Biology Honors 12

Part II. Scientific Method: Controlled Variables

There are many different types of experimental procedures that can present the experimenter with problems that must be solved before reliable data can be collected. One such problem presents itself when many variables affect the dependent variable. For example, you want to determine the best method for studying for a test. You have taken many tests and have an idea that making note cards before a test will help you get a good grade. You pose a question, "Will using note cards help me get a good grade on tests?" You set up a test in which you use note cards for one test (experimental group) and plan to take the next test without note cards (control group). Your independent and experimental variable will be the note cards, the dependent variable will be the grade you get on the test.

Immediately, you see the problems. What if one test is a math test (hard) and the other is a health test (no-brainer)? What if you have time to study for one test and don't have the time to study for the other test? What if you are feeling great the day you take one test and feel lousy the day you take the next test? All of these differences are variables that can affect the dependent variable (your grade). You need a way to control these variables so that you can be sure that <u>any differences between the data in the control group and the experimental group is caused by the experimental variable alone.</u>

Controlled variable -variables that can affect the dependent variable. Controlled variables are 'controlled' by the experimenter. **They are held same between both the control group and the experimental group** so that the only variable that is different between the two groups is the experimental variable.

Once you recognize what variables you need to control, you can set up your experiment. You use note cards for two different *history* tests. You plan to study *2 hours* for each test. You *eat breakfast before each test* and only use the data from a test *if you feel good*. You are reducing the variables that may interfere with the reliability of your results. The only variable remaining is the use of note cards during one test. That is your experimental variable.

Independent and Dependent Variables

The graphs you just looked at are drawn using specific methods. For example, in the body mass vs. heart mass graph, the body mass is on the **X**, or horizontal axis and the heart mass is on the **Y** or vertical axis. Why did the experimenter do this? Couldn't the body mass have be graphed on the vertical axis and the heart mass on the horizontal axis? The answer lies in the identification of two different variables:

Independent Variable- Independent variables may affect the data or the outcome of the experiment. In all experiments, the *experimental variable is an independent variable*. It is the factor in the experiment that the experimenter is most interested in. If there is only one independent variable (the experimental variable), it is graphed on the X-axis. If an experiment has an experimental variable and an additional independent variable, such as time, time would be graphed on the X axis, and the experimental variable is drawn as different lines on the graph. Keep in mind that in some experiments, time will be the experimental variable.

Dependent Variable- The 'd' in dependent stands for 'data.' Don't be confused by the name 'variable.' The dependent variable is simply the data collected during the experiment. The dependent variable is *always* graphed on the Y axis.

Knowing this, you can understand why the experimenter graphed the body/heart data the way he did. The prediction statement indicated that the size of the heart was dependent on the size of the organism, not that the size of the body was dependent on the size of the heart! The heart mass is therefore the dependent variable and the body mass is the independent variable.

The second graph with the oxygen uptake by lungs and skin of the frog includes TWO independent variables. The dependent variable was the oxygen uptake measured in milliliters of O_2. What two things did the oxygen uptake depend on? One was the month of the year and the other was whether the measurement was taken in the skin or in the lungs. Both are independent variables. But which is the experimental variable?

When an experiment has more than one independent variable, the experimental variable is the one the experimenter is MOST interested in. Although time is also considered an independent variable, in many experiments, it is not the experimental variable because BOTH groups are tested over the same period of time. In the frog experiment, the experimenter wanted to determine if the oxygen uptake was the same between the frog lungs and the frog skin. The respiratory organs (lungs and skin) are the experimental variable. The additional independent variable, the 'month of the year,' adds information to the experiment. If the experimenter had only looked at the data at the end of February, he might have concluded that his hypothesis was supported. By looking at the data over several months, he was able to determine much more!

Questions:

7) Identify the **independent** and **dependent variables** in each of the following statements. Note that some statements will have *more than one* independent variable.

Circle the dependent variable, underline the independent variable(s).

a) Guinea pigs are raised at **different temperatures**. **Percent weight gain** is recorded **each week**.

b) **Height of bean plants** treated with **two different fertilizers** is recorded daily for **2 weeks**.

c) **Number of minutes** required for a **two different species of snake** to kill and consume a prey animal based on the **age of the snake**.

d) Batches of seeds are soaked in salt solutions of different concentrations (1%, 10%, 20%) and the number of seeds germinating is counted for each batch.

