Biology and the Scientific Method

1. **Think of Interesting Questions**
   - Why does that pattern occur?

2. **Formulate Hypotheses**
   - What are the general causes of the phenomenon I am wondering about?

3. **Develop Testable Predictions**
   - If my hypothesis is correct, then I expect a, b, c, ...

4. **Gather Data to Test Predictions**
   - Relevant data can come from the literature, new observations, or formal experiments. Thorough testing requires replication to verify results.

5. **Refine, Alter, Expand, or Reject Hypotheses**

6. **Develop General Theories**
   - General theories must be consistent with most or all available data and with other current theories.

7. **Make Observations**
   - What do I see in nature? This can be from one's own experiences, thoughts, or reading.
Observations are a critical component of science. Come up with your own definition for observations and inferences and distinguish between the two.

Observation: ________________________________________________________________

Inference: ________________________________________________________________
Hypotheses

A hypothesis is a proposed solution for an observable phenomena (or an “educated guess”).

A hypothesis should include a _______________ and ________________ prediction (that includes the _______________ being tested and the _______________ being measured) and a ________________.

An “If …then…because” format can help you determine if your hypothesis is complete.
Observations are made by using one of your 5 senses.

Inferences are assumptions made from your observations and previous understandings.
Variables

Manipulated (or Independent) Variable:
The factor being ____________ in an experiment. It should be the only difference between the experimental group and the ____________ group.

- maltose food
- starch food
Responding (or Dependent) Variable:
The outcome being _________________ and ______________ related to the effect by the manipulated variable in an experiment.

Quantitative data: ____________ values that are not subjective
Qualitative data: ______________ data that has a level of subjectivity
**Controlled Variables (or Constants):**

The many factors that should be kept the ____________ between the control group and the experimental group.
Why is it critical that there is only one manipulated variable?
Multiple Samples or Repeated Trials

An experiment should have multiple samples or repeated trials in order to ensure that the results of the experiment are _____________ and the results are not due to _____________________________________________________________________________.

What is the minimum number of trials you should have? ______
Confirmation Bias

Confirmation bias is the natural human tendency to notice information that matches our ________________, and to ignore information that does not match our expectations.

A good scientist must always be aware of the problem of confirmation bias and must attempt to design experiments to avoid this problem.
Double Blind Studies

A double blind study is an experiment in which neither the research subject nor the scientist knows whether the subject is in the experimental group or the control group. (The information is encoded only after the data is recorded do the researchers learn which group the subject is in.)

This experimental design aims to reduce potential sources of bias (placebo effect, confirmation bias).
Avoiding Bias: Double-Blind Experiments

At least 12 double blind randomized controlled trials have examined how children react to diets containing different levels of sugar. None of these studies, not even studies looking specifically at children with attention-deficit/hyperactivity disorder, could detect any differences in behavior between the children who had sugar and those who did not. This includes sugar from sweets, chocolate, and natural sources.

Continued
Scientists have even studied how parents react to their kids on sugar. When parents are told their child has been given a drink containing sugar, but it is actually sugar-free, they rate the behavior as more hyperactive than those not given the drink. In fact, the differences in behavior between the two groups were all in the parents’ minds.
Scientific Theory

In science, the word theory has a very different meaning than in everyday conversation.

A scientific theory is a general explanation for a broad range of data. A scientific theory is ________________ ______.

It is as close to fact as you can get in science.
Qualitative Data

Qualitative Data - Data that __________ what is being observed.

Examples: color (if not measured), level of pain

Qualitative data tends to be subjective (subject to personal opinion of the evaluator.)
Quantitative Data - Data that has a ________________________________.

Examples: height, temperature

Quantitative data tends to be objective (outside values that are not subject to personal opinion.)
Peer Review

Scientists provide detailed procedures for peer review (evaluation by fellow scientists and others).

- Evaluate ___________ used.
- ______________________ of results.
Conclusions

Conclusions should:

- Compare your ________________________________.

- Be clearly stated. Explain what effect the ____________________ (independent) variable had on the ____________________ (dependent) variable.

- Provide specific ________________________________.

- Connect the data to the conclusion with explanatory language.
Sample EOC question: How Did That Plant Get Here?

Directions: Use the following information to answer questions 1 through 7.
Demetri did the following investigation in a local college laboratory to see how carbon dioxide (CO$_2$) affects plant growth.

Demetri grew bean plants in growth chambers where he could control the amount of oxygen (O$_2$) and CO$_2$ in the air around the plants. He grew the bean plants in water with mineral nutrients instead of soil. Demetri had to completely dry the plants in an oven to get the plants’ dry mass.

**Question:** What is the effect of different amounts of carbon dioxide (CO$_2$) in air on the dry mass of bean plants?

**Hypothesis:** As the concentration of CO$_2$ in air increases, the dry mass of bean plants will increase because bean plants use CO$_2$ for growth.

