Python plotting

A modern approach with Pandas and Seaborn

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Recap

What have we learned about basic Python?

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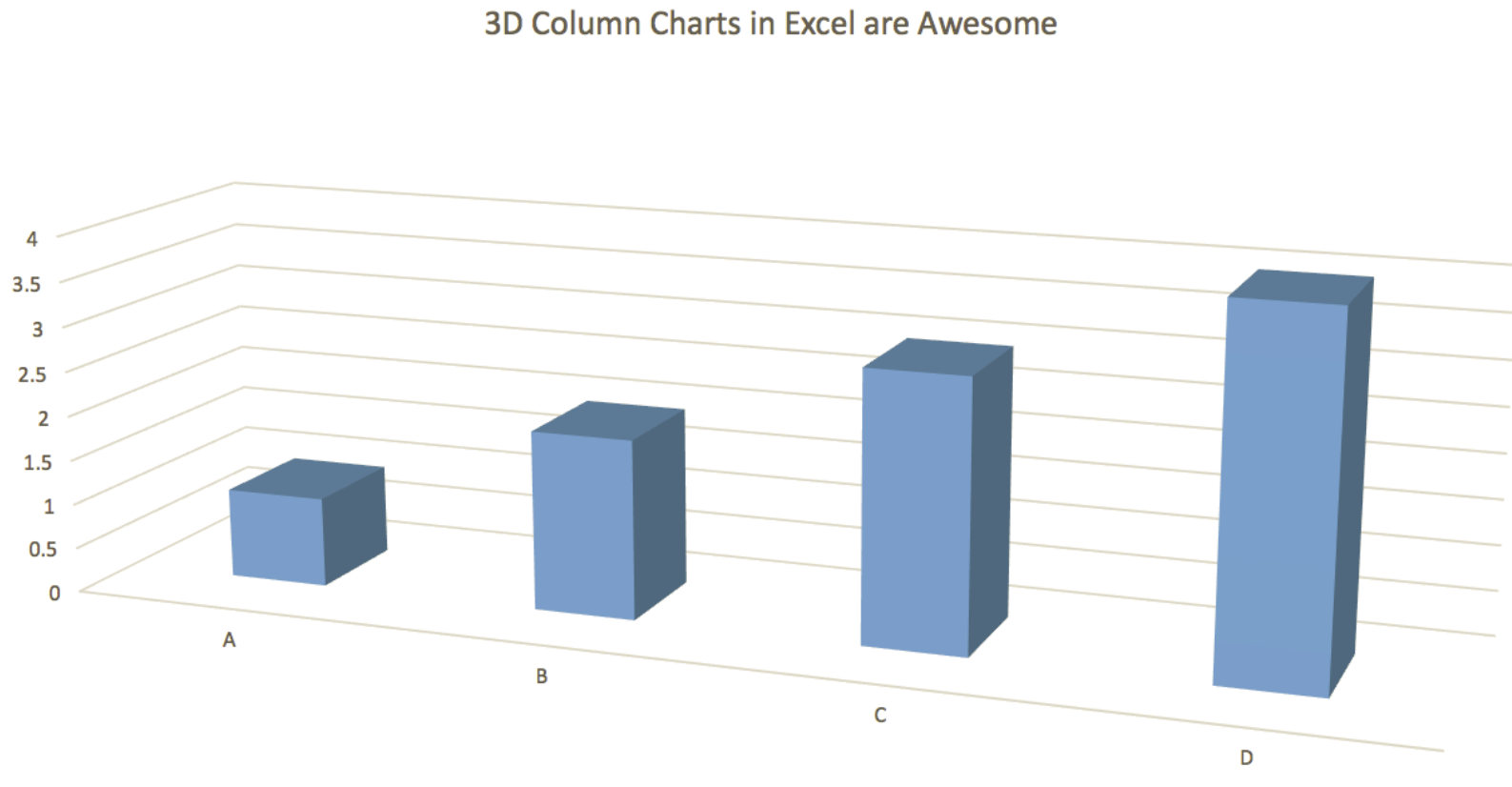
Agenda

1. Basic exploratory plots with Pandas and Seaborn.
    - plots for single variables (histograms etc.)
    - plots for relationship between two or more variables (box, scatter, etc.)
2. Making explanatory plots useful and beautiful

