Survival Manual for BIOLOGY

Develop your Curiosity

Ask lots of questions! Ask your yourself, ask the book, ask the internet, ask friends, ask parents, ask your data, ask the teacher….

ASK *Absolutely*, it is in wanting to know something that you will learn!!

APPLY Biology is about application and NOT memorization. Every time you approach something new, you need to ask yourself, "What do I already know that can guide me? How can I apply what I already know to a concept that appears new?

Get Organized

Use a planner.
- Internal Assessments in other subjects
- Group 4 project
- Labs, field trips and tests
- Activities like clubs, plays, sports, performances
- College applications & trips

Keep yourself up-to-date; get help if you start slipping behind!!
Use *flex time*

Study aids

Textbook, use it!! Focus on diagrams and their annotations, as well as bold faced words and summaries. Choose a time to read when you can pay attention. Use the book to prepare for note-taking; or use it to refresh notes afterward.
On line—use animations, simulations, etc. Check out the bottom of my website.
Syllabus (use it as a guide when reading & studying)

Vocabulary & Writing

Flash cards by topic (Look for over-lapping terms)
Use the Command Terms
Completely understand all of the "Essential Questions"—practice writing them

Techniques

Draw to enhance understanding and to express yourself
Use Cornell Notes - Review notes within 24 hours
Write-up labs before you forget what happened; use your teacher for coaching.
Color-mark your labs or use the checklists given to you
Work regularly with a study group
Do corrections to work; rewrite essays or parts of essays & short answer questions
Practice DBQs (data-based questions)
Use math---don't expect math to "go away"

Practice Personal Integrity

Survival Manual revised by Maggie Raczek 2019

Command Terms

Objective 1

Define	give the precise meaning of a word, phrase or physical quantity.
Draw	represent by means of a labelled, accurate diagram or graph, using a pencil. A ruler (straight edge) should be used for straight lines. Diagrams should be drawn to scale. Graphs should have points correctly plotted (if appropriate) and joined in a straight or smooth curve.
Label	Add labels to a diagram.
List	give a sequence of names or other brief answers with no explanation.
Measure	obtain a value for a quantity.
State	give a specific name, value or other brief answer without explanation or calculation.

Objective 2

Annotate	add brief notes to a diagram or graph.
Calculate	obtain a numerical answer showing the relevant stages in the working (unless instructed not to do so).
Describe	give a detailed account.
Distinguish	make clear the differences between two or more concepts or items.
Estimate	obtain an approximate value.
Identify	provide an answer from a number of possibilities.
Outline	give a brief account or summary.

Objective 3

Analyse	break down in order to bring out the essential elements or structure.
Comment	give a judgment based on a given statement or result of a calculation.
Compare	give an account of similarities between two (or more) items or situations, referring to both (all) of them throughout.
Compare & Contrast	Give an account of similarities and differences between two (or more) items or situations, reffering to both (all) of them throughout.
Construct	display information in a diagrammatic or logical form.
Deduce	reach a conclusion from the information given.
Design	produce a plan, simulation or model.
Determine	obtain the only possible answer.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses. Opinions or conclusions should be presented clearly and supported by appropriate evidence.
Evaluate	Make an appraisal by weighing up the strengths and limiations.
Explain	give a detailed account including reasons or causes.
Predict	give an expected result.
Sketch	represent by means of a diagram or graph (labelled as appropriate). The sketch should give a general idea of the required shape or relationship, and should include relevant features.
Suggest	propose a solution, hypothesis or other possible answer.

OBJECTIVES

It is the intention of the Diploma Programme experimental science courses that students should achieve the following objectives.

1. Demonstrate a knowledge and understanding of:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    d. communicating scientific information.

2. Apply:
    a. facts, concepts, and terminology
    b. methodologies and techniques
    d. methods of communicating scientific information.

3. Formulate, analyse and evaluate:
    a. hypotheses, research questions and predictions
    b. methodologies and techniques
    c. primary and secondary data
    d. scientific explanations.

4. Demonstrate the appropriate research, experimental, and personal skills necessary to carry out insightful an ethical investigations.

Directions for a Written Report

Purpose: You have fiddled with your subjects and determined a question worth investigating. In the process you may have adjusted your ideas until you eventually collected data that could answer either your original question or a modification of it. During your procedure you chose a variable and watched for a response to it. You tried to decide what other factors might detract from the meaning of your collected data. You controlled these detractor factors. Because you collected some numeric data, you will be able to transform the data to search for more meaning. You will then draw conclusions and evaluate the quality of both the data and the procedure of the experiment. NOW you need to report this process in a formal way:

Before you begin writing, do the following things:
(1) Get the notes that you took in this class
(2) Get notes you took as you planned and performed the experiment
(3) Read through this page and talk with your partners about what you think needs to be included in each section of the report-make notes if you want to do so. **Once you begin writing, the work should be your own individual best effort.**

Elements of the formal report: Whenever you are writing a formal lab report, this format is your default format. Sometimes there will be additional expectations that attend an individual assignment.