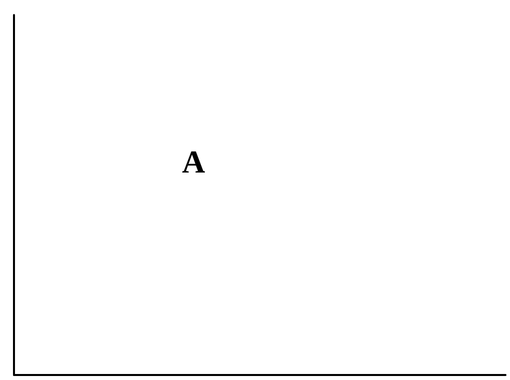
e) The number of correct answers on a memory test is recorded for students who ate breakfast compared to students who didn't eat breakfast.

f) Yield of cotton plants (bales of cotton per acre) is determined for two different varieties or types of cotton plants grown in both Texas and Georgia.

g) Customers from New York City and Omaha Nebraska rated the level of violence in three different police shows.

h) Label the X and Y axis on the following graphs (be sure to include the units of measurement):

Table **A**. A test in which the amount of food (in grams) given to fish affects the weight of the guppies (grams).



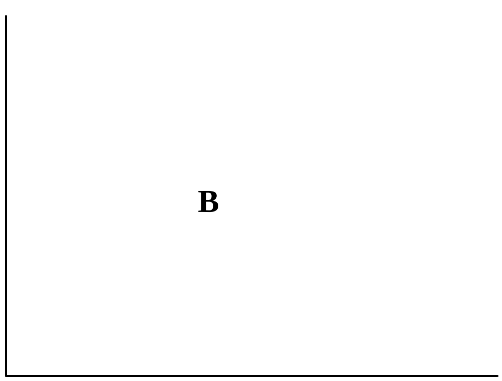


Table B. A test in which the weight of a water balloon (grams) affects the diameter of the splash it makes (centimeters).

Questions:

8) In your own words, why is it important to test only one variable at a time?

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9) ***Describe*** three **controlled variables** in each of the following experiments:

a) A medication is used to reduce swelling after insect bites.

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b) Three different concentrations of air freshener are tested on public bathrooms.

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c) Plants are grown red, blue and green light.

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d) A taste-test is used to compare a new flavor of cherry Jell-o to the regular cherry flavor.

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A Special Case: The Placebo Effect

A difficulty arises when performing experiments on human subjects that can affect or invalidate the results of an experiment. When patients are given a substance that is supposed to help their condition, a psychological phenomenon known as the **"placebo effect"** may occur. The placebo effect causes patients to experience an improvement in their condition even if the substance that they took did not contain any therapeutic ingredient. For example, you might give someone a pill that contains harmless sugar and flour and tell them it will cure their headache. A patient experiencing the placebo effect will describe a lessening or outright end to their headache even though the pill did not contain a headache remedy. The patient may think that just because you gave them a pill, their headache has been cured. This psychological placebo effect can actually end the patient's headache!

The placebo effect can be considered a variable that must be controlled. If one group of participants receives a pill for a headache, and the other does not receive a pill, the first group will experience the placebo effect while the second group will not. The experimenter won't know if the difference between the two groups is due to the placebo effect or the medication! <u>Both the control group and the experimental group must experience the placebo effect equally otherwise the data will not accurately reflect the effectiveness of the drug.</u> The use of a placebo in the control group will help to control the placebo effect.

Placebo- Control treatment given to the subjects in the control group. It is a substance without the ingredient under study. A placebo is identical to the experimental substance in every way except it will not contain the **active ingredient**.

Example: A cough syrup contains the medicine (*active ingredient*) as well as water, sugar syrup, flavoring, coloring, etc. The placebo will have water, sugar syrup, flavoring, coloring, etc.—that is, everything except the active ingredient.

It is pretty obvious that an experimenter must not tell the participant if they are receiving the placebo or the active ingredient. Humans are biased (prejudiced) and will come to their own conclusion if told, "Take this but it's just sugar syrup and flavoring." To minimize any bias, researchers use **blind** and **double-blind studies**.

Blind Study- This is an experimental study in which the patient *does not know* if he/she has received the experimental treatment or the placebo (control treatment).