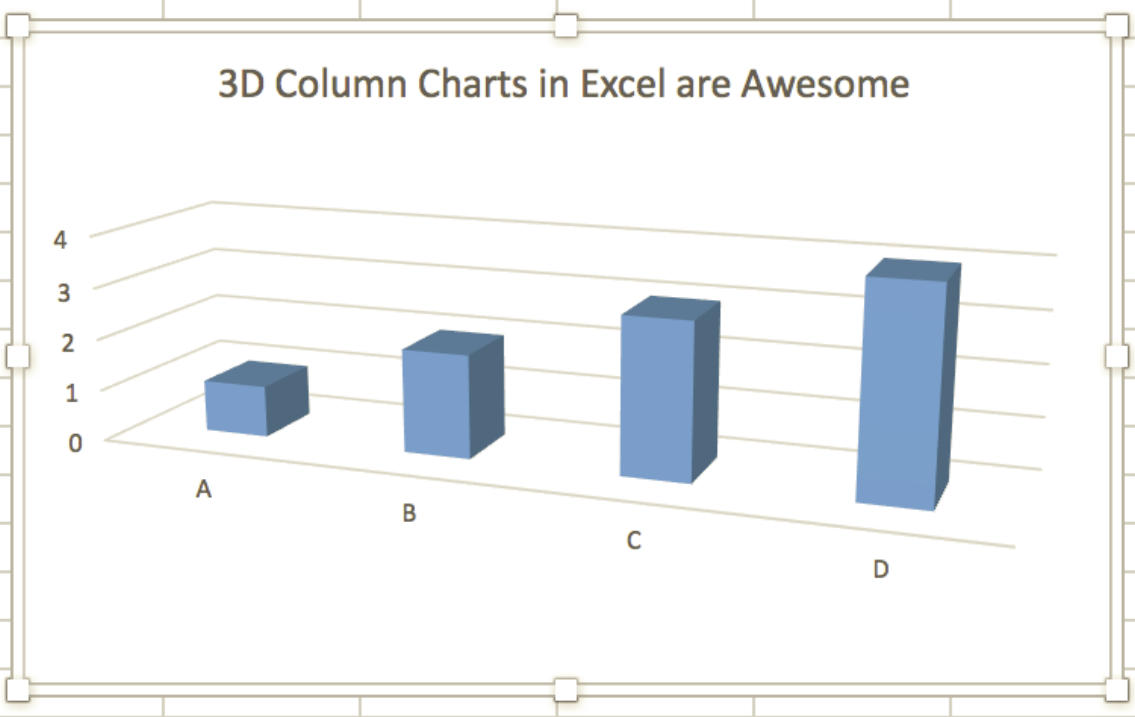
Understanding plotting

What values do A,B,C,D have?



The shocking answer

A	1
B	2
C	3
D	4



What are you trying to accomplish?

1. Who's the audience?
    - Exploratory (use defaults) vs. explanatory (customize)
    - Raw data vs. model results
    - Data type: numerical vs. non-numeric (categorical)
2. Graphs should be self explanatory
3. A graph is a narrative - should convey key point(s)

Analysis preparation

Getting prepared (1)

How do we start our analysis?

We first load the relevant modules

In [2]:
```
import matplotlib.pyplot as plt # fundamental plotting
import numpy as np # matrix framework like matlab
import pandas as pd
import seaborn as sns # high level plotting library

# allow printing in notebook
%matplotlib inline
```

Getting prepared (2)

How do we load some data?

We load a standard dataset: tips.

In [3]:
```
tips = sns.load_dataset('tips')
```

Getting prepared (3)

How do we see what is in the DataFrame?

