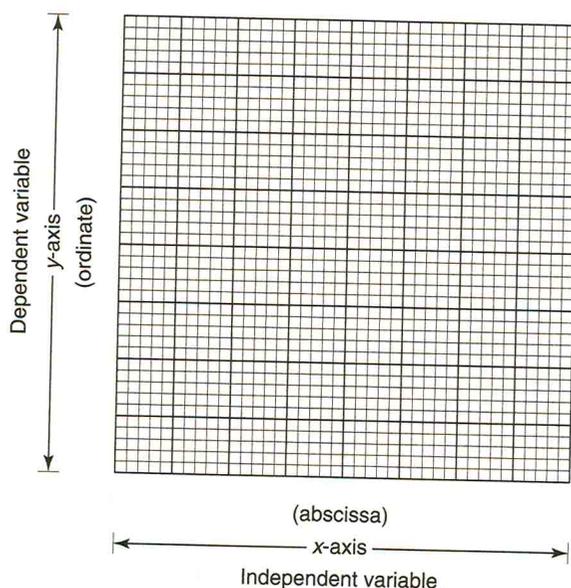


## STUDY AID 3

### Preparing and Reading A Graph

A graph is often the most convenient way to present or display a set of data. Various kinds of graphs have been devised, but the most common type uses a set of horizontal and vertical coordinates,  $x$  and  $y$ , to show the relationship between two variables, the independent and dependent variables. The dependent variable is a measurement that changes as a result of changes in the independent variable. The independent variable either changes itself (like time) or is controlled by the experimenter. Usually the independent variable is plotted on the  $x$ -axis (abscissa) and the dependent variable is plotted on the  $y$ -axis (ordinate). See Figure S3.1.



**Figure S3.1** Rectangular coordinate graph paper

The values for each variable are called data and listed in a data table to facilitate the construction of a graph. As a specific example of how a graph is constructed, let us graph the relationship between the volume of a liquid and its mass. A chemist measured increasing volumes of a liquid and determined the mass of each volume. The data are recorded in Table S3.1. In this study aid, we will use this data to illustrate the steps for making graphs by hand (Part A) and by computer (Part C).

#### A. STEPS IN PREPARING A GRAPH

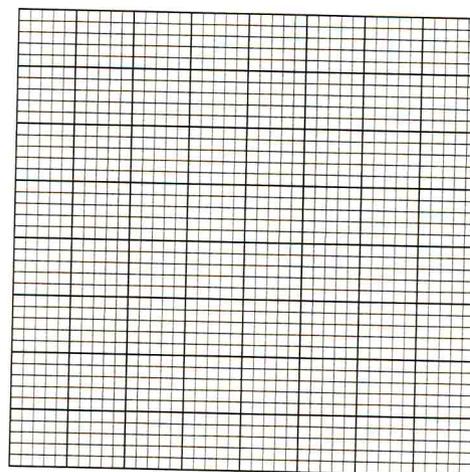
Most scientists today use computers to help them make graphs from their data. Before we show you how to work with a computer to do this, it is important to learn how to make a graph with pencil, ruler, and graph paper. Use the following step-by-step procedure to plot the data in Table S3.1 on the graph paper provided in Figure S3.2. Your completed graph should resemble the graph in Figure S3.3 very closely. After you complete this first graph, practice your graphing skills by making another graph using the data in Table S3.2 and the grid provided in Figure S3.4.

## PROCEDURE

1. Examine the graph paper in Figure S3.2 and count how many blocks are available along each axis: This paper has 40 blocks along the  $x$ -axis and 40 blocks along the  $y$ -axis.

