Name ____________________

Math and Laboratory Skills Lab

This is a lab course, which means that not only will we be spending up to half of each class working on laboratory activities, they will make up fully one third of your final grade in the course.

This lab activity is designed to give you the skills you will need to complete the other lab activities in this course. It is not the most exciting lab activity that you will do, but it may be the most important. You should refer back to this OFTEN as you complete the other lab activities. Work with your lab partner and utilize the other groups in the classroom and the instructor. Compare answers and ask for clarification when you're unsure. Generally speaking, focus on the methodology of unit conversions, scientific notation, etc. You will use these often over the course of the semester, so ask as many questions as you need to in order to leave today feeling relatively confident with those things.

Part 1: Practice
Scientific Notation and Significant Figures

Rewrite the following numbers in scientific notation.

10,000 =	_______	-0.00004 =	_______
100,000,000 =	_______	900 =	_______
0.00153 =	_______	0.023 =	_______
42,386 =	_______	-8,599 =	_______

Now, go through the same set of numbers and write the number of significant figures in each blank

10,000 =	_______	-0.00004 =	_______
100,000,000 =	_______	900 =	_______
0.00153 =	_______	0.023 =	_______
42,386 =	_______	-8,599 =	_______

Manipulation of Numbers in Scientific Notation

As you discovered in class, there are some special rules to employ when doing addition, subtraction, multiplication and division in scientific notation. Your best tool in evaluating your answer here is a little *common sense*. If you're dividing a very large number by a very small one, (or vice versa) for example, do you expect your answer to be very large or very small? Generally speaking, ask yourself before you begin any problem whether you expect you answer to be large or small, positive or negative and compare the answer you get to your expectation. If they don't match, talk to another group or your instructor to check your answer.

Complete the following calculations. In each case, write out the exact answer and then below that write the answer *rounded to the correct number of significant figures* (remember, your answer is only as good as your *least* precise measurement). Make sure your final answer is in scientific notation in either case!

$3.150 \times 10^{6} - 4.2 \times 10^{5} =$

$-1.592348 \times 10^{2} - 5.5 \times 10^{1} =$

$5.234 \times 10^{-2} + 8.1 \times 10^{-3} =$

$9.65 \times 10^{5} + 2.333 \times 10^{-1} =$

$-1.32 \times 10^{12} \times 7.94 \times 10^{2} =$

$6.77 \times 10^{-2} \times 3.56789 \times 10^{8} =$

$$\frac{8.52 \times 10^{5}}{9 \times 10^{-2}} =$$

$$\frac{1.49598 \times 10^{11}}{2.998 \times 10^{8}} =$$

Unit Conversions

For your reference, below you will find a table of metric system prefixes as well as a list of useful conversion factors.

TABLE 1.5 Selected Prefixes Used in the Metric System

Prefix	Abbreviation	Meaning	Example	
Giga	G	10^9	1 gigameter (Gm)	$= 1 \times 10^9$ m
Mega	M	10^6	1 megameter (Mm)	$= 1 \times 10^6$ m
Kilo	k	10^3	1 kilometer (km)	$= 1 \times 10^3$ m
Deci	d	10^{-1}	1 decimeter (dm)	= 0.1 m
Centi	c	10^{-2}	1 centimeter (cm)	= 0.01 m
Milli	m	10^{-3}	1 millimeter (mm)	= 0.001 m
Micro	μ[a]	10^{-6}	1 micrometer (μm)	$= 1 \times 10^{-6}$ m
Nano	n	10^{-9}	1 nanometer (nm)	$= 1 \times 10^{-9}$ m
Pico	p	10^{-12}	1 picometer (pm)	$= 1 \times 10^{-12}$ m
Femto	f	10^{-15}	1 femtometer (fm)	$= 1 \times 10^{-15}$ m

[a] This is the Greek letter mu (pronounced "mew").

