Introductory Notes: Matplotlib

Preliminaries

Start by importing these Python modules

```
import numpy as np
import pandas as pd
from pandas import DataFrame, Series
import matplotlib.pyplot as plt
import matplotlib
```

Which Application Programming Interface?

The two worlds of Matplotlib

There are 2 broad ways of using pyplot:

1. The first (and most common) way is not pythonic. It relies on global functions to build and display a global figure using matplotlib as a global state machine. (This is an easy approach for interactive use).
2. The second way is pythonic and object oriented. You obtain an empty Figure from a global factory, and then build the plot explicitly using the methods of the Figure and the classes it contains. (This is the best approach for programmatic use).

While these notes focus on second approach, let's begin with a quick look at the first.

Using matplotlib in a non-pythonic way

1. Get some (fake) data - monthly time series

```
x = pd.period_range('1980-01-01',
    periods=410, freq='M')
x = x.to_timestamp().to_pydatetime()
y = np.random.randn(len(x)).cumsum()
```

2. Plot the data

```
plt.plot(x, y, label='FDI')
```

3. Add your labels and pretty-up the plot

```
plt.title('Fake Data Index')
plt.xlabel('Date')
plt.ylabel('Index')
plt.grid(True)
plt.figtext(0.995, 0.01, 'Footnote',
    ha='right', va='bottom')
plt.legend(loc='best', framealpha=0.5,
    prop={'size':'small'})
plt.tight_layout(pad=1)
plt.gcf().set_size_inches(8, 4)
```

4. SAVE the figure

```
plt.savefig('filename.png')
```

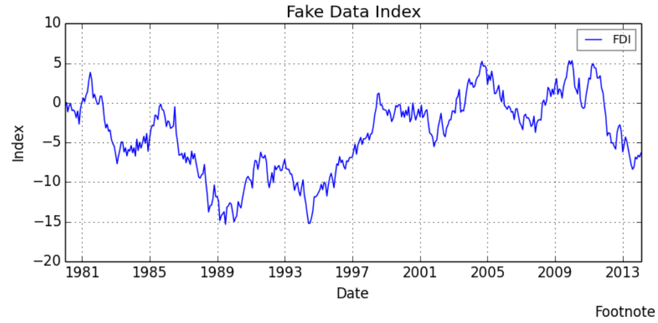
5. Finally, close the figure

```
plt.close()
```

Alternatively, SHOW the figure

With IPython, follow steps 1 to 3 above then

```
plt.show() # Note: also closes the figure
```



Matplotlib: intro to the object oriented way

The Figure

Figure is the top-level container for everything on a canvas. It was obtained from the global Figure factory.

```
fig = plt.figure(num=None, figsize=None,
      dpi=None, facecolor=None,
      edgecolor=None)
```

num – integer or string identifier of figure
    if num exists, it is selected
    if num is None, a new one is allocated
figsize – tuple of (width, height) in inches
dpi – dots per inch
facecolor – background; edgecolor – border

Iterating over the open figures

```
for i in plt.get_fignums():
    fig = plt.figure(i) # get the figure
    print (fig.number)  # do something
```

Close a figure

```
plt.close(fig.number) # close figure
plt.close()      # close the current figure
plt.close(i)     # close figure numbered i
plt.close(name) # close figure by str name
plt.close('all')# close all figures
```

An Axes or Subplot (a subclass of Axes)

An Axes is a container class for a specific plot. A figure may contain many Axes and/or Subplots. Subplots are laid out in a grid within the Figure. Axes can be placed anywhere on the Figure. There are a number of methods that yield an Axes, including:

```
ax = fig.add_subplot(2,2,1) # row-col-num
ax = fig.add_axes([0.1,0.1,0.8,0.8])
```

All at once

We can use the subplots factory to get the Figure and all the desired Axes at once.

```
fig, ax = plt.subplots()
fig,(ax1,ax2,ax3) = plt.subplots(nrows=3,
    ncols=1, sharex=True, figsize=(8,4))
```

Iterating the Axes within a Figure

```
for ax in fig.get_axes():
    pass # do something
```

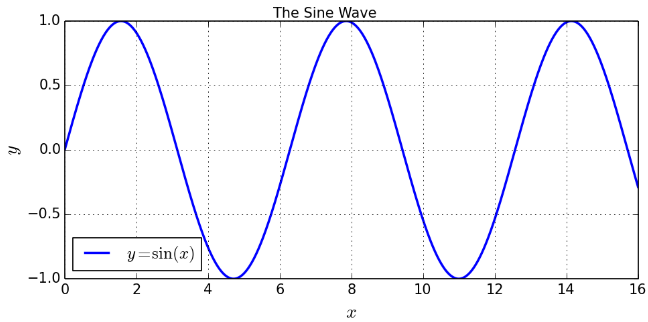
Remove an Axes from a Figure

```
fig.delaxes(ax)
```

