PLOTTING

(download slides and .py files to follow along)

6.100L Lecture 25

Ana Bell

WHY PLOTTING?

- Sooner or later, everyone needs to produce plots
  - Helps us **visualize** data to see trends, pose **computational questions** to probe
  - If you join 6.100B, you will make extensive use of them
  - For those of you leaving us after next week, this is a valuable way to visualize data
- Example of **leveraging an existing library**, rather than writing procedures from scratch
- Python provides libraries for:
  - Plotting
  - Numerical computation
  - Stochastic computation
  - Many others

MATPLOTLIB

- Can **import library** into computing environment

  ```
  import matplotlib.pyplot as plt
  ```

  - Allows **code to reference library** procedures as `plt.<processName>`
- Provides access to existing set of graphing/plotting procedures
- Today will just show some simple examples; lots of additional information available in documentation associated with `matplotlib`
- Will see many other examples and details of these ideas if you take 6.100B

A SIMPLE EXAMPLE

- Idea – create different functions of a variable (n), and visualize their differences

```
nVals = []
linear = []
quadratic = []
cubic = []
exponential = []

for n in range(0, 30):
    nVals.append(n)
    linear.append(n)
    quadratic.append(n**2)
    cubic.append(n**3)
    exponential.append(1.5**n)
```

List of values of variable

Lists of values of functions of variable

Used 1.5 to keep displays visible, more common value for order of growth example would be 2

PLOTTING THE DATA

- To generate a plot:

  Typically n

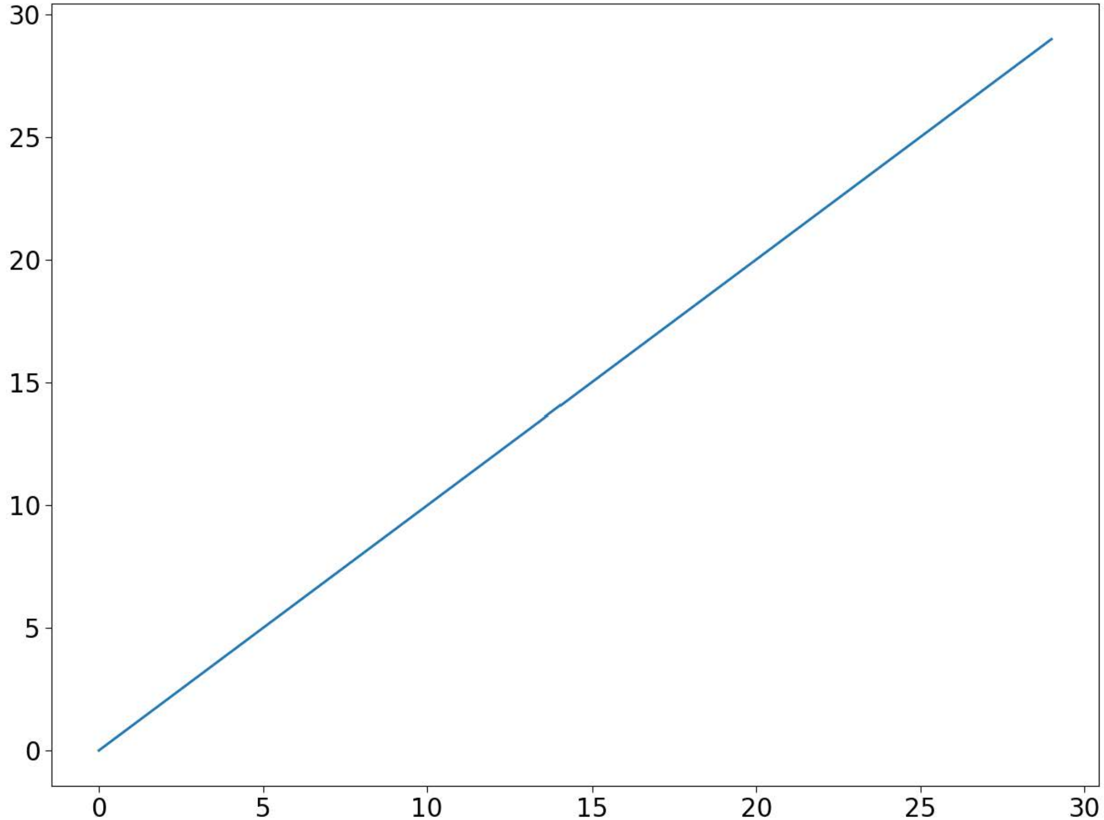
  Typically a function of n, e,g., f(n)

  `plt.plot(<x values>, <y values>)`

- Arguments are lists (or sequences) of numbers
  - Lists must be of the same length
  - Generates a sequence of <x, y> values on a Cartesian grid
  - Plotted in order, then connected with lines
- Can change iPython console to **generate plots in a new window** through Preferences
  - Inline in the console
  - In a new window

EXAMPLE

```
plt.plot(nVals, linear)
```



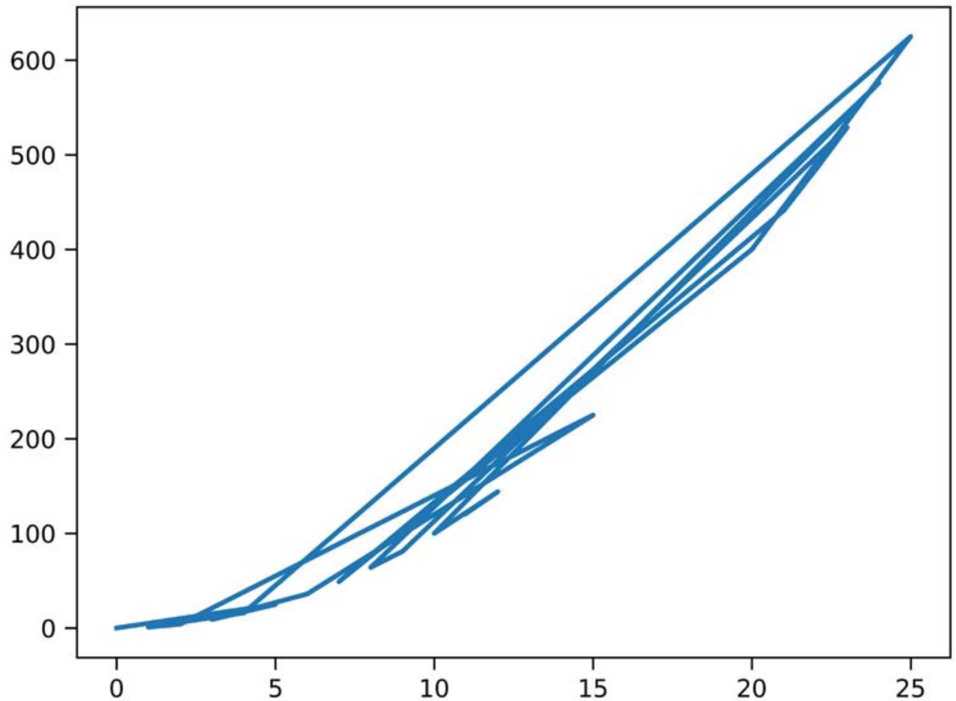
Note how `matplotlib` automatically fits plot within frame

ORDER OF POINTS MATTERS

- Suppose I create a set of values for n and for n^2, but in arbitrary order
- Python plots using the order of the points and connecting consecutive points

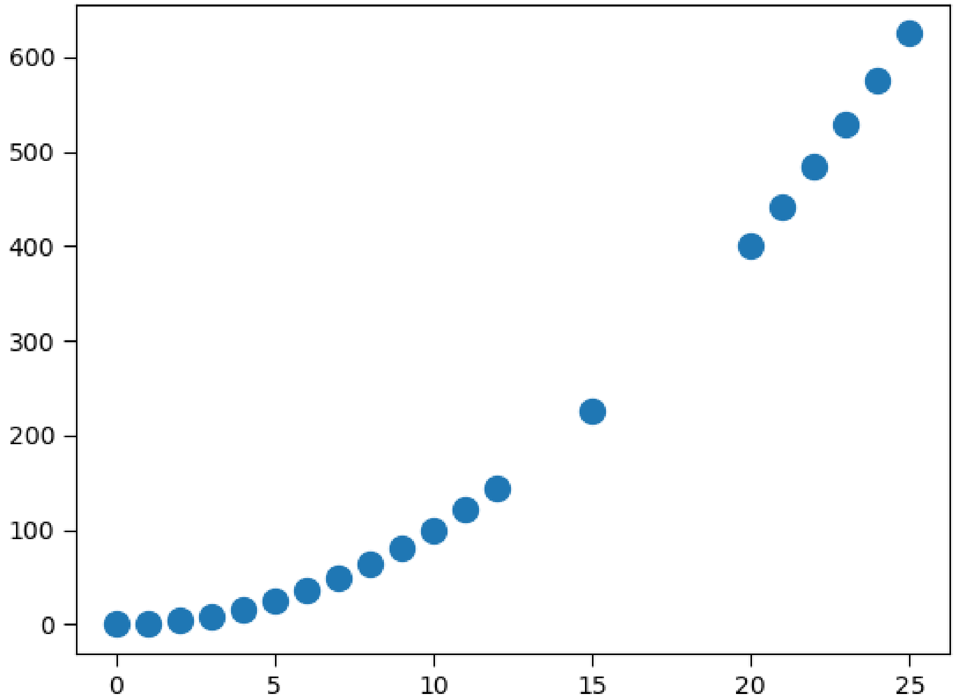
UNORDERED EXAMPLE

```
testSamples = [0,5,3,6,15,2,1,4,25,20,7,21,22,23,9,8,24,10,12,11]
testValues =  [0,25,9,36,225,4,1,16,625,400,49,441,484,529,81,64,576,100,144,121]
## plot connects the points
plt.plot(testSamples, testValues)
```



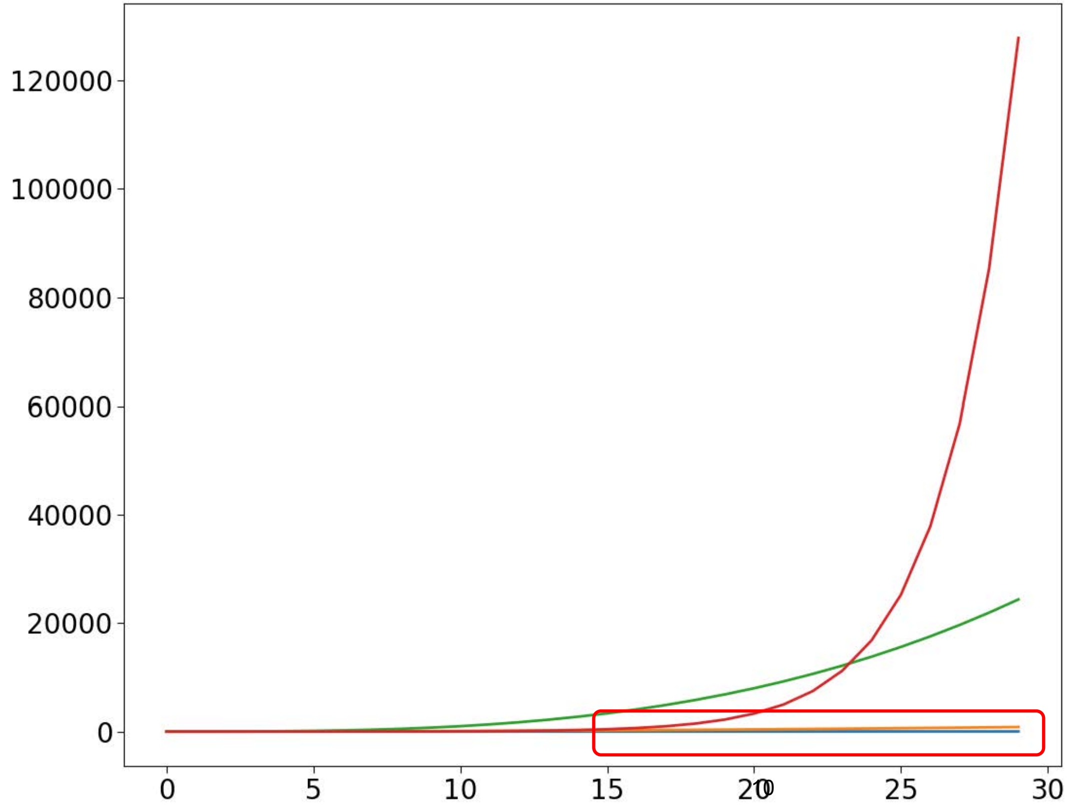
SCATTER PLOT DOES NOT CONNECT DATA POINTS

```
testSamples = [0,5,3,6,15,2,1,4,25,20,7,21,22,23,9,8,24,10,12,11]
testValues =  [0,25,9,36,225,4,1,16,625,400,49,441,484,529,81,64,576,100,144,121]
## scatter plot does not connect the points
plt.scatter(testSamples, testValues)
```



SHOWING ALL DATA ON ONE PLOT

```
plt.plot(nVals, linear)
plt.plot(nVals, quadratic)
plt.plot(nVals, cubic)
plt.plot(nVals, exponential)
```



Impossible to see linear graph, or even quadratic graph

Problem is that scales are very different

PRODUCING MULTIPLE PLOTS

- Let’s graph each one in separate frame/window
- Call

```
plt.figure(<arg>)
```

gives a name to this figure; allows us to reference for future use

  - Creates a new display with that name if one does not already exist
  - If a display with that name exists, reopens it for additional processing

EXAMPLE CODE

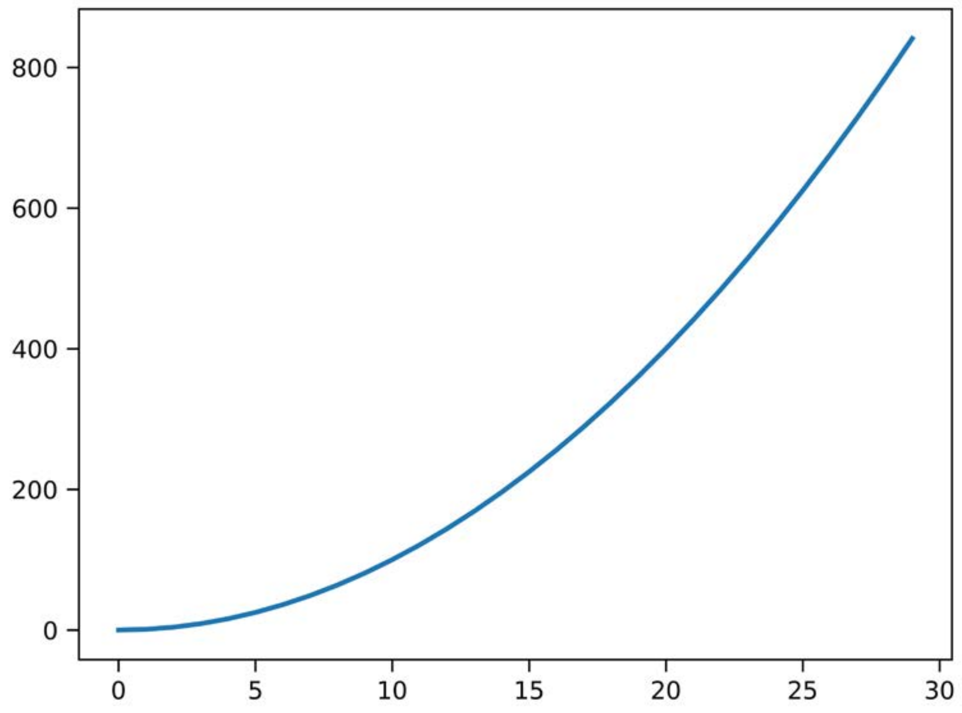
```
plt.figure('expo')
plt.plot(nVals, exponential)
plt.figure('lin')
plt.plot(nVals, linear)
plt.figure('quad')
plt.plot(nVals, quadratic)
plt.figure('cube')
plt.plot(nVals, cubic)
newExpo = []
for i in range(30):
    newExpo.append(1.6**i)
plt.figure('expo')
plt.plot(nVals, newExpo)
```

New figure with name expo
Plot inside that figure
New figure with name lin
Plot inside that figure

