Presenting Scientific Data and Results in Figures and Tables

Suppose you are studying the growth of a magic beanstalk as function of time, recording data in your laboratory notebook, as shown below.

> August 28, 2004
>
> A bean from lot AG12, identified as AG12a, was planted at 10:05 AM and promptly watered and fertilized with a solution of Alice's Miracle Grow. The beanstalk's height was measured using a Jack & Son Model X15 laser-based tape measure, with the height taken as the distance between the ground and the point where the topmost leaf is attached to the beanstalk.
>
> 10:15 am: the beanstalk emerged from the ground
>
> 10:30 am: height is 9.96 m
>
> 10:45 am: height is 107 m
>
> 11:00 am: height is 329 m
>
> 11:25 am: height is 763 m
>
> 12:05 pm: height is 1.21 km
>
> 12:35 pm: height is 1.32 km
>
> 1:00 pm: height is 1.34 km
>
> 2:00 pm: height is 1.34 km

In preparing a report of this study, how might you consider presenting your data? Obviously you will not just transfer the writing in your notebook directly into your report; as written, the information is difficult for the reader to extract and understand.

Using Tables to Present Data. One way to present this data is in a table such as the one here:

Table 1. Height of beanstalk from bean AG12a at different times after planting

Elapsed Time (min)	Height of Beanstalk (km)[a]
0	0
10	0
25	0.00966
40	0.107
55	0.329
80	0.763
120	1.21
150	1.32
175	1.34
235	1.34

[a] As measured from the ground to the point where the topmost leaf is attached to the beanstalk.

Note that the table is numbered—this is Table 1—and includes an informative title (positioned above the table), that each column begins with a descriptive entry and includes units (when appropriate), that the data in a column are aligned using the decimal points and that a footnote is included

below the table to supply information not included in the report's text. Note, as well, that the less useful measurement of absolute real time is converted into an elapsed time and that the heights are converted to a common unit. This table contains all the information recorded in the lab notebook in a format that makes it easy for the reader to see the relationship between time and the height of the beanstalk.

Although not appropriate for the data in Table 1, it often is useful to include a statistical summary of your data. Table 2, for example, reports the maximum height of bean stalks grown from beans taken from the same lot, along with the mean and standard deviation.

Table 2. Maximum Heights of Beanstalks From Different Seeds

Sample ID[a]	Maximum Height (km)
AG12a	1.34
AG12b	1.24
AG12c	1.48
AG12d	1.38
AG12f	1.31
mean	1.35
std dev	8.89×10^{-2}

[a] Sample AG12e did not germinate and is not included in this summary.

Using Figures to Present Data. Another way to present the data in Table 1 is as a figure that shows height as a function of elapsed time (see figure to the right). Note that the figure is numbered and includes an informative title (positioned below the figure), that the data points are clearly marked with point protectors (○), that the scales for the axes spread the data over the figure's available space, and that the axes are labeled with descriptive titles (including units where appropriate). One advantage of a figure is that it allows you to highlight your analysis of the data. For example, this figure shows the result of modeling the data using the following equation

$$\text{height} = A\times e^{-(\text{elapsed time}-B)^2/c^2} + D$$

where *A, B, C,* and *D*, are variables used to fit the model to the data. A figure also is a useful way to display several related sets of data. For example, the figure on the next page shows results for three trials. Note that the figure includes a legend to help identify each set of data. This figure also connects the points with line segments to further highlight the relative trend in each data set. Note, as well, that this figure includes a grid to aid in reading the graph. Connecting points with line segments and including grid lines are not common choices but they are effective in some situations; use them judiciously.

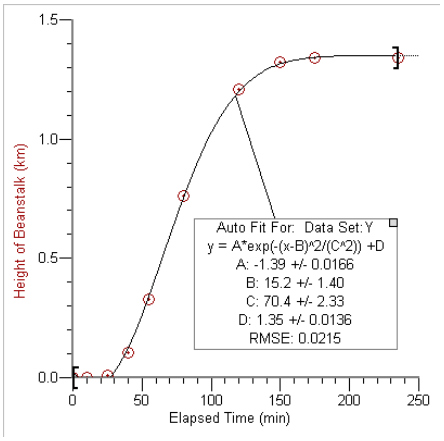


Figure 1. Height of a beanstalk from bean AG12a as a function of time after planting.