**Materials:**
- bean plants with the same mass
- water with mineral nutrients
- identical growth chambers labeled A, B, and C
- containers of CO$_2$ and O$_2$ gas
- monitors for CO$_2$ and O$_2$ gas
- oven
- balance
Investigation Setup

- Growth chamber with grow lamps and plant support material
- Bean plants
- Water
- Chamber A
- Gas monitors: 210 O₂, 000 CO₂
- Gas containers: O₂, CO₂
- Electrical outlet
Procedure:
1. Put 12 bean plants into Chamber A as shown in the Investigation Setup diagram. Do the same to Chambers B and C.
2. Make sure each chamber receives the same amount of light and water. Keep the chambers at a constant temperature and pressure.
3. Adjust the $O_2$ level of the air in each chamber to the normal amount of $O_2$ in the atmosphere.
4. Remove 4 bean plants from each chamber. Dry the plants in the oven and measure their dry masses.
5. Calculate and record the average dry masses as Day 1.
6. Set and keep the $CO_2$ level in Chamber A at 0 parts per million (ppm), Chamber B at 700 ppm, and Chamber C at 1,400 ppm.
7. Repeat steps 4 and 5 for Day 7 and Day 14.
## Data:

**Amount of CO$_2$ vs. Bean Plant Dry Mass**

<table>
<thead>
<tr>
<th>Amount of CO$_2$ (parts per million)</th>
<th>Bean Plant Dry Mass (averages in grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>0 (Chamber A)</td>
<td>0.8</td>
</tr>
<tr>
<td>700 (Chamber B)</td>
<td>0.8</td>
</tr>
<tr>
<td>1,400 (Chamber C)</td>
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1. Which two variables were controlled (kept the same) variables in this investigation?

- A. Final bean plant dry mass and amount of light
- B. Amount of CO$_2$ and type of growth chamber
- C. Growth of plants and amount of O$_2$
- D. Type of plants and amount of O$_2$

2. Which variable was the responding (dependent) variable in this investigation?

- A. Hours of light
- B. Bean plant dry mass
- C. Total days bean plants grew
- D. Mineral nutrients in the water
Why did Demetri have growth chamber A adjusted to 0 ppm of CO$_2$?

- **A.** To show bean plants can make their own CO$_2$ when none is available
- **B.** To make the bean plants use oxygen for photosynthesis instead of CO$_2$
- **C.** To ensure the amount of CO$_2$ caused the differences in dry mass
- **D.** To demonstrate that CO$_2$ is used by the bean plants for respiration
Assess the following conclusions. Remember that a conclusion should:

- Clearly answer the investigative question
- Provide supporting data
- Explain how the data supports the conclusion
This experiment showed that carbon dioxide is good for plants. Plants that were grown with no CO₂ did not show an increase in mass after 14 days, while plants grown in the container that had 1400 ppm of CO₂ gained an average of 10 grams after 14 days.

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The effect of different amounts of CO$_2$ in the air on the dry mass of bean plants differs with the level of CO$_2$. Higher levels of CO$_2$ make the plants grow more which raises the dry mass. This is shown when 1,400 ppm CO$_2$ renders an average dry mass of 10.8 g on the 14th day.

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As the CO$_2$ increased in the air, the dry mass of the beans also increased. In Chamber A, the bean plants were exposed to no CO$_2$ and had a consistent mass of 0.8 grams. In Chamber B, the beans were exposed to 700 ppm of CO$_2$ and had an average mass of 4.5 grams on day 7 and 8.6 grams on day 14. In Chamber C, the beans were exposed to 1400 ppm of CO$_2$, by far the most. Their mass on day 7 was 4.7 grams (on average) and their average mass on day 14 was 10.8 grams. This data shows a trend that as CO$_2$ levels increase the dry mass of the plant increased as well.

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Graphing Review

• Always place the ________________variable on the vertical axis. (Y axis). Remember: DRY MIX

• DRY: Dependant / Responding on ________ axis

• MIX: Manipulated/Independent on ___________axis

• Make sure the lines are numbered with even _________________. (by 5’s, by 10’s etc.)

• When the data follows a trend but does not form a straight line, average out the variation by drawing a ________________line or curve in which about __________the points are above and half the points are below the line or curve.
Calculating the Slope of the Line

- Identify 2 points on the line.
- Calculate the change in the Y coordinates. (_______)
- Calculate the change in the X coordinates (_______)
- Divide the change in _______by the change in _________ (Rise/Run)
Slope Units

- The unit for the slope is the Y unit / X unit.

The unit for the graph on the right would be _________ / _________.

One way to double check that you have set up the axes correctly is to see if the slope unit is correct.
Common Slope Calculation Mistake

A common error in calculating the slope of a line is to count the number of lines up and over instead of finding the change in the Y and the X.

This doesn’t work on many graphs in science because the two axes often use different

________________________.