Line plots – using ax.plot()

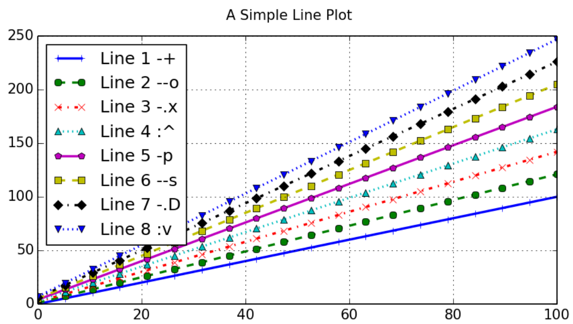
Single plot constructed with Figure and Axes

```
# --- get the data
x = np.linspace(0, 16, 800)
y = np.sin(x)
# --- get an empty figure and add an Axes
fig = plt.figure(figsize=(8,4))
ax = fig.add_subplot(1,1,1) # row-col-num
# --- line plot data on the Axes
ax.plot(x, y, 'b-', linewidth=2,
    label=r'$y=\sin(x)$')
# --- add title, labels and legend, etc.
ax.set_ylabel(r'$y$', fontsize=16);
ax.set_xlabel(r'$x$', fontsize=16)
ax.legend(loc='best')
ax.grid(True)
fig.suptitle('The Sine Wave')
fig.tight_layout(pad=1)
fig.savefig('filename.png', dpi=125)
```



Multiple lines with markers on a line plot

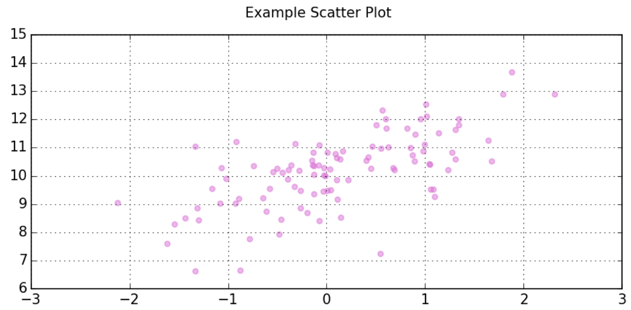
```
# --- get the Figure and Axes all at once
fig, ax = plt.subplots(figsize=(8,4))
# --- plot some lines
N = 8 # the number of lines we will plot
styles =  ['-', '--', '-.', ':']
markers = list('+ox^psDv')
x = np.linspace(0, 100, 20)
for i in range(N): # add line-by-line
    y = x + x/5*i + i
    s = styles[i % len(styles)]
    m = markers[i % len(markers)]
    ax.plot(x, y,
      label='Line '+str(i+1)+' '+s+m,
      marker=m, linewidth=2, linestyle=s)
# --- add grid, legend, title and save
ax.grid(True)
ax.legend(loc='best', prop={'size':'large'})
fig.suptitle('A Simple Line Plot')
fig.savefig('filename.png', dpi=125)
```



Scatter plots – using ax.scatter()

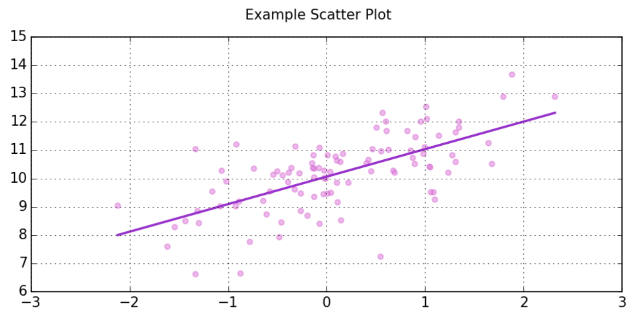
A simple scatter plot

```
x = np.random.randn(100)
y = x + np.random.randn(100) + 10
fig, ax = plt.subplots(figsize=(8, 3))
ax.scatter(x, y, alpha=0.5, color='orchid')
fig.suptitle('Example Scatter Plot')
fig.tight_layout(pad=2);
ax.grid(True)
fig.savefig('filename1.png', dpi=125)
```