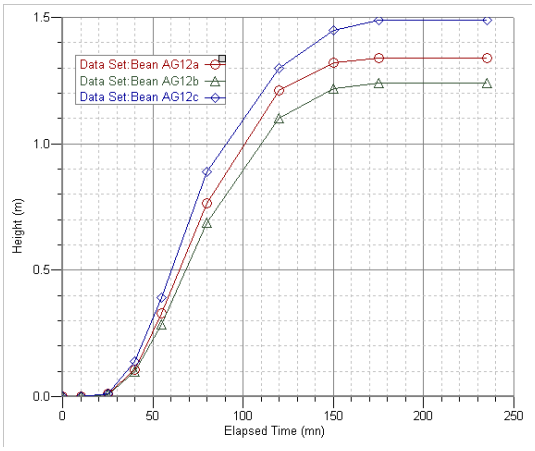


Figure 2. Heights of beanstalks grown from three beans selected at random from lot AG12 as a function of time after planting

Figures 1 and 2 are examples of good figures. In Figure 1, for example, the actual data are identified clearly using data point protectors, making it easier to evaluate how well the equation fits the data. In both figures the data occupy the available space, making it easier to appreciate the data's trend. For example, in Figure 2 we see that all three growth curves are sigmoidal in shape with a similar lag time between the planting of the seed and emergence of the bean stalk. We also see that there is some variation between the three beans with respect to their growth rate and the maximum height of the mature plant.

A poorly prepared figure hides important information. Consider, for example, Figure 3 (below on the left), which shows the temperature of a sample of porridge as it cools. Including the thermometer's full scale on the *y*-axis (0°C to 240°C) compresses the data to a small portion of the axis, making the nature of the cooling more difficult to see. Furthermore, the absence of point protectors obscures the data. Finally, the caption does not suggest why the first part of the data was not included when modeling the data.

A better figure is shown in Figure 4 (below on the right). Note that in this figure the scale on the *y*-axis spans the relevant temperatures only, making it easier to see the cooling curve. The use of point protectors makes the data easier to see and improves our ability to evaluate the quality of the fit between the data and the theoretical equation. Note, as well, that the figure's caption clarifies why the first 25 seconds of data were not included when modeling the data. This figure is one that provides the reader with a useful summary of the data.

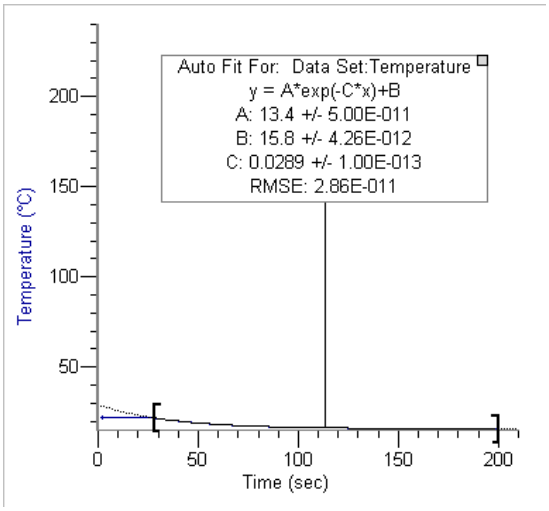


Figure 3. Cooling curve for Baby Bear's porridge.

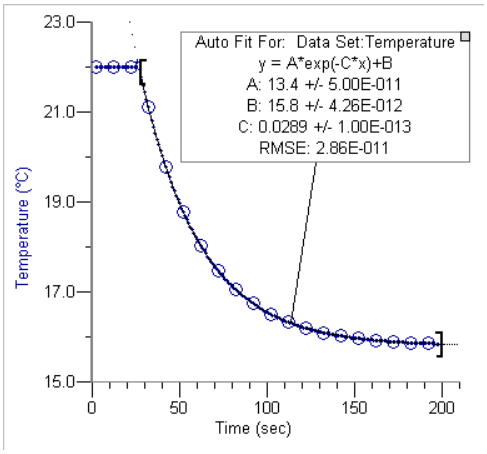
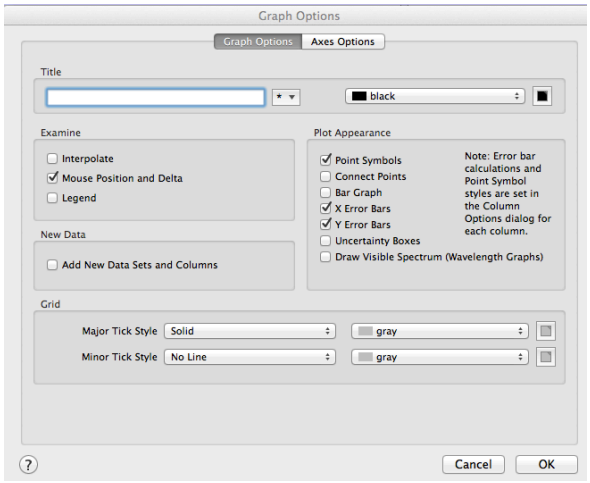