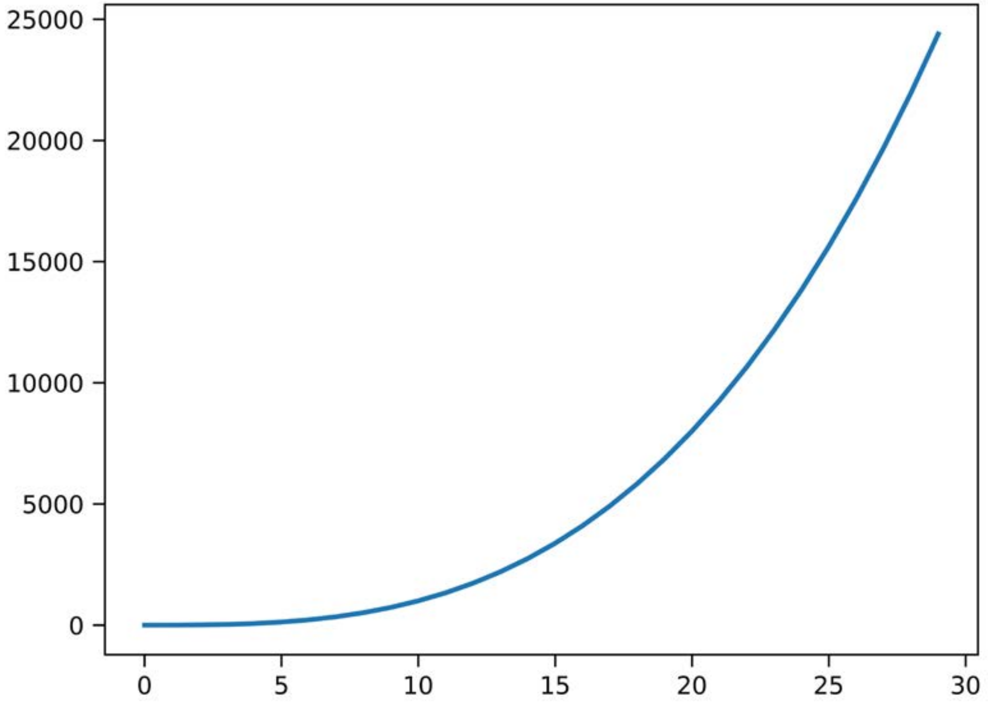
Make another exponential function

Go back to expo
Add another plot to that figure

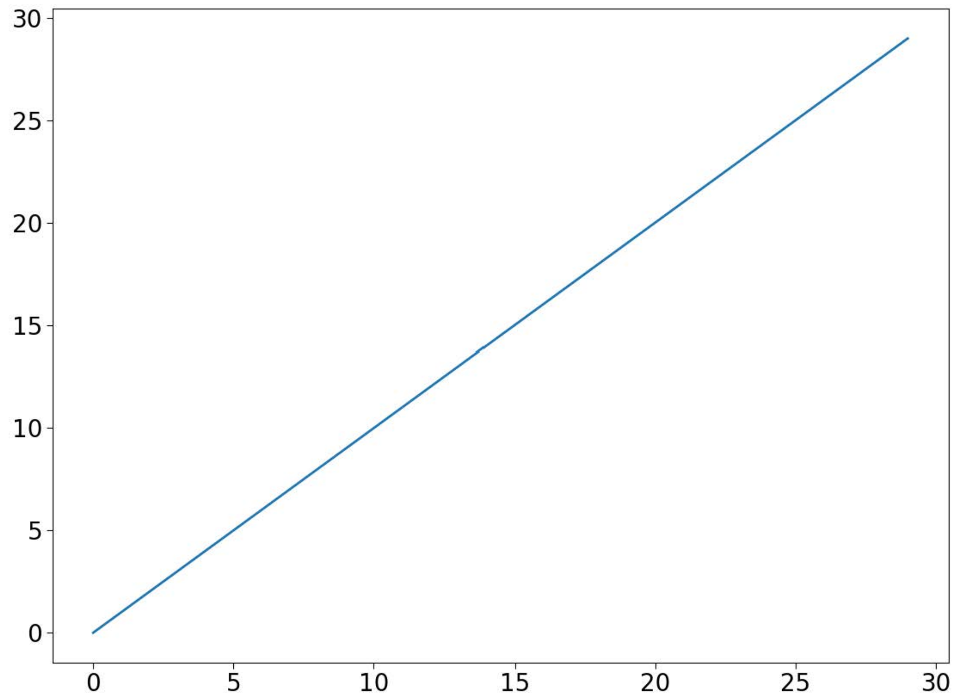
DISPLAY OF `quad`



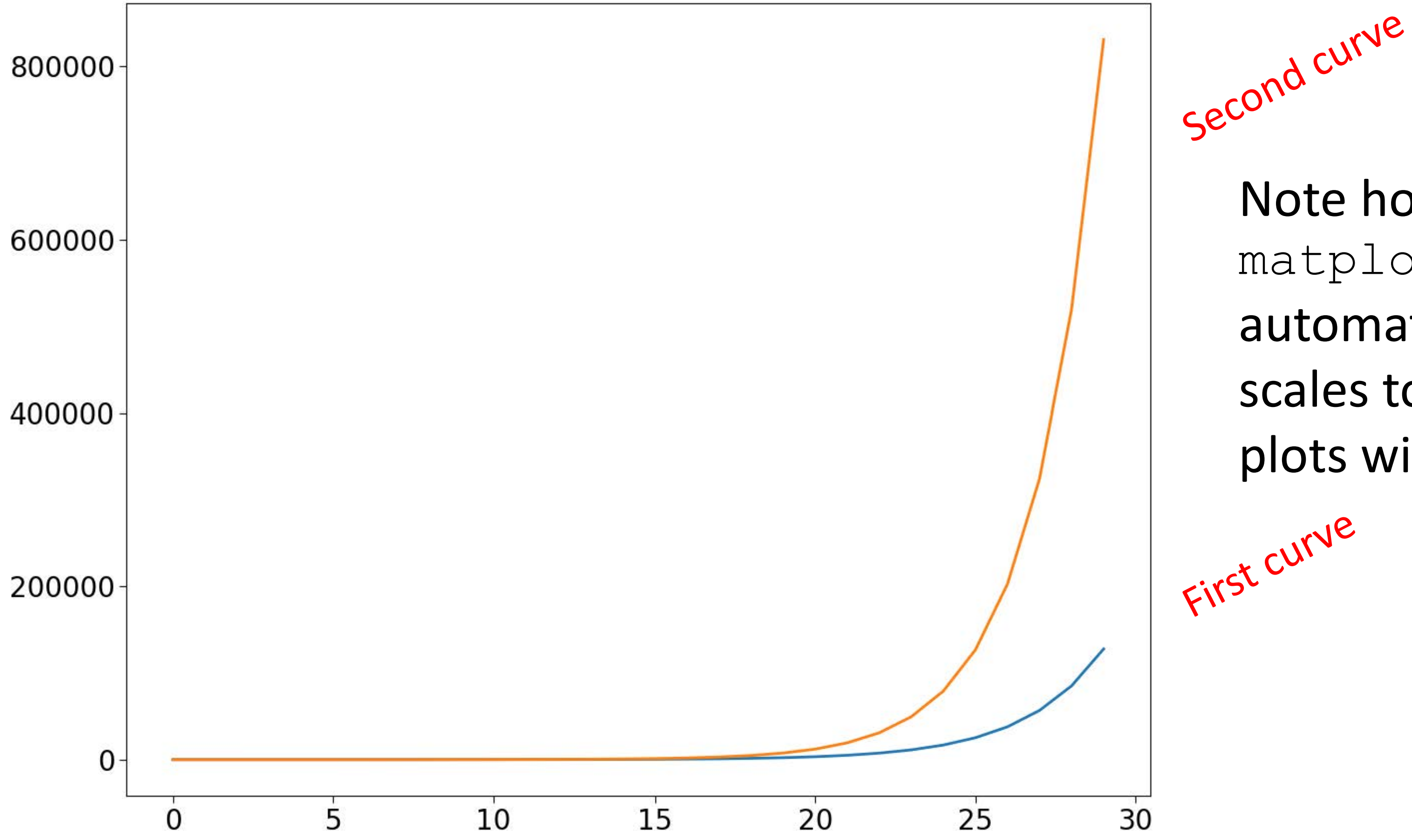
DISPLAY OF `cube`



DISPLAY OF `lin`



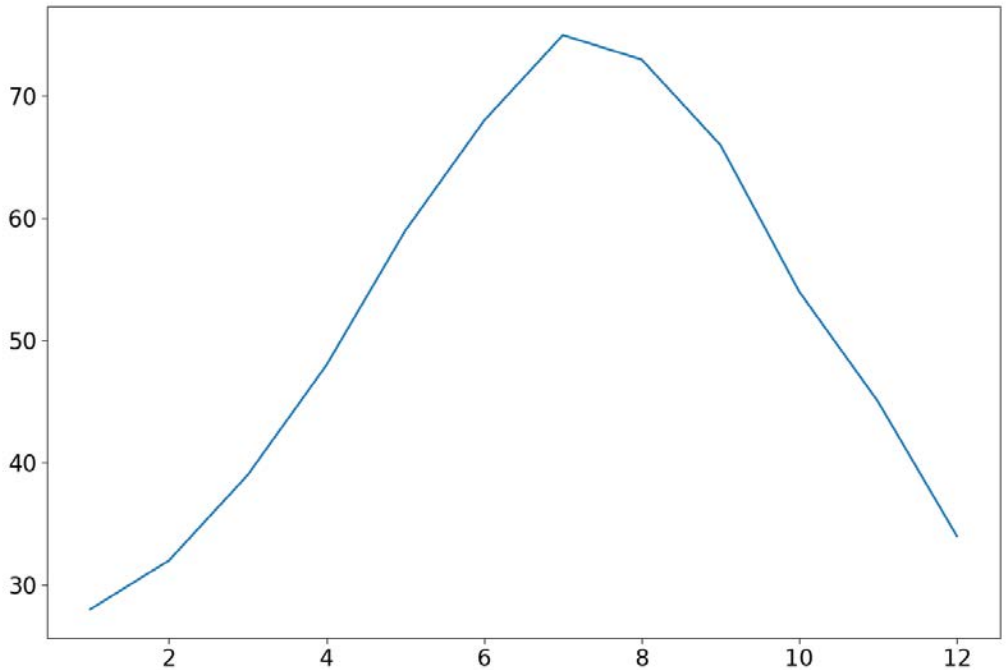
DISPLAY OF `expo`



Note how `matplotlib` automatically scales to fit both plots within frame

A “REAL” EXAMPLE

```
months = range(1, 13, 1)
temps = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, temps)
```



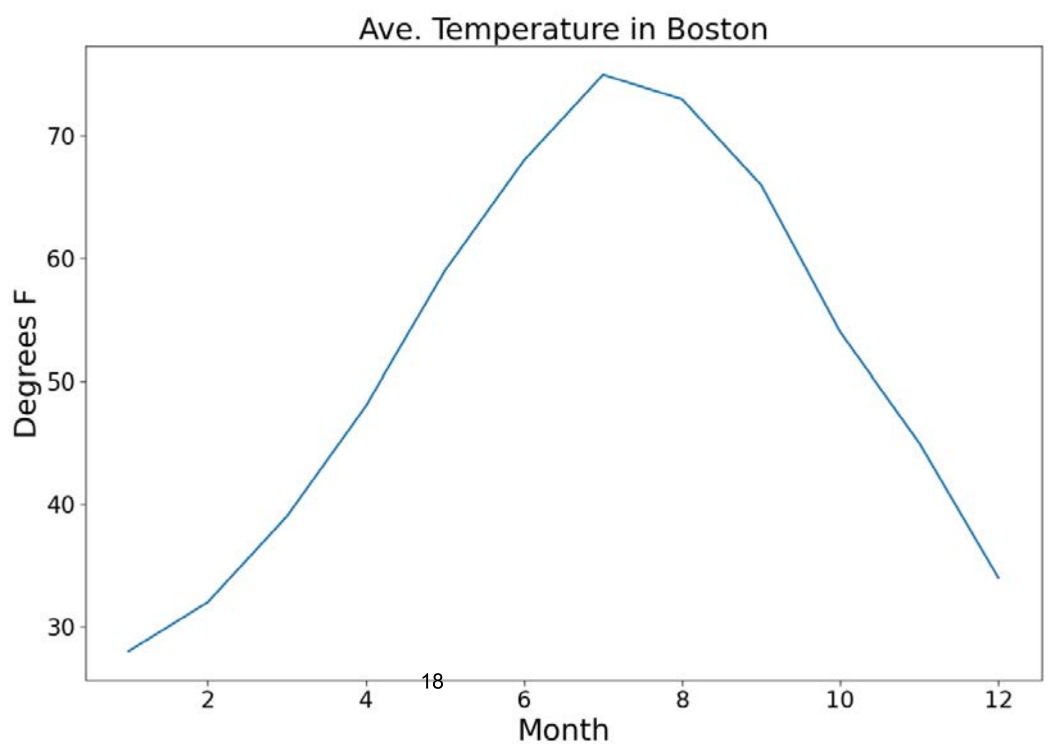
`matplotlib` has automatically selected x and y scales to best fit data

But what is this trying to tell us?
Suppose I just showed you the graph; how do you know its meaning?

A "REAL" EXAMPLE

```
months = range(1, 13, 1)
temps = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, temps)
```

```
plt.title('Ave. Temperature in Boston')
plt.xlabel('Month')
plt.ylabel('Degrees F')
```

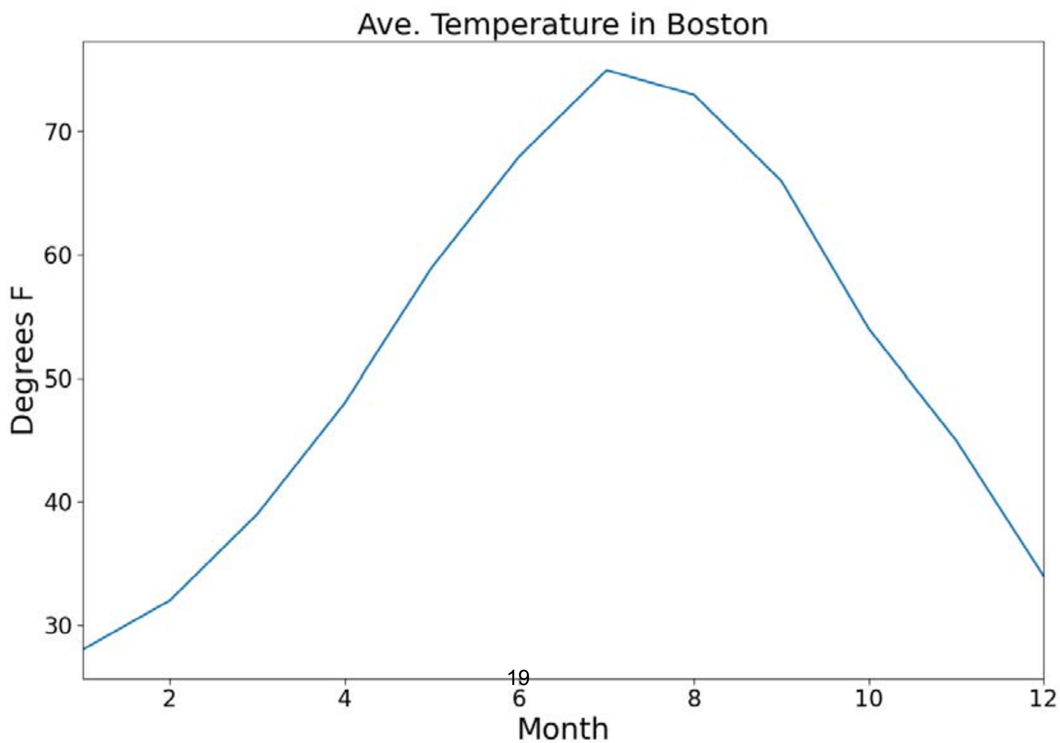


Still a bit weird looking

A “REAL” EXAMPLE

```
months = range(1, 13, 1)
temps = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, temps)

plt.title('Ave. Temperature in Boston')
plt.xlabel('Month')
plt.ylabel('Degrees F')

plt.xlim(1, 12)
```

This sets limits on display for x axis

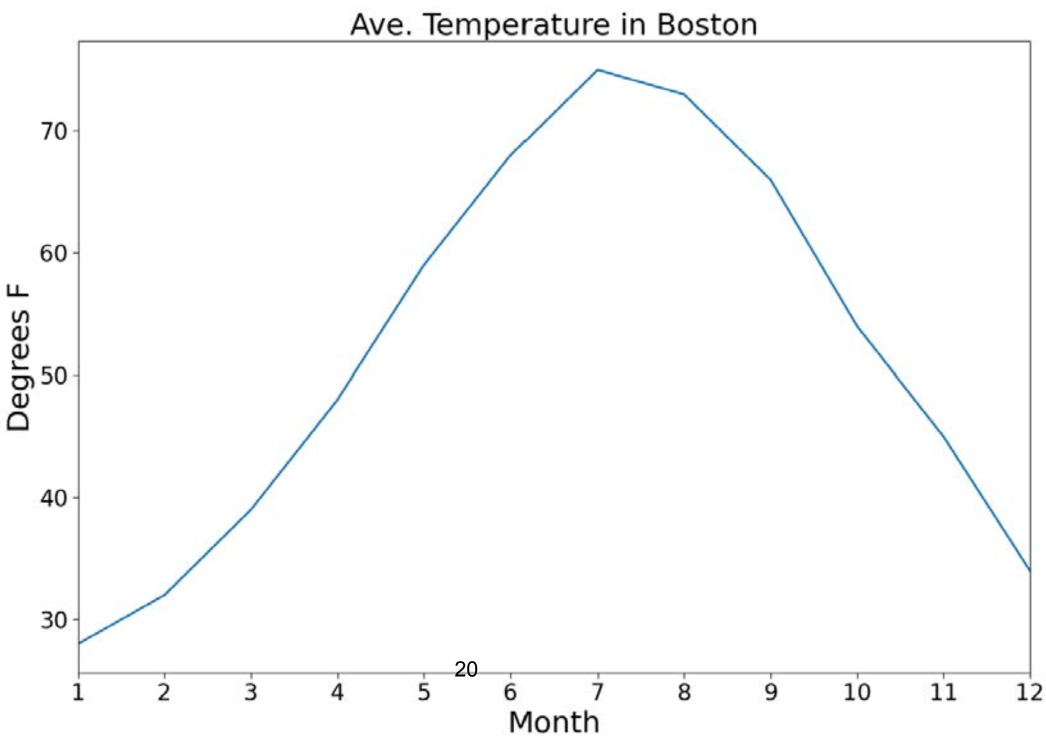


Suppose I want to see each month on x-axis?