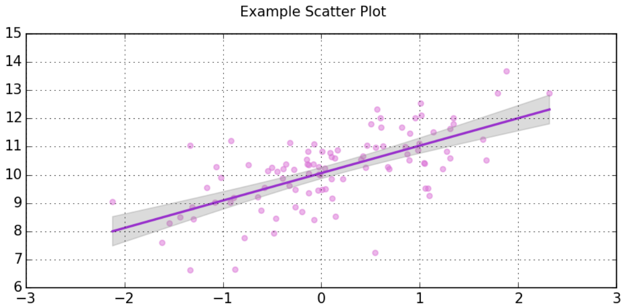
Add a regression line (using statsmodels)

```
import statsmodels.api as sm
x = sm.add_constant(x) # intercept
# Model: y ~ x + c
model = sm.OLS(y, x)
fitted = model.fit()
x_pred = np.linspace(x.min(), x.max(), 50)
x_pred2 = sm.add_constant(x_pred)
y_pred = fitted.predict(x_pred2)
ax.plot(x_pred, y_pred, '-',
    color='darkorchid', linewidth=2)
fig.savefig('filename2.png', dpi=125)
```



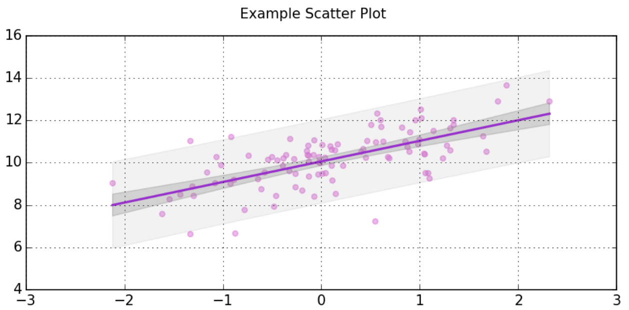
Add confidence bands for the regression line

```
y_hat = fitted.predict(x)
y_err = y - y_hat
mean_x = x.T[1].mean()
n = len(x)
dof = n - fitted.df_model - 1
from scipy import stats
t = stats.t.ppf(1-0.025, df=dof) # 2-tail
s_err = np.sum(np.power(y_err, 2))
conf = t * np.sqrt((s_err/(n-2))*(1.0/n +
    (np.power((x_pred-mean_x),2) /
    ((np.sum(np.power(x_pred,2))) -
    n*(np.power(mean_x,2))))))
upper = y_pred + abs(conf)
lower = y_pred - abs(conf)
ax.fill_between(x_pred, lower, upper,
    color='#888888', alpha=0.3)
fig.savefig('filename3.png', dpi=125)
```



Add a prediction interval for the regression line

```
from statsmodels.sandbox.regression.predstd\
 import wls_prediction_std
sdev, lower, upper =
wls_prediction_std(fitted,
    exog=x_pred2, alpha=0.05)
ax.fill_between(x_pred, lower, upper,
    color='#888888', alpha=0.1)
fig.savefig('filename4.png', dpi=125)
```

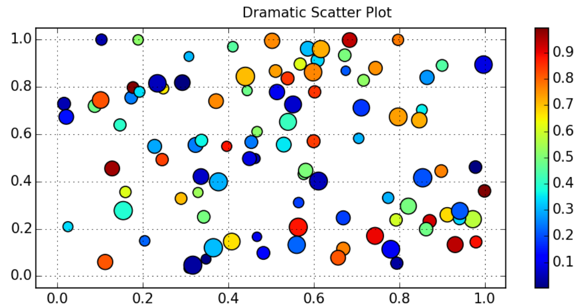


Note: The confidence interval relates to the location of the regression line. The predication interval relates to the location of data points around the regression line.

Changing the marker size and colour

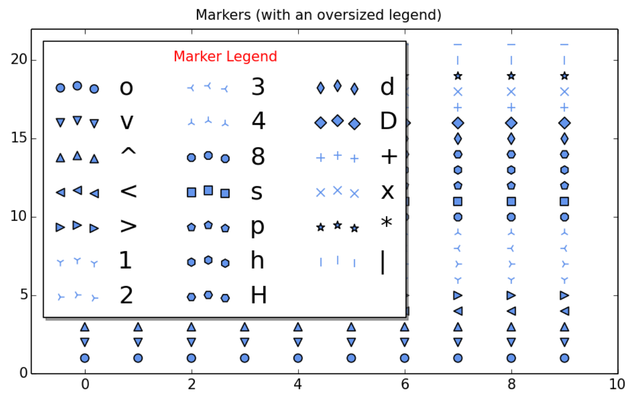
```
N = 100
x = np.random.rand(N)
y = np.random.rand(N)
size = ((np.random.rand(N) + 1) * 8) ** 2
colours = np.random.rand(N)
fig, ax = plt.subplots(figsize=(8,4))
l = ax.scatter(x, y, s=size, c=colours)
fig.colorbar(l)
ax.set_xlim((-0.05, 1.05))
ax.set_ylim((-0.05, 1.05))
fig.suptitle('Dramatic Scatter Plot')
fig.tight_layout(pad=2);
ax.grid(True)
fig.savefig('filename.png', dpi=125)
```

Note: matplotlib has a huge range of colour maps in addition to the default used here.