This report is to be written in sections as indicated below using the language forms indicated.

BACKGROUND INFORMATION – Background information should be appropriate and relevant, enhancing the understanding of the context of the investigation. It should include observations, information given in class, and researched information related to your question. (Be sure to properly cite sources if you went to an outside source.) It should also include your personal significance, interest, or curiosity in the topic. If you changed the question during the course of the experiment, because of what happened or failed to happen, discuss the shift in this section. Write this section in paragraph form.

FOCUSED QUESTION-Write your question in its final form. Use the interrogative form.

DESIGN-- Explain how what you knew led you to your experimental design. Explain your assumptions and reasoning but not the details of your steps. Describe your manipulated variable. Specifically describe the factors that are to be controlled (controlled variables). Describe what you will watch, measure and use as your criterion (responding variables). If there was a shift in your question during your work time, discussed that process in your background.

MATERIALS - List the materials (not in sentence format).

PROCEDURE Describe the steps that you took as a set of ***numbered statements*.** Make your description sufficiently clear that I could repeat your experiment and get the same results. Be certain to include quantities, dimensions, and other measurements that would be helpful to a person trying to repeat your results. Make use of an economy of words. Specifically describe the factors that needed to be controlled including how control was achieved. What factors did you monitor? Draw a diagram of the experimental plan and refer to the diagram in your description if helpful. Pay attention to any significant safety, ethical, or environmental issues that are relevant to your methodology. Include your plans for analyzing the data you collect.

RESULTS - Express the raw data by using a data chart. Be careful to report only what was observed, expressing the observation in measurable terms. Include both **qualitative** and **quantitative** data. Show the transformations of this raw data that you used to bring meaning to your observations. To assist you in your interpretation, you may want to process your data by finding averages, ranges, medians, modes, or percent difference to see if any patterns pop out. If the data can be expressed in the form of a graph, do so. Use the four-step method to show sample calculations and other transformations. Include **uncertainty** in your data charts and graphs and show its propagation in your sample calculations. **Annotate** your data charts. Tell me how you determined your uncertainty and which data you personally measured. **Annotate** your graphs. Include a brief description of the trend illustrated under the graph and what the error bars represent.

CONCLUSIONS --Discuss and evaluate how your results answer the focused question. Use data to justify your conclusions. Compare your conclusion to the accepted scientific context. Discuss the uncertainty of your measurements and its impact on your analysis. Given all this, discuss your confidence in your conclusions. Discuss the limitations of your conclusions. In this section you are evaluating **your data and its interpretation.** Write this section in paragraph form.

EVALUATION - Review and evaluate the procedures you used. Discuss the strengths of your investigation. Discuss the weaknesses of your procedure including any sources of error and their impact on your data. Discuss realistic and relevant suggestions for improvement that would lead to more reliable results and greater validity of conclusions. **Organize the errors and weaknesses into a data chart**. Suggest an extension of the investigation.

Your lab report will also earn a Communication score. Your report should be well structured and clear. It should also be relevant and concise. Your use of subject-specific terminology and conventions should be appropriate and correct. A bibliography with full citations should be attached.

Proof read your paper—Does it make sense? If not, fix it!

Turn in your paper & CELEBRATE!!

Internal Assessment Criteria

Personal Engagement

The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative, or insight.

The justification given for choosing the research question and/or the topic under investigation demonstrates personal significance, interest, or curiosity.

There is evidence of personal input and initiative in the designing, implementation or presentation of the investigation.

Exploration

The topic of the investigation is identified and a relevant focused research question is clearly described.

The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation.

The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data.

The report shows evidence of full awareness of the significant safety, ethical or environmental issues that are relevant to the methodology of the investigation.

Analysis

The report includes sufficient relevant quanititative and qualitative raw data that could support a detailed and valid conclusion to the research question.

Appropriate and sufficient data processing is carried out with the accuracy required to enable a conclusion to the research question to be drawn that is fully consistent with the experimental data.

The report shows evidence of full and appropriate consideration of the impact of measurement uncertaintiy on the analysis.

The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

Evaluation

A detailed conclusion is described and justified which is entirely relevant to the research question and fully supported by the data presented.

A conclusion is correctly described and justified through relevant comparison to the accepted scientific context.

Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are discussed and provide evidence of a clear understanding of the methodological issues involved in establishing the conclusion.

The student has discussed realistic and relevant suggestions for improvement and extension of the investigation.

Communication

The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes.

The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way.

The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation.

The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.