Conversion Factors
2.54cm = 1in
12in = 1ft
5280ft = 1mi = 1609 m
3.1mi = 5km
1 hr=3600 sec
1 day = 24 hr
1 year = 365.25 days

Note that all of the conversion factors I've listed are units of distance or time. In this class, we will mostly be measuring and manipulating distances, times and velocities/speeds (which have units of distance/time)

Special Units for Astronomy
1 "Astronomical Unit" (AU) = 1.50 x 10^8 km
1 light year = 9.46 x 10^{12} km
1 parsec = 3.26 light years
1 arcminute = 1/60 degree
1 arcsecond = 1/3600 degree

Show your work for all practice problems (and don't forget significant figures in the answer!)

1. Alpha Centauri, the closest star to the Sun, is 4.365 light years away. How far away is that in parsecs?

2. How many seconds are in one year? Give your answer in scientific notation!

3. How many mm are in 1km?

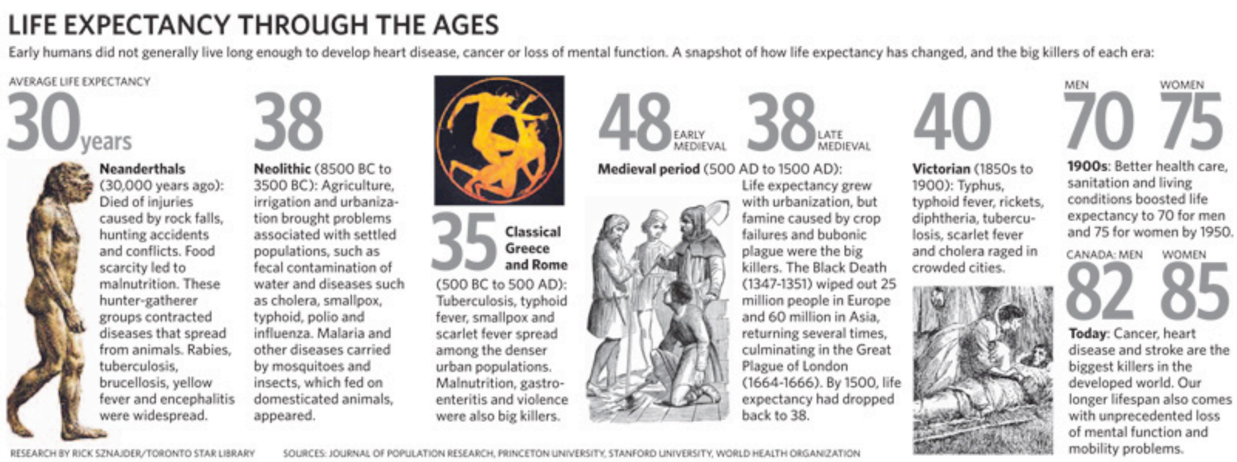
4. How many meters are in 1 light year?

5. The moon subtends (takes up) an angle of 0.54 degrees in the sky. How big is that in arcseconds? (note: the moon is very large in the sky compared to most of the things we'll be talking about in this class, so arcseconds are usually what we'll use to talk about angles in the sky!)

Graphing

Another thing you will be asked to do frequently in this course is to examine graphs, and extract specific information and/or general trends for them.

The figure below describes some of the general trends in human life expectancy with time. Using the data in the table, make a chart of human life expectancy from 4000BC to 2000AD using a separate sheet of graph paper.



Some things to keep in mind when making your chart:
1) LABEL LABEL LABEL! You should choose a title for your chart and should label both the x and y axes with their units.
2) IT SHOULD TAKE UP THE WHOLE PAGE. Make an intelligent choice of the spacing on your axes so that you use up most of the space on the page.

A chart, graph, or table is only a tool in the process of science, and they can be very enlightening OR very misleading. When considering a graph, you should always think critically about how the data it shows were obtained. You should ALWAYS be suspicious of data presented without an explanation of the source, procedure, or method behind it.

Data in science are only useful insofar as they can be explained and used to predict future outcomes.

