- **Negative control(s):** This is a control where you know the outcome should not show expected results.

⇨ **Table 2. Groups.** Identify the experimental group and control groups in the experiment determining the effect of CO_2 on yawning.

Experimental group The group, and what independent variable it is exposed to.	
Control group **Positive control** (This is the group you would expect to have a normal amount of yawning)	
Control group **Negative control** Hint: If the hypothesis is that increased CO_2 in the air causes yawing, which group would you expect not to yawn?	

Note: Standardized variables should be kept constant between your experimental group and the controls.

Step 5 of the scientific method
RESULTS: Your recorded data, i.e. the dependent variables
There are many ways to record results (sentence form, graphs, tables, etc.).

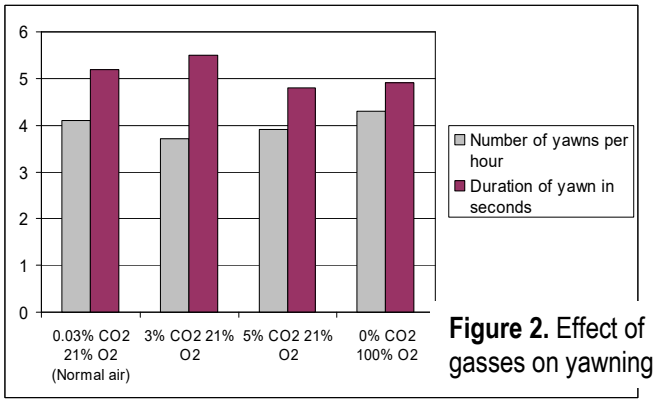

Figure 2. Effect of gasses on yawning

Table 3. Average number of yawns and duration of yawns under different concentrations of CO_2.

Trials, changes in CO_2 amounts	Number of yawns per hour (ave. of 18 subjects)	Duration of yawn in seconds (ave. of 18 subjects)
0.03% CO_2 21% O_2 (Normal air)	4.1	5.2
3% CO_2 21% O_2	3.7	5.5
5% CO_2 21% O_2	3.9	4.8
0% CO_2 100% O_2	4.3	4.9

Step 6 of the scientific method
CONCLUSIONS: Compare results to the expected results from hypotheses and prediction.

Results (Fig.2 & Table 3) did not support the hypothesis. Statistical analysis of the data shows no significant change in either the number of yawns or the yawn duration due to changes in CO_2 concentrations.

An important part of conclusions is error analysis. If the hypothesis turns out to be false, there are some questions to ask to find out why:

⇨ **Error analysis**

Do you think this experiment was designed well?

What things that might be done to clarify the design of this experiment?

Your error analysis is part of the process of peer review.

Step 7 of the scientific method
DOCUMENTATION/PEER REVIEW:

The conclusions that science make only have value if the information is available for others to evaluate. The above experiment has been published and is available online.

Provine, Tate, and Geldmacher. (1987). Yawning: No Effect of 3-5% CO_2, 100% O_2, and Exercise. *Behavioral and Neural Biology*, 48(3), 382-393.
http://www.baillement.com/provine5.html

Note: Major scientific breakthroughs are rare. Most science is the slow accumulation of experimental results leading to a bigger picture of what is happening. This is true of yawning research.
About 30 peer-reviewed articles are published each year looking at yawning.

PEER REVIEW

Some conclusions must be confirmed by the observation and experiments of more than one individual before they can be widely accepted. Since its publication in 1987, other researchers have found similar results indicating that both CO_2 and O_2 have no measurable effect on yawning.

If no one has found a link between yawning and a need for more oxygen, why is it still believed by the general public?

A good experiment is clear enough so that other investigators can understand the procedure, repeat the experiment and get similar results. This is also part of the peer review processes, i.e. that the experiment can be replicated.

⇨ Do you feel that, given proper supplies and materials, you could conduct a similar experiment as above?

The Scientific Method- a process for studying natural phenomena.

We are using yawning as a way to show how the scientific method is used to study things we see or observe everyday.
Biology is the study of life. Why would biologist be interested in yawning?

Hypothesis #2. Yawning is contagious

Yawning may not be caused by just one thing, but yawning does not seem to be caused by either CO_2 or by O_2 concentrations (Provine et al., 1987 and others researchers).

If an experiment shows a hypothesis to be false (refuted), a new hypothesis can be purposed. **Common knowledge** is that yawning is contagious (not like a cold virus of course) just that seeing someone yawn makes you more likely to yawn yourself.