Blind studies are great but researchers are human and biased themselves. If a patient tells the researcher that they experienced a lessening of their headaches, the researcher, who knows the patient received only a placebo, may be biased and record that the patient still had headaches. The researcher may form opinions or conclusions about the effectiveness of the experimental drug before the end of the trial. A double-blind study will eliminate bias on the part of the researcher *and* the patient.

Double-blind Study- This is an experimental study in which neither the patient not the Dr./researcher knows if the patient has received the experimental substance or the placebo (control). Treatments/placebo have no labels and look exactly alike.

How do you analyze the results of data from a double-blind study? Doesn't someone need to know which patients received the active ingredient and which received the placebo? A technician will set up the treatments so that although the researcher/doctor administering the drug doesn't know what the patient is receiving, a record of the treatment is available. When it is time to analyze the data, the researcher will be given the information as to which patients received the placebo or the active ingredient.

Blind and double-blind trials also help researchers understand the nature and appearance of **side effects** associated with medications. For example, a new drug for indigestion is being tested with a double blind trial. The side effects recorded for the experimental group were that 3% experienced stomach cramping. This may seem significant (important) but when compared to the control group in which 3% also experienced stomach cramping, it was not. The stomach cramping may have been a function of the indigestion for which the patients had entered the study and not a function of the medicine being tested at all.

Questions:

10) Describe an appropriate **control treatment** for the following experiments. For human studies, identify when a **placebo** is used:

a) A doctor tests the effectiveness of a sunburn ointment with the active ingredient NOBURN.®

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b) A researcher injects humans with a medication to reduce the size of cancer tumors.

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c) Jellyfish, normally reared in 20% salt water, are reared in 3 higher concentrations of salt water.

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d) Children are given a liquid medication to reduce cavities in their teeth.

Numbers of Test Subjects

A new vaccine has just been discovered. It will keep you from contracting Lyme disease. It is hailed as a miracle drug and the first 100 people to receive the drug will get it for free. Sounds pretty good until you find out it has been tested successfully only *one* time, on *one* individual. Perhaps that individual is healthier or genetically superior to you. Will the vaccine work on you too? To be sure of the validity of a hypothesis, researchers must test it on many individuals. By having many test subjects, any individual or genetic differences that may affect the results are minimized. When designing the experiment, it is also important to randomly select test subjects to the test groups. Then each test group has the same chance of having an unusual participant.

Randomization-When individual subjects are randomly assigned to either the control or experimental groups. Randomization ensures that both the control and experimental subjects are representative samples of the original population. When any test group is not representative of the original population, sampling error is introduced into the experiment. Then one can argue that any experimental results were due to difference in the composition of the different test groups, instead of a result of the independent variable.

The **number of test subjects** within an experiment depends on many factors. How many test subjects are available? What is the cost of administering the treatment? How long will the experiment last? The researcher must use enough test subjects such that he/she is certain of the validity of the data. In addition, the numbers of subjects in control and test groups should be the same.

Example: A medication is tested to determine its efficacy (usefulness) in reducing heart disease. The medication is tested on a male, age 40 who is overweight and suffers from diabetes. The results conclude that the medication did not help this individual. The experimenter decides to try again. This time, he sets up a controlled experiment with 100 individuals. All the participants are male, age 40, overweight and suffer from diabetes. Fifty individuals are randomly assigned to the test group and 50 to the control group (receiving a placebo). This time the medication works.

11) What could be a reason why the medication didn't work on the first individual?

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12) Testing a medication on 50 people sounds great but the test subjects were strictly controlled (male, age 40, overweight, etc.). What about the effect of the medication on other groups of people? What additional types of tests would you consider to determine the efficacy of the medication?

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Replication, or repeating an experiment, further validates a hypothesis.

Replication- The process of repeating an experiment to validate the results. If several different research firms test a vaccine on several hundred people, and find it effective in preventing Lyme disease, the general public will be more likely to take the vaccine.

Levels of the Experimental/Independent Variable

Many times an experimenter is interested in determining the correct level of the experimental variable. For example, how much herbicide (weed killer) is necessary to control dandelions in lawns? If the researcher is interested in trying three different levels of the herbicide, instead of conducting three different experiments at different times, it would be better to conduct all three experiments *at the same time*. In that way, differences in rainfall, temperature and season (controlled variables) won't affect the results.