**Table S3.1** Volume vs. Mass Data

Volume, mL	Mass, g
21.0	19.1
30.0	27.3
37.5	34.1
44.0	40.0
47.0	42.8
50.0	45.5



**Figure S3.2** Graph paper sample

2. Examine the data in Table S3.1 and determine the independent and dependent variables: The amount of liquid in each sample was varied by the experimenter, so volume is the independent variable and will be plotted along the  $x$ -axis. The mass of each sample changed as the volume was changed, so mass is the dependent variable and will be plotted along the  $y$ -axis. Usually the independent-versus-dependent-variable decision can be reasoned out like this example. If not, then the placement of the variables on the axes can be arbitrary.

3. Determine the range for each variable: The independent variable ranges from 21.0 mL to 50.0 mL. This is a range of 29.0 mL. The dependent variable ranges from 19.1 g to 45.5 g. This is a range of 26.4 g.

4. Determine the scale for each axis; that is, how many units each block will represent. The calculation for the independent variable using this particular piece of graph paper is:

$$\text{independent variable scale} = 29.0 \text{ mL}/40 \text{ blocks} = 0.73 \text{ mL/block}$$

But, if we adopted this scale, the graph would be extremely awkward to plot and read. So, we round **up** (never round down) this preliminary scale to a more convenient value per block. The most convenient scales to use are generally 0.5, 1, 2, 5, or 10 units per block. The scale is never rounded up to more than double its preliminary value. For this sample data, 0.73 mL/block is rounded up to 1.0 mL/block because it is convenient and less than 1.46 (double 0.73).

Now, we do the same calculations for the dependent variable on the  $y$ -axis.

$$\text{dependent variable scale} = 26.4 \text{ g}/40 \text{ blocks} = 0.66 \text{ g/block. It is not very convenient to count by units of 0.66, so this value is rounded up to 1.0 g per block.}$$

5. Determine the starting values for each coordinate: Although it is common for the axes to be numbered starting with zero at the origin (lower left corner), it is not required and some-

times it is a poor choice. For instance, in our example, all of the data for the independent variable are greater than 20.0, so from 0–20, there would be no data plotted. Therefore, we start numbering the  $x$ -axis at 20.0 mL and the  $y$ -axis at 15.0 g.

6. Determine the major and minor increments for each axis: We never number every block. Instead we number in major increments of several blocks with minor, unnumbered increments (blocks) in between. Because of our choice of scales, we will label both the  $x$ -axis and the  $y$ -axis every 5 blocks. The axes do not have to be numbered every 5 divisions, but often the graph paper has darker lines every five blocks and it is convenient to number at these heavier lines. The numbered increments must be on lines.

7. Label each axis so it is clear what each one represents: In our example, we label the  $x$ -axis as Volume, mL, and the  $y$ -axis as Mass, g. Labels and units on the coordinates are absolutely essential.

8. Plot the data points: Here is how a point is located on the graph: Using the 44.0 mL and 40.0 g data as an example, trace a vertical line up from 44.0 mL on the  $x$ -axis and a horizontal line across from 40.0 g on the  $y$ -axis and mark the point where the two lines intersect. This process is called plotting. The remaining five points are plotted on the graph in the same way. It is often helpful if each data point is neatly circled so it will be more visible. Then, if more than one set of data is plotted on the same graph, another symbol (an open triangle or square, for example) can be used.

9. Draw a smooth line through the plotted points: In our example, if the six points have been plotted correctly, they lie on a straight line so that a straight edge can be used to draw the smooth line connecting the six points. When plotting data collected in the laboratory, the best smooth line will not necessarily touch each of the plotted points. Thus, some judgment must be exercised in locating the best smooth line, whether it be straight or curved.

10. Title the graph: Every graph should have a title that clearly expresses what the graph represents. Titles may be placed above the graph or on the upper part of the graph. The latter choice, which is illustrated in Figure S3.3, is the most common for student laboratory reports. Of course, the title must be placed so as not to interfere with the plot on the graph. A completed graph of the data in Table S3.1 is shown in Figure S3.3.