A "REAL" EXAMPLE

```
months = range(1, 13, 1)
temps = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, temps)

plt.title('Ave. Temperature in Boston')
plt.xlabel('Month')
plt.ylabel('Degrees F')

plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12))
```

This specifies which x values to mark



But what about those who can't map numbers to months?

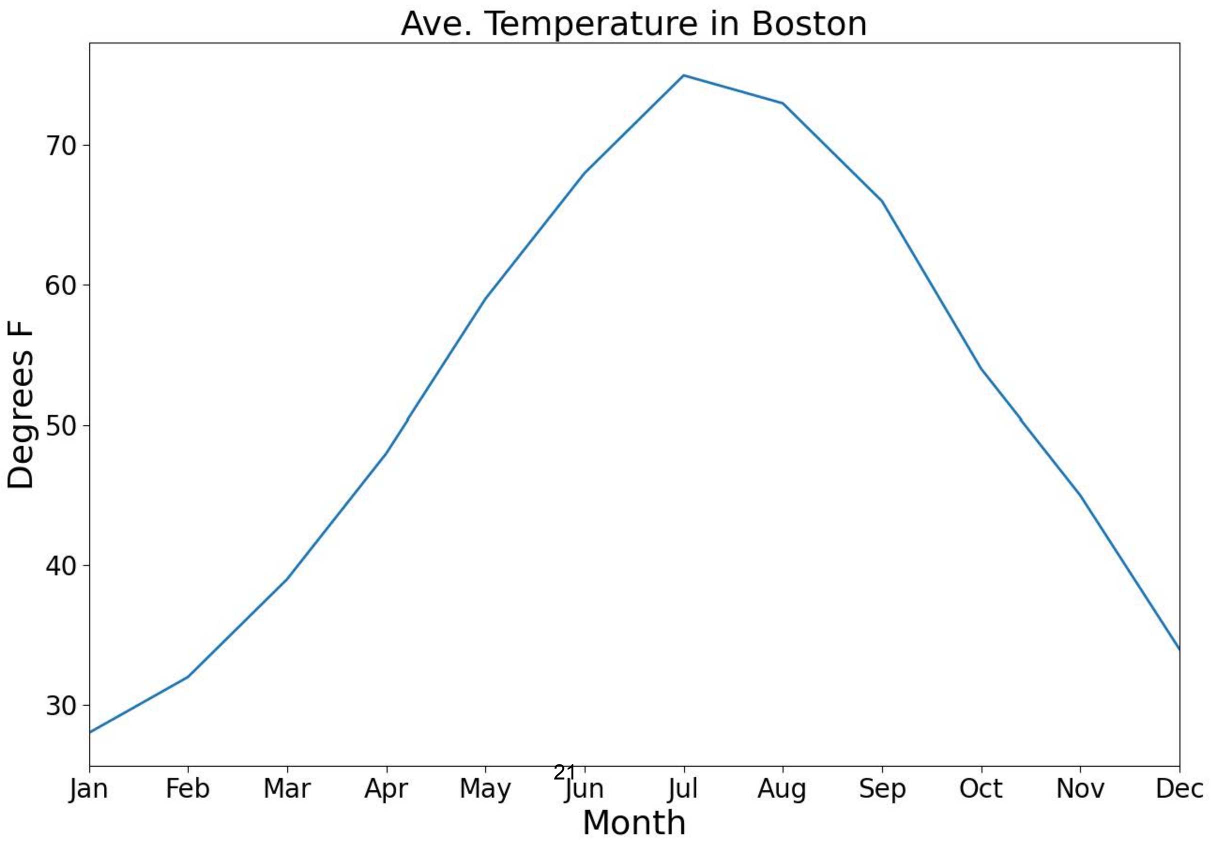
A "REAL" EXAMPLE

Locations of tick marks

The \ tells Python to continue the next line as part of same line

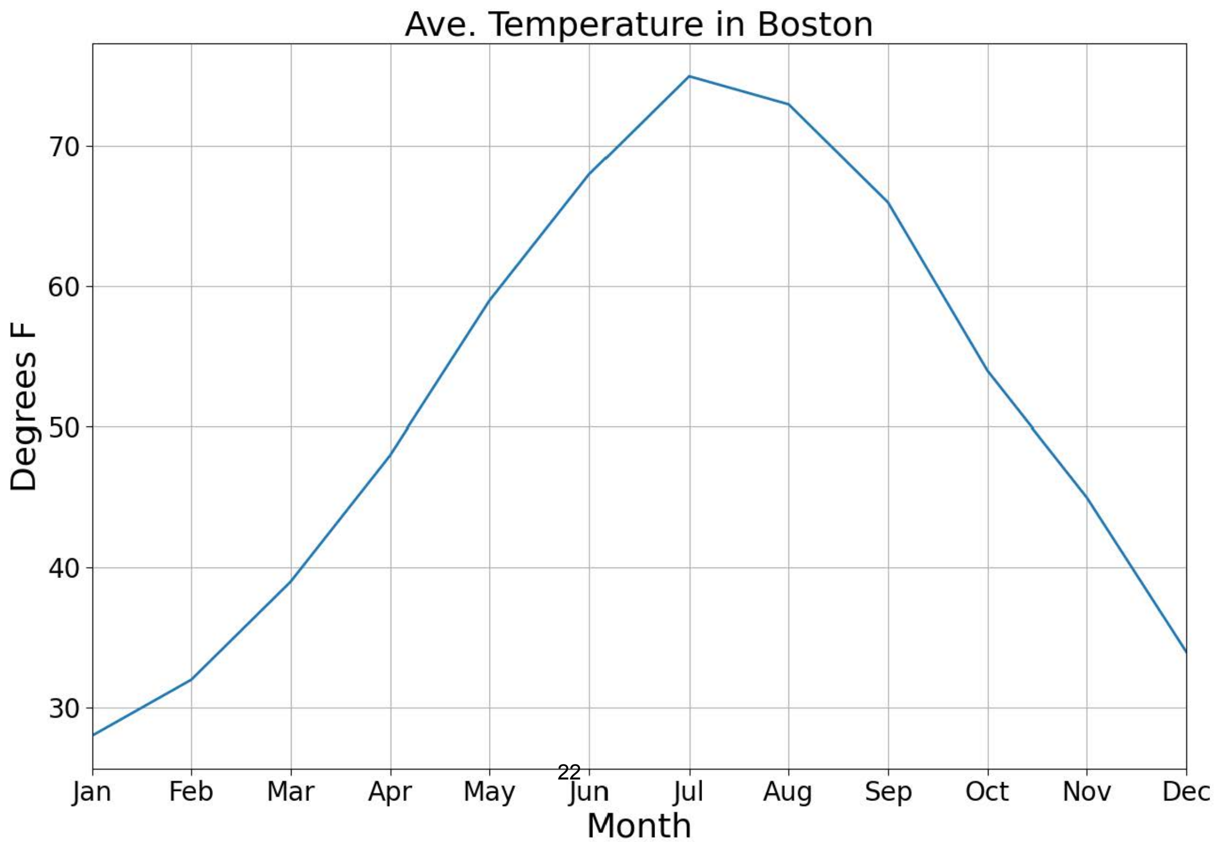
```
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
           ('Jan','Feb','Mar','Apr','May','Jun',\
            'Jul','Aug','Sep','Oct','Nov','Dec'))
```

Labels for tick marks



ADDING GRID LINES

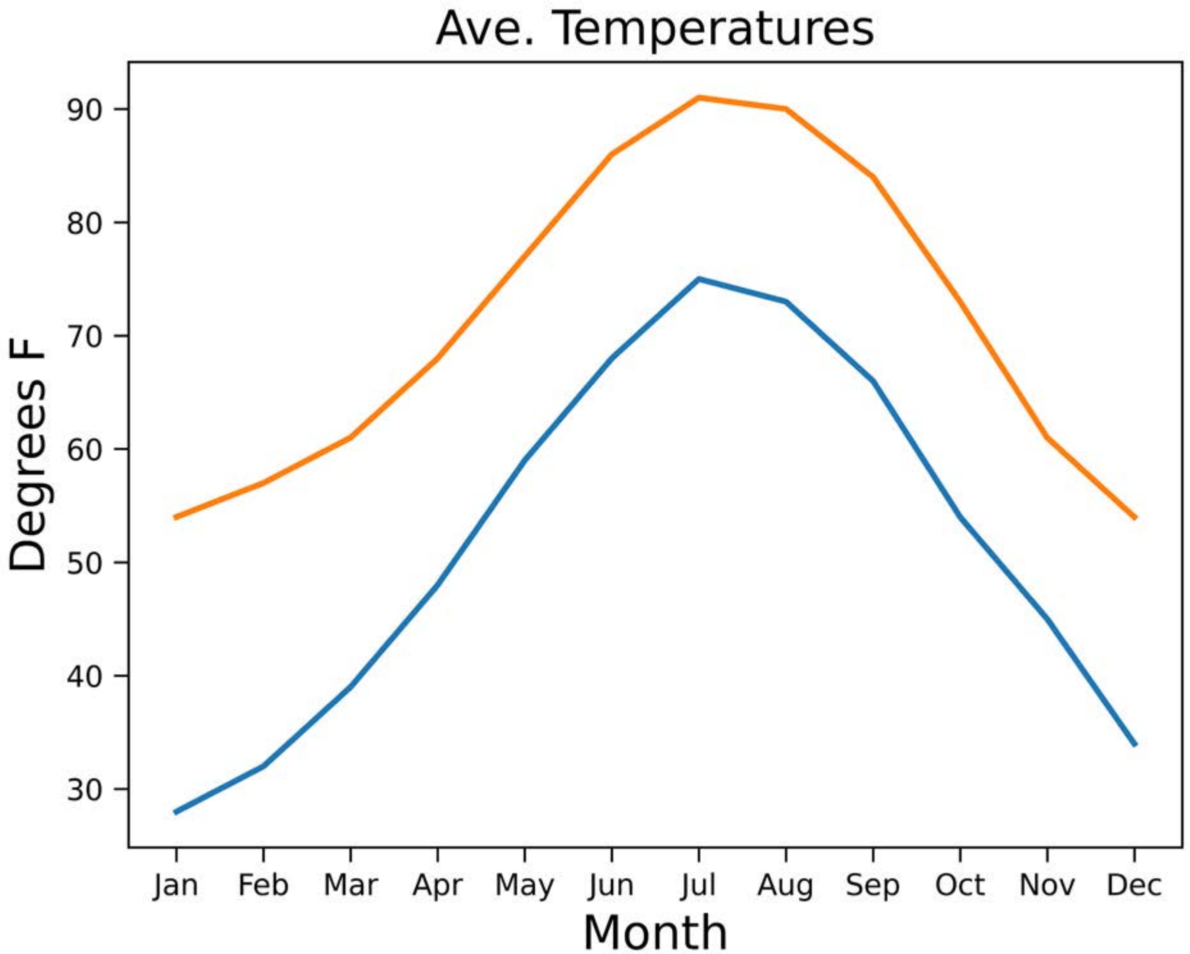
Can toggle grid lines on/off with `plt.grid()`



LET'S ADD ANOTHER CITY

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston )
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix )
# Add labels and title
plt.title('Ave. Temperatures')
plt.xlabel('Month')
plt.ylabel('Degrees F')
```

BUT WHERE AM I?



LET'S ADD ANOTHER CITY

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston, label = 'Boston')
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix, label = 'Phoenix')
# Add labels and title
plt.title('Ave. Temperatures')
plt.xlabel('Month')
plt.ylabel('Degrees F')
plt.legend(loc = 'best')
```

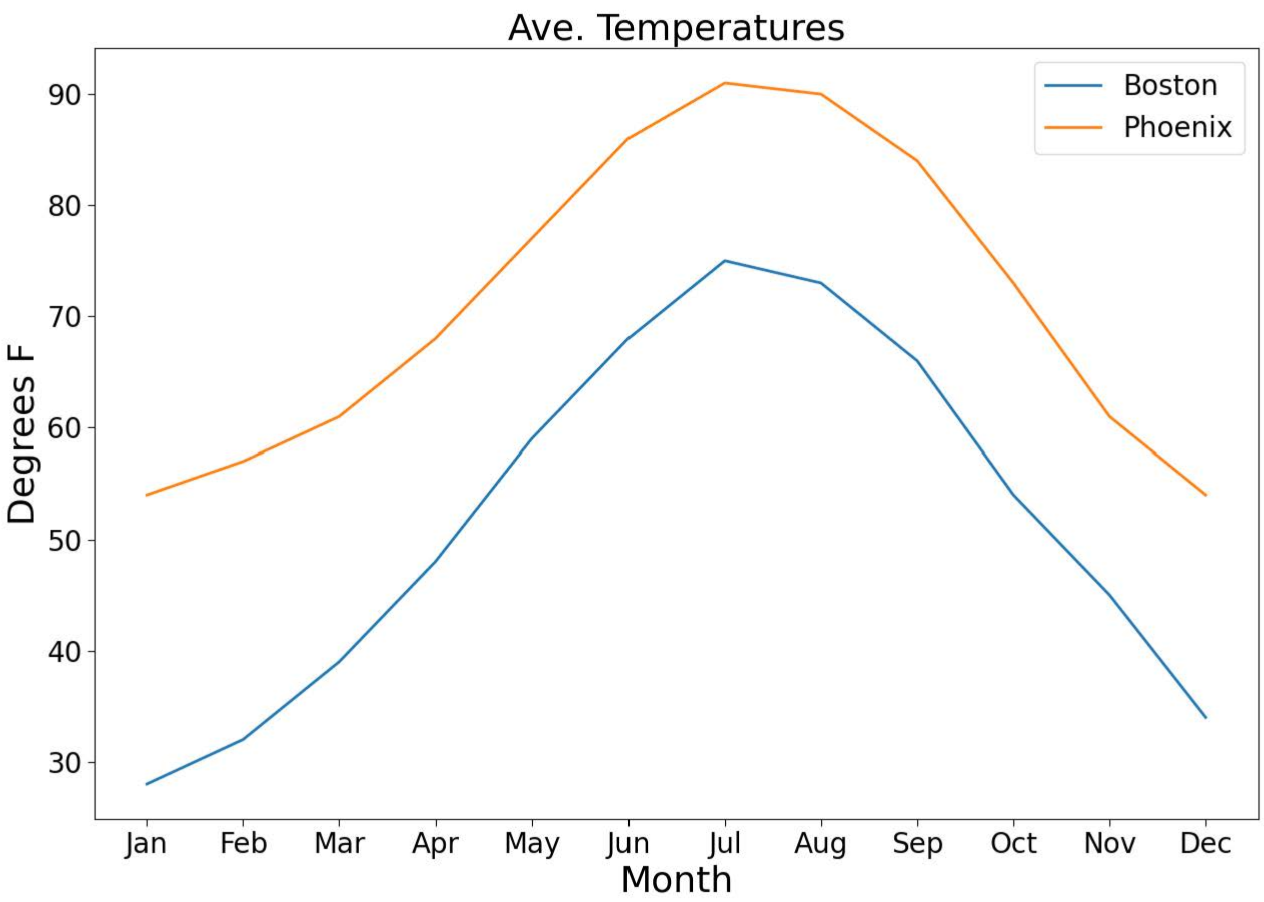
keyword

Choice for where to place legend

Other options:

- upper left
- upper right
- lower left
- lower right
- upper center
- lower center
- center right
- center left
- center

PLOT WITH TWO CURVES



Note: Python picked different colors for each plot; we could specify if we wanted