Changing the marker symbol

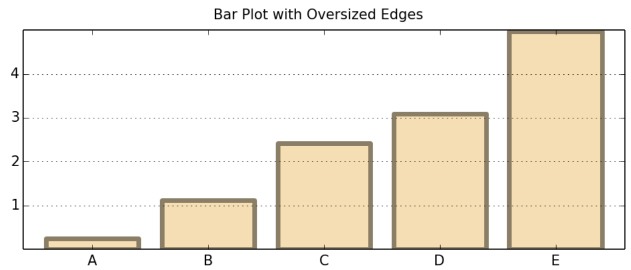
```
fig, ax = plt.subplots(figsize=(8,5))
markers = list('ov^<>12348sphHdD+x*|_')
N = 10
for i, m in enumerate(markers):
    x = np.arange(N)
    y = np.repeat(i+1, N)
    ax.scatter(x, y, marker=m, label=m,
        s=50, c='cornflowerblue')

ax.set_xlim((-1,N))
ax.set_ylim((0,len(markers)+1))
ax.legend(loc='upper left', ncol=3,
    prop={'size':'xx-large'},
    shadow=True, title='Marker Legend')
ax.get_legend().get_title().set_color("red")
fig.suptitle('Markers ' +
    '(with an oversized legend)')
fig.tight_layout(pad=2);
fig.savefig('filename.png', dpi=125)
```



Bar plots – using ax.bar() and ax.barh()

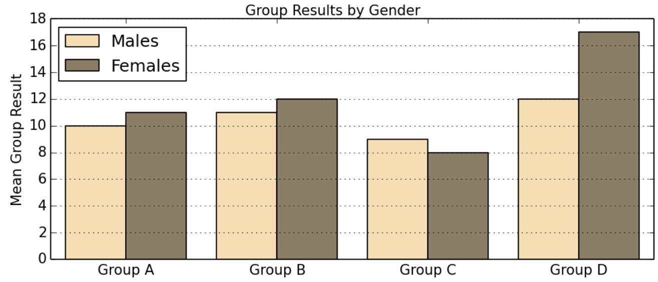
A simple bar chart
The bars in a bar-plot are placed to the right of the bar x-axis location by default. Centred labels require a little jiggling with the bar and label positions.

```
# --- get the data
N = 5
labels = list('ABCDEFGHIJKLM'[0:N])
data = np.array(range(N)) +
np.random.rand(N)
# --- plot the data
fig, ax = plt.subplots(figsize=(8, 3.5))
width = 0.8;
tickLocations = np.arange(N)
rectLocations = tickLocations-(width/2.0)
ax.bar(rectLocations, data, width,
    color='wheat',
    edgecolor='#8B7E66', linewidth=4.0)
# --- pretty-up the plot
ax.set_xticks(ticks= tickLocations)
ax.set_xticklabels(labels)
ax.set_xlim(min(tickLocations)-0.6,
    max(tickLocations)+0.6)
ax.set_yticks(range(N)[1:])
ax.set_ylim((0,N))
ax.yaxis.grid(True)
# --- title and save
fig.suptitle("Bar Plot with " +
    "Oversized Edges")
fig.tight_layout(pad=2)
fig.savefig('filename.png', dpi=125)
```



