AP BIOLOGY
SUMMER ASSIGNMENT

SCIENTIFIC INVESTIGATION

Part 1: Developing an Appropriate Area of Investigation

The questions that are answered by scientific investigations are based on observations, on information gained through previous research, or on a combination of both. Just because a question can be answered, however, doesn't mean it can be answered scientifically.

Highlight each of the following questions that you think can be answered scientifically.

- What is the cause of AIDS?
- Is communism evil?
- Why is grass green?
- Does watching television cause children to have shorter attention spans?
- Was the malignant tumor found in the lungs of a 70-year old man caused by his 45 year habit of smoking cigarettes?
- Do mice require calcium for developing strong bones?
- Was the earth created by an all-powerful being?
- Are dogs are happy when you feed them steak?
- Can an active volcano be prevented from erupting by throwing a virgin into it during each full moon?
- How old is the earth?

What 3 characteristics determine whether a question can be answered scientifically?

Part 2: The elements of an Experiment

An experimental design must consist of several critical elements: the dependent variable. The independent variable, the constants, the hypothesis, levels of treatment, repetition, sample size and the control treatment.

A: Determining the Dependent Variable

The **dependent variable** is what the investigator measures (or counts or records). It is what the investigator thinks will be affected during the experiment. For example, the investigator might want to measure soybean growth. There are several measurable characteristics of soybean growth, each of which could serve as the dependent variable.

List several examples of measurable soybean characteristics that can be used to determine growth?

For any experiment, there may be a number of possible dependent variables. The investigator must choose the one that he or she thinks is most important and illustrates the principle being investigated the most clearly. However, the investigator may choose to measure more than one dependent variable, if he or she thinks the results will lead to a more complete understanding of the principle under investigation.

B: Determining the Independent Variable

The **independent variable** is what the investigator manipulates during the experiment. It is what the investigator believes is influencing the outcome of the experiment. It is what the investigator thinks will affect the measurement of the dependent variable.

For the soybean example above, name as many factors as possible that might affect the mass of soybean plants. These are independent variables that may or may not be tested in a scientific investigation.

How many independent variables are possible in any experiment? Why?

*Any correctly designed experiment has ONLY ONE independent variable. If more than one independent variable is manipulated at the same time, there will be no way to determine a direct causal relationship. In other words, how will the scientist know what change caused a particular effect if there was more than one change at a time?

TIME is a special type of independent variable. The investigator might test how some variable changes over the course of time, where the only cause of change is simply the passage of time.

C: The Constants (Controlled Variables)

Because any minute differences among treatment groups can influence the outcome of an experiment, it is critical that only the independent variable changes. It is not enough to state that everything else will stay the same. The scientist must consider what other elements might influence the outcome and specifically indicate that these will remain **constant** in the experiment

For example, consider an experiment studying the effects of increasing amounts of fertilizer on soybean growth, where the scientist has chosen the amount as fertilizer as the independent variable. The scientist must be sure that there are no differences in the type of fertilizer used.

What other elements in the above experiment must remain **constant**? List as many as you can think of

Part 3: Designing the Procedure

A: Developing an hypothesis

Before you begin any experiment, you should have a very good expectation of your results. This prediction of what will happen is called the hypothesis, and it is written in a very concise and predictable format. The hypothesis assumes that if you manipulate some variable (the independent variable), a predictable and measurable change will occur (the dependent variable), and that this pattern is predictable over some range of the variable you manipulate

The hypothesis is ALWAYS stated as an "if/then" prediction. The hypothesis is then based on increasing or decreasing the independent variable and predicting what the change in the dependent variable will be. A good hypothesis can be plugged into this simple grammatical formula: If the independent variable is increased/decreased, then the dependent variable will increase/decrease, replacing the underlined words and choosing either increased or decreased to complete the phrase.

For example, in an experiment measuring the effect of light intensity on bean plant mass, the independent variable is the intensity of light and the dependent variable is bean plant mass. An appropriate hypothesis would be stated: If the intensity of light a plant receives is increased, the plant mass will increase.

Note: An hypothesis provides an initial point of reference for an investigation. We know that you cannot increase the light intensity infinitely without negative effects on growth. However, we make hypothesis simplistic intentionally, with an implication that further and more detailed study will reveal more information on the process.