Words you know, but not really

data—information collected from a field experience, observation or controlled experiment including all measurements and counts.

precision—level of exactness; instruments have precision depending upon what the smallest calibration interval is.

significant figures—number of digits used to express an experimental value. Since measurements are limited by the precision of the instrument, it is important not to imply that numbers are more exact than they are. The simplified rule is that you can estimate one digit beyond the calibration. Any calculations should not exceed that degree of exactness.

uncertainty—When taking a measurement, there is always a sense of accuracy that is plus or minus some value. That value is called uncertainty. Sometimes you will look at your instrument to determine the uncertainty; other times you will have to include the uncertainty as part of your procedure.

accurate (accuracy)—This is the degree to which the measured value matches the true value. Accuracy depends upon the precision of the instrument and on the skills of the person using the instrument.

reliable (reliability)—This is the repeatability of a result. Something is reliable if the same answer or measurement is obtained consistently.

percent error—calculation done to determine how far from true an answer is. The formula is : $\frac{\text{EXPERIMENTAL VALUE} - \text{TRUE VALUE}}{\text{TRUE VALUE}} \times 100 = \%\text{ERROR}$

data processing—whatever the person does to raw data to find patterns or provide meaning such as graphing or calculating averages, ranges, distribution, frequency, etc. Data processing includes using statistical tools such as standard deviation and student's t-test to examine how significant the difference is between two sets of numbers.

correlation—the degree at which two things occur together. A correlation can be observed, graphed by scatter plot, or calculated. A correlation may be either positive or negative. *Caution:* A correlation does not indicate cause and effect.

significance--After sets of data have been collected in response to variables, a scientist compares them to see if the results are adequately different. The scientist wants to be able to say that the differences in the conditions are responsible for the differences in the data sets. Generally, if the two sets of data are far apart, they are "significant". Statistical tools such as standard deviation and t-test can be used to establish significance.

Dumas 09

Drawing in Science

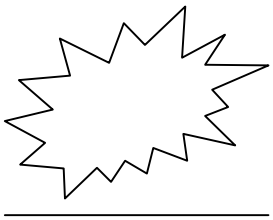
Drawings in science are very useful as a way to explain how an experiment is set up. They are also used to record what has been observed. Furthermore drawings and diagrams can often make a concept easier to understand. Students are encouraged to develop their drawing skills in Biology. Not everyone has been taught to draw. Some people are quite talented and draw easily, while others avoid drawing. Regardless of previous experience or success, everyone can be come better at seeing the world through this medium. So everyone is expected to try to become more expressive through drawing.

Generally the rule for scientists is this: Express the reality of the situation!
Beauty is of less value.

Scientific Illustration is a professional field that has a specific style that may be helpful to understand: Drawings are usually done as line drawings with no shading. If shading is done it is done as stippling or graded lines. Drawings originate as black and white illustrations in either pencil or pen. Sometimes color is added for clarity. Many of these style parameters will probably disappear as more and more computer generated drawings are used.

Some things are unlikely to change. Labeling arrows should be used to touch the item being labeled. Labels are to be placed off of the drawing and parallel to the bottom of the page. Each drawing needs a title or caption that explains it to the observer.

It is often useful to indicate whether the drawing is of something smaller than the picture or larger than the picture. We call that the magnification of the drawing:



This drawing is 1.5 inches across. If the actual object from which it was drawn were 3 inches across its magnification would be .5x meaning that the drawing is only half the real size. On the other hand, if the actual size of the object were .5 inches across, then the magnification would be 3x meaning it was drawn 3 times larger than life.

(Actual size) x (magnification) = drawing size

OR magnification = drawing size /actual size

*Both measurements must be in the same unit or a conversion factor must be applied.

TIPS FOR SCIENTIFIC ILLUSTRATION

By Russell Glenn

Before you start, know what you are going to draw and where you are going to draw it.
--If you are doing a complicated drawing, it may help to do a rough sketch on another piece of paper before starting.
--Do the drawing lightly at first, so you can erase. Darken the lines when you are sure that everything is where you want it to be.

Arrange your drawing so that it highlights the point you are trying to make.
--What view of the drawing will give the most information in the clearest manner?
--Think about what is important to bring to the viewer's attention. Then find a way to emphasize it in your drawing. For example, making an object darker is a good way to make it stand out.
–Make the drawing simple. Do not give more information than is needed.
--If you feel it will help to show the drawing from different views, label which view is which. (example: Which is the front and which is the back?)
--You might first want to show the whole drawing to give the viewer some perspective of what is being looked at. Then you may want to zoom in on certain details.

Proportion your drawing so it looks good on the page.
--Try to leave at least an inch or so margin on all sides of the paper.
--Carefully choose the size of your drawing. Make it large enough so that it is readable and understandable.
--Center your drawing in the space you are using. Find the center of the drawing space and put the object you have decided upon there. This gives you a point of reference from which to locate other objects.

Use symbols to enhance your drawing.
--If your drawing looks like it might become cluttered with information, make a key and show what some of the objects are by using symbols.
--You can show hidden lines, such as lines that are behind an object , with dashed lines.
--Use arrows to show direction.