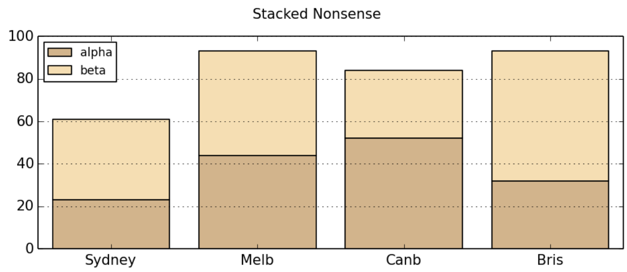
Side by side bar chart

```
# --- get the data
before = np.array([10, 11, 9, 12])
after = np.array([11, 12, 8, 17])
labels=['Group '+x for x in list('ABCD')]
# --- the plot – left then right
fig, ax = plt.subplots(figsize=(8, 3.5))
width = 0.4 # bar width
xlocs = np.arange(len(before))
ax.bar(xlocs-width, before, width,
     color='wheat', label='Males')
ax.bar(xlocs, after, width,
     color='#8B7E66', label='Females')
# --- labels, grids and title, then save
ax.set_xticks(ticks=range(len(before)))
ax.set_xticklabels(labels)
ax.yaxis.grid(True)
ax.legend(loc='best')
ax.set_ylabel('Mean Group Result')
fig.suptitle('Group Results by Gender')
fig.tight_layout(pad=1)
fig.savefig('filename.png', dpi=125)
```



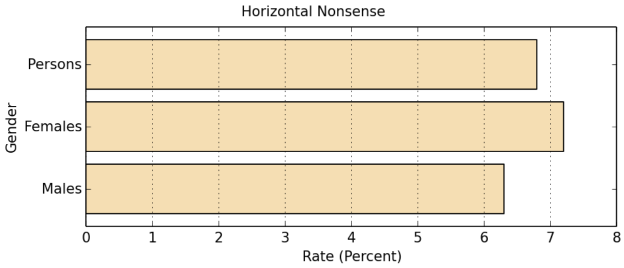
Stacked bar

```
# --- get some data
alphas = np.array( [23, 44, 52, 32] )
betas = np.array( [38, 49, 32, 61] )
labels = ['Sydney', 'Melb', 'Canb', 'Bris']
# --- the plot
fig, ax = plt.subplots(figsize=(8, 3.5))
width = 0.8;
xlocations=np.array(range(len(alphas)+2))
adjlocs = xlocations[1:-1] - width/2.0
ax.bar(adjlocs, alphas, width,
    label='alpha', color='tan')
ax.bar(adjlocs, betas, width,
    label='beta', color='wheat',
    bottom=alphas)
# --- pretty-up and save
ax.set_xticks(ticks=xlocations[1:-1])
ax.set_xticklabels(labels)
ax.yaxis.grid(True)
ax.legend(loc='best', prop={'size':'small'})
fig.suptitle("Stacked Nonsense")
fig.tight_layout(pad=2)
fig.savefig('filename.png', dpi=125)
```



Horizontal bar charts
Just as tick placement needs to be managed with vertical bars; so with horizontal bars (which are above the y-tick mark)

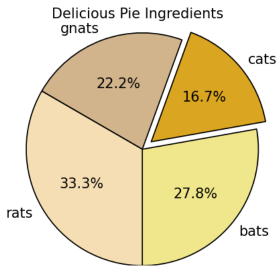
```
labels = ['Males', 'Females', 'Persons']
data = [6.3, 7.2, 6.8]
width = 0.8
yTickPos = np.arange(len(data))
yBarPos = yTickPos - (width/2.0)
fig, ax = plt.subplots(figsize=(8, 3.5))
ax.barh(yBarPos,data,width,color='wheat')
ax.set_yticks(ticks= yTickPos)
ax.set_yticklabels(labels)
ax.set_ylim((min(yTickPos)-0.6,
    max(yTickPos)+0.6))
ax.xaxis.grid(True)
ax.set_ylabel('Gender');
ax.set_xlabel('Rate (Percent)')
fig.suptitle("Horizontal Nonsense")
fig.tight_layout(pad=2)
fig.savefig('filename.png', dpi=125)
```



Pie Chart – using ax.pie()

As nice as pie

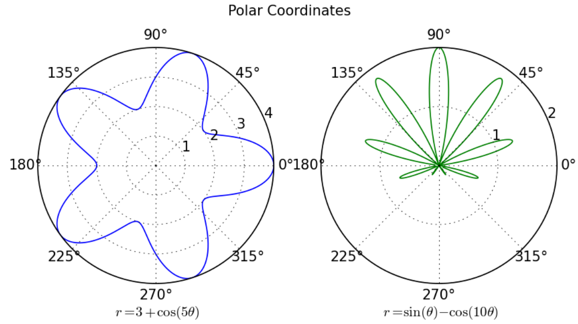
```
# --- get some data
data = np.array([5,3,4,6])
labels = ['bats', 'cats', 'gnats', 'rats']
explode = (0, 0.1, 0, 0) # explode cats
colrs=['khaki', 'goldenrod', 'tan', 'wheat']
# --- the plot
fig, ax = plt.subplots(figsize=(8, 3.5))
ax.pie(data, explode=explode,
    labels=labels, autopct='%1.1f%%',
    startangle=270, colors=colrs)
ax.axis('equal') # keep it a circle
# --- tidy-up and save
fig.suptitle("Delicious Pie Ingredients")
fig.savefig('filename.png', dpi=125)
```