We get preview as follows:

In [5]:
```
tips.head()
```

Out[5]:

	total_bill	tip	sex	smoker	day	time	size
0	16.99	1.01	Female	No	Sun	Dinner	2
1	10.34	1.66	Male	No	Sun	Dinner	3
2	21.01	3.50	Male	No	Sun	Dinner	3
3	23.68	3.31	Male	No	Sun	Dinner	2
4	24.59	3.61	Female	No	Sun	Dinner	4

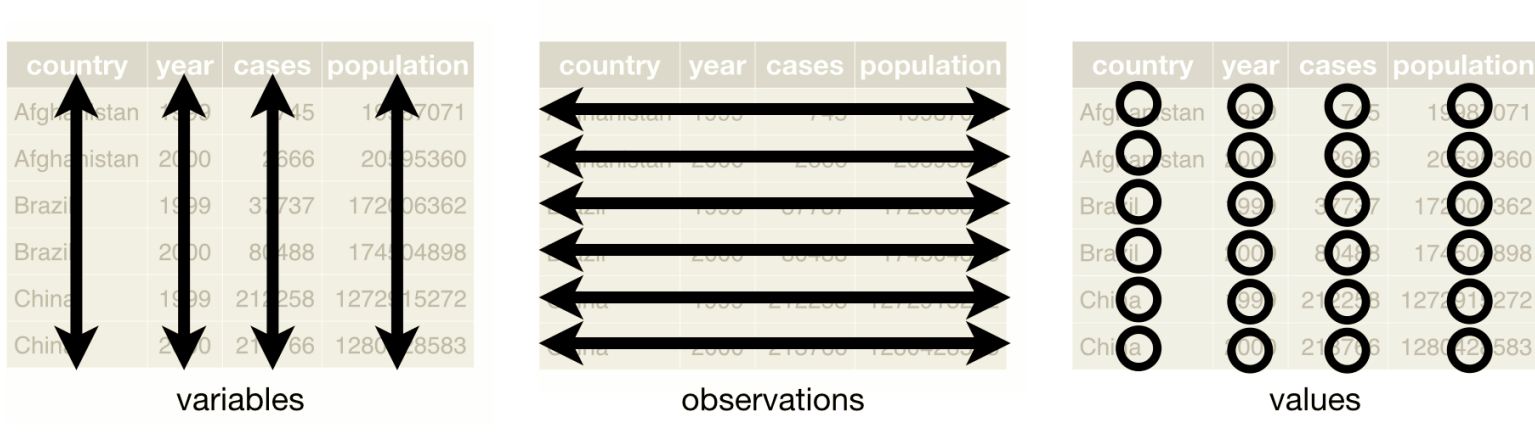
Quiz: which variables/columns are available in the tips DataFrame?

DataFrame structures

Table format

How do we define a tidy/long table?

One row for each observation:



Quiz: *Is our DataFrame, `tips`, in wide format? Why is tidy smart?*

Table format (2)

How do we define a wide table?

When columns could be a variable

In [75]:
```
df_wide = pd.DataFrame(data=[[1,2,3],[4,5,6], [7,8,9]],
                       index=['US', 'EU', 'China'],
                       columns=[1990,2000,2010])

df_wide#.stack().reset_index()
```

Out[75]:

	1990	2000	2010
US	1	2	3
EU	4	5	6
China	7	8	9

Plotting format

When plotting data there are two canonical formats: numeric and categorical.

- Have different plotting techniques.
- Note: numeric data can be binned and be regarded as categorical.