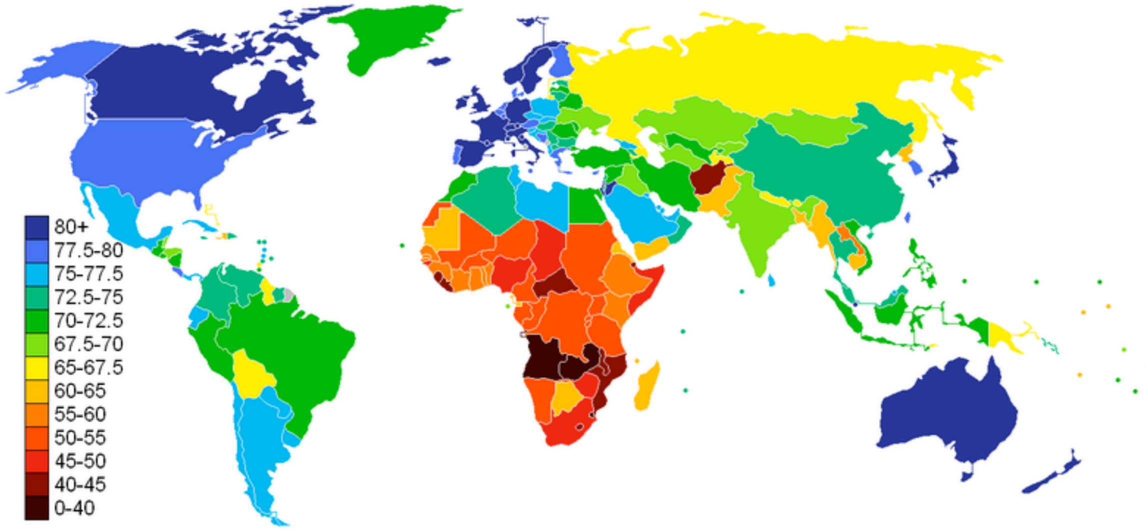
On the next page are three interesting details about the history of human life expectancy. Together with your lab partner, in each case create a hypothesis about what may have caused these phenomena and then explain how you might use data to prove or disprove your hypothesis.

Why was male life expectancy higher in Neolithic times than female?

These numbers are generally life expectancies for humans who lived past a certain age (say, 15 years old). How would they change if you were to include people of all ages? Should this effect change over time (say from the Middle Ages vs. modern times)? How?

If you connect the data points on your chart, you will see a VERY rapid increase in life expectancy in modern times. What do you think changed to cause this to happen?

Let’s practice reading graphs using more data on human life expectancy. The chart below shows a political map of the world with countries color coded by life expectancy.



CIA World Factbook data

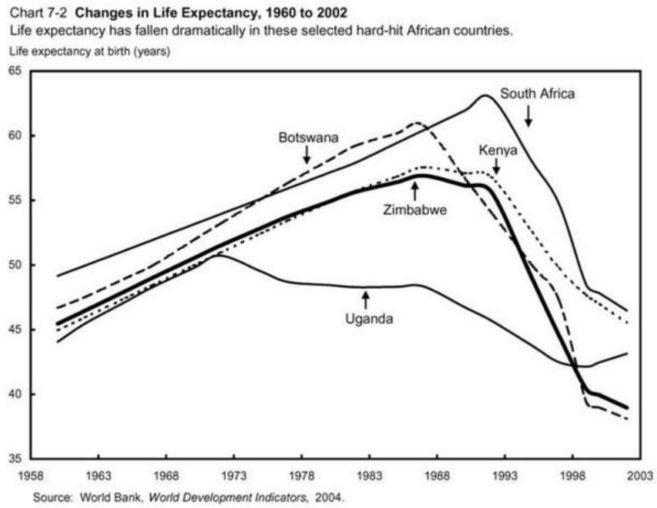
As you may have noticed, this chart contains a lot of data. When confronted with a graph, your first thought should always be: what is this graph *really* telling me? Note that in introductory science (and in real life!) we are talking about the *big picture* here. In other words, what does the graph show in general terms? As with much of the data we will see in this class, there are complex factors that affect the details of the graph, but the ability to pull out the big picture is very important.

Read the summary statement below and decide whether you agree or disagree with it:

World life expectancy varies by more than 40 years from country to country, with the longest lived (70+ years) countries concentrated in North America and Western Europe and the shortest-lived countries (<40 years) in Sub-Saharan Africa.

Does this summarize the “big picture” to your satisfaction? Would you add anything to the statement above?

Give an example using specific countries where the “big picture” may fall short in explaining the whole truth.