Polar – using ax.plot()

Polar coordinates

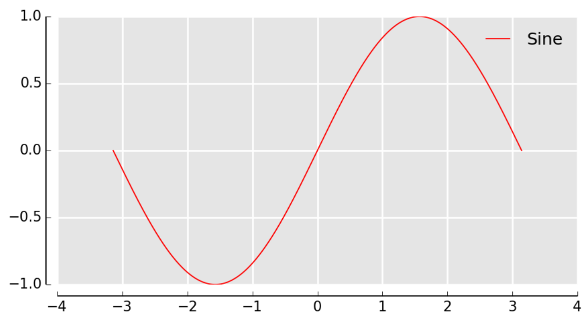
```
# --- theta
theta = np.linspace(-np.pi, np.pi, 800)
# --- get us a Figure
fig = plt.figure(figsize=(8,4))
# --- left hand plot
ax = fig.add_subplot(1,2,1, polar=True)
r = 3 + np.cos(5*theta)
ax.plot(theta, r)
ax.set_yticks([1,2,3,4])
# --- right hand plot
ax = fig.add_subplot(1,2,2, polar=True)
r = (np.sin(theta)) - (np.cos(10*theta))
ax.plot(theta, r, color='green')
ax.set_yticks([1,2])
# --- title, explanatory text and save
fig.suptitle('Polar Coordinates')
fig.text(x=0.24, y=0.05,
   s=r'$r = 3 + \cos(5 \theta)$')
fig.text(x=0.64, y=0.05,
   s=r'$r = \sin(\theta) - \cos(10' +
       r'\theta)$')
fig.savefig('filename.png', dpi=125)
```



Plot spines

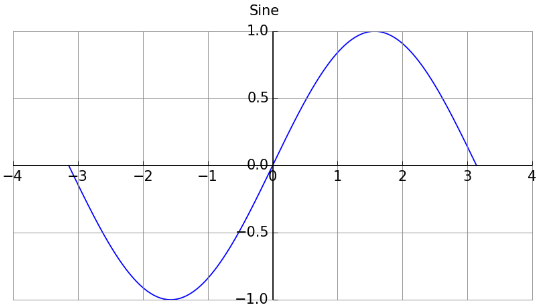
Hiding the top and right spines

```
x = np.linspace(-np.pi, np.pi, 800)
y = np.sin(x)
fig, ax = plt.subplots(figsize=(8, 4))
ax.plot(x, y, label='Sine', color='red')
ax.set_axis_bgcolor('#e5e5e5')
ax.spines['right'].set_color('none')
ax.spines['top'].set_color('none')
ax.spines['left'].set_position(
    ('outward',10))
ax.spines['bottom'].set_position(
    ('outward',10))
ax.xaxis.set_ticks_position('bottom')
ax.yaxis.set_ticks_position('left')
# do the ax.grid() after setting ticks
ax.grid(b=True, which='both',
    color='white', linestyle='-',
    linewidth=1.5)
ax.set_axisbelow(True)
ax.legend(loc='best', frameon=False)
fig.savefig('filename.png', dpi=125)
```



Spines in the middle

```
x = np.linspace(-np.pi, np.pi, 800)
y = np.sin(x)
fig, ax = plt.subplots(figsize=(8, 4))
ax.plot(x, y, label='Sine')
ax.spines['right'].set_color('none')
ax.spines['top'].set_color('none')
ax.xaxis.set_ticks_position('bottom')
ax.spines['bottom'].set_position((
    'data',0))
ax.yaxis.set_ticks_position('left')
ax.spines['left'].set_position((
    'data',0))
ax.grid(b=True, which='both',
    color='#888888', linestyle='-',
    linewidth=0.5)
fig.suptitle('Sine')
fig.savefig('filename.png', dpi=125)
```