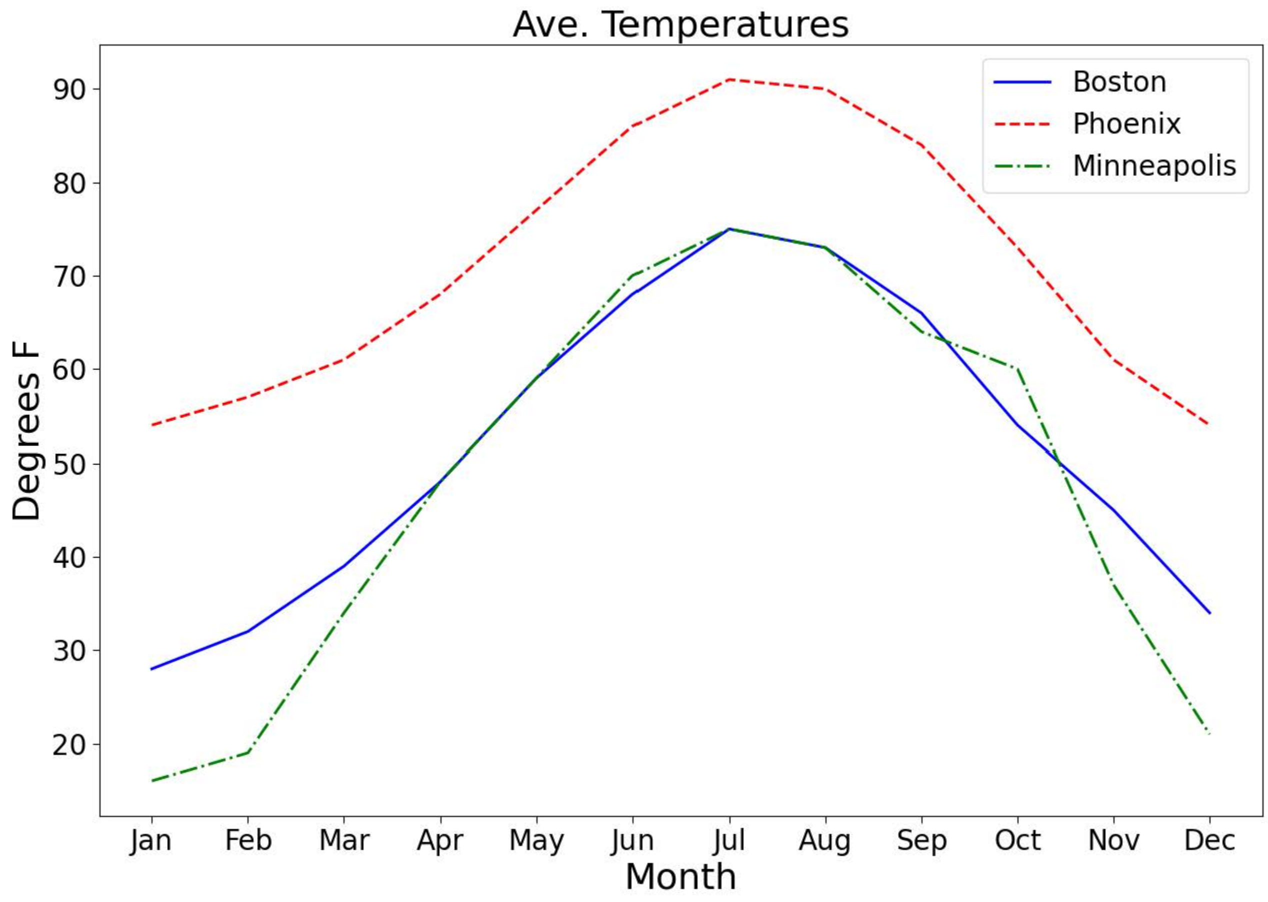
CONTROLLING PARAMETERS

- Suppose we want to control **details of the displays**
- Examples:
  - Changing **color** or style of data sets
  - Changing **width** of lines or displays
  - Using **subplots**
- Can provide a “format” argument to plot
  - “marker”, “line”, “color”
  - Can skip any of these choices, plot takes default
  - Order doesn’t matter, as no confusion between symbols

CONTROLLING COLOR AND STYLE

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston, 'b-', label = 'Boston')
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix, 'r--', label = 'Phoenix')
msp = [16,19,34,48,59,70,75,73,64,60,37,21]
plt.plot(months, msp, 'g-.', label = 'Minneapolis')
plt.legend(loc = 'best', fontsize=20)
```

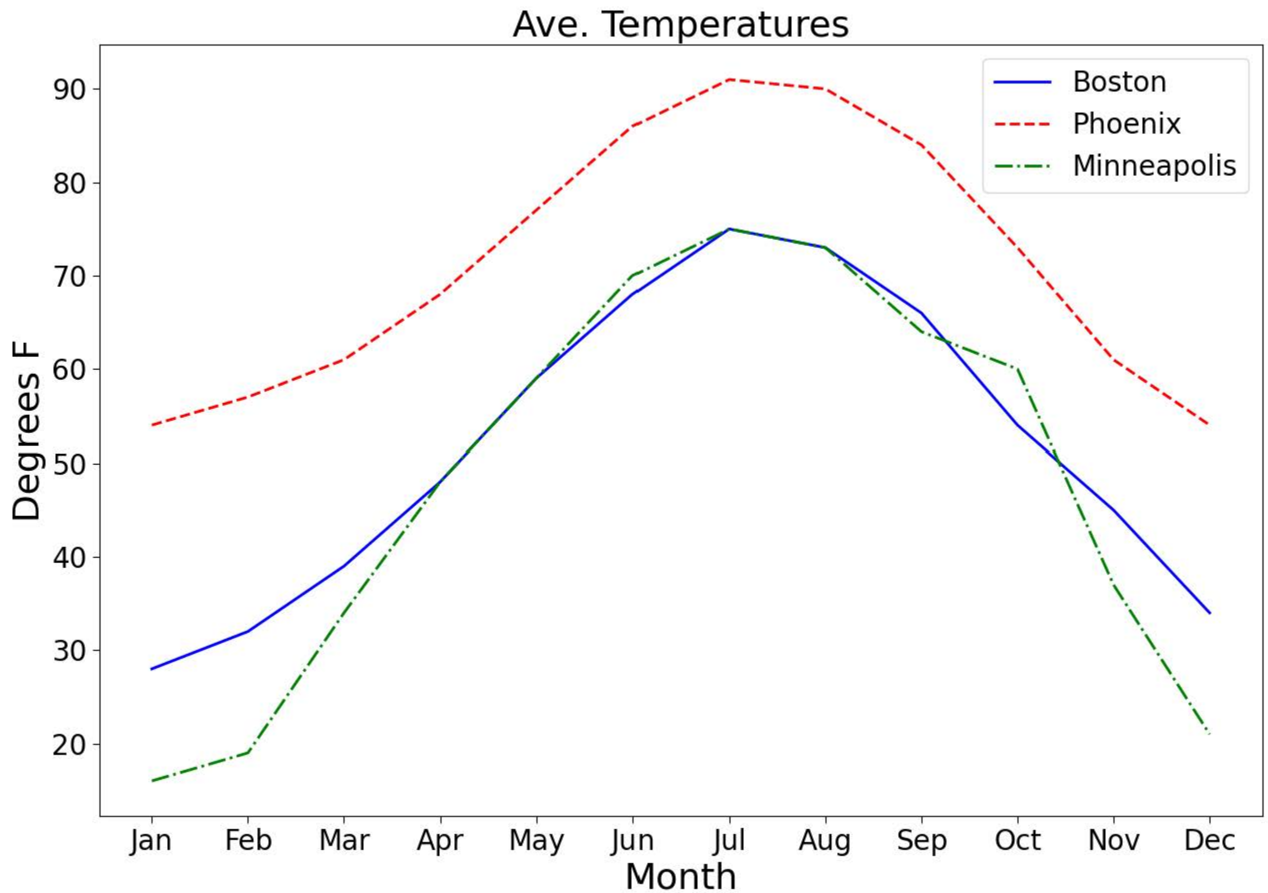
CONTROLLING COLOR AND STYLE



USING KEYWORDS

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston, label = 'Boston',\
          color = 'b', linestyle = '-')
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix, label = 'Phoenix',\
          color = 'r', linestyle = '--')
msp = [16,19,34,48,59,70,75,73,64,60,37,21]
plt.plot(months, msp, label = 'Minneapolis',\
          color = 'g', linestyle = '-.')
plt.legend(loc = 'best', fontsize=20)
plt.title('Ave. Temperatures')
plt.xlabel('Month')
plt.ylabel(('Degrees F'))
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
          ('Jan','Feb','Mar','Apr','May','Jun',\
           'Jul','Aug','Sep','Oct','Nov','Dec'))
```

CONTROLLING COLOR AND STYLE



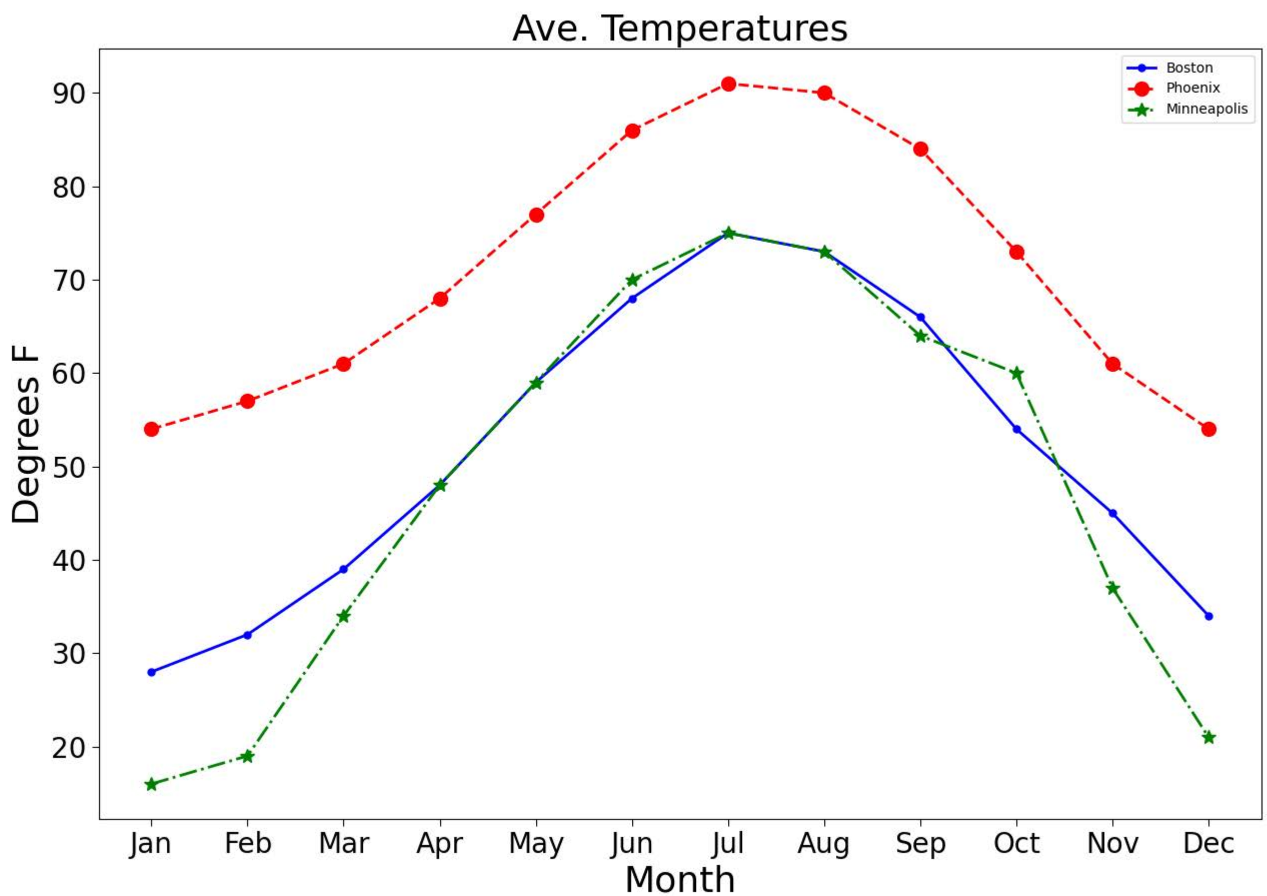
LINE, COLOR, MARKER OPTIONS

- Line Style
  - – solid line
  - – – dashed line
  - – . dash dot line
  - : dotted line
- Color Options (plus many more)
  - b blue
  - g green
  - r red
  - c cyan
  - m magenta
  - y yellow
  - k black
  - w white
- Marker Options (plus many more)
  - . point
  - o circle
  - v triangle down
  - ^ triangle up
  - * star

CONTROLLING COLOR AND STYLE

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston, '.b-', label = 'Boston')
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix, 'or--', label = 'Phoenix')
msp = [16,19,34,48,59,70,75,73,64,60,37,21]
plt.plot(months, msp, '*g-.', label = 'Minneapolis')
plt.legend(loc = 'best', fontsize=20)
```

WITH MARKERS



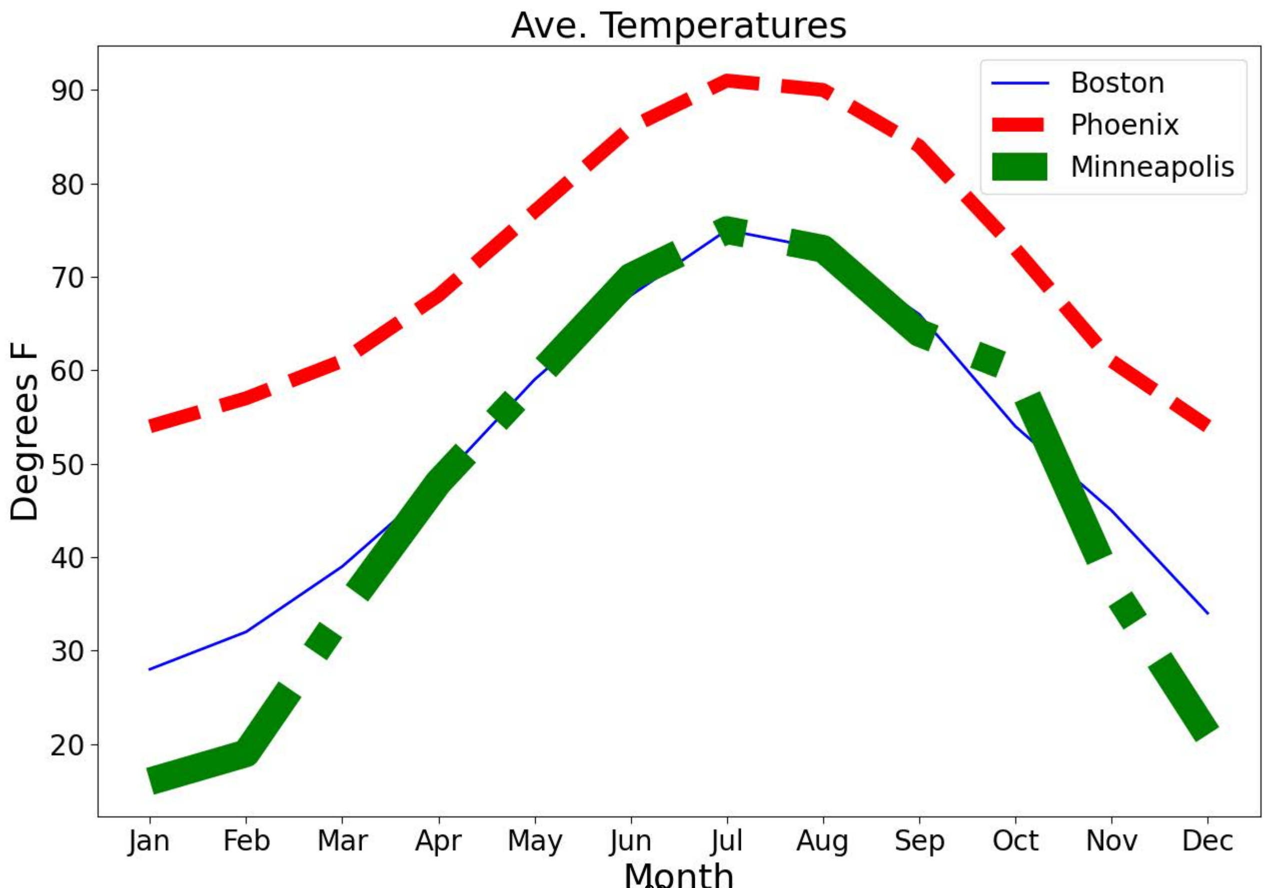
Note how actual points being plotted are now marked

CONTROLLING LINE WIDTH

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.plot(months, boston, label = 'Boston',\
           color = 'b', linestyle = '-', linewidth = 2)
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.plot(months, phoenix, label = 'Phoenix',\
           color = 'r', linestyle = '--', linewidth = 10)
msp = [16,19,34,48,59,70,75,73,64,60,37,21]
plt.plot(months, msp, label = 'Minneapolis',\
           color = 'g', linestyle = '-.', linewidth = 20)
plt.legend(loc = 'best', fontsize=20)
```

MANY OTHER OPTIONS

- Using the linewidth keyword (in pixels)