Example: The control group is a 1 acre lawn that does not get any herbicide. The researcher then sets up three experimental subgroups. *Each* experimental subgroup is composed of a 1 acre lawn. The three subgroups receive 2%, 4% and 8% concentrations of herbicide, respectively. The number of dandelions per acre in the control and each experimental subgroup is counted. The results of *each* experimental subgroup can be directly compared to the control group.

Questions:

13) Given the following information, describe the control and experimental subgroups. Be sure to include the **number of test subjects** in the control and experimental subgroups and describe the different **levels of the experimental variable**. Identify if a **placebo** is used.
If you are not sure how to describe the subgroup levels, you can use words like, "high, medium, low" or you can make up any percent or metric measurement (grams, centimeters, liters) you wish. You won't be expected to know exactly which levels to use.

a) A researcher wants to test different levels of a medication to control warts.

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b) Test to determine the level of fluoride in toothpaste that produces the fewest cavities in children.

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c) Nesting boxes for bluebirds are usually placed 10 feet above ground. Determine the preferred height of nesting boxes for bluebirds. How will you determine if a nesting box is preferred by the birds?

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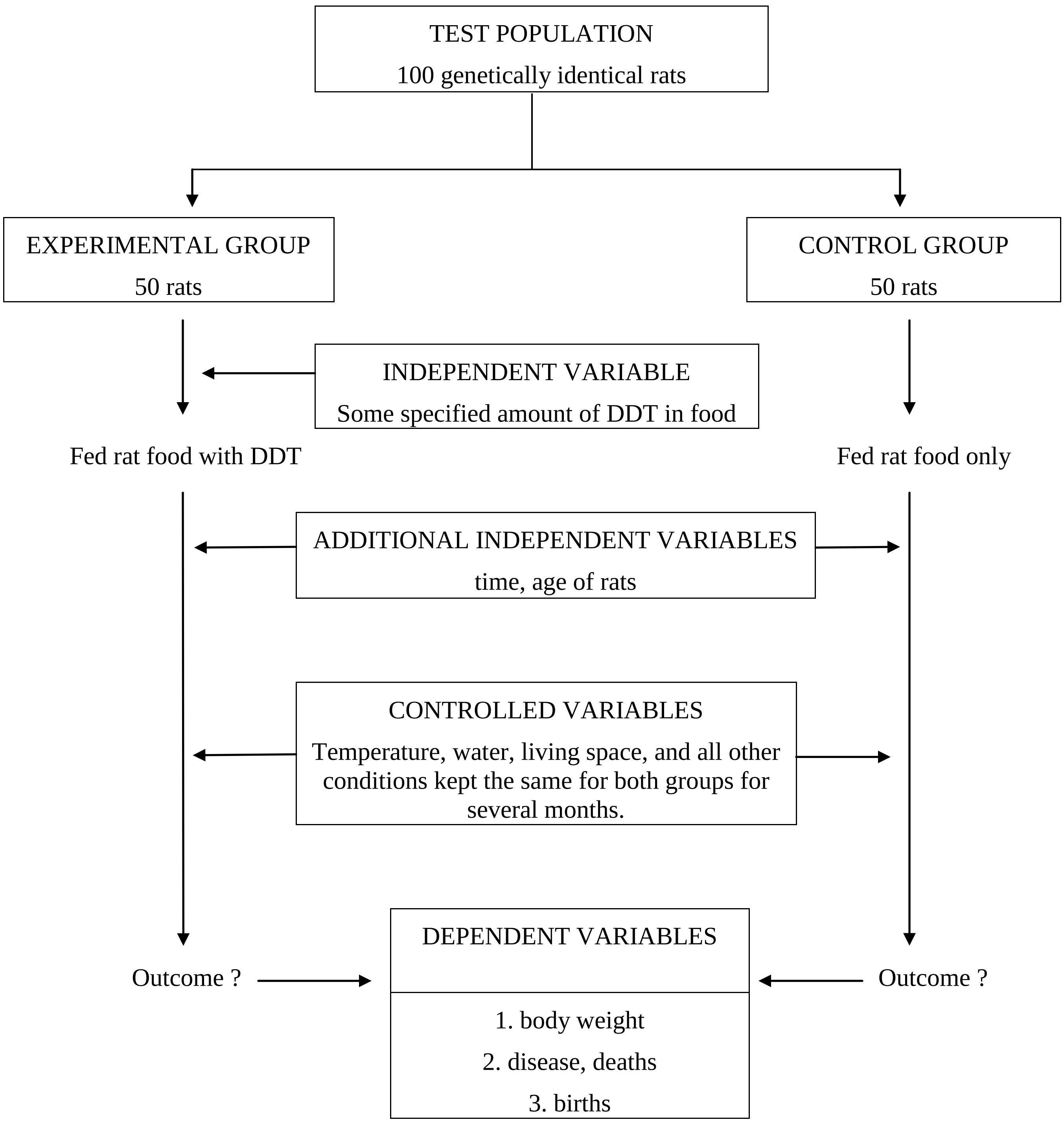
d) In the last experiment, how many total nesting boxes did you use in the experiment? ______________