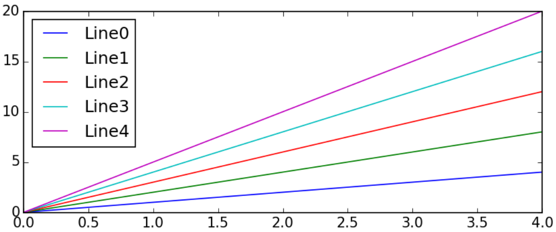


Legends

Legend within the plot

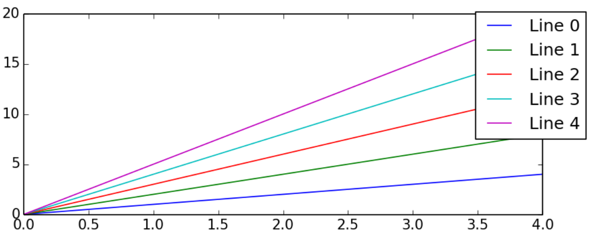
Use the 'loc' argument to place the legend

```
N = 5
x = np.arange(N)
fig, ax = plt.subplots(figsize=(8, 3))
for j in range(5):
  ax.plot(x, x*(j+1),label='Line'+str(j))

ax.legend(loc='upper left')
fig.savefig('filename.png', dpi=125)
```



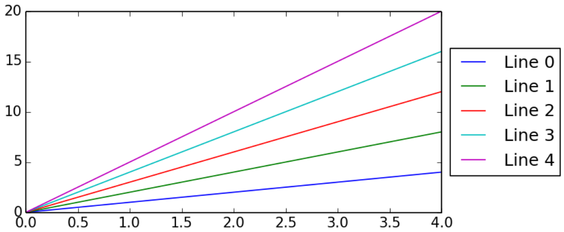
Legend slightly outside of the plot

```
N = 5
x = np.arange(N)
fig, ax = plt.subplots(figsize=(8, 3))
for j in range(5):
    ax.plot(x, x*(j+1),
        label='Line '+str(j))

ax.legend(bbox_to_anchor=(1.1, 1.05))
fig.savefig('filename.png', dpi=125)
```



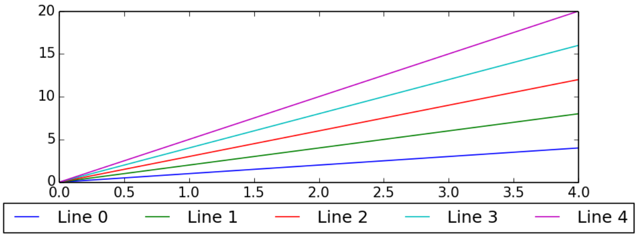
Legend to the right of the plot

```
N = 5
x = np.arange(N)
fig, ax = plt.subplots(figsize=(8, 3))
for j in range(5):
    ax.plot(x, x*(j+1),
        label='Line '+str(j))

box = ax.get_position()  # Shrink plot
ax.set_position([box.x0, box.y0,
    box.width * 0.8, box.height])
ax.legend(bbox_to_anchor=(1, 0.5),
    loc='center left')    # Put legend
fig.savefig('filename.png', dpi=125)
```



Legend below the plot

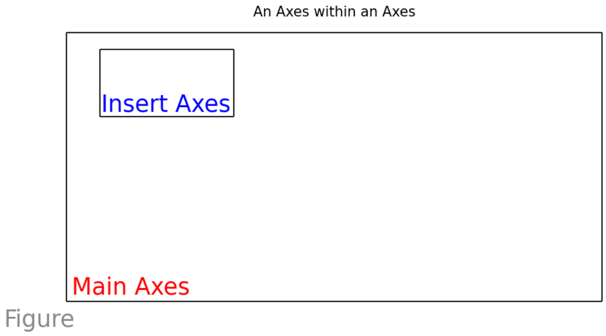
```
N = 5
x = np.arange(N)
fig, ax = plt.subplots(figsize=(8, 3))
for j in range(5):
    ax.plot(x, x*(j+1),
        label='Line '+str(j))

box = ax.get_position()
ax.set_position([box.x0,
    box.y0 + box.height * 0.15,
    box.width, box.height * 0.85])
ax.legend(bbox_to_anchor=(0.5, -0.075),
    loc='upper center', ncol=N)
fig.savefig('filename.png', dpi=125)
```