Case: Plotting one numerical variable

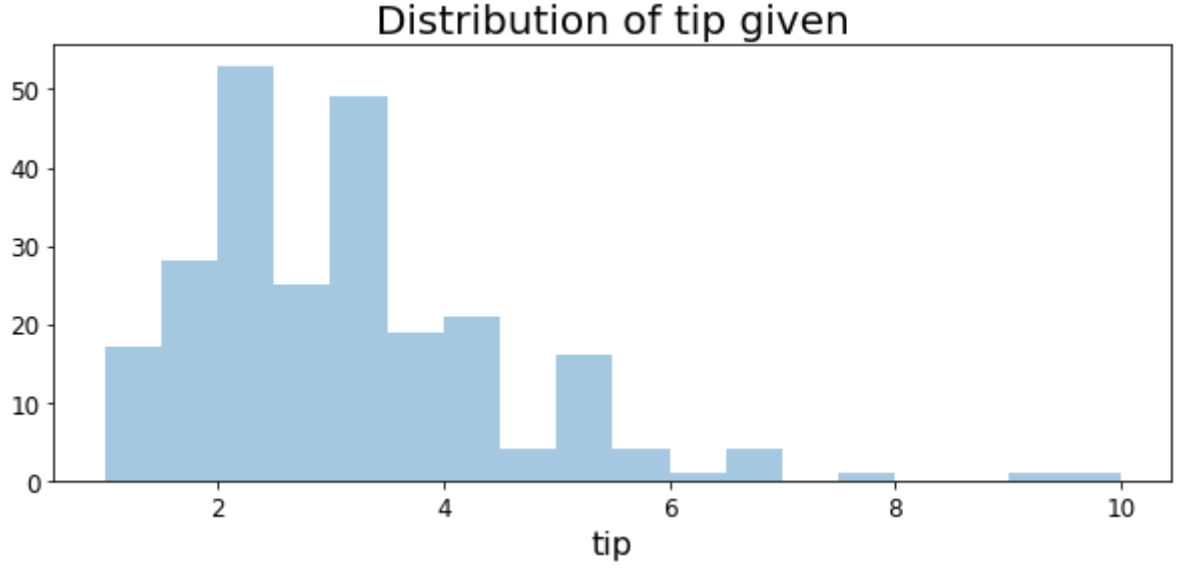
From exploratory to final output

How do we plot the distribution of numerical variables?

We often use the histogram. Let's see what it is:

In [4]:
```
histplot
```

Out[4]:



Choosing your tool

In this course you will be exposed to several ways of plotting. All tools have their advantages.

Our options:

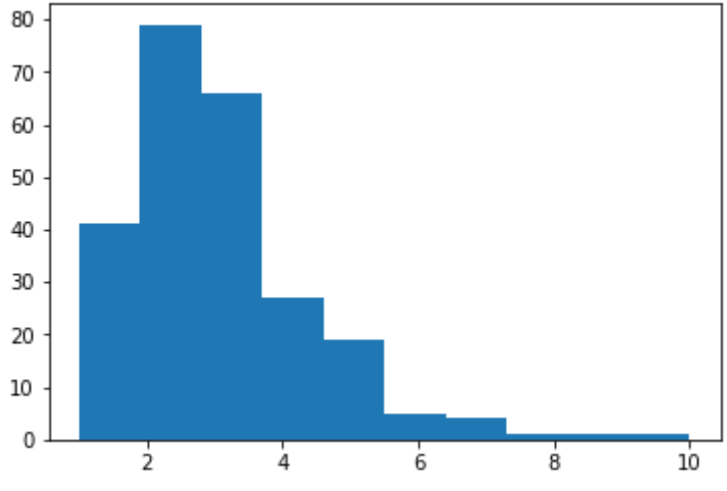
- the fundamental and flexible ~ matplotlib
- quick and dirty for wide format ~ pandas
- a smart choice for long (i.e. tidy) format~ seaborn

Histogram with matplotlib

We will begin with the fundamental and flexible way. An old-school way of doing things.

In [18]:
```
f,ax = plt.subplots() # create placeholder for plot
ax.hist(tips.tip) # make plot
```

Out[18]:
```
(array([ 41.,  79.,  66.,  27.,  19.,   5.,   4.,   1.,   1.,   1.]),
 array([  1. ,   1.9,   2.8,   3.7,   4.6,   5.5,   6.4,   7.3,   8.2,
          9.1,  10. ]),
 <a list of 10 Patch objects>)
```



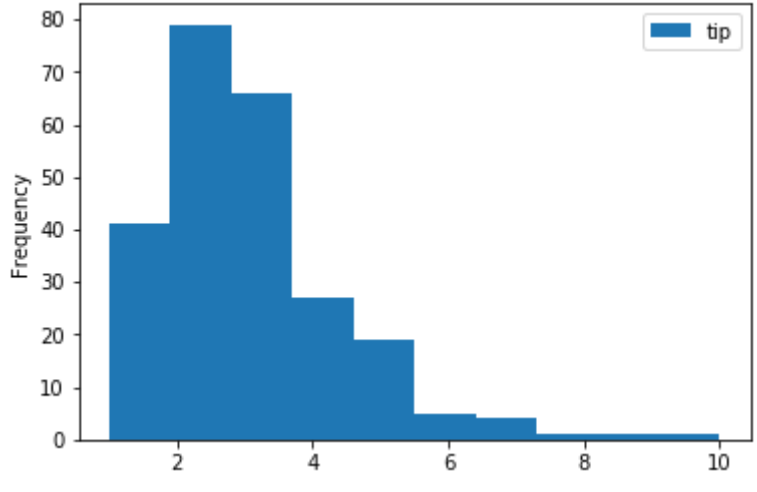
What might we change about this?