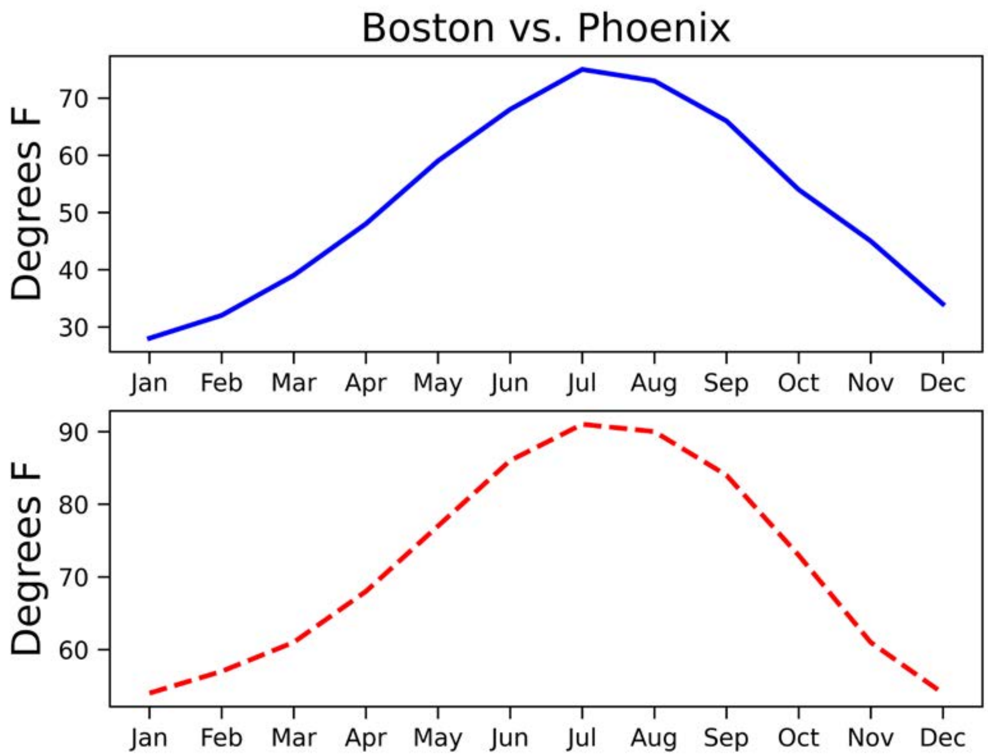
PLOTS WITHIN PLOTS

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.subplot(2,1,1)
plt.plot(months, boston, 'b-')
plt.ylabel('Degrees F')
plt.title('Boston vs. Phoenix')
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
          ('Jan','Feb','Mar','Apr','May','Jun',\
           'Jul','Aug','Sep','Oct','Nov','Dec'))
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.subplot(2,1,2)
plt.plot(months, phoenix, 'r--')
plt.ylabel('Degrees F')
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
          ('Jan','Feb','Mar','Apr','May','Jun',\
           'Jul','Aug','Sep','Oct','Nov','Dec'))
```

Plot with 2 rows, 1 column, this is first

Plot with 2 rows, 1 column, this is second

AND THE PLOT THICKENS



But this can be misleading?

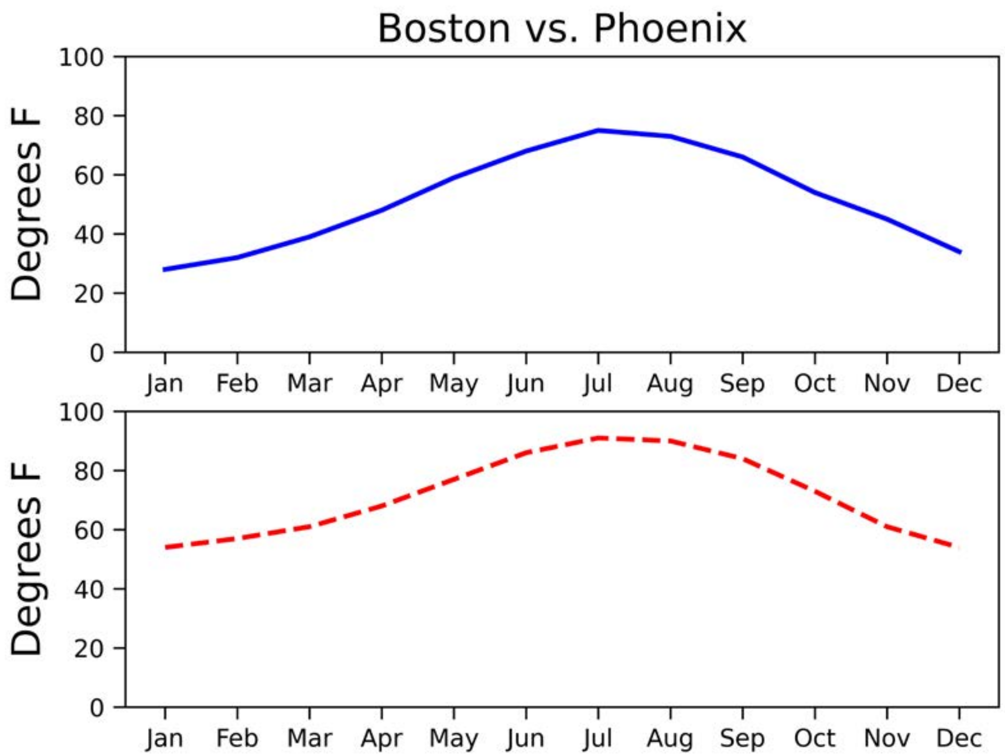
Y scales are different!

PLOTS WITHIN PLOTS

Fix y axis so plots are similar

```
months = range(1, 13, 1)
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.subplot(2,1,1)
plt.ylim(0, 100)
plt.plot(months, boston, 'b-')
plt.ylabel('Degrees F')
plt.title('Boston vs. Phoenix')
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
           ('Jan','Feb','Mar','Apr','May','Jun',\
            'Jul','Aug','Sep','Oct','Nov','Dec'))
phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.subplot(2,1,2)
plt.ylim(0, 100)
plt.plot(months, phoenix, 'r--')
plt.ylabel('Degrees F')
plt.xticks((1,2,3,4,5,6,7,8,9,10,11,12),
           ('Jan','Feb','Mar','Apr','May','Jun',\
            'Jul','Aug','Sep','Oct','Nov','Dec'))
```

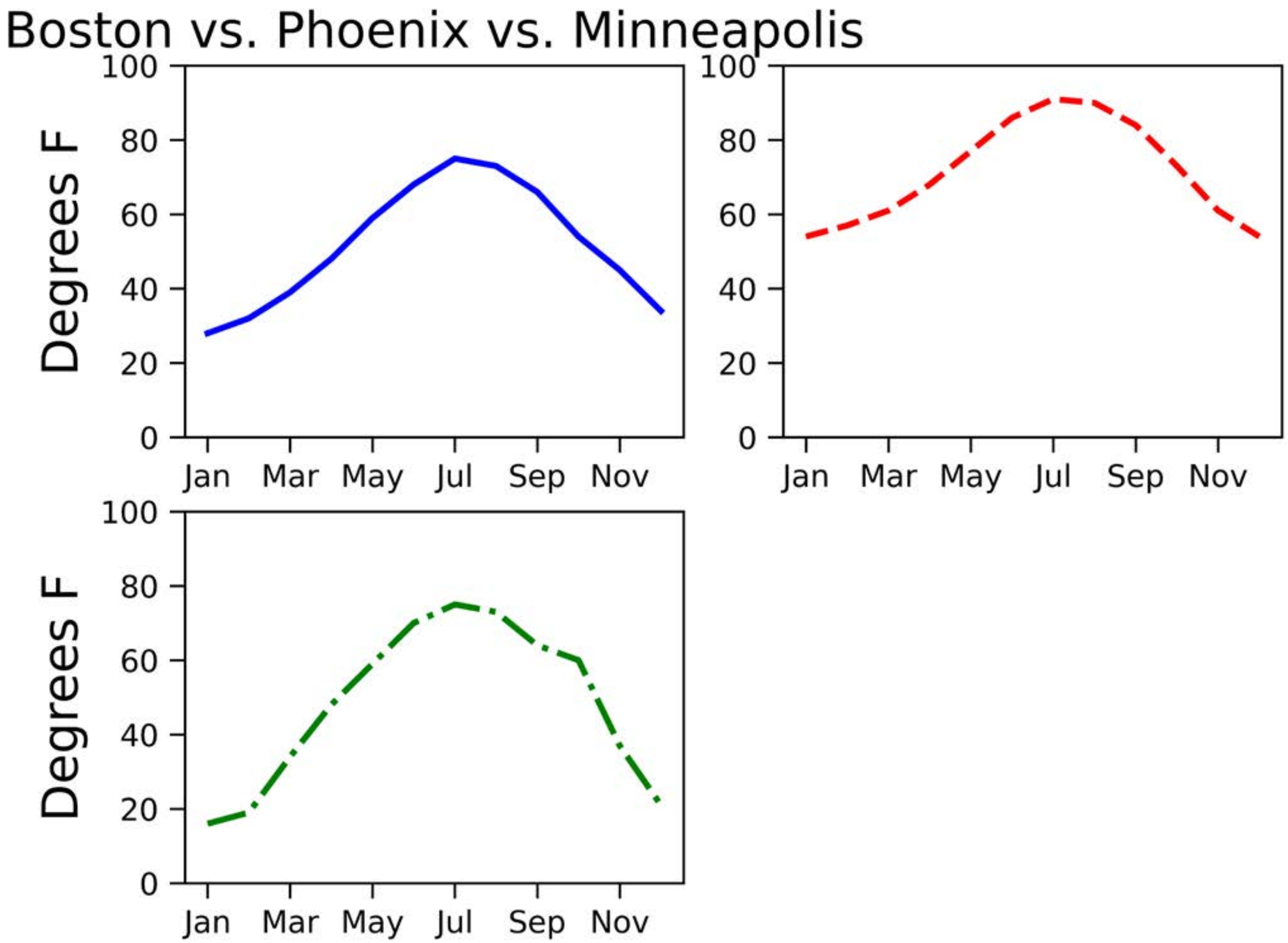
AND THE PLOT THICKENS



LOTS OF SUBPLOTS

```
boston = [28,32,39,48,59,68,75,73,66,54,45,34]
plt.subplot(2,2,1)
plt.ylim(0, 100)
plt.plot(months, boston, 'b-')
plt.ylabel('Degrees F')
plt.title('Boston')
plt.xticks((1,3,5,7,9,11),('Jan','Mar','May','Jul','Sep','Nov'))

phoenix = [54,57,61,68,77,86,91,90,84,73,61,54]
plt.subplot(2,2,2)
plt.ylim(0, 100)
plt.plot(months, phoenix, 'r--')
plt.title('Phoenix')
plt.xticks((1,3,5,7,9,11),('Jan','Mar','May','Jul','Sep','Nov'))

msp = [16,19,34,48,59,70,75,73,64,60,37,21]
plt.subplot(2,2,3)
plt.ylim(0, 100)
plt.plot(months, msp, 'g-.')
plt.ylabel('Degrees F')
plt.title('Minneapolis')
plt.xticks((1,3,5,7,9,11),('Jan','Mar','May','Jul','Sep','Nov'))
```

AND THE PLOT THICKENS



US POPULATION EXAMPLE

A MORE INTERESTING EXAMPLE

- Let’s try plotting some more complicated data
- We have provided a file with the US population recorded every 10 years for four centuries
- Would like to use plotting to examine that data
  - Use plotting to help **visualize** trends in the data
  - Use plotting to raise questions that might be **tested computationally** (you’ll see much more of this if you take 6.100B)

THE INPUT FILE
USPopulation.txt

```
1610 350
1620 2,302
1630 4,646
1640 26,634
1650 50,368
1660 75,058
1670 111,935
1680 151,507
1690 210,372
1700 250,888
1710 331,711
1720 466,185
1730 629,445
1740 905,563
…

1960 179,323,175
1970 203,211,926
1980 226,545,805
1990 248,709,873
2000 281,421,906
2010 308,745,538
```

PLOTTING THE DATA

```
1610 350
1620 2,302
1630 4,646
1640 26,634
```

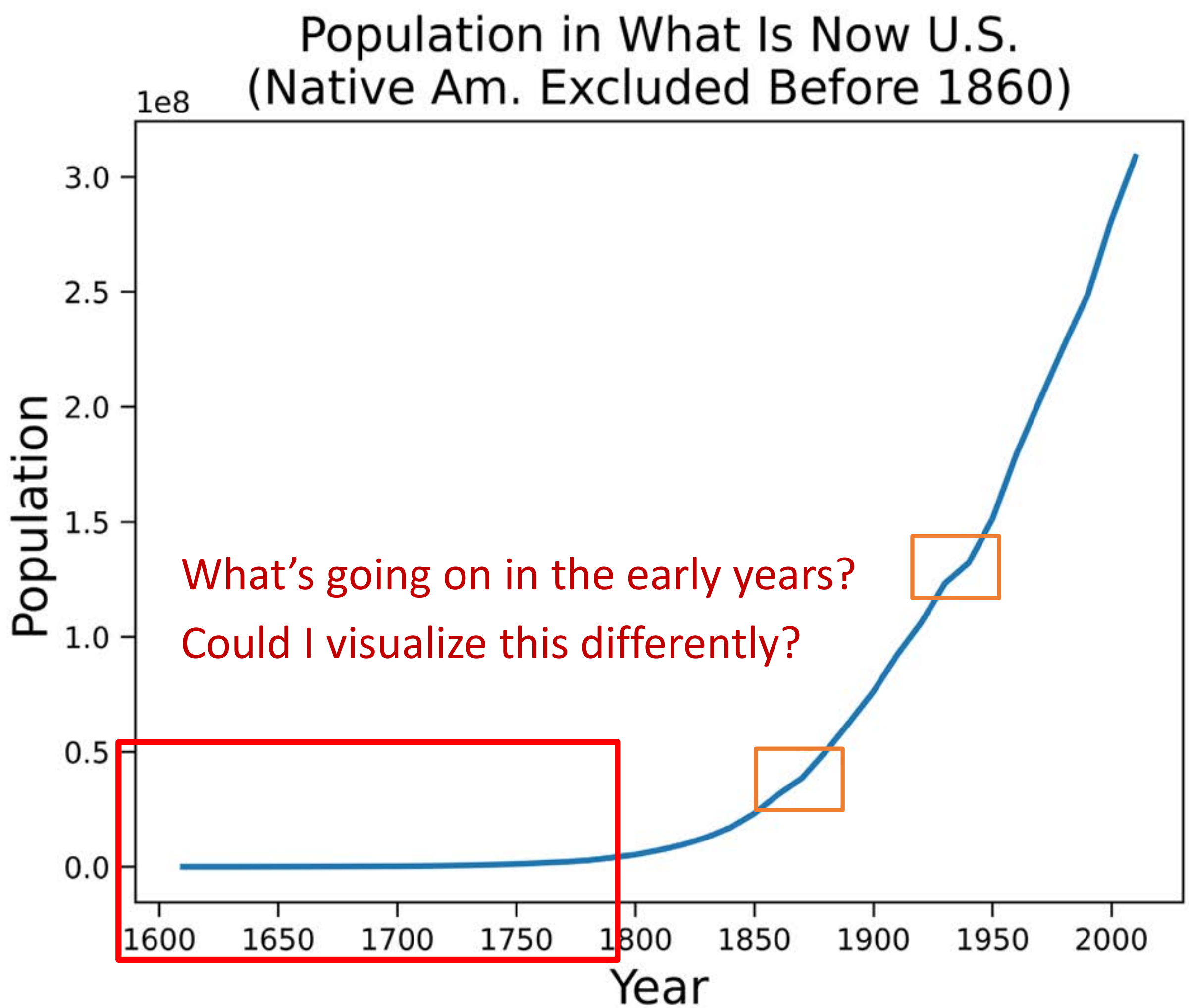
```
def getUSPop(fileName):
    inFile = open(fileName, 'r')
    dates, pops = [], []
    for l in inFile:
        line = ''
        for c in l:
            if c in '0123456789 ':
                line += c
        line = line.split(' ')
        dates.append(int(line[0]))
        pops.append(int(line[1]))
    return dates, pops