For the following statements:

1. circle the independent variable
2. place a box around the dependent variable
3. write a hypothesis

a. What is the effect of light on bean seed production in green beans?

b. What is the effect of humidity on mold growth?

c. Which gender has a stronger heart?

d. What type of food do iguanas prefer: fruits, vegetables, grains or meats?

B: Levels of Treatment

Early in the development of the procedure, the investigator must determine appropriate values to use for the independent variable. These values are called the levels of treatment. This judgment is usually based on prior knowledge of the system. For example if the purpose of the experiment is to investigate the effect of temperature on weight gain in guinea pigs, the scientist should have enough knowledge of the physiology of guinea pigs to use levels of treatment within a biologically relevant range. Subjecting the animals to extremely high and low temperatures could kill the organisms, and no useful data would be obtained (important note: if your experimental organisms die, this is generally considered an unsuccessful experiment). At the same time, you must choose an upper and lower level of treatment that will reveal an interesting result. For example, if you choose to test your animals at 22° C and at 24° C you will probably not see anything interesting and have wasted valuable resources.

As a general rule, you should have at least five levels of treatment across a biologically relevant range of treatment.

Choose levels of treatment for the following experiments:

a. The effect of light intensity, in Watts, on the number of bean pods produced by bean plants.

b. The effect of humidity, in %, on mold growth measured as number of mold colonies.

c. The effect of amount of light, in hours, on rose bush mass.

C. Sample Size

When conducting an experiment, you must have a reasonable number of organisms, at each level of treatment for your results to be meaningful. For example, if I test one bean plant at each level of treatment, I will probably not find a useful pattern. What if one of my plants is ill and dies, or is a genetic mutant, which has an unusual growth pattern?

The scientist must use his or her knowledge of the organism and its growth pattern to determine an appropriate sample size for each level of treatment. For example, I will not choose to do genetic experiments on elephants whose gestational cycle takes almost a year and a half, nor will I choose a mere 10 fruit flies, as their life cycles are short and number of offspring is high. It is reasonable to expect to measure thousands of fruit flies within the course of an experiment.

Think about what number of organisms would be appropriate sample size at each level of treatment in the following experiments:

a. The effect of time in the light on mustard plant mass.

b. The effect of estrogen on pig reproduction

c. The effect of oxygen on the growth of E. coli bacteria.

D: Repetition and Statistical Analysis

A result is only valid as long as it is reproducible. Any number of variables can influence an experiment conducted only one time. Therefore, it is assumed that the investigator repeats all experiments three independent times. This is called repetition. In addition, variations that result from minute differences on each occasion are minimized by statistical analysis, which means averaging the results.

E. Control Treatment

The control treatment is a level of treatment in which the independent variable is either eliminated or set at a standard value. In this way, the investigator is assured that the independent variable being tested is having an effect. For example, in the example "a" above, to measure the effect of time in light on mustard plant mass, one level of treatment is established with NO light. However, as is the case for temperature, the investigator cannot eliminate temperature. The control treatment is set at a standard such that if your hypothesis states a change as you increase the temperature, the control is the coldest level of treatment and vise versa.

For each of the following examples, describe an appropriate control treatment:

a. An investigator studies the amount of alcohol produced by yeast when incubated with different types of sugars.

b. An investigator measures the effect of light intensity on photosynthesis by collecting oxygen produced by a plant.

c. An investigator measures iguana's preference for the following foods: vegetables, grain and meat.

Part 4: Presenting and Analyzing Data

Once you have conducted your experiment and the data are collected, they must be organized and summarized so that the scientist can observe patterns in the result and determine if the hypothesis has been supported or negated. Tables and graphs are used to present data. Tables are entitled "Table 1", Table 2", etc. but all other visual representations, including graphs, drawings, or photographs are entitled FIGURES: "Figure 1", "Figure 2" etc.