The chart above shows human life expectancy data for 5 African countries for the second half of the 20th century. To help you get started with writing your own "big picture" summaries, a general structure is provided below. Fill in the blanks and circle the appropriate options to complete it.

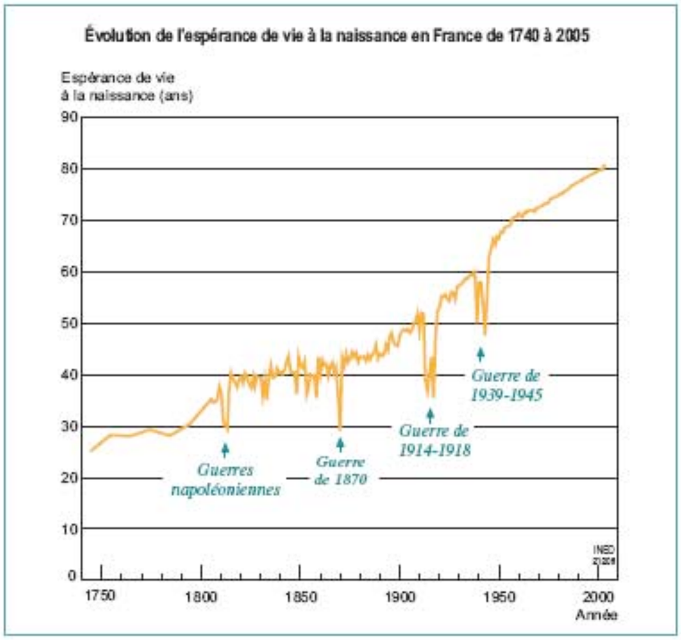
Average life expectancy in this region of Africa increased/decreased steadily from about

_____ to about ______, then _________________________________.

Which trend is more dramatic – the increase in life expectancy prior to the late 1980s or the decrease afterwards? How can you tell? What may have caused this reversal?

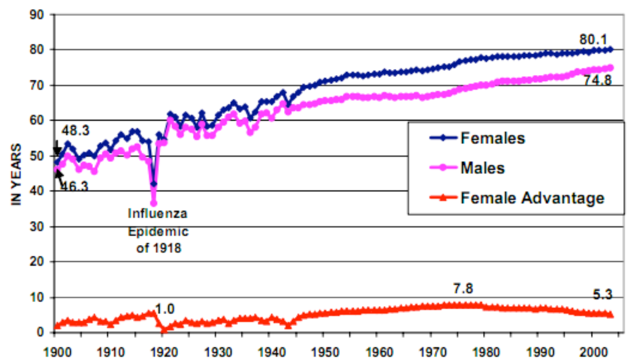
The property you were describing on the last page is called *slope* in graphical terms and it means rate of change. Really, it is a judge of steepness in a graph, with steeper lines indicating more rapid change and shallower lines indicating more gradual change.

Do all of the countries on the chart follow the same general trend as described above? Are there any that deviate significantly from it? If so, why might this be?



Source: French National Institute for Demographic Studies

Figure 1. Life Expectancy at Birth, by Sex: 1900 to 2003.



Source: For 1900-2002, CRS analysis based on data contained in NCHS, United States Life Tables, 2002, *National Vital Statistics Report*, vol. 53, no. 6, Nov. 10, 2004. For 2003, CRS analysis based on NCHS, Deaths: Final Data for 2003, *National Vital Statistics Report*, vol. 54, no. 13, Apr. 19, 2006.

Notes: Later year estimates are more reliable than those of the early 20th century.

Above you will find two charts of life expectancy over time. One of them is for the United States and the other for France. Describe the general trend shown in each of the charts in one sentence below:

United States:

France:

Note that the axes on these two charts are different, so it is difficult to make a specific comparison between the two simply by looking. Is life expectancy increasing faster or slower in the US than in France? In order to really compare the rate of change, or slope, of life expectancy in these two countries, we need to put them on the same footing.

The mathematical formula "slope = rise / run" can help us with this. In the most general sense, rise/run just expresses how much the quantity on the y axis of a graph changed over a given x-axis interval. Since the x-axis here is time, the slope of the trend is how much the average life expectancy in each country changed over a given interval of time. Let's use the interval 1900 to 2000.