dates, pops = getUSPop('lec25_USPopulation.txt')
plt.plot(dates, pops)
plt.title('Population in What Is Now U.S.\n' +\
          '(Native Am. Excluded Before 1860)')
plt.xlabel('Year')
plt.ylabel('Population')
```

Remove commas for each line

Split into date and population

Convert to ints, and add to lists

POPULATION GROWTH



Visualizing data can expose things not easily seen in raw data

Impact of WWII

Impact of Civil War

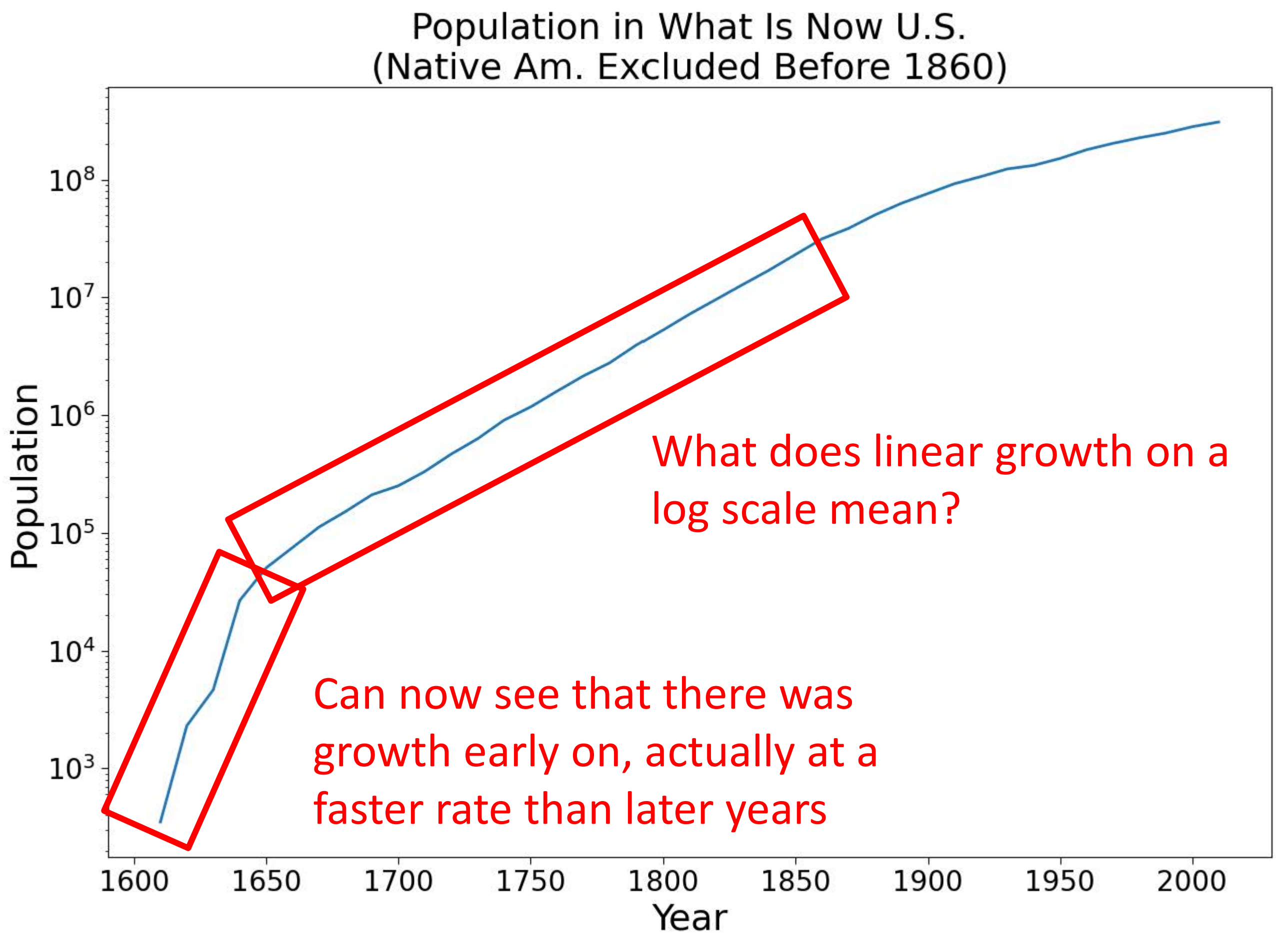
CHANGING THE SCALING

```
dates, pops = getUSPop('USPopulation.txt')
plt.plot(dates, pops)
plt.title('Population in What Is Now U.S\n' +\
          '(Native Am. Excluded Before 1860)')
plt.xlabel('Year')
plt.ylabel('Population')
plt.semilogy()
```

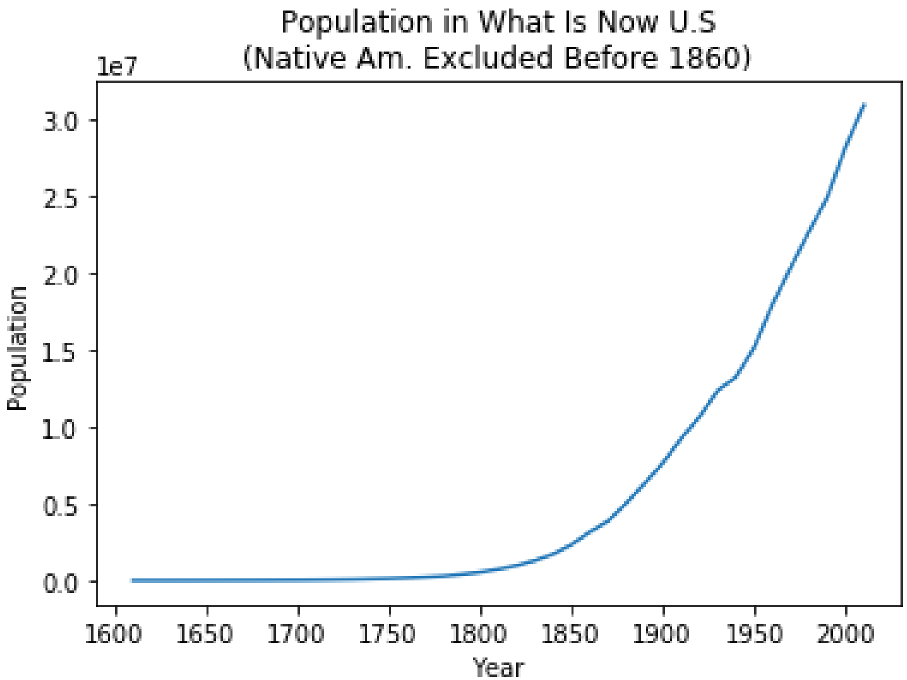
Use log scale on y axis

Log scale means each increment along axis corresponds to exponential increase in size; while in normal scale each increment corresponds to linear increase in size

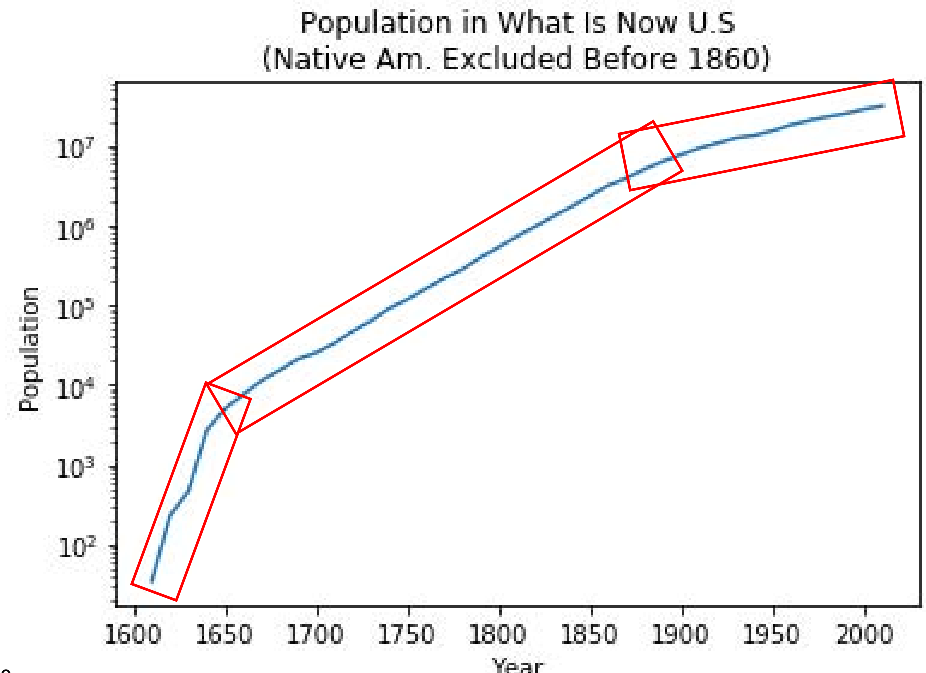
POPULATION GROWTH



WHICH DO YOU FIND MORE INFORMATIVE?



Changing visualization can help expose trends in data not seen with standard plotting



Visualization can raise questions: for ex. by eye, it appears that there are three different exponential growth periods

COUNTRY POPULATION EXAMPLE

THE DATA FILE

`countryPops.txt`

Notice pesky commas again in this value

```
1    China    1,379,302,771   July 2017 est.
2    India    1,281,935,911   July 2017 est.
3    United States   326,625,791 July 2017 est.
4    Indonesia   260,580,739 July 2017 est.
5    Brazil  207,353,391 July 2017 est.
6    Pakistan    204,924,861 July 2017 est.
7    Nigeria 190,632,261 July 2017 est.
8    Bangladesh  157,826,578 July 2017 est.
9    Russia  142,257,519 July 2017 est.
10   Japan   126,451,398 July 2017 est.

 ...
228 Montserrat  5,292   July 2017 est.
229 Falkland Islands (Islas Malvinas)   2,931   2014 est.
230 Svalbard    2,667   July 2016 est.
231 Norfolk Island  2,210   July 2014 est.
232 Christmas Island    2,205   July 2016 est.
233 Niue    1,626   June 2015 est.
234 Tokelau 1,285   2016 est.
235 Holy See (Vatican City) 1,000   2015 est.
236 Cocos (Keeling) Islands 596 July 2014 est.
237 Pitcairn Islands    54  July 2016 est.
```

Interested in analyzing the population numbers. Don't care about rank, country, or year.

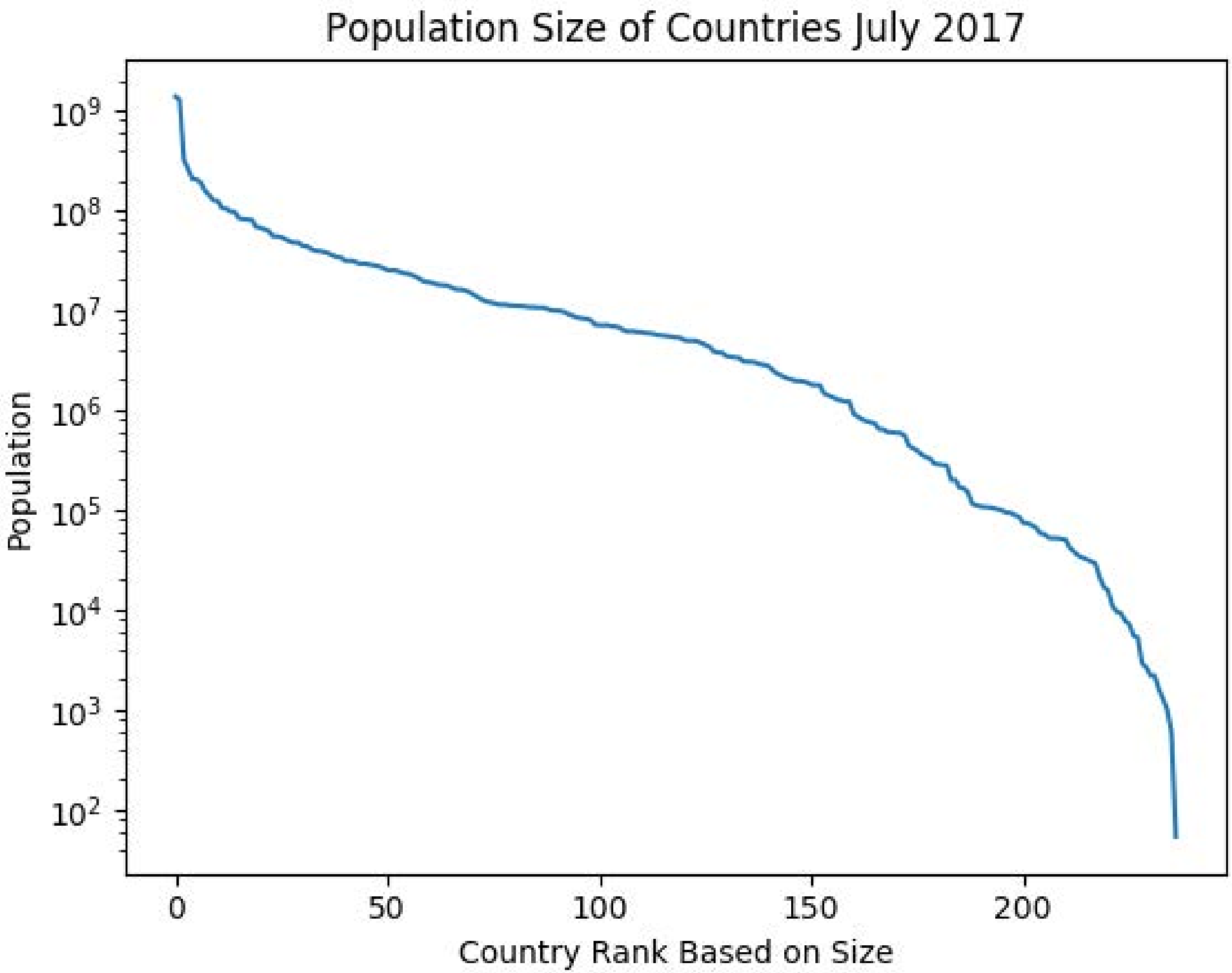
LOADING AND PLOTTING THE DATA

```
1    China    1,379,302,771    July 2017 est.
2    India    1,281,935,911    July 2017 est.
3    United States    326,625,791 July 2017 est.
4    Indonesia    260,580,739 July 2017 est.
```

```
def getCountryPops(fileName):
    inFile = open(fileName, 'r')
    pops = []
    for l in inFile:
        line = l.split('\t')
        l = line[2]
        pop = ''
        for c in l:
            if c in '0123456789':
                pop += c
        pops.append(int(pop))
    return pops

pops = getCountryPops('lec25_countryPops.txt')

plt.plot(pops)
plt.title('Population Size of Countries July 2017')
plt.ylabel('Population')
plt.xlabel('Country Rank Based on Size')
plt.semilogy()
```

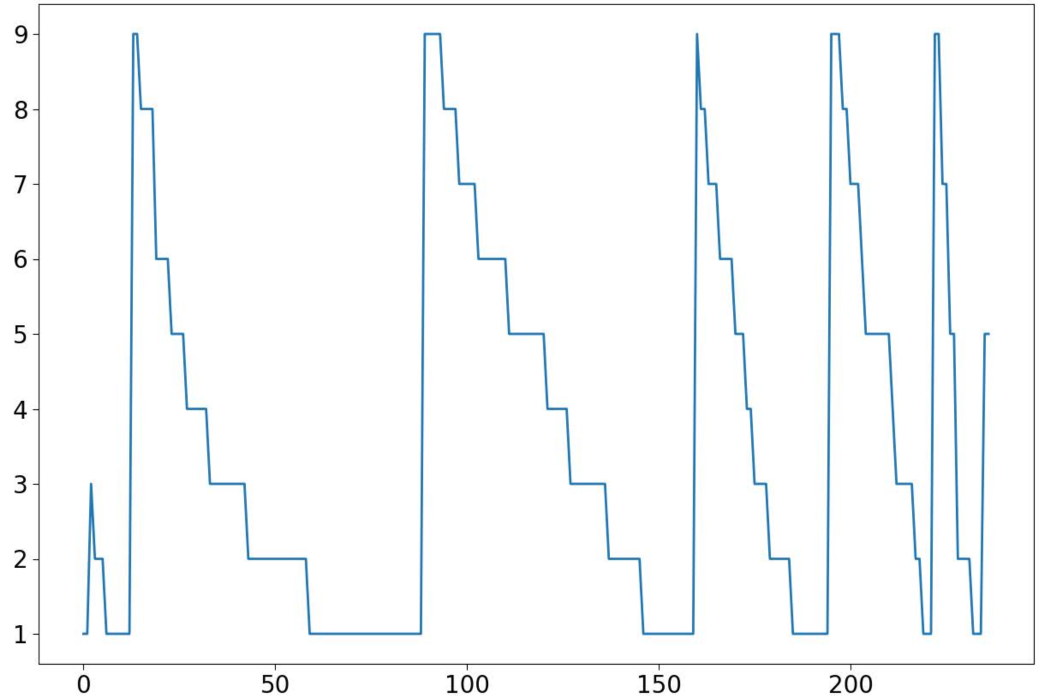
Grab only the population number column

POPULATION SIZES



STRANGE INVESTIGATION: FIRST DIGITS

