Appendixes

A. Reporting quantitative data

Obviously, a number that is intended to represent a physical quantity is useless unless it is accompanied by an appropriate unit. The International System of Units employs the cgs system (centimeters, grams, seconds). Although the gram is a unit of mass, in physiology we also use the gram as a measure of force (tension) for convenience. "One gram of tension" is the force required to hold a weight of one gram against the pull of gravity. The physicists would cringe, of course.

A student of the natural sciences must be aware of the significance of prefixes used to describe units - or so we all think, until the reports come in. Here's a list, which I hope that you will find familiar.

It should never be necessary to use qualifying adjectives such as "approximately," "about," "on the order of," etc. Whenever you report a quantity, the precision with which you describe the quantity indicates the precision of the measurement. Develop the habit of reporting uncertain values with an appropriate number of significant digits, no more and no less.

For example, if you report a length of 7.2 mm you are saying that the length was no less than 7.15 mm and less than or equal to 7.25 mm. If you can't be that confident, then report a length of 7 mm, not 7.2.

The same rules apply to derived quantities, including means, standard deviations, slopes, etc. The usual practice when making calculations is to maintain full precision during the calculations, suppressing excess digits in the final result.

Table 1. Prefixes used by the International System of Units (SI)

Prefix	Factor	Symbol
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f
atto	10^{-18}	a
deca	10	da
hecto	10^{2}	h
kilo	10^{3}	k
mega	10^{6}	M
giga	10^{9}	G
tera	10^{12}	T
peta	10^{15}	P
exa	10^{18}	E

Prefixes are incorporated into the SI unit itself in order to avoid using scientific notation or writing numbers with multiple zeroes. For example, 0.001 ($10^{-3)}$ volt is simply 1 milivolt (mV). One million (10^{6}) ohms is simply 1 gigaohm.

B. Analog-to-digital (A/D) data acquisition

An analog-to-digital (A/D) recording system displays signals on a computer screen and stores them in files that can be analyzed at one's convenience. Our system consists of an A/D converter,s a built-in physiological stimulator, filters for signal conditioning, and software for recording slow to moderately fast frequency signals (chart program or mode) or very fast signals (scope program or mode).

A digital recording system replaces the traditional oscilloscope, chart recorder, pulse generator, stimulator and similar separate devices used in electrophysiology. It adds considerable versatility and convenience to data management. Virtually all recordable information from a physiological experiment can be digitized and saved in a computer file and re-displayed later for analysis.

On the minus side, when we digitize a signal for display and analysis we lose some information. After all, an analog recording is continuous, while a digital recording only samples the signal at selected time intervals. This limitation should not interfere with your objectives, provided that you know something about the signal you are measuring and select appropriate sampling speeds. Figure 1 illustrates the point. As sampling frequency increases the true appearance of the waveform is revealed.

With nearly all software programs, there is too much detail in the accompanying manual to go through for the amount of time you or I are willing to spend on it. Once you are familiar with the basics you should consult the original manual to advance your skills using the program.

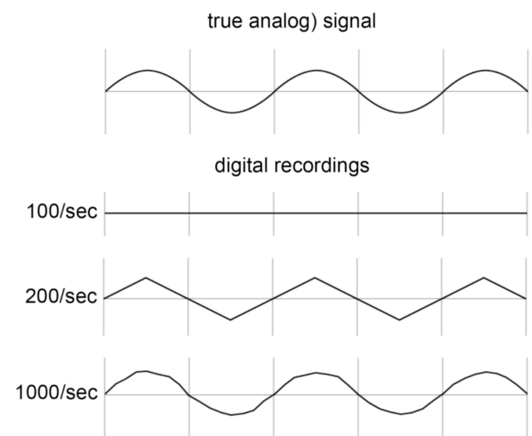

Fig.1. Effect of increasing sampling rate on appearance of a continuously varying signal. At 100 samples/sec the sampling rate is synchronous with the wave frequency.

C. Suggestions for designing experiments

At the minimum, include the following information when you design your experiments. Don't forget to consider possible complications and to describe experimental controls, if applicable. On the other hand, there is no need to discuss specific methodology, such as how to do a dissection.

1. One or more objectives in the form of questions or testable statements
2. A description of the kinds of data that will be collected
3. A well designed plan for analyzing the data
4. A detailed plan for collecting data

You may be thinking that items 3 and 4 are switched. Even experienced researchers often make the mistake of conducting experiments before planning the analysis, only to discover that the way they collected data makes it difficult or even impossible to draw a clear conclusion. Once you've established what sorts of data to collect and how to analyze them, how to collect the data should naturally follow.

Should data be presented in table form, should they be plotted, should you conduct a statistical analysis, should you present actual chart records? Such decisions depend on the original question. If the plan is to conduct replicate sampling of quantitative data, then you will probably need to present them as sample means ± standard deviation. If you plot mean values you will need to plot means ± standard deviations of the means. How will you test the hypothesis? You may need to conduct a two sample test such as "Student's" t test. You may be able to plot the data and test your hypothesis by inspection of the trends.

Remember the importance of using physically meaningful units, rounding data to reflect uncertainty, how to express uncertainty (experimental error), how to plot data, and how to prepare figures and tables for a manuscript. Use the resources on line to refresh your memory if necessary.

Remember that if you need to illustrate a pattern, trend, or relationship, then you probably want to plot the data. A graph is especially important when looking at a relationship between two continuous variables. If you need to present numerical values that don't lend themselves to a graph, then plan to use a table. If you can easily summarize the data in text and do so in an effective, informative manner, then plan on reporting the data in text rather than using a figure or table.

Plan to collect more rather than less data than you might need. You can always cut down on the quantity of information that you report, but if you don't have it in the first place you can't go back and fill in the blanks. On the other hand, don't take on more than you can reasonably accomplish. For example, if you conduct timed experiments give yourself time to collect the data, take notes, and to change directions if necessary. Plan to collect plenty of data but try to design the experiment so that if your plan is overly ambitious you can cut down on the amount of data you collect and still accomplish your objective.

Good science requires that experiments be replicated to ensure that results are reproducible. There won't be time for you to repeat an entire experiment, however you are working in pairs and there are multiple pairs of students working on the same objectives. Some communication will be necessary if you are to take advantage of having multiple groups attack the same objectives. For example, your plans for analysis and data collection would have to be consistent. You can, if necessary, change your plans after the session starts.