A: Tables

You have collected data from your experiment in the form of a list of numbers that may appear at first glance to have little meaning. Shown below is an appropriate Table representing data collected from an experiment investigating the effect of smoking or pulse rate:

Table 1: Averages of Pulse Rate for Smokers and Nonsmokers

	Pulse Rate (*Average Beats/Min)	
	Before Step Test	After Step Test
Smokers	80	146
Nonsmokers	72	120

*Average of six smokers and ten nonsmokers

Notice the following important elements:

- Title with a number and a heading describing the contents of the table. Tables are numbered consecutively within one laboratory paper. Tables and Figures are numbered independently of one another.
- Column and row headings indicating the independent and dependent variables.
- All headings will have units where appropriate.
- Keys with important additional information are located directly below table and referred to with an asterisk.

Use the following information to create a data table:

A scientist wants to measure the rate at which goldfish grow. She measures the size of 100 goldfish every week for 12 weeks and averages the results of each week. At the end of week 1 the fish were an average of 1 cm in length, at the end of week 2 the average size of the fish was 3.5 cm, at the end of week 3, the average size was 4.5, at end of week 4, average size was 7 cm, at end of week 5 average size was 9cm, at end of week 6 average size was 11 cm, at end of week 7 average size was 13.5, at end of week 8, average size was 15 cm, at end of week 9, the average size was 18, at the end of week 10, the average size was 19 cm.

B: Graphs

Data collected in an experiment is often presented in the form of a graph, a diagram showing the relationships among the independent and dependent variables. The independent variable is graphed on the x-axis (horizontal) and the dependent variable is graphed on the y-axis (vertical axis). Since a graph is a picture of the results, it can often be more easily interpreted than a table. By looking at a graph, you can visualize the effect that the independent variable has on the dependent variable. A pattern in their relationship may be easily seen.

When preparing a graph, keep in mind that your objective is to show the data in the clearest, most readable form possible. Follow these guidelines:

- Use graph paper or computer program that will print a graph with lines.
- Plot the independent variable on the x-axis and dependent variable on the y-axis.
- The intervals labeled on each axis should be appropriate for the range of data so that most of the area of the graph can be used. For example, if the highest data point is 147, the highest value labeled on the axis would be 150. If you labeled intervals on up to 200, there would be a large unused area of the graph. Generally, begin both axes of the graph at zero (the extreme left corner). To avoid generating graphs with wasted space, you may signify unused graph space by two vertical tic marks between the zero and your lowest number on one or both axes.
- The intervals labeled on the graph should be evenly spaced. For example, if the values range from 0-50, you might label the axis at 0, 10, 20, 30, 40, and 50. It would be confusing to have labels that correspond to the actual data points (for example, 2, 17, 24, 30, 42, 47)
- Label each axis with the name of the variable and specify the units used to measure it. For example, the x-axis might be fecundity in numbers of offspring per cycle and the y-axis might be amount of protein in pounds consumed per day.
- Choose the type of graph that best presents your data. Line graphs and bar graphs are most frequently used in scientific presentation.

LINE GRAPHS

Line graphs show changes in the quantity of the chosen variable and emphasize the rise and fall of the values over their range. For example, changes in the dependent variable pulse rate, measured over time, would be depicted best in a line graph. Use a line graph to present continuous data.

- Plot data as separate points.
- Generally **do not connect the points dot-to-dot,** but draw smooth curves or straight lines to fit the values plotted for any one data set. You should know this as a best fit line.
- If more than one set of data is presented on a graph, use different symbols or colors to label different data sets and provide a key to indicate the information in each data set.

BAR GRAPHS

Bar graphs are constructed like line graphs, except that a series of vertical bars are drawn down the horizontal axis. Bar graphs are often used for data that represents separate separate or discrete groups or categories, thus emphasizing difference between the groups. In general, use a bar graph when one of the variables cannot be represented numerically. For example, a bar graph might be used to depict the differences in pulse rate for smokers and nonsmokers.

You will be asked to design graphs throughout the course. Remember, the primary function of the figure is to present your results in the clearest manner to enhance the interpretation of your data.

Using the data from the Table you created above (for the fish); design a graph to represent the data. Remember the title begins "Figure 1: "and must be followed by a description of the information contained within the Figure (typically the independent and dependent variable). Label your axes completely with labels and units, and provide a key if necessary.