In Summary:

The example below illustrates a classic experimental design in biology. This experiment is designed to test the hypothesis that DDT ingested with food will not have harmful effects on laboratory rats over a period of time. Rats similar in genetic background were randomly assigned to one of two different test groups. The control group did not receive the independent variable (DDT) while the experimental group received DDT with food. Subgroups were not used in this experiment. Additional independent variables like time or age of rat could be measured for both test groups. Controlled variables were held constant such that test results should refute or support the hypothesis. Note that more than one dependent variable was measured during this experiment.



Part III: Building Tables and Line Graphs From the Data:

Data Table- a convenient way to organize data in a visual manner. Although not as visual as a graph, tables can hold a large amount of data in a minimum amount of space. Placing data in a table is far better than putting it in paragraph format.

Example: An experimenter wants to know if increased light intensity will affect the amount of oxygen produced by Elodea plants during the day. Plants in test tubes were exposed to the light for 12 hours from 9:00 am to 9:00 pm. Measurements for oxygen production in a test tube were taken every 4 hours while the light was on. The following data were collected:

Data table for the amount of oxygen produced by Elodea plants at 2 different light intensities measured four different times during the day.

	Amount of oxygen produced (ml) by each plant, in 5 minutes			
Plants receiving **normal** (0.152 photons per footcandle) light intensity	9:00 am	1:00 pm	5:00 pm	9:00 pm
Plant 1	0.6	1.0	2.6	1.8
Plant 2	0.8	1.2	2.5	1.5
Plant 3	0.5	1.1	2.4	1.9
Average of Data	**0.6 ml**			
Plants receiving **high** (0.222 photons per foot candle) light intensity	9:00 am	1:00 pm	5:00 pm	9:00 pm
Plant 4	1.2	3.2	3.6	2.8
Plant 5	1.1	2.5	3.8	2.0
Plant 6	1.3	3.5	4.0	3.5
Average of Data				

=>14) In the experiment above, three plants in each test group were measured at each time of the day. Before the data is graphed, it must be averaged. Fill in the averages for the data above. The first average has been calculated for you.

Graph- a visual representation of data. Graphs are more useful than a data table because they can enable the researcher to make predictions of the dependent variable between the data points.