Histogram - pandas

Pandas has a quick and dirty implemention. Let's try the code below.

In [8]:
```
tips.plot(y=['tip'], kind= 'hist')
```

Out[8]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa51a85710>
```

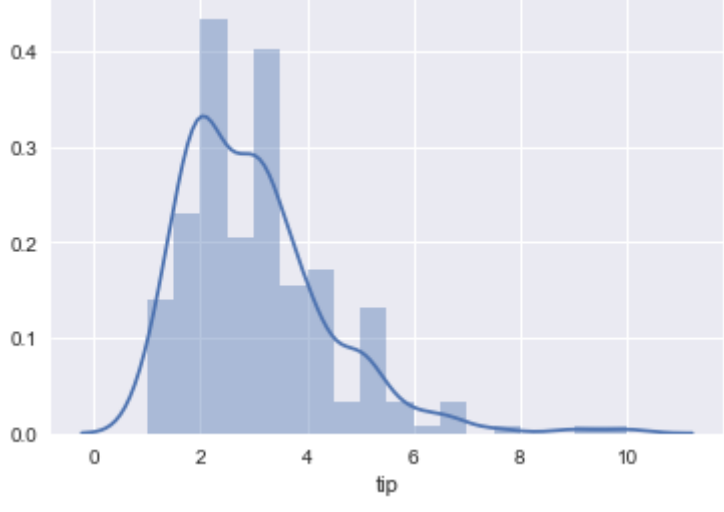


Histogram - seaborn

In [9]:
```
sns.set() # seaborn default
```

In [10]:
```
sns.distplot(tips.tip)  # histogram for seaborn
```

Out[10]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa51b58ef0>
```



What is the line?

Summing up

Group discussion (2 minutes):

- How did our tools perform?
  - Seaborn best immediate plot.
- Which one seems most adequate for exploratory analysis? Which one for explanatory?
  - Seaborn seems best for exploratory.
  - Matplotlib but requires much work with customizations.
- Which steps could be taken towards improving the Seaborn histogram?
  - Size, add title, bins of histogram, font of labels/title/axis ticks

Explanatory plotting: the histogram

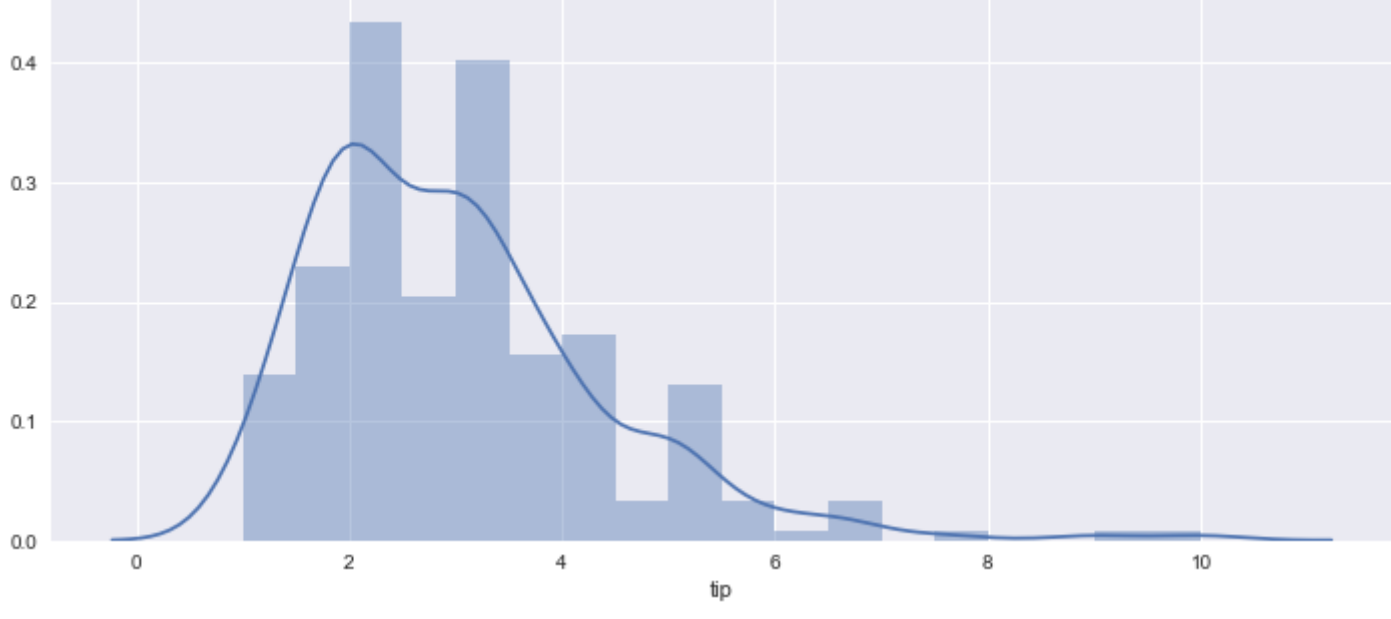
What can be done change this histogram?