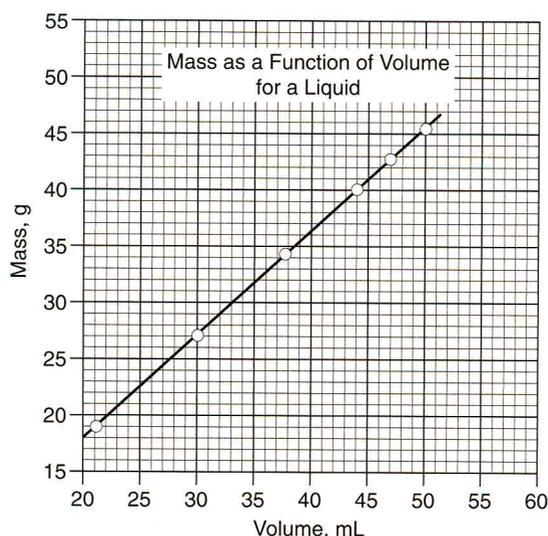


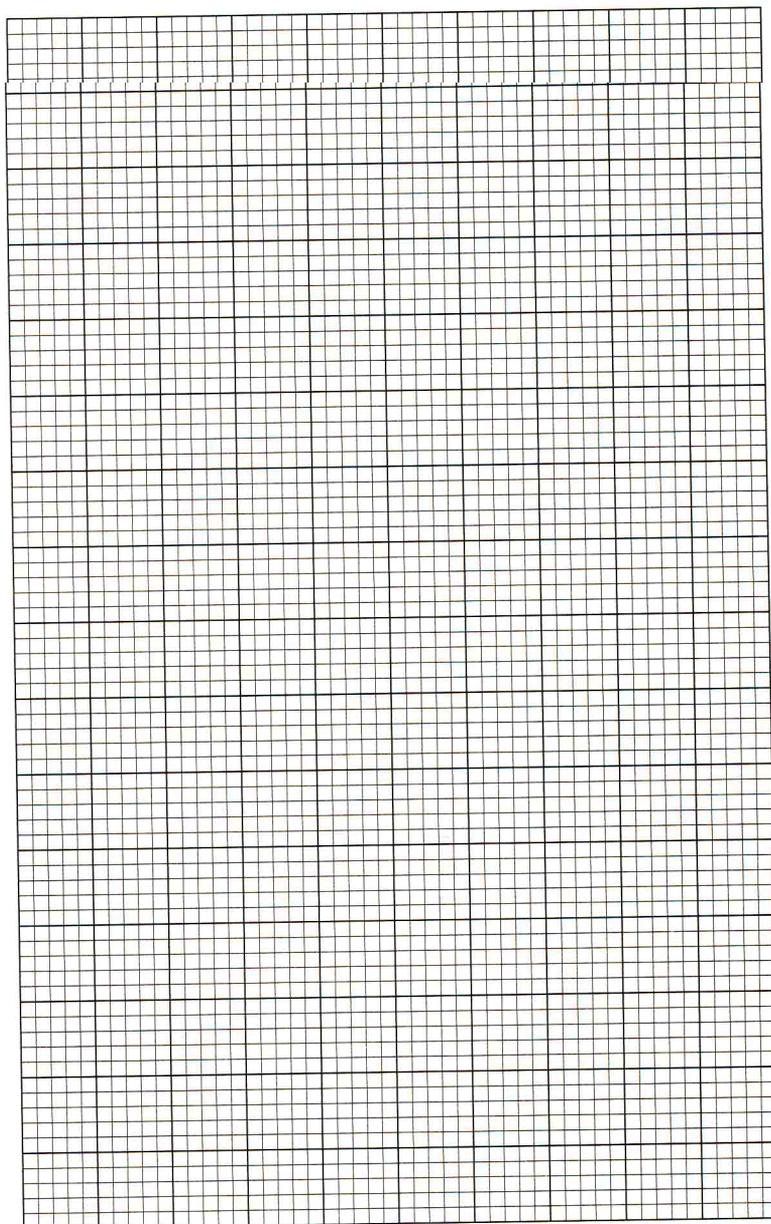
Figure S3.3 Sample graph of volume vs. mass in Table S3.1

## Practice Plotting: Sample Data

Table S3.2 is a set of data for you to practice plotting a graph with the steps just described. Use the graph paper in Figure S3.4. Plot  $^{\circ}\text{C}$  on the  $x$ -axis and  $^{\circ}\text{F}$  on the  $y$ -axis.