```
pops = getCountryPops('lec25_countryPops.txt')
firstDigits = []
for p in pops:
    firstDigits.append(int(str(p)[0]))
### Plot the fist digits, as found in order in the file
plt.plot(firstDigits)
```



Why the saw tooth pattern?

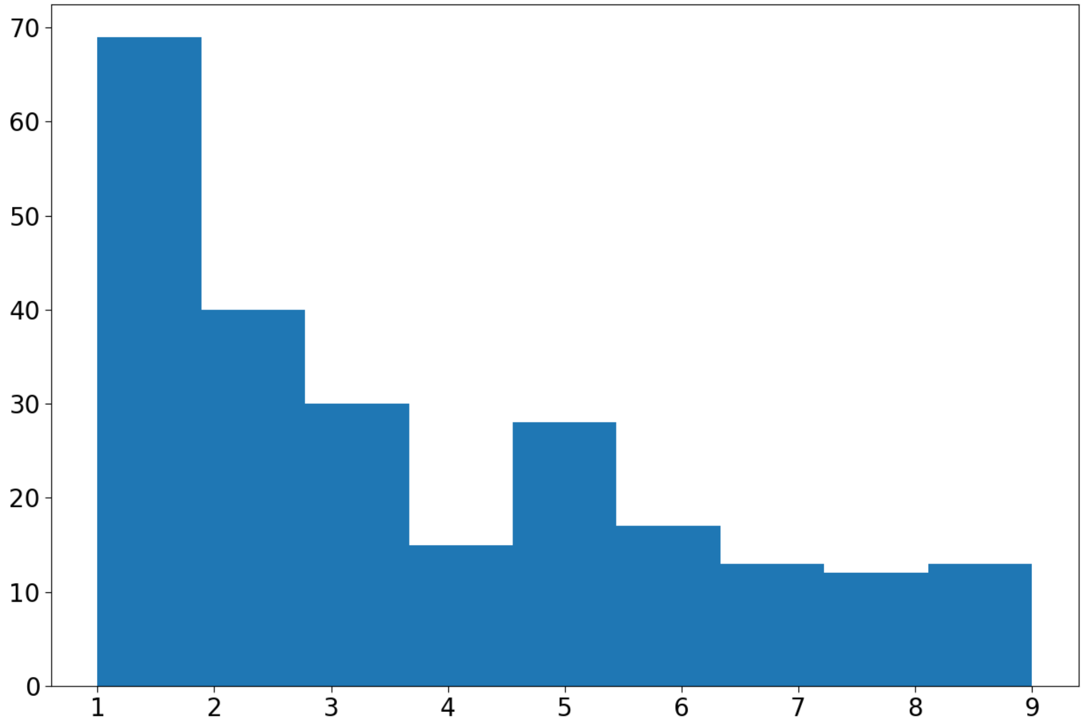
Countries are in order of biggest pop to smallest pop.

First digit pattern is: 9,8,7,...,2,1,9,8,7,6,5,...

FREQUENCY OF EACH DIGIT

```
plt.hist(firstDigits, bins = 9)
```

Surprising?
28% 1's



Benford's Law

$$P(d) = log_{10}(1+\frac{1}{d})$$

Many datasets follow this:

- # social media followers
- Stock values
- Grocery prices
- Sports stats
- Building heights
- Taxes paid

COMPARING CITIES EXAMPLE

AN EXTENDED EXAMPLE

- Let's use another example to examine how plotting allows us to explore data in different ways, and how it provides a valuable way to visualize that data
- Won't be looking at the code in detail
- Example data set
  - Mean daily temperature for each day for 55 years for 21 different US cities
  - Want to explore variations across years, and across cities

THE DATA FILE

temperatures.csv

```
CITY,TEMP,DATE
SEATTLE,3.1,19610101
SEATTLE,0.55,19610102
SEATTLE,0,19610103
SEATTLE,4.45,19610104
SEATTLE,8.35,19610105
SEATTLE,6.7,19610106
SEATTLE,9.7,19610107
SEATTLE,7.2,19610108
SEATTLE,9.45,19610109

...

CHICAGO,9.7,20151223
CHICAGO,3.35,20151224
CHICAGO,3.35,20151225
CHICAGO,4.2,20151226
CHICAGO,3.05,20151227
CHICAGO,1.7,20151228
CHICAGO,1.15,20151229
CHICAGO,-2.15,20151230
CHICAGO,-3.8,20151231
```

Temp in Celsius

Date in YYYYMMDD

temperatures.csv

CITY,TEMP,DATE
SEATTLE,3.1,19610101
SEATTLE,0.55,19610102
SEATTLE,0,19610103
SEATTLE,4.45,19610104

EXTRACTING DATA

This will return a list of temperatures (in F) and a corresponding list of dates for a specific city

```
def CtoF(c):
    return (c * 9/5) + 32

def getTempsForCity(city):
    inFile = open('temperatures.csv')
    temps = []
    dates = []
    for l in inFile:
        data = l.split(',')
        c = data[0]
        tem = data[1]
        date = data[2]
        if c == city:
            temps.append(CtoF(float(tem)))
            dates.append(date)
    return temps, dates
```

Only want temp for a specific city

File stores data as str, need to convert

AVERAGE TEMPERATURES

This will calculate the average temp over every day for 55 years, for every city.

```
def getAverageTemps():
    cities = getCities()[1:]
    xPts = range(len(cities))
    aveTemp = []
    cityLabels = []
    for c in cities:
        temps, dates = getTempsForCity(c)
        aveTemp.append(sum(temps)/len(temps))
        cityLabels.append(c[0:2])
        print(c[0:2], sum(temps)/len(temps))

    plt.figure('Temps')
    plt.scatter(xPts, aveTemp)
    plt.title('Ave. Temperatures')
    plt.xlabel('City')
    plt.ylabel(('Degrees F'))
    plt.xticks(xPts, cityLabels)
```

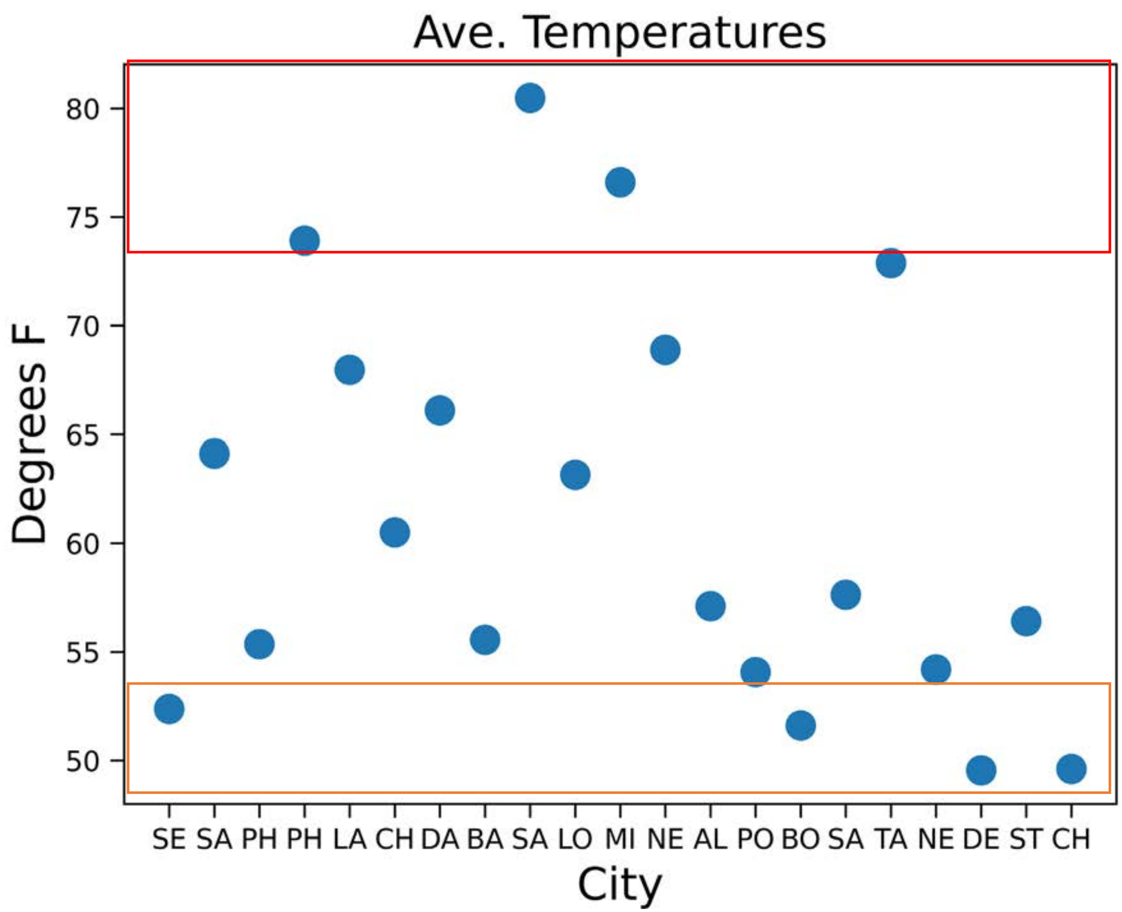
Get list of cities

Compute average temperature

Using first two characters as label

Just plotting points as a scatter plot (no connecting lines)

AND THE TEMPERATURE IS ...



San Juan, Miami, Phoenix

Detroit, Chicago, Boston

BUT MORE INTERESTING TO LOOK AT CHANGE OVER TIME

For one city, calculate the average temperature over each year.

```
def getTempsForYear(tem, dat, y):
    yearlyTemps = []
    for i in range(len(tem)):
        if y == dat[i][:4]:
            yearlyTemps.append(tem[i])
    return sum(yearlyTemps)/len(yearlyTemps), y
```

Check that entry is for right year

```
def getTempsByYearForCity(city):
    temps, dates = getTempsForCity(city)
    averages = []
    years = []
    for y in range(1961,2016):
        tem = getTempsForYear(temps, dates, str(y))[0]
        averages.append(tem)
        years.append(str(y))
    return averages, years
```

Previous code

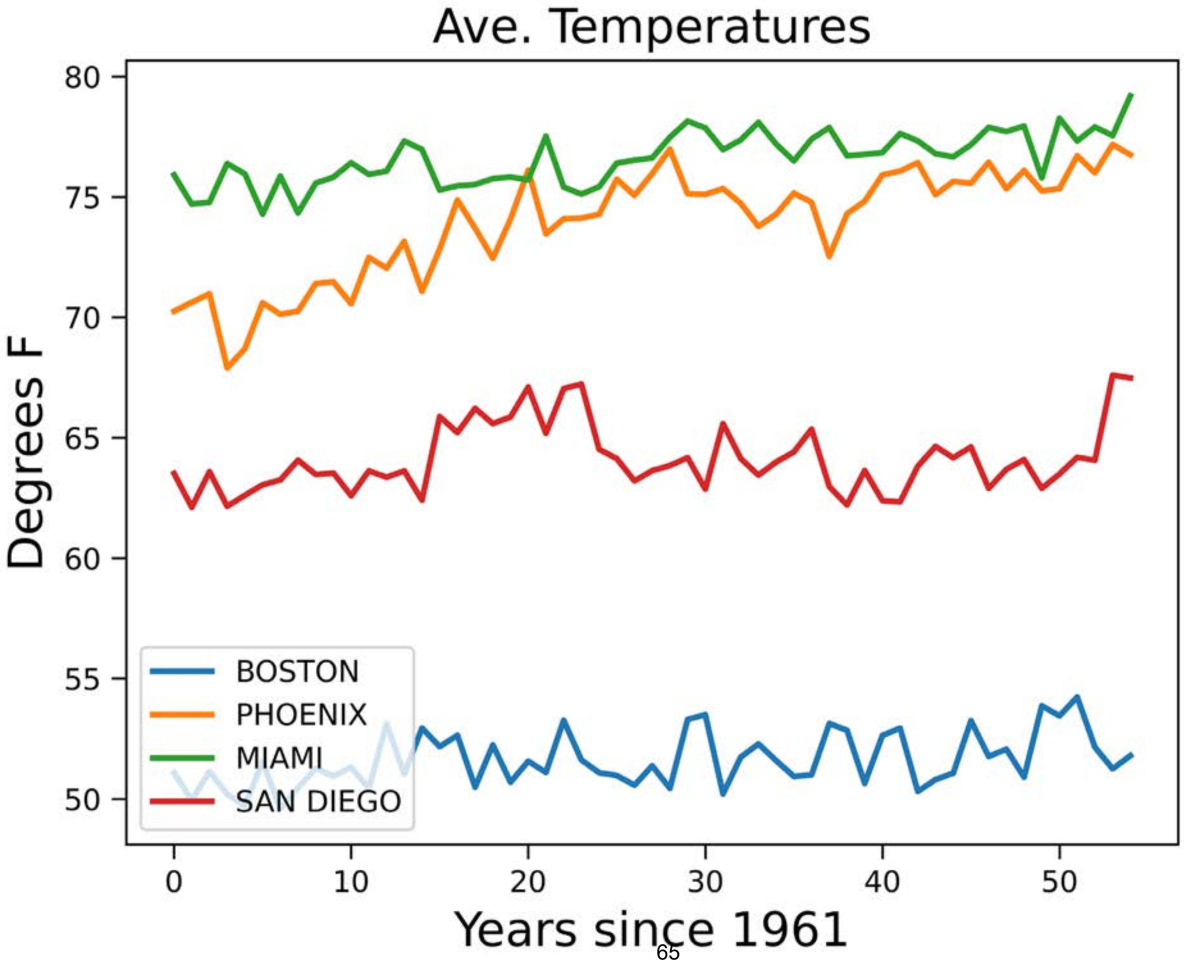
Get temp data for year

BUT MORE INTERESTING TO LOOK AT CHANGE OVER TIME

Pick some cities to plot 55 temps (avg temp over each year)

```
if True:
    plt.close()
    for c in ('BOSTON','PHOENIX', 'MIAMI', 'SAN DIEGO'):

        av, yr = getTempsByYearForCity(c)
        xPts = range(len(yr))
        plt.figure('Temps by City')
        plt.plot(xPts, av, label = c)
        plt.title('Ave. Temperatures')
        plt.xlabel('Years since 1961')
        plt.ylabel(('Degrees F'))
        plt.legend(loc = 'best')
```

BABY IT'S COLD OUTSIDE!



BUT WHAT IS VARIATION?
high, low, avg temps by year

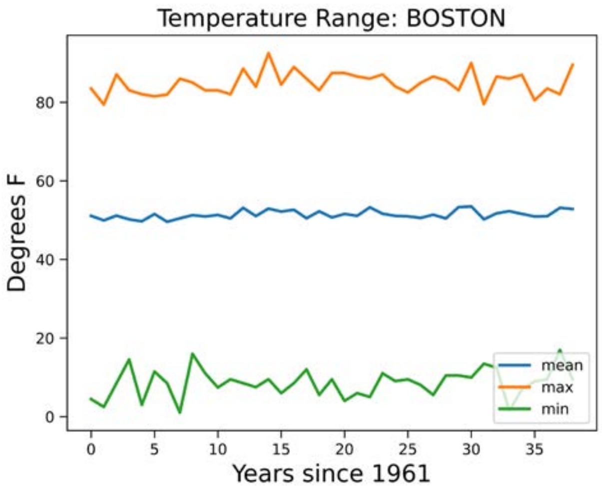
```
def getTempsForYearRange(tem, dat, y):
    yearly = []
    for i in range(len(tem)):
        if y == dat[i][:4]:
            yearly.append(tem[i])
    return sum(yearly)/len(yearly), max(yearly), min(yearly), y