Questions for Review

A. Match the terms with their definition

1. Things that must stay the same during the experiment	a. sample size
2. Testable prediction of the outcome of the experiment	b. levels of treatment
3. The appropriate values to use for the independent variable	c. repetition
4. The treatment that eliminates the independent variable or sets it at a standard value	d. independent variable
5. What the investigator measures, counts or records; it is Being changed by changes to the independent variable	e. dependent variable
6. The number of times the experiment is repeated	f. constants
7. The number of individuals at each level of treatment	g. control treatment
8. What the investigator is testing; the cause of a change in the dependent variable	h. hypothesis

B. For the following experiments, circle the independent variable and place a box around the dependent variable.

1. Height of bean plants is recorded daily for two weeks.

2. Guinea pigs are kept at different temperatures for 6 weeks. Percent weight gain is recorded.

3. Percent absorption by a pigment is measured for red, blue, green and yellow wavelength of light.

4. Batches of seeds are soaked in salt solutions of different concentrations and germination is counted for each batch.

Suggest a control treatment for each of the following experiments.

1. The effect of Nutrasweet® on tumor development in laboratory rats is investigated.

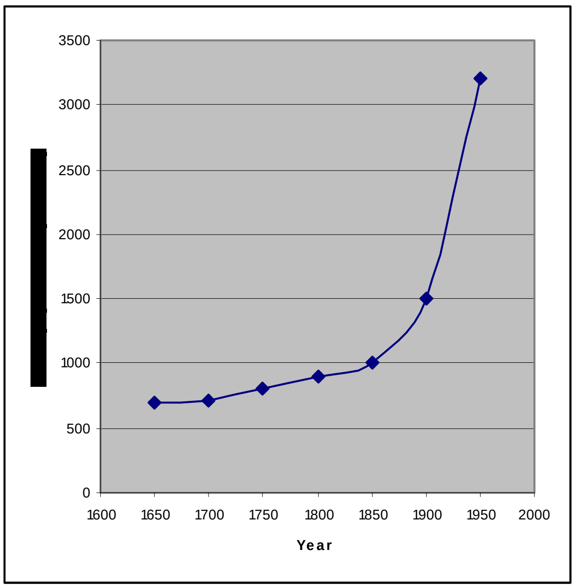
2. Subjects are given squares of paper that have been soaked in a bitter tasting chemical. The investigator records whether each person can taste the chemical.

3. Rolaid tablets are dissolved in water. The investigator then measures the pH of the solution when different amounts of acid are added.

4. The effects of increasing concentrations of a new drug on ADD are tested on children. The investigator measures length of time of concentration when solving math problem.

C. *Create a title for each graph shown below and answer the associated questions.*

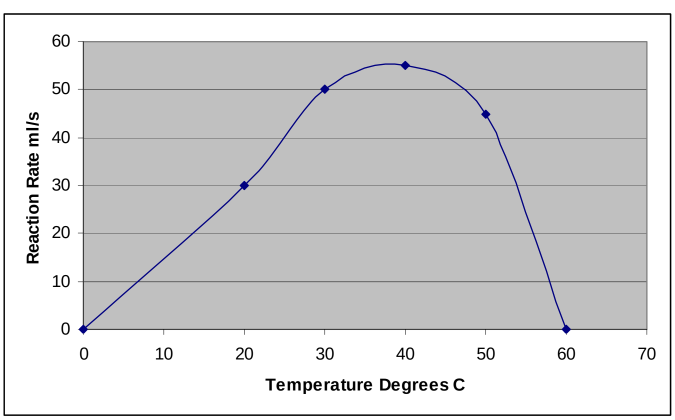
1.



What was the world's population in 1900?