**Table S3.2**  
**Temperature Scales**

Temperature, $^{\circ}\text{C}$	Temperature, $^{\circ}\text{F}$
0	32
20	68
37	98.6
50	122
100	212



**Figure S3.4** Grid for practice plotting of Table S3.2 temperature data

## B. READING A GRAPH

Although graphs are prepared from a limited number of data points (the graph in Figure S3.5 was prepared from six data points), it is possible to extract reliable data for points between the experimental data points and to infer information beyond the range of the plotted data. These skills require that you understand how to read a graph.

**Table S3.3**

Temperature °C	Solubility, g $\text{KClO}_3$ /100 g water
10	5.0
20	7.4
30	10.5
50	19.3
60	24.5
80	38.5

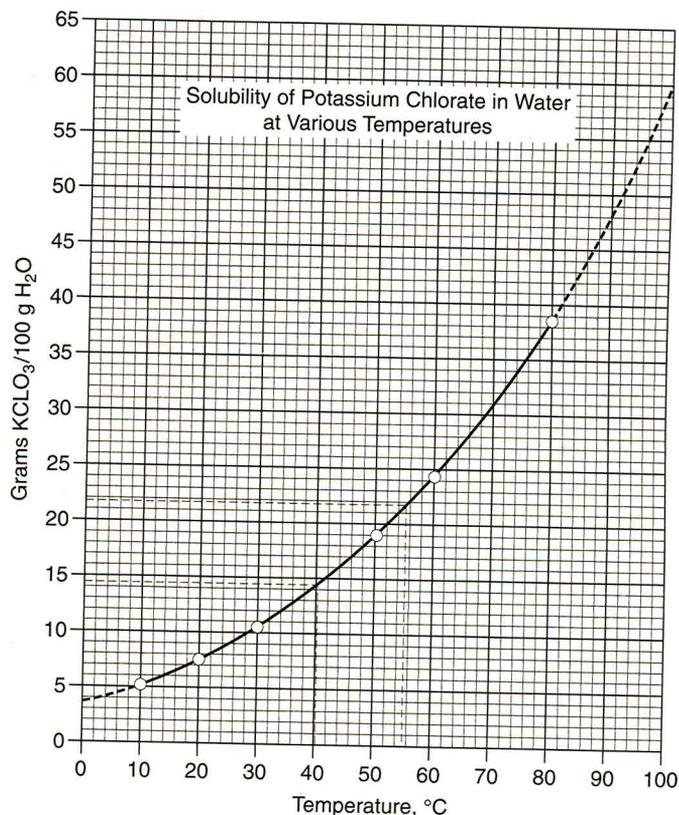
**Figure S3.5 Solubility vs. temperature data from Table S3.3**

Figure S3.5 is a graph showing the solubility of potassium chlorate in water at various temperatures. The solubility curve on this graph was plotted from experimentally determined solubilities at six temperatures shown in Table S3.3.

These experimentally determined solubilities are all located on the smooth curve traced by the solid line portion of the graph. We are therefore confident that the solid line represents a very good approximation of the solubility data for potassium chlorate covering the temperature range from 10°C to 80°C. All points on the plotted curve represent the composition of saturated solutions. Any point below the curve represents an unsaturated solution.

The dashed line portions of the curve are extrapolations; that is, they extend the curve above and below the temperature range actually covered by the plotted data. Curves such as this are often extrapolated a short distance beyond the range of the known data although the extrapolated portions may not be highly accurate. Extrapolation is justified only in the absence of more reliable information.