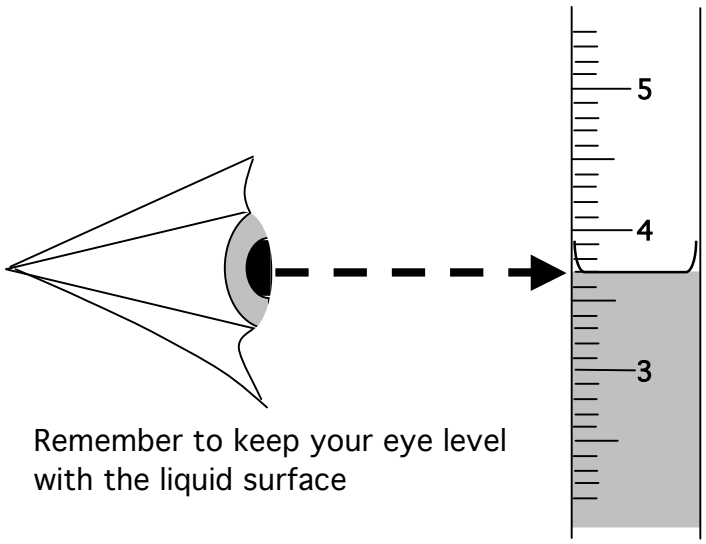
Finish your work with an appropriate title and a caption to let the reader know how the illustration fits with the over-all purpose of the larger work or investigation. Indicate the scale or magnification of your drawing. If measurements are appropriate, clearly indicate them.

ERROR ANALYSIS IN BIOLOGY

Error analysis in biology is no different from that in other sciences. Biology, however, is not an exact science, much of the data collected by biologists is qualitative. Furthermore, biological systems are very complex and difficult to control. Biological investigations, nevertheless, do often require measurements and biologists do need to be aware of the sources of error in their data.

Human error

Obviously data which is carefully recorded will be more reliable than data collected carelessly. Human error can occur when tools or instruments are used or read incorrectly. For example a temperature reading from a thermometer in a liquid should be taken after stirring the liquid and whilst the bulb of the thermometer is still in the liquid. Thermometers and other instruments should be read with the eye level with the liquid otherwise this results in parallax error.
Human errors can be systematic because the experimenter does not know how to use the apparatus properly or they can be random because the power of concentration of the experimenter is fading.



Remember to keep your eye level with the liquid surface

Systematic errors

If an electronic water bath is set to 37°C the thermometer in the water bath should also read 37°C. If they do not agree then there will be an error at any other temperature being used. Some instruments need calibrating before you use them. If this is done correctly and regularly it can reduce the risk of systematic error.

Random errors

In biological investigations a lot of errors can be caused by the changes in the material used or the conditions in which it is carried out.

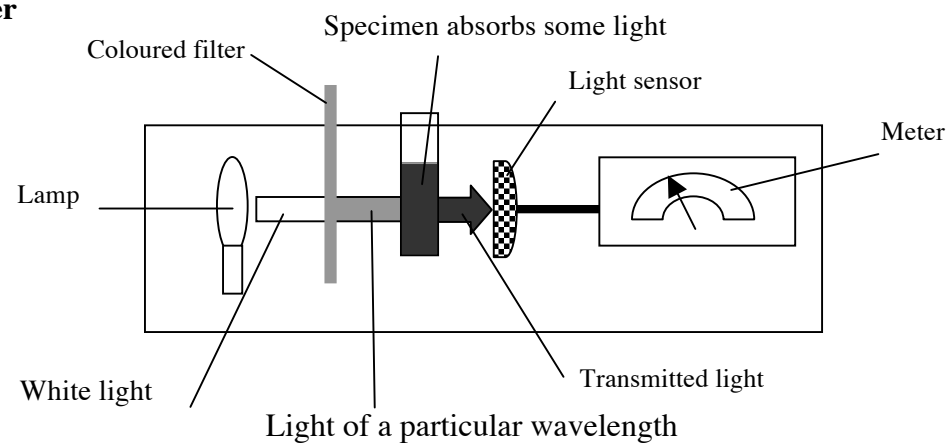
For example the rate of respiration or a small animal measured using a manometric respirometer can be influenced by changes in air temperature and barometric pressure.
Biological material is notably variable.

For example, the water potential of potato tissue may be calculated by soaking pieces of tissue in a range of concentrations of sucrose solutions. However, different pieces of tissue will vary in their water potential especially if they have been taken from different potatoes.

The problem of random errors can be kept to a minimal by careful selection of material and careful control of variables (e.g. using a water bath or a blank).

As we saw above, human errors can become random when you have to make a lot of tedious measurements, your concentration span can vary. Automated measuring using a data-logger system can help reduce the likelihood of this error, alternatively you can take a break from measuring from time to time.

The colorimeter



Colorimeters will "drift" so they need to be periodically re-calibrated using a blank (a specimen that the instrument can be reliably set against e.g. the solvent only).

Replicates and samples

Because of their complexity and variability, biological systems require replicate observations and multiple samples of material. As a rule the lower limit is 5 measurements or a sample size of 5. Very small samples run from 5 to 20, small samples from 20 to 30 and big samples above 30.