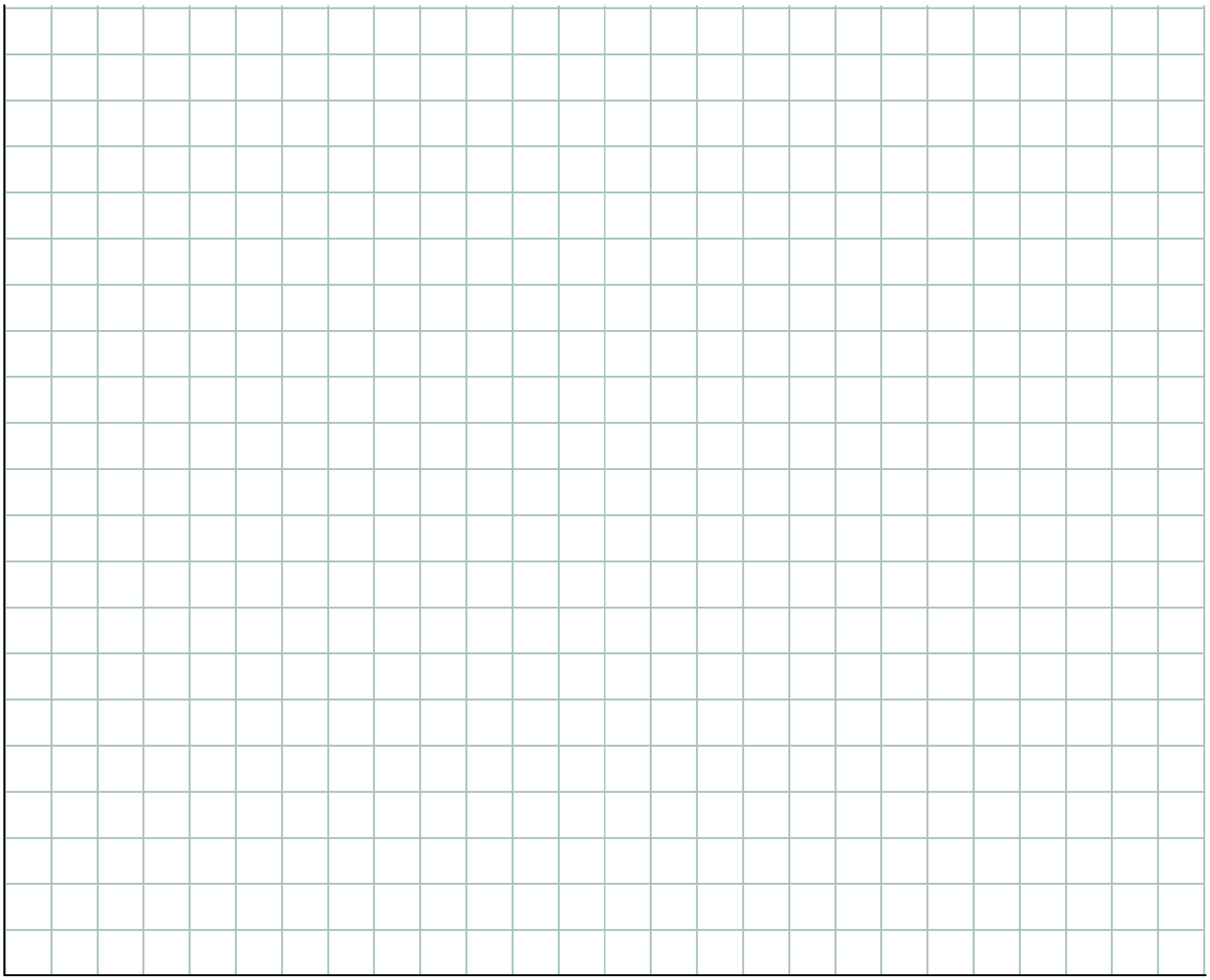
Here are some rules to follow when building a line graph to illustrate your data:

- Dependent variable measurements go on the Y-axis,
- Independent variable measurements go on the X-axis.
  If you have an additional independent variable, for example, "time" or "date," it is graphed on the X axis. The primary independent variable will be charted as two or more different lines on the graph.
- Be sure to correctly and fully label the axes, remembering to include the measurement unit that was used For example, "Number of eggs per leaf," or "Height of Flowers, cm."
- Scales are the measurement charts along the X and Y axes. Make sure that whatever scale you use is properly spaced and is in regular intervals. The purpose of making a graph is to see the pattern that the data illustrates. Without appropriate scales, you do not see the true picture of the data.
- Generally it's a good idea to make your graph nice and large. When you're looking at a picture of data (which is really what a graph is), it's better if the picture is LARGE. Use the whole paper. Space out your scales, skipping lines if necessary, while maintaining proper scaling patterns.
- Titles should include a description of all independent and dependent variables.
  You can use the following plan: "Effect of (independent variable) on (dependent variable) given (additional independent variable like time or age, if present)."
- Double-check that each point on your graph is correct. Connect the points on a line graph.

15) Graph the data from the previous experiment on the graph below. Include appropriate labels for each axis.
Hint: You will be graphing the averaged data. The additional independent variable is the time of day.

Title: Effect of ____________________________ on average __________________________________

given ____



16) Fill in the following for the above experiment:

a) experimental variable/independent variable ________________________________

b) dependent variable _______________________________

c) additional independent variable _______________________________

d) Type of data (quantitative/qualitative) _______________________________

e) Control group ____

f) Experimental group ____

g) State the conclusion to the experiment ____

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