The graph in Figure S3.5 can be used with confidence to obtain the solubility of  $\text{KClO}_3$  at any temperature between 10°C and 80°C but the solubilities between 0°C and 10°C and between 80°C and 100°C are less reliable. For example, what is the solubility of  $\text{KClO}_3$  at 40°C, at 55°C, and at 100°C? First, draw a vertical line from each temperature to the plotted solubility curve. Now from each of these points on the curve, draw a horizontal line to the solubility axis and read the corresponding solubility. The values that we read from the graph are

40°C	14.6 g $\text{KClO}_3$ /100 g water
55°C	21.9 g $\text{KClO}_3$ /100 g water
100°C	59.8 g $\text{KClO}_3$ /100 g water

Of these solubilities, the one corresponding to 55°C is probably the most reliable because experimental points are plotted at 50°C and 60°C. The 40°C solubility value is probably a bit less reliable because the nearest plotted points are at 30°C and 50°C. The 100°C solubility is the least reliable of the three values because it was taken from the extrapolated part of the curve, and the nearest plotted point is 80°C. Actual handbook solubility values are 14.0 g and 57.0 g of  $\text{KClO}_3$ /100 g water at 40°C and 100°C respectively.

Although making and reading graphs by hand in this way gets easier with practice, most scientists now use computers to graph their experimental data. If you have access to a computer either in the laboratory, library, or at home, we encourage you to learn computer graphing after you have mastered all the skills of graphing data by hand. Instructions for computer graphing are provided in Part C of this study aid.

### Requirements for Computer Graphing

There are several software programs that can be used to generate graphs of scientific data. We have chosen **Microsoft Excel**, a program within *Microsoft Office 2000*. It requires PC Windows 98 or later or Macintosh OS X. You should be sitting in front of a PC computer with Microsoft Excel 2000 active as you begin these instructions. (Or a Power Mac computer with Microsoft Excel v.X). These instructions assume that you have some knowledge of Microsoft Excel and that you know how to write graphs manually as instructed in Part A of this Study Aid. Unless you are comfortable with your computer and have used this software, there should be someone around that can help you out occasionally when you try this the first time.

## C. COMPUTER GRAPHING

Preparing a computer graph involves the same steps as the paper and pencil graph. The difference is that the computer will do most of the steps for you. However, you must provide the computer with the necessary information (data) that is being graphed. After you complete all the instructions in this section, you should have a graph that looks like Figure S3.6 below.

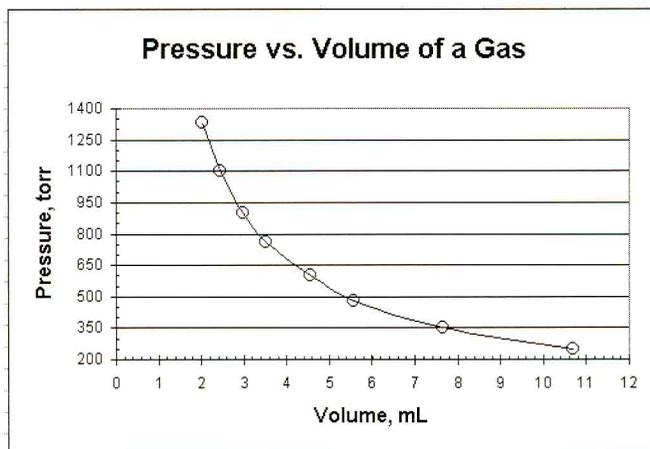
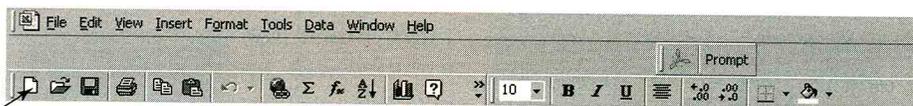