Multiple plots on a canvas

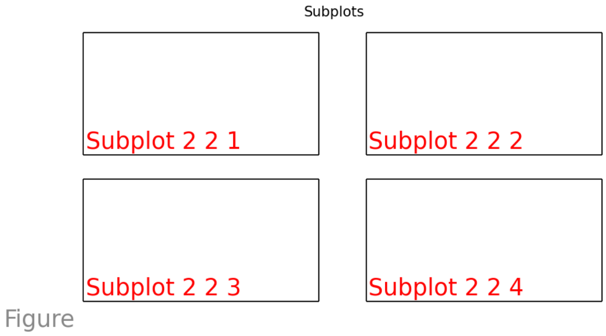
Using Axes to place a plot within a plot

```
fig = plt.figure(figsize=(8,4))
fig.text(x=0.01, y=0.01, s='Figure',
    color='#888888', ha='left',
    va='bottom', fontsize=20)
# --- Main Axes
ax = fig.add_axes([0.1,0.1,0.8,0.8])
ax.text(x=0.01, y=0.01, s='Main Axes',
    color='red', ha='left', va='bottom',
    fontsize=20)
ax.set_xticks([]); ax.set_yticks([])
# --- Insert Axes
ax= fig.add_axes([0.15,0.65,0.2,0.2])
ax.text(x=0.01, y=0.01, s='Insert Axes',
    color='blue', ha='left', va='bottom',
    fontsize=20)
ax.set_xticks([]); ax.set_yticks([])
fig.suptitle('An Axes within an Axes')
fig.savefig('filename.png', dpi=125)
```



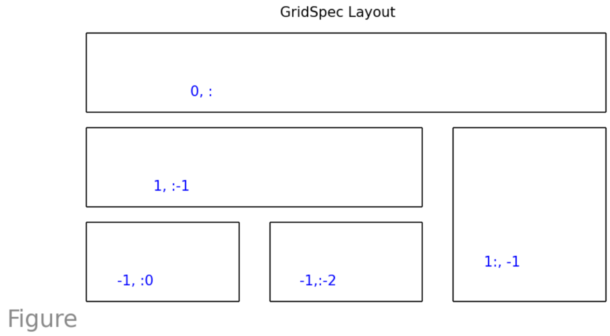
Simple subplot grid layouts

```
fig = plt.figure(figsize=(8,4))
fig.text(x=0.01, y=0.01, s='Figure',
    color='#888888', ha='left',
    va='bottom', fontsize=20)

for i in range(4):
    # fig.add_subplot(nrows, ncols, num)
    ax = fig.add_subplot(2, 2, i+1)
    ax.text(x=0.01, y=0.01,
        s='Subplot 2 2 '+str(i+1),
        color='red', ha='left',
        va='bottom', fontsize=20)
    ax.set_xticks([]); ax.set_yticks([])

ax.set_xticks([]); ax.set_yticks([])
fig.suptitle('Subplots')
fig.savefig('filename.png', dpi=125)
```



Using GridSpec layouts (like list slicing)

```
import matplotlib.gridspec as gs
gs = gs.GridSpec(3, 3) # nrows, ncols
fig = plt.figure(figsize=(8,4))
fig.text(x=0.01, y=0.01, s='Figure',
    color='#888888', ha='left',
    va='bottom', fontsize=20)
ax1 = fig.add_subplot(gs[0, :]) # row,col
ax1.text(x=0.2,y=0.2,s='0, :', color='b')
ax2 = fig.add_subplot(gs[1,:-1])
ax2.text(x=0.2,y=0.2,s='1, :-1', color='b')
ax3 = fig.add_subplot(gs[1:, -1])
ax3.text(x=0.2,y=0.2, s='1:, -1', color='b')
ax4 = fig.add_subplot(gs[-1,0])
ax4.text(x=0.2,y=0.2, s='-1, :0', color='b')
ax5 = fig.add_subplot(gs[-1,-2])
ax5.text(x=0.2,y=0.2, s='-1,:-2', color='b')
for a in fig.get_axes():
    a.set_xticks([])
    a.set_yticks([])

fig.suptitle('GridSpec Layout')
fig.savefig('filename.png', dpi=125)
```



Plotting – defaults

Configuration files

Matplotlib uses configuration files to set the defaults. So that you can edit it, the location of the configuration file can be found as follows:

```
print (matplotlib.matplotlib_fname())
```

Configuration settings

The current configuration settings

```
print (matplotlib.rcParams)
```

Change the default settings

```
plt.rc('figure', figsize=(8,4), dpi=125,
    facecolor='white', edgecolor='white')
plt.rc('axes', facecolor='#e5e5e5',
    grid=True, linewidth=1.0,
axisbelow=True)
plt.rc('grid', color='white', linestyle='-',
    linewidth=2.0, alpha=1.0)
plt.rc('xtick', direction='out')
plt.rc('ytick', direction='out')
plt.rc('legend', loc='best')
```

Cautionary notes

This cheat sheet was cobbled together by bots roaming the dark recesses of the Internet seeking ursine and pythonic myths. There is no guarantee the narratives were captured and transcribed accurately. You use these notes at your own risk. You have been warned.