def getTempsByYearForCityRange(city):
    temps, dates = getTempsForCity(city)
    averages = []
    maxes = []
    mins = []
    years = []
    for y in range(1961,2000):
        tem, mx, mn, y = getTempsForYearRange(temps, dates, str(y))
        averages.append(tem)
        maxes.append(mx)
        mins.append(mn)
        years.append(str(y))
    return averages, maxes, mins, years
```

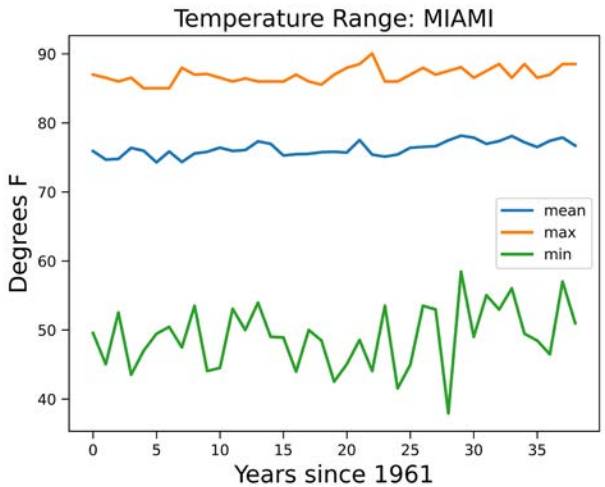
BUT WHAT IS VARIATION?
high, low, avg temps by year

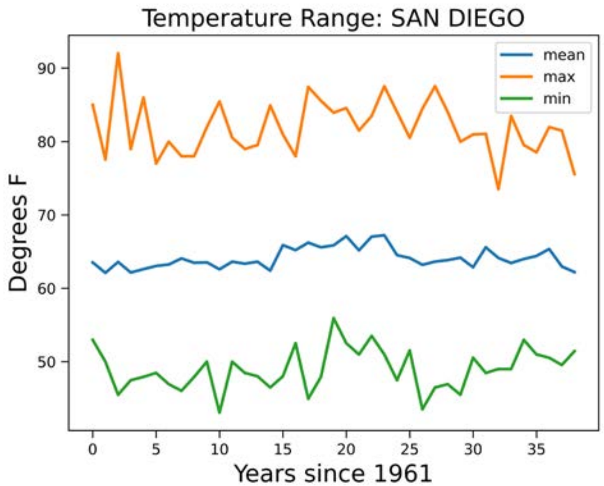
```
if True:
    plt.close()
    for c in ('BOSTON',):  # try for BOSTON, SAN DIEGO, MIAMI
        av, mx, mn, yr = getTempsByYearForCityRange(c)
        xPts = range(len(yr))
        plt.figure('Temps by City')
        plt.plot(xPts, av, label = 'mean')
        plt.plot(xPts, mx, label = 'max')
        plt.plot(xPts, mn, label = 'min')
        plt.title('Temperature Range: ' + c)
        plt.xlabel('Years since 1961')
        plt.ylabel(('Degrees F'))
        plt.legend(loc = 'best')
```

SOME CITY EXAMPLES

- Can see range for each city
- Not helpful for comparison between cities
  - Y axis for Boston is 0 to 80
  - Y axis for Miami is 40 to 90
  - Y axis for San Diego is 50 to 90







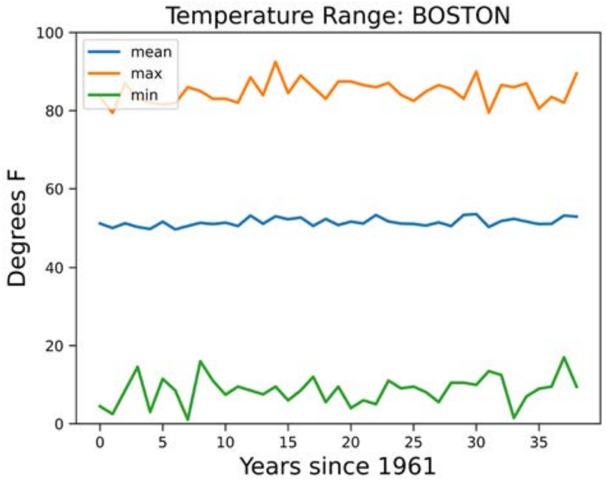
USE SAME Y RANGE FOR ALL PLOTS

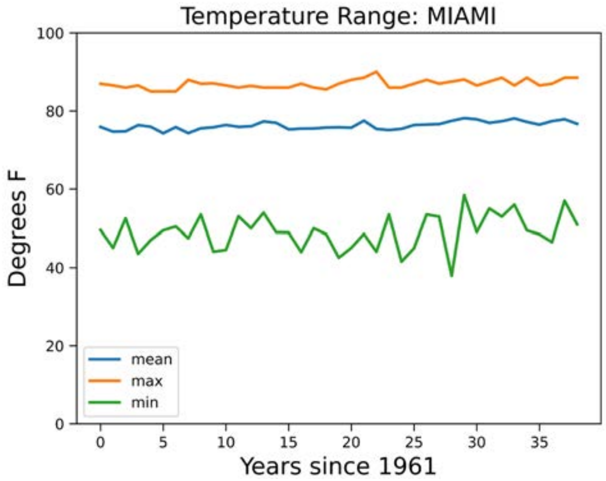
Fix the display range for y axis

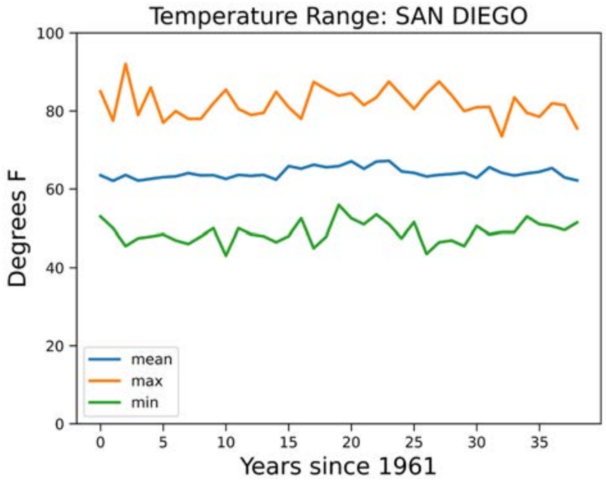
```
if True:
    plt.close()
    for c in ('MIAMI',):  # try for BOSTON, SAN DIEGO, MIAMI
        av, mx, mn, yr = getTempsByYearForCityRange(c)
        xPts = range(len(yr))
        plt.figure('Temps by City')
        plt.ylim(0, 100)
        plt.plot(xPts, av, label = 'mean')
        plt.plot(xPts, mx, label = 'max')
        plt.plot(xPts, mn, label = 'min')
        plt.title('Temperature Range: ' + c)
        plt.xlabel('Years since 1961')
        plt.ylabel(('Degrees F'))
        plt.legend(loc = 'best')
```

BETTER CITY COMPARISON

- One reason to plot is to visualize data
- Can see that range of variation is quite different for Boston, compared to Miami or San Diego
- Can also see that mean for Miami much closer to max than min. Different from Boston and San Diego







HOW MANY DAYS AT A TEMP in 1961?

Set up a list of 100 elements, making a histogram-like structure.

- Index 0 stores how many days had a temp of 0
- Index 1 stores how many days had a temp of 1

  …

- Index 99 stores how many days had a temp of 99.

```
def getDayDistributionForCity(city, year):
    # assume a range of temperatures from 0 to 100
    temps, dates = getTempsForCity(city)
    newTemps = []
    for i in range(len(dates)):
        if year == dates[i][:4]:
            newTemps.append(temps[i])
    ## want to map temperature to number of occurences
    d = [0]*100
    for t in newTemps:
        tRound = round(t)
        d[tRound] += 1
    return d
```

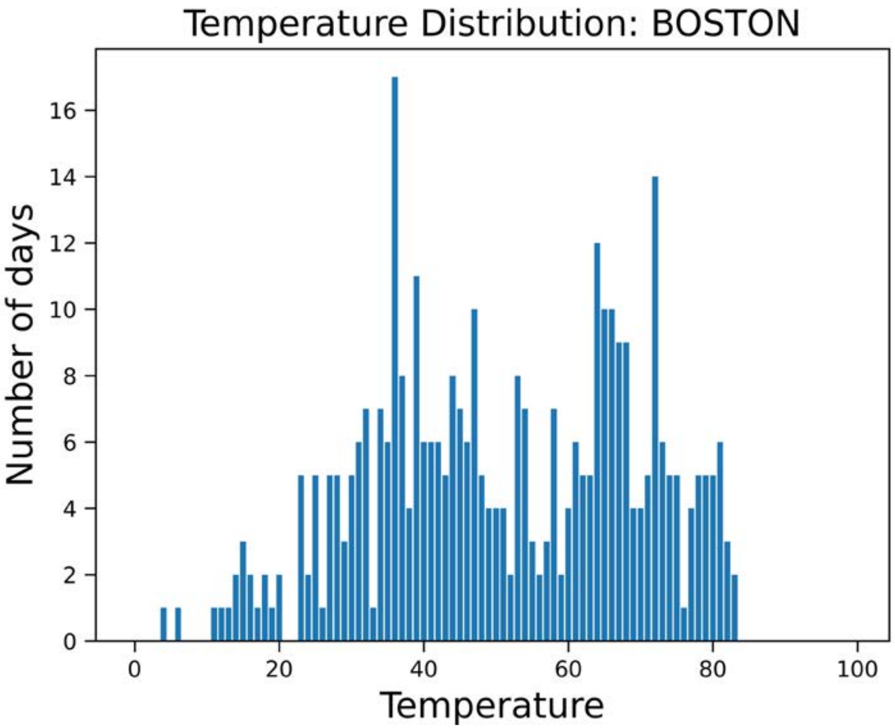
Create a list of temperatures for a specific year

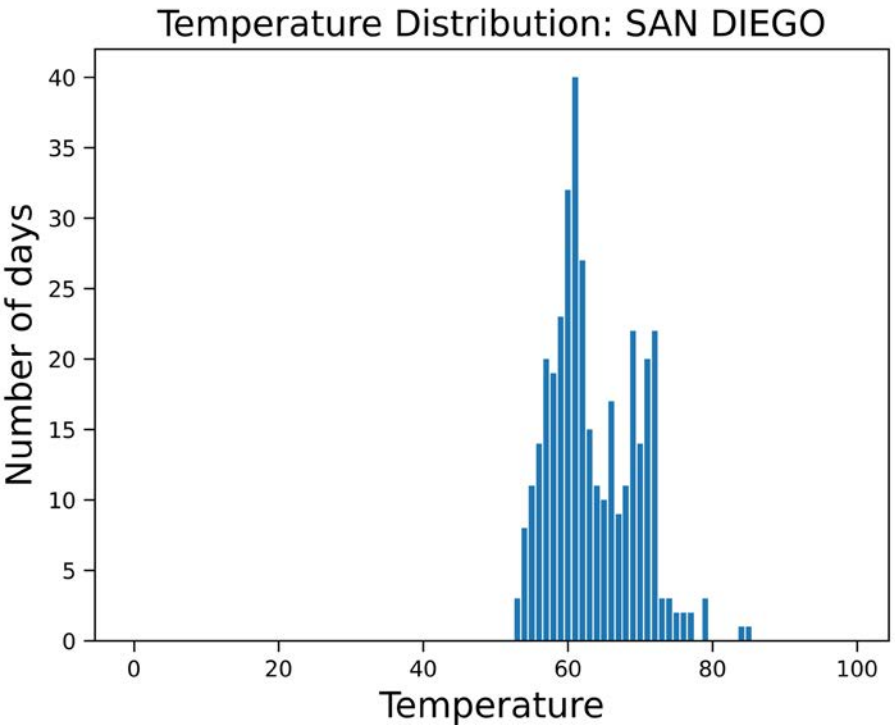
Count number of days of a particular year for which a specific temperature was the daily average

HOW MANY DAYS AT A TEMP IN 1961?

```
if True:
    plt.close()
    for c in ('BOSTON',):  # try for BOSTON, SAN DIEGO, MIAMI
        ans = getDayDistributionForCity(c, '1961')
        temps = []
        for i in range(100):
            temps.append(i)
        plt.figure('Distribution of Temps by City')
        plt.bar(temps, ans)

        plt.title('Temperature Distribution: ' + c)
        plt.xlabel('Temperature')
        plt.ylabel(('Number of days'))
```

SAN DIEGO IS BORING?





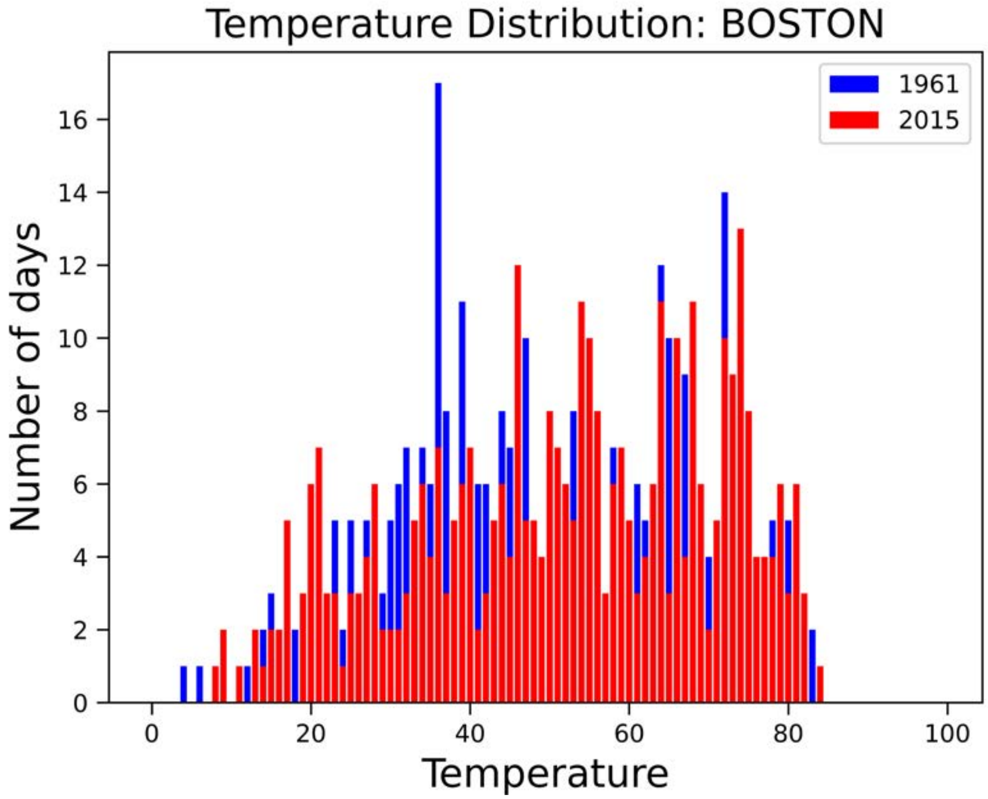
Could we fit a curve to parts of this data?
Uniform? Gaussian (aka bell)?

CHANGE OVER TIME?

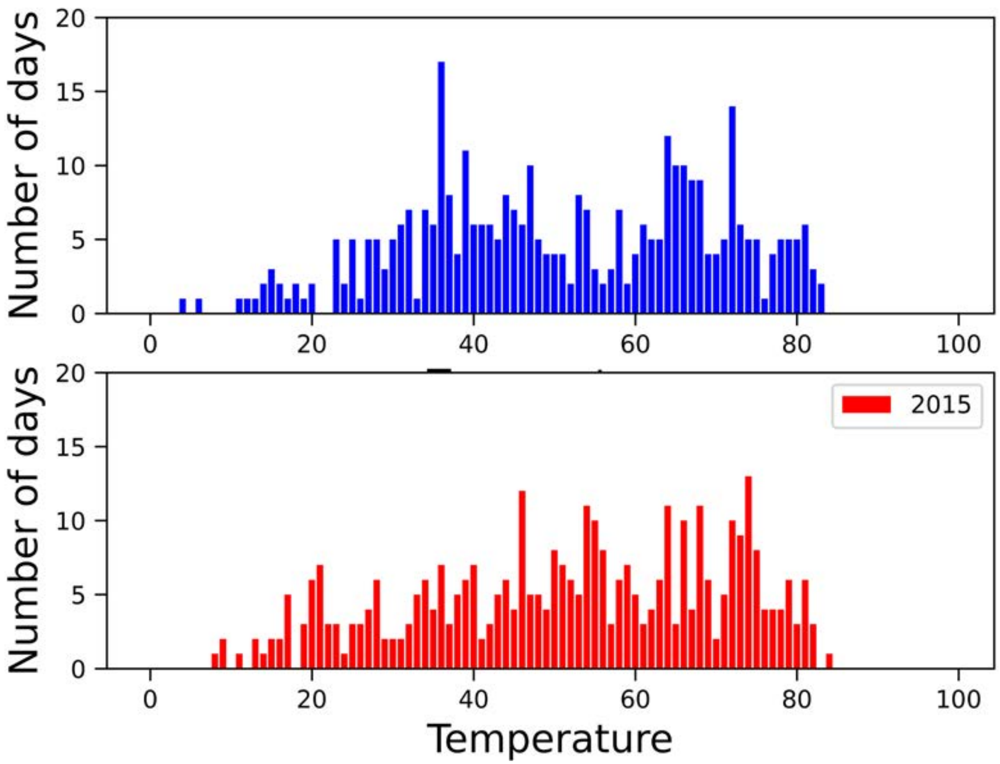
Plot two distributions, one for 1961 and one for 2015

```
if True:
    plt.close()
    for c in ('BOSTON',):  # try for BOSTON, SAN DIEGO
        plt.figure('Distribution of Temps by City')
        for y in ('1961', '2015'):
            ans = getDayDistributionForCity(c, y)
            temps = []
            for i in range(100):
                temps.append(i)
            if y == '1961':
                plt.bar(temps, ans, color = 'blue', label = y)
            else:
                plt.bar(temps, ans, color = 'red', label = y)

        plt.title('Temperature Distribution: ' + c)
        plt.xlabel('Temperature')
        plt.ylabel(('Number of days'))
        plt.legend(loc = 'best')
```

OVERLAY BAR CHARTS



OR CAN PLOT SEPARATELY



CAN CONTROL LOTS OF OTHER THINGS

- Size of
  - Markers
  - Lines
  - Title
  - Labels
  - x and y ticks
- Scales of both axes
- Subplots
- Text boxes
- Kind of plot
  - Scatter plots
  - Bar plots
  - Histograms
  - …

Scratched the surface today!