Figure S3.6 Sample Computer Graph Using Excel

1. Open up a clean page (called an Excel “sheet”) on which to begin the graph (called a “chart”)



New sheet bottom

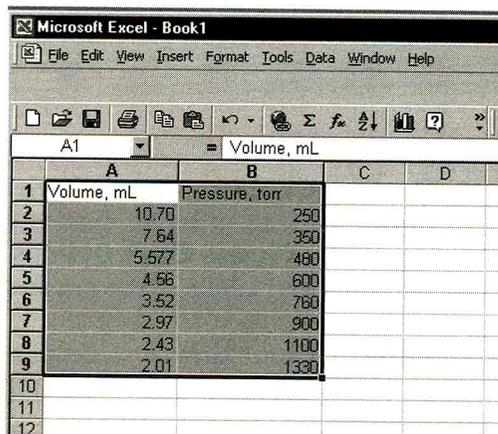
**Figure S3.7 Excel Toolbar**

To do this, click on the new sheet icon on the far left of the tool bar (Figure S3.7)

2. Add the data table to the sheet so the graphing of the data can begin.  
The data graphed for this exercise is the same data that was graphed in Exercise 9, B2.

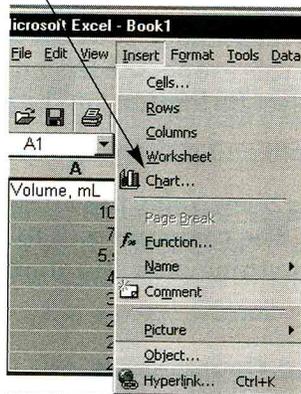
<b>Volume, mL</b>	10.70	7.64	5.57	4.56	3.52	2.97	2.43	2.01
<b>Pressure, torr</b>	250	350	480	600	760	900	1100	1330

Go to Column A on the new Excel sheet that was opened. In cell A1, type **Volume, mL** and in B1, type **Pressure, torr**. Adjust the width of the column if necessary. Then, enter the volume and pressure values in the columns from the data shown above. Highlight the cells that are filled in with the data. When this is done, the left side of your screen should look like Figure S3.8.

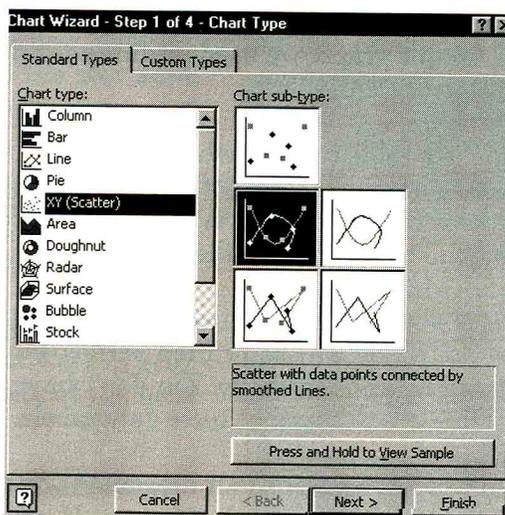


**Figure S3.8**

3. Convert the data table into a “chart” by choosing the **Insert** tab and then **chart** from the pull down menu (Figure S3.9). This should immediately result in the appearance of a Graph Wizard (Figure S3.10a) on the sheet. From this window, select XY Scatter for Chart Type and **SCATTER WITH SMOOTHED LINES** (Figure S3.10b) for the sub-type. We are not going to use the remaining steps on the Graph wizard. Select **Finish**.



**Figure S3.9**



**Figure S3.10a**



**Figure S3.10b**

4. The graph on the sheet should now appear similar to Figure S3.11. The remaining steps in this procedure will explain how to convert this very primitive graph into the finished graph at the beginning of this section of Study Aid 3 (Figure S3.6).