Selecting data

Replicates permit you to see if data is consistent. If a reading is very different from the others it may be left out from the processing and analysis. However, you must always be ready to justify why you do this.

Degrees of precision

If you use a ruler, graduated in millimeters, to measure an object (e.g. the length of a leaf) you will probably find the edges of the object lie close to a millimeter division but probably not right on it. Recording the leaf is "4.5cm and a bit" long is not very useful. The accepted rule is that the degree of precision is ± half the smallest division on the instrument, in this case half a millimeter. However, you have estimated at both ends of the leaf and must add the uncertainties together. So the leaf in this example is 4.5cm ± 0.1cm.

The degree of precision will influence the instrument that you choose to make a measurement. For example of you used the same ruler to measure an object 0.5cm long the degree of precision (± 0.1cm) is 20% of the measurement which is very large and, so, not very precise. Therefore, we must choose an appropriate instrument for measuring a particular length, volume, pH, light intensity etc.

The act of measuring

When a measurement is taken this can affect the environment of the experiment. For example when a cold thermometer is put in a test tube of warm water, the water will be cooled by the presence of the thermometer. When the behaviour of animals is being recorded the presence of the experimenter may influence them.

Why bother?

You might think that with all these sources of error and imprecision experimental results are worthless. This is not true, it is understood that experimental results are only **estimates**. What is expected of a scientist is that they:

(i) make the best effort to avoid errors in their design of investigations and the use of instruments.

(ii) are aware of the source of errors and to appreciate their magnitude.

Paul Billiet 30/08/01

RULES FOR PROPAGATION OF UNCERTAINTY

These are approximate rules that simplify the computation and slightly exaggerate the uncertainty at each step.

Addition and Subtraction:

e.g. (4.35 ± 0.02) Hz + (2.12 ± 0.01) Hz
$= (6.47 \pm 0.03)$ Hz

RULE: Add absolute uncertainties

Multiplication and Division:

e.g. (44.01 ± 0.05) m / (2.1 ± 0.05) s

$= (44.01 \text{ m} \pm 0.11\%) / (2.1 \text{ s} \pm 2.4\%)$

This was derived by taking the ± value and dividing it by the given value and then multiplying by 100 to get a percentage.

For the above:

$0.05/ 44.01 = 0.11\%$ $0.05/2.1 = 2.4\ \%$

After this is done, the two relative uncertainties are added: $0.11 + 2.4 = 2.5$

e.g. (44.01 ± 0.05) m / (2.1 ± 0.05) s

= 21. ms-1 ± 2.5 %

To finish the problem, the relative uncertainty must be converted back into the absolute uncertainty: (21) (2.5%) = .525, but to one significant digit = ± 0.5

Therefore:

e.g. (44.01 ± 0.05) m / (2.1 ± 0.05) s

= 21. ms-1 ± 0.5

RULE: Convert the absolute uncertainties to relative uncertainties, add the relative uncertainties, then convert this relative uncertainty back to an absolute uncertainty.

Multiplying or Dividing by a pure number (with no uncertainty)

e.g. (12.3 ± .01)m (3.00)

= 36.9 m ± .03

RULE: Multiple or divide the absolute uncertainty by the pure number

Uncertainty Continued…

Uncertainty Controversies

There are issues surrounding the definition of uncertainty. Here is what seems to be:

The TOLERANCE INTERVAL is 0.5 of the smallest unit of calibration and is also called "standard uncertainty"
Simple "uncertainty" is the smallest unit in the calibration of the instrument.
So
Use ± notation when dealing with tolerance interval and standard uncertainty, but do not use ± notation when using the smallest unit as your definition of "uncertainty".

Most of your teachers will expect you to use ± and 0.5 of the smallest calibration of the instrument

How Accurate must I be? To how many sig. figs. should I measure?

30-300 Rule This rule is used to determine how accurately to measure a variable. The number of significant digits should be such that there are 30 to 300 units (approximately) between the largest and smallest measurement.
For example: When measuring sardine lengths that range between 4 and 8 cm, there are only 4 cm between the largest and smallest values. The degree of accuracy that
1 cm intervals provides is not adequate. If the sardines are measured in 0.1 cm, then between 4.0 and 8.0 there are 40 units of 0.1 cm between the largest and smallest values (8.0 - 4.0 in 0.1) = 40

Rules for Counting Significant Figures

1. All non-zero digits are significant.
   Example: 123.7 has 4 significant figures

2. All zeros between non-zero digits are significant.
   Example: 1207 has 4 sig. figs., 120.007 has 6 sig. figs.

3. All zeros at the left of the number are NOT significant.
   Example: 0.00032 has 2 sig. figs, 0.03 has 1 sig. fig.

4. When zeros are at the right of the number:
   a) If there is no decimal, the zeros are NOT significant.
      Example: 300 has 1 sig. fig., 25400 has 3 sig. figs.

   b) If there is a decimal, the zeros ARE significant.
      Example: 60.0 has 3 sig. figs., 0.00045300 has 5 sig. figs. (the 4 zeros at the left of the number do not count, but the 2 zeros at the right of the number do count).