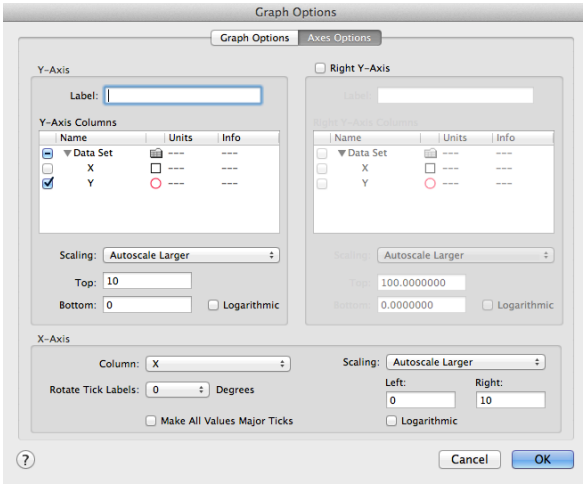
Figure 4. Cooling curve for Baby Bear's porridge. The sample was removed from the stove at $t = 25$ sec.

Preparing Figures Using LoggerPro. Much of the data you will collect in lab this semester will be through Vernier's LabQuest interface using Vernier's LoggerPro software. Because this software has very good tools for displaying data, you will find it is an excellent way to prepare figures. The remainder of this section provides useful information about altering the appearance of your figures.

To modify the program's default choices for displaying data, right click on the figure and select Options: Graph Options… from the main menu. This brings up the Graph Options window, which has two tabs. On the Graph Options tab (shown on the right) you can choose to display point protectors (point symbols), to connect individual data points with straight line segments, and to add a legend to your figure. You also can add a title and change the style of the major and minor gridlines (including the choice to omit gridlines).



From the Axes Options tab (shown on the left) you can choose which variable to plot on *x*-axis and which set(s) of data to plot on the *y*-axis and whether you want to display two *y*-axes. You also can adjust the scale of each axis. To replace the default title for the *y*-axis, enter the desired title in the box for the y-axis label. To change the title for the *x*-axis, click on the data table and select Data:Column Options and the *x*-axis data. On the column definition tab enter the title you wish to display on the *x*-axis.



Further manipulations of the figure are accomplished using the Column Options. Right click on the figure and select Column Options and the y-axis data you wish to modify. Select the Options tab (shown below to the right). Here you can choose the symbol for the point protectors and how frequently they are displayed. Although all data points are shown on the figure, it often is best to highlight only a limited number of points with protectors to improve visibility and readability. You can also change the color used to display the data set.

Preparing Figures Using Excel. Although you are encouraged to use LoggerPro to prepare figures, you may, at time, wish to use Excel instead. To use the directions here your data must be organized such that the left-most column contains the *x*-axis data with the remaining columns containing one or more series of data for the *y*-axis. Click and drag over the data and select Insert:Chart from the main menu. Select the type of chart and sub-chart you wish to use (an *xy*-scatter plot without lines usually is the best choice) to insert the chart into your spreadsheet. You can format the chart using the Format menu.

When to Use Tables and When to Use Figures. So, which is the best method for presenting data: a table or a figure? If you wish to show a trend or to demonstrate that a theoretical model explains your data, then a figure is usually the best choice. On the other hand, when exact numerical values or a statistical summary are important, then a table is the better choice. In general, for any data set, you should use a figure or a table, but not both.