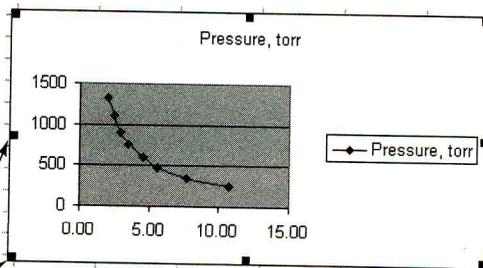


Figure S3.11

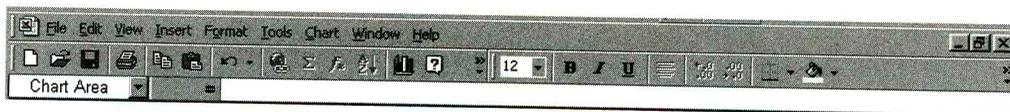


Figure S3.12 Chart Toolbar

5. The Chart tool bar shown above will be used to complete the formatting of the graph. **Important:** in order to display this toolbar, the chart must be selected as shown in Fig. S3.11. Choose **Chart Options** from the pull-down **Chart** menu. Chart options allow the titles and labels of the graph to be added. For the sample graph, select as follows:

**Titles:** Chart title: Gas Pressure vs. Volume  
 Value (X) axis: Volume, mL,  
 Value (Y) axis: Pressure, torr

**Axes:** Primary axis  
 Select X  
 Select Y (Dependent variable)

**Gridlines:** This step allows you to put grid lines on your graph if you want to make it look like it is drawn on graph paper. Gridlines extend tick marks into lines across and up/down the plot area. To insert gridlines, put a  beside the ticks that you want to extend. In the sample graph, we used gridlines for the major ticks only. You are welcome to experiment.

**Legend:** This is a table to show which symbol and line corresponds to each set of data points. Since there is only one kind of symbol and one line in this graph, the legend is not needed. If you keep the legend, this is the place where you select its location on the paper. Deselect the legend by clicking on the .

**Data Labels:** Usually the choice here is None. If you choose Show Value then the actual data value for the y-axis will be printed beside the symbol. The computer will take the value from the table automatically. You don't have to do anything once you make this choice. The sample graph does not have data labels.

Click **OK** when you have finished all the options on the Chart Option screen.

6. **Select Format Axis:** Click once on each axis and then select Format from the chart toolbar. The pulldown menu will read Format selected axis and the Format Axis window will appear, Fig S3.13. Complete all the axis options for each axis as follows:

	X-axis (Independent Variable)	Y-axis (Dependent Variable)
<b>Patterns</b>		
lines	automatic	automatic
major tick	Cross	Cross
minor tick	Inside	Inside
tick labels	Next to axis	Next to axis
<b>Scale</b>		
minimum	0	200
maximum	12	1400
major unit	1	150
minor unit	0.2	50
Value y cross at	0	—
Value x cross at	—	200
<b>Font</b>	Arial	Arial
Style	Bold	Regular
Size	9	9
Underline	None	None
Color	Automatic	Automatic
Background	Automatic	Automatic
Effects	None	None
<b>Number</b>	General	General
<b>Alignment</b>	Horizontal	Horizontal

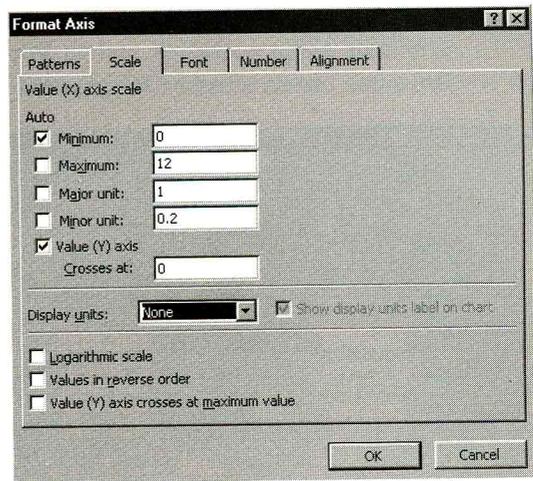


Figure S3.13

7. To Format the Plot Area (which is now grey with a fine line around it), select the Plot Area by clicking on the border around the plot area. Then, go to Format and select Format selected plot area.