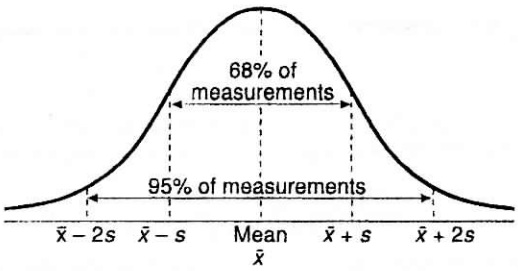
Statistical Analysis of Data

Dumas 09

There are several statistical tools that you will be expected to use and interpret. They fall into a couple of categories: measures of central tendency are those techniques that show us the approximate middle of a set of numbers including **mean** (average), **median** (middle) and **mode** (most frequent) Although there can be only one average and one middle number, there may be more than one mode. You are probably familiar with these terms. Use averages when measurements are more alike than different; use range when measurements have a marked variability. Often it is useful to give both.

When you have many measurements a frequency distribution of all of the numbers can me made. The typical results of such a distribution appear as a curve called a bell curve. When the curve has a symmetrical shape, we say that it is a normal distribution. In a normal distribution 68% of the data are within one standard deviation of the average value of the sample and 95% are within two standard deviations. Therefore, a person can calculate a standard deviation to find out how spread out the values of a set of numbers are. Examine the graph below until it makes sense to you.

x = numbers in the list and n = number of numbers in the list



Standard Deviation is a method of determining how spread out a set of values is.

$$s_x = \sqrt{\left[\frac{\sum(x - \overline{x})^2}{n-1}\right]}$$

Note: s_x is used when you are sampling a population, σ_x is used when you have surveyed the whole population.

***t-Test** is used to determine whether the differences observed between two sets of values are close enough to each other that they could have been the result of chance alone. If a t-test result has high numbers then something other than chance is likely to have caused the differences. This is especially useful when there is lots of data that seems different and you wonder if it is different enough.

$$t = \frac{|\overline{x}_A - \overline{x}_B|}{\sqrt{\frac{s^2_A}{n_A} + \frac{s^2_B}{n_B}}}$$

x = average of each set
n = number of samples in each data set
s = standard deviation

Simpson's Diversity Index is a tool to determine which location has the greatest variety of organisms.

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

D = diversity
n = number of a species
N = total number of organisms

Capture-Mark-Release-Recapture: Either the **Peterson Method** or the **Lincoln Index** can be used for determining the size of a population after collecting capture-mark-release-recapture data.

Peterson Formula

$$N = \frac{M}{p}$$

N = population size (unknown)
M = marked individuals in first sample
p = percent marked in second sample

Lincoln Index

$$\text{population size} = \frac{n_1 \times n_2}{n_3}$$

n_1 = number of individuals initially caught
n_2 = total number caught in the second sample
n_3 = number of marked individuals in second sample

Hardy-Weinberg Equilibrium is used to determine whether or not natural selection is acting on the relationship between a pair of alleles in a population. It can also be used to find frequency of an allele in a population. Recall that there are 6 assumptions that are required for the Hardy-Weinberg Equilibrium to provide useful information.

$p^2 + 2pq + q^2 = 1.0$ *where p is one allele and q is the other*

***Chi Square Test** is a technique designed to answer the question "Are our results close enough to our prediction to support the hypothesis?" Actually the language with this test is a bit strange since when properly done the person states a null hypothesis and the results of the null hypothesis support or fail to support the null hypothesis. By using a table one can determine whether or not you would support the null hypothesis erroneously less than 5% of the time. A small chi square value means that your results are very closely aligned with your prediction and that any variation is due to random chance occurrences only.

$$X^2 = \frac{\sum (o - e)^2}{e}$$

o = observed

e = expected

Percent Error Although this test feels similar to the chi square test, it is not the same thing. In this case you are calculating how far off your results are from the accepted true value

$$\% \text{ error} = \frac{\text{experimental value} - \text{true value}}{\text{true value}} \times 100$$

Correlation Coefficient

- The quantity *r*, called the *linear correlation coefficient*, measures the strength and the direction of a linear relationship between two variables. The linear correlation coefficient is sometimes referred to as the *Pearson product moment correlation coefficient* in honor of its developer Karl Pearson.
- The mathematical formula for computing ***r*** is:

$$r = \frac{n\sum xy - \left(\sum x\right)\left(\sum y\right)}{\sqrt{n\left(\sum x^2\right) - \left(\sum x\right)^2}\sqrt{n\left(\sum y^2\right) - \left(\sum y\right)^2}}$$

where *n* is the number of pairs of data.

(Aren't you glad you have a graphing program that computes this formula?)