Science does not make conclusions based on common knowledge! Science relies on testing.

Step 1 of the scientific method
OBERVATIONS: Review your observations above concerning yawning

Step 2 of the scientific method
QUESTION: Recall the question to be answered is, "**Why do people yawn?"**

Step 3
HYPOTHESIS: (a tentative explanation of the yawning phenomena)

Hypothesis- Yawning is contagious. How can this hypothesis be tested?

As you start to imagine an experiment that you could perform to test this hypothesis, work in your group to answer the following.

Prediction

Recall: A prediction is a restatement of your hypothesis as an If-Then statement. A prediction is often useful in the development of an experiment.

1. Make a prediction based on the hypothesis that "yawning is contagious".

⇨

Cause
↓
Effect

Summarize your experiment below. How are you going to test your hypothesis and prediction? You will detail the lay out of your experiment later as you determine experimental variables and control groups.

⇨

1. Experimental variables (independent, dependent & standardized variables)
Recall: The things that have an effect on an experiment are called variables. Use your prediction to guide you here. What are you changing in the prediction, and what will this effect? MAKE SURE PREDICTION RELATES TO VARIABLES!

Table 4. Experimental variables. Identify the experimental variables in your experiment

Independent variable The one thing you change	
Dependent variables All the things you will measure.	
Standardized variables Kept constant	

2. Experimental group and control(s)

Remember that you are going to need an experimental group and at least one control group to compare to each other. These different groups could easily have the same people in them, just measured at different times. What is different is that the independent variable is changed between the groups.

Table 5. Groups. Identify the experimental group and control groups in your experiment.

Experimental group The group, and what independent variable exposed to.	
Control group **Positive control** (This is the group you would expect to have a normal amount of yawning	
Control group **Negative control** Do you have both a positive and negative control? (note: it is not always possible to have both)	

Null Hypothesis

Your prediction states what will happen if your hypothesis is correct. A null hypothesis predicts the results if your hypothesis is not correct, i.e. that your results for both your experimental group and the control group will be the same.

What is your null hypothesis?

Now that you have all the components of your experiment, clearly outline it below. Recall this should include enough detail that you (on anyone else) can understand and perform the experiment.

Your experiment. This should include the variables you identified, your experimental group and your control(s).

Step 4 of the scientific method
TEST: of the hypothesis

If you have time, perform your experiment. If there is not enough time, think about how you might do this experiment as homework (at home, work, or the library).

**** Note: Stress from not having enough time to complete experiments can lead to sloppy research or completely made up results. *******

What part of the scientific method is designed to maintain standards, improve performance and provide credibility of scientific research?
⇨

There is a very good chance that there will not be enough lab time to complete your experiment in lab. Ask your instructor what you need to complete below.

Step 5 of the scientific method
RESULTS: your recorded data, i.e. the dependent variable

Describe what happened in your experiment. What were your results? You could include a table or graph to make your results easier to read.

Results (you may need a separate paper to record your result)

Remember; a good scientist is a good observer. What are some additional observations you made during the experiment? These can be used to refine your experiment or to develop whole new ideas.

Additional observations made during your experiment

Step 6 of the scientific method
CONCLUSIONS: Compare results to the expected results from your hypotheses and prediction.

a. Did you get your expected results? Why? Why not? b. What do your results suggest about the hypothesis that yawns are contagious?

Error analysis/Troubleshoot "Error" does not necessarily mean that you did something wrong, it just means that there is more research that could be done to improve experimental design, implementation or observations.

If the hypothesis turns out to be false, some questions to ask to find out why include:

a. What was wrong with the original hypothesis?

b. Was your experiment flawed?

c. Did you make poor observations?

d. What are weaknesses of your experiment and how could they be corrected?

Recall science is a process. If you were to discover that yawning is contagious, what kinds of questions might this lead to?

Step 7 of the scientific method
DOCUMENTATION/ PEER REVIEW

If time and instructor permits, record your data on the board.

a. Did every group come up with the same experiment?

b. Did every group get the same results? If no, why?

Documentation and peer review are times to further examine potential experimental errors or address ambiguous results.

If time does not permit the completion of your experiment, or to compare your results to that done by others; check out the 5 minute Myth Busters "test" on Is Yawning Contagious? At

https://www.youtube.com/watch?v=GjHFvOzNiCo