**Border:** Allows you to select the style, color, and weight of the line around the plot area. The sample graph is a fine black, continuous line.

**Area:** Allows you to select the background color in the plot area. The default color is grey. Select white or some other light color (if you have access to a color printer).

**Fill Effects:** This allows some texture or color gradients to be added to the plot area. Do not add this for this graph.

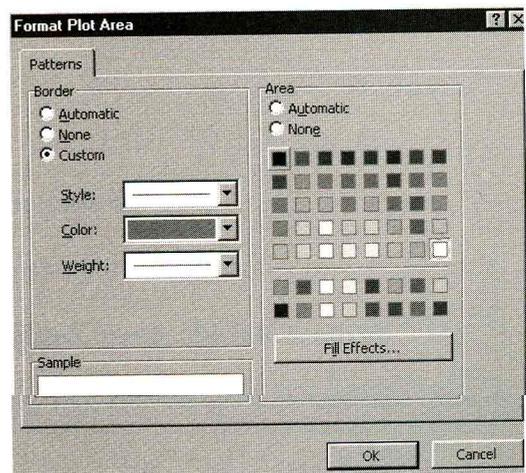


Figure S3.14

- To format the data points and the line which connects them, put the arrow on the line or any data point and click. Select Format Data Series from the Chart toolbar. Make choices from the menu window (Figure which appears).

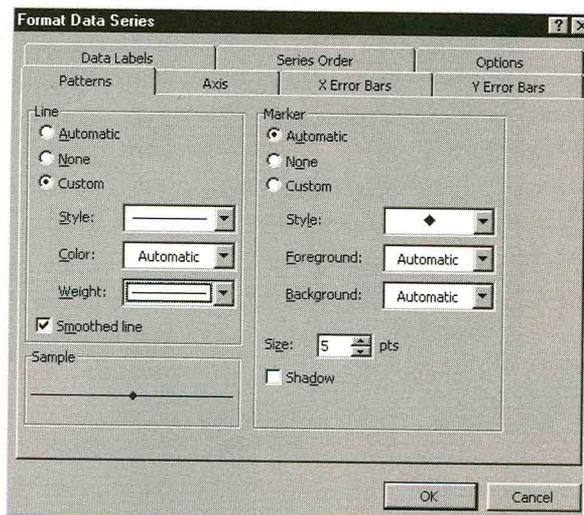


Figure S3.15

### Patterns:

**Line:** Choose custom followed by the style, color, and weight that you prefer. Experiment with this. The appearance of the line you design will appear under sample. The sample graph has a solid line in a dark color.

**Marker:** This will format the symbol for each data series. Choose custom here then click and drag on the style menu and choose the shape of the symbol that you like best. If you choose the same color for the foreground and background, the symbol will be filled and solid. If you choose a dark color for the foreground with light color (white) for the background the result is an open symbol.

▲ = solid symbol    △ = open symbol

**Size** can be increased by increasing the pts.

**Y error Bars**  
**X error Bars** } These choices do not apply to this data

- A last Look:** Now look at the title and axis titles again. If they need to be moved, click on them. This will put a border around the words which can then be dragged to a new location. You can adjust the size by clicking on the lower right corner of the selected chart and pulling on the corner.
- To Print the graph:** Click on File and choose Print Preview from the pull-down menu. This will bring up a screen with the graph filling the page. Use the tool bar on the Print Preview page to adjust margins, the orientation of the graph (portrait or landscape) and other options. If you notice something you don't like, go back to the chart on the sheet and make a change. When everything is the way you want it, close the Print Preview and select Print.