- The value of *r* is such that $-1 \le r \le +1$. The + and – signs are used for positive linear correlations and negative linear correlations, respectively.
- *Positive correlation:* If *x* and *y* have a strong positive linear correlation, *r* is close to +1. An *r* value of exactly +1 indicates a perfect positive fit. Positive values indicate a relationship between *x* and *y* variables such that as values for *x* increases, values for *y* also increase.
- *Negative correlation:* If *x* and *y* have a strong negative linear correlation, *r* is close to -1. An *r* value of exactly -1 indicates a perfect negative fit. Negative values indicate a relationship between *x* and *y* such that as values for *x* increase, values for *y* decrease.
- *No correlation:* If there is no linear correlation or a weak linear correlation, *r* is close to 0. A value near zero means that there is a random, nonlinear relationship between the two variables
- Note that *r* is a dimensionless quantity; that is, it does not depend on the units employed.
- A *perfect* correlation of ± 1 occurs only when the data points all lie exactly on a straight line. If *r* = +1, the slope of this line is positive. If *r* = -1, the slope of this line is negative.
- A correlation **greater than 0.8 is generally described as *strong***, whereas a correlation **less than 0.5 is generally described as *weak***. A correlation of **0.5 to 0.8 is generally described as *moderate***. These values can vary based upon the "type" of data being examined. A study utilizing scientific data may require a stronger correlation than a study using social science data.

*For test such as the Chi Square and the t-test, there is a table of values that is used to interpret the results. To use the table you will need to know the number of degrees of freedom. This is the number of classes being examined minus 1. For biology 5% is the significant value from these charts.

CRITICAL VALUES FOR THE CHI-SQUARED TEST

Degrees of freedom (df)	Level of significance (P)						Level of significance (P)					
	0.05	0.025	0.01	0.005	0.001		0.05	0.025	0.01	0.005	0.001
1	3.84	5.02	6.63	7.88	10.83	20	31.41	34.17	37.57	40.00	45.32
2	5.99	7.38	9.21	10.60	13.81	21	32.67	35.48	38.93	41.40	46.80
3	7.31	9.35	11.34	12.84	16.27	22	33.92	36.78	40.29	42.80	48.27
4	9.49	11.14	13.26	14.86	18.47	23	35.17	38.08	41.64	44.18	49.73
5	11.07	12.83	15.09	16.75	20.52	24	36.42	39.36	42.98	45.56	51.13
6	12.59	14.45	16.81	18.55	22.46	25	37.65	40.65	44.31	46.93	52.62
7	14.07	16.01	18.48	20.28	24.32	26	38.89	41.92	45.64	48.29	54.05
8	15.51	17.53	20.09	21.98	26.13	27	40.11	43.19	46.96	49.64	55.48
9	16.92	19.02	21.67	23.59	27.88	28	41.34	44.46	48.28	50.99	56.89
10	18.31	20.48	23.21	25.19	29.59	29	42.56	45.72	49.59	52.34	58.30
11	19.68	21.92	24.73	26.76	31.26	30	43.77	46.98	50.89	53.67	59.70
12	21.03	23.34	26.22	28.30	32.91	40	43.77	46.98	50.89	53.57	59.70
13	22.36	24.74	27.69	29.82	34.53	50	67.50	71.42	76.16	79.49	86.66
14	23.68	26.12	29.14	31.32	36.12	60	79.08	83.30	88.38	91.95	99.61
15	25.00	27.49	30.58	32.80	37.70	70	90.53	95.02	100.43	104.22	112.32
16	26.30	28.85	32.00	34.27	39.25	80	101.88	106.63	100.43	104.22	112.32
17	27.59	30.19	33.41	35.72	40.79	90	113.15	118.14	124.12	128.30	137.21
18	28.87	31.53	34.81	37.16	42.31	100	124.34	129.56	135.81	140.17	149.44
19	30.14	32.85	36.19	28.58	43.82						

Table of critical values of *t*

Degrees of freedom	Level of significance (P)					
	0.2	0.1	0.05	0.02	0.01	0.002
1	3.078	6.314	12.706	31.821	83.657	318.310
2	1.886	2.920	4.303	6.985	9.925	27.327
3	1.638	2.353	3.182	4.541	5.841	10.215
4	1.533	2.132	2.776	3.747	4.604	7.173
5	1.476	2.015	2.571	3.365	4.032	5.893
6	1.440	1.943	2.447	3.143	3.707	5.208
7	1.415	1.895	2.385	2.998	3.499	4.785
8	1.397	1.860	2.308	2.896	3.355	4.501
9	1.383	1.833	2.262	2.821	3.250	4.297
10	1.372	1.812	2.228	2.764	3.169	4.144
11	1.363	1.796	2.201	2.718	3.106	4.025
12	1.356	1.782	2.179	2.681	3.055	3.930
13	1.350	1.771	2.180	2.650	3.012	3.852
14	1.345	1.761	2.145	2.624	2.977	3.787
15	1.341	1.753	2.131	2.602	2.947	3.733
16	1.337	1.746	2.120	2.583	2.921	3.686
17	1.333	1.740	2.110	2.567	2.898	3.646
18	1.330	1.734	2.101	2.552	2.878	3.610
19	1.328	1.729	2.093	2.539	2.861	3.579
20	1.325	1.725	2.086	2.528	2.845	3.552

<u>Conclusion Writing Check-list for a Statistical Analysis</u>
(see Directions for a Writen Report on pg 4-5 for additional parts of a Conclusion)

Standard Deviation

√ Report averages for each condition.
√ Report difference in averages and compare to standard deviations.
√ Does this indicate a <u>likely</u> significant difference? Interpret the test results.
√ Report what the significant difference is (or isn't) in terms of the focused question.