Note that by studying a long-term trend, any temporary changes in life expectancy such as those due to war, disease or famine are "smoothed out". Fill in the life expectancy of US and French citizens at each date below.

	1900	2000
United States		
France		

To calculate the slope, first calculate the difference between the life expectancies in 2000 and 1900.

US:

France:

Now, divide by the "run" of 100 years to get the average change in life expectancy per year between 1900 and 2000 in the two countries

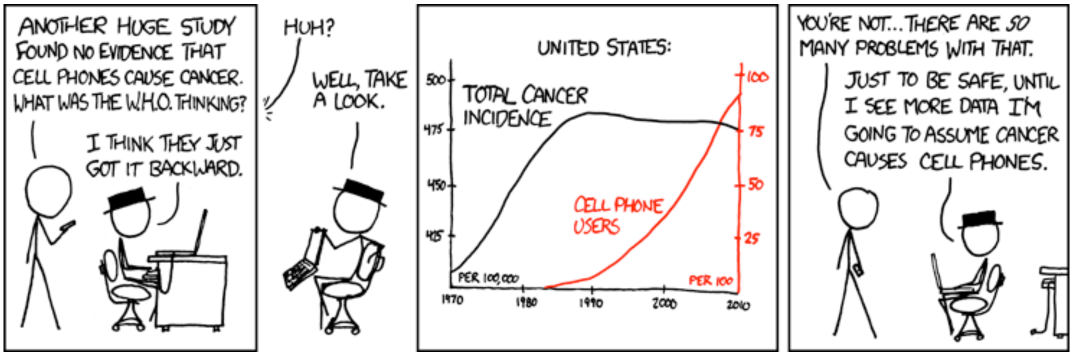
US:

France:

Is it possible for this change (your slope) to have been a negative number? Why or why not?

Use the slope you calculated to answer the question: If this trend continues, what will the average life expectancy be of a US citizen be in the year 2050?

Correlation vs. Causation

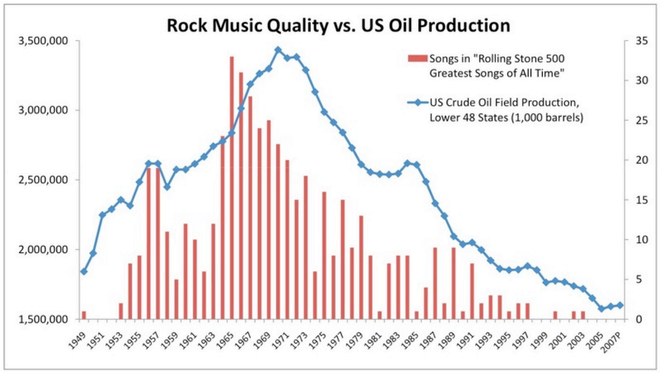


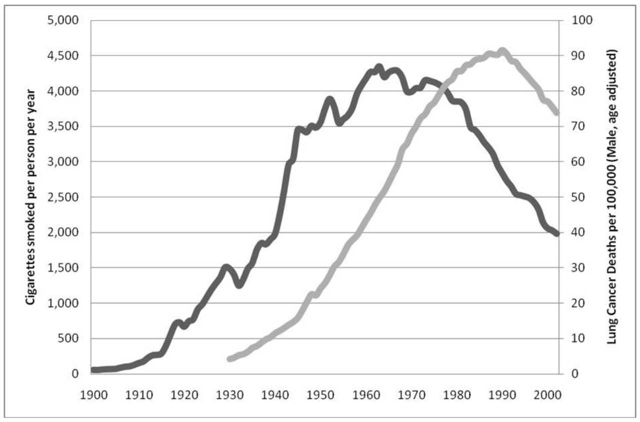
It is also important when examining graphs, particularly those that are presented to convince you of a trend (that two quantities are related to each other somehow) to consider correlation and causation.
Two quantities that are correlated track each other, in the sense that as one increases so does the other OR as one increases the other decreases proportionally. If two quantities are correlated they will show similar trends over the same[1] interval of time.