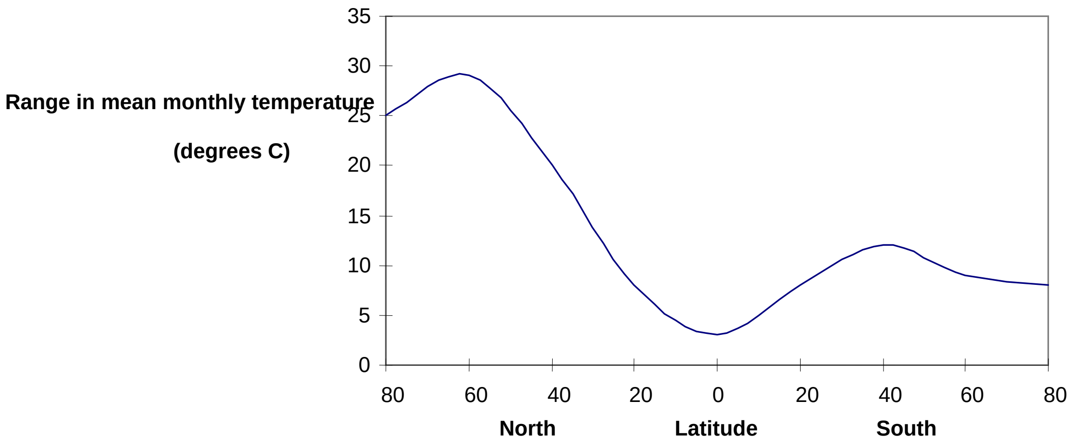
Predict the world's population in 2050?

2.



At what temperature is the reaction rate the highest?

3.



At what latitude does the least variation in temperature occur?
What is the range in mean monthly temperature in New Orleans, Louisiana (latitude 30 degrees N)?

D. *Practicing Experimental Design*

1. A group of students hypothesize that the amount of alcohol produced during fermentation depends on the amount of glucose supplied to the yeast. They want to use 5%, 10%, 15%, 20%, and 30% glucose solutions.
   a. What is the independent variable?

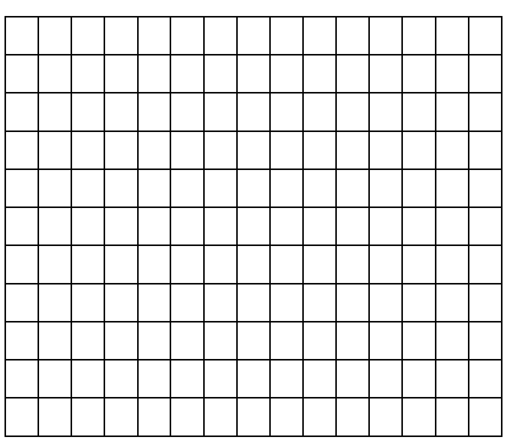
   b. What is the dependent variable?

   c. What control treatment should be used?

   d. What are at least five elements that should remain constant (controlled variables)?

   e. What type of graph is appropriate for presenting the data?

   f. Sketch a graph to present these data, labeling the axis and composing a correct title



2. Having learned the optimum sugar concentration, the students next decide to investigate whether different strains of yeast produce different amounts of alcohol.

    a. Briefly explain how this experiment would be set up.

    b. If you were going to graph the data from this experiment, what type of graph would you use?

3. A group of students wants to study the effect of temperature on bacterial growth. To get the bacteria, they leave Petri dishes of nutrient agar open on a shelf. They then put the dishes in different places: an incubator (42° C), another incubator (37° C), a lab room (22 ° C), a refrigerator (10 ° C), and a freezer (0 ° C). Bacterial growth is measured by estimating what percentage of each dish is covered by bacteria at the end of a three day growth period.

    a. What is the independent variable?

    b. What is the dependent variable?

    c. What elements of the experiment should remain constant (controlled variables)?

    d. What type of graph should be used to present these data?

Sketch the axes for the graph, create a title and sketch the predicted results

4. A team of scientists is testing a new drug on AIDS patients. They expect patients to develop fewer AIDS-related illnesses when given the drug, but they don't expect the drug to cure AIDS.

    a. Write a hypothesis for this experiment.

    b. What is the independent variable?

    c. What is the dependent variable?

    d. What is the control treatment for this group?

    e. What are some constants (controlled variables) in this experiment?

    f. The scientists monitor patients for symptoms of 12 different diseases. What would be the best way for them to present the data?

5. A group of students decides to investigate the loss of chlorophyll in autumn leaves. They collect green leaves that have turned color from sugar maple, sweet gum, beech and aspen trees. Each leaf is subjected to analysis to determine how much chlorophyll is present

    a. What is a reasonable hypothesis for this experiment?

    b. What is the independent variable?

    c. What is the dependent variable?

    d. What would you advise students about sample size in this experiment?

    e. What type of graph would be the most appropriate for presenting the results of this experiment

    f. What is the control treatment in this experiment?