T-Test

√ Report the averages for each condition.
√ Report your calculated value of t, the critical value of t, the p-value and the degrees of freedom.
√ Does this indicate a significant difference? Interpret the test results.
√ Report what the significant difference is (or isn't) in terms of the focused question.

Characteristics of Good Data Tables

- It is easy to understand the data
- Columns and rows have useful labels
- Units have been indicated with their uncertainties usually in the label of a row or column
- There is a title that provides the reader with an understanding of the meaning of the data
- There is an annotation that indicates how uncertainty was determined and what specific data was measured by the author.
- Use a ruler!

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Characteristics of Good Graphs

- The display of data helps to clarify how the data answers the question or connects the data to the hypothesis
- An appropriate style of graph has been chosen (partly depending upon whether or not the data are continuous) ie: bar graph, scatter plot, line graph, line graph with measure of spread, histogram, pie graph or kite graph, box and whiskers
- If multiple trials were done, are there calculations that should be done prior to graphing the data?
- Both axes have useful labels with units & uncertainties
- There is a title that provides the reader with an understanding of the meaning of the data.
- There is an annotation under the graph that describes any trend shown and what the error bars represent.
- Use a ruler to draw axes

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How to Display Sample Calculations

(using the 4-step method)

When showing work for science, you set the problem in at least 4 steps given on separate lines:

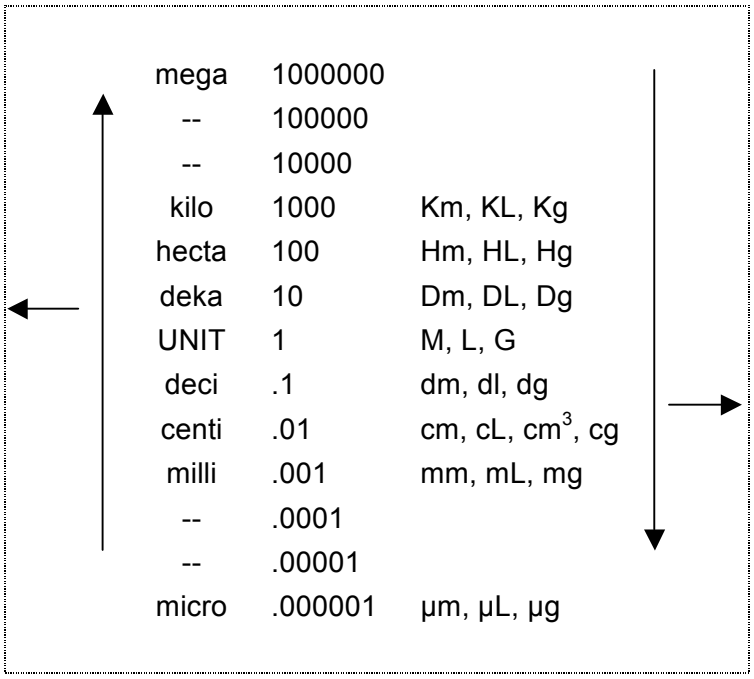
1) Define the problem
   - list given information
   - identify the unknown
   - make conversions here if necessary
2) Choose the formula
3) Substitute into the formula with units
4) Find the solution and give the answer with units and correct significant figures

Sometimes a series of formulas is needed.

Each formula should be set as described above to show the work

When there are many repetitions of the same operation, it is only useful to show one sample calculation of each type.

Dancing Decimals



mega	1000000	
--	100000	
--	10000	
kilo	1000	Km, KL, Kg
hecta	100	Hm, HL, Hg
deka	10	Dm, DL, Dg
UNIT	1	M, L, G
deci	.1	dm, dl, dg
centi	.01	cm, cL, cm^3, cg
milli	.001	mm, mL, mg
--	.0001	
--	.00001	
micro	.000001	µm, µL, µg

This chart is designed to help you change units by moving the decimal. When you go from cm to mm (down) then the decimal moves to the right because there are more mm than cm in a distance. . . . and vice versa

Examples: 7.52 cm = 75.2 mm

2 m = .002 km

Scientific Notation

In scientific writing numbers are usually written using scientific notation. Scientific notation makes use of significant digits and powers of ten. It helps make numbers manageable.

Examples: $1{,}200{,}000 = 1.2 \times 10^{6}$

$0.0030 = 3.0 \times 10^{-3}$