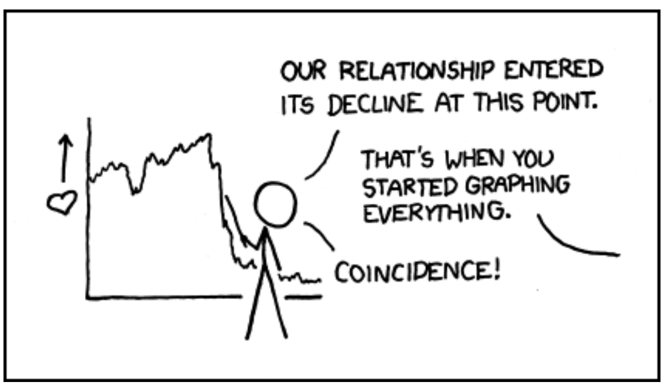
"Correlation does not imply causation" is a warning that is often given when considering results, scientific or otherwise. Just because two quantities increase or decrease together in a particular way, does not necessarily mean that one of the quantities is changing BECAUSE the other is changing. In other words, just because two quantities are correlated, that does not mean that one is the cause and the other the effect. They could follow similar trends for a variety of reasons, including random chance or a relationship to another quantity not considered. Proving that two quantities are *correlated* is the first step on the way to showing that they have a cause-effect relationship, but is by no means the last.

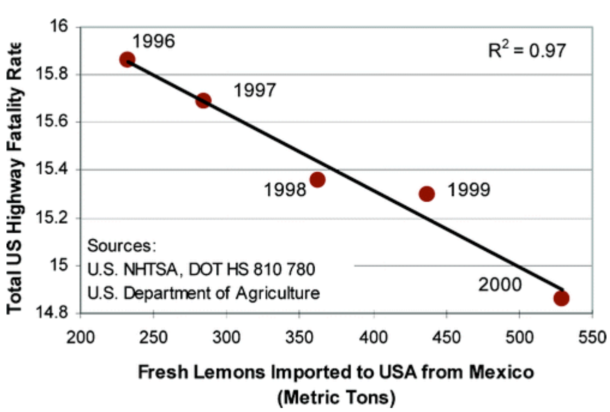
Examine the trends shown in the following four graphs. All four graphs show a *correlation*, but only two have a legitimate claim for *causation*. In the space to the right of each graph, write a one-sentence explanation of the trend being shown and then write one sentence about whether and why (or why not) this trend is likely to be a cause and effect relationship.

[1] Note that it is also possible for one quantity to lead or lag the other in time. For example, a "leading indicator" of the number of new houses in the US could be the number of applications for building permits for new homes. An example of a "lagging indicator" is unemployment, which changes only after the economy has changed, and businesses have had time to adjust their workforce. This is the case with one of the four graphs you will examine in the next section.


Rock Music Quality vs. US Oil Production
Songs in "Rolling Stone 500 Greatest Songs of All Time"
US Crude Oil Field Production, Lower 48 States (1,000 barrels)
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
35
30
25
20
15
10
5
0


Cigarettes smoked per person per year
Lung Cancer Deaths per 100,000 (Male, age adjusted)
1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000


OUR RELATIONSHIP ENTERED ITS DECLINE AT THIS POINT.
THAT'S WHEN YOU STARTED GRAPHING EVERYTHING.
COINCIDENCE!


Total US Highway Fatality Rate
Fresh Lemons Imported to USA from Mexico (Metric Tons)
$R^2 = 0.97$
1996
1997
1998
1999
2000
Sources:
U.S. NHTSA, DOT HS 810 780
U.S. Department of Agriculture

Trend Lines

Extrapolation is an important component of science. It involves taking a trend shown in data and projecting it forward to predict the future. This technique is used, for example, to calculate the date when the US will run out of domestic oil reserves or when the global population will reach 7 billion.

You were using this technique when you estimated the average life expectancy of a US adult in the year 2050 earlier. What assumptions did you make in doing that extrapolation?

Extrapolation, sometimes called regression, has its limitations, and is often applied in a misleading way in the media. You should always consider how reasonable extrapolation of a certain trend is and how long it is likely to stay valid before other factors come into play.

As an example, can you see anything wrong with the extrapolation shown below?