- How can we achieve the improvements?

Changing the figure size

In [12]:
```
f,ax = plt.subplots(figsize=(12,4)) # set the plot size
sns.distplot(a=tips.tip,
             ax=ax) # use matplotlib defined plot for size)
```

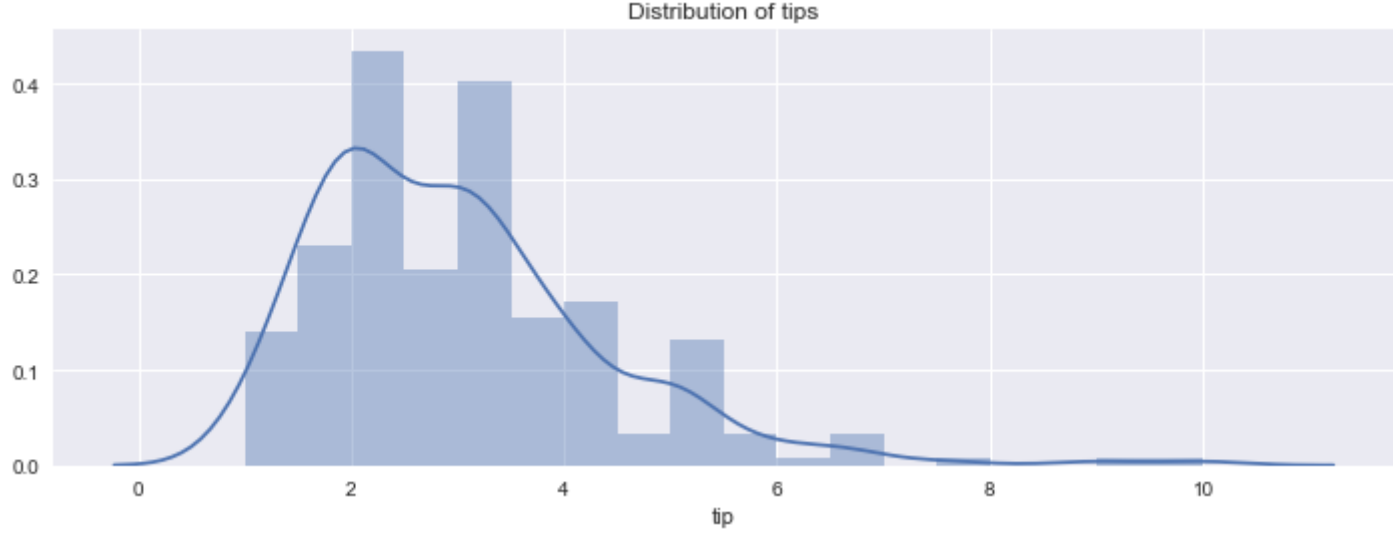
Out[12]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa52d35b70>
```



Set title

In [13]:
```
f,ax = plt.subplots(figsize=(12,4))
sns.distplot(a=tips.tip,
             ax=ax)

ax.set_title('Distribution of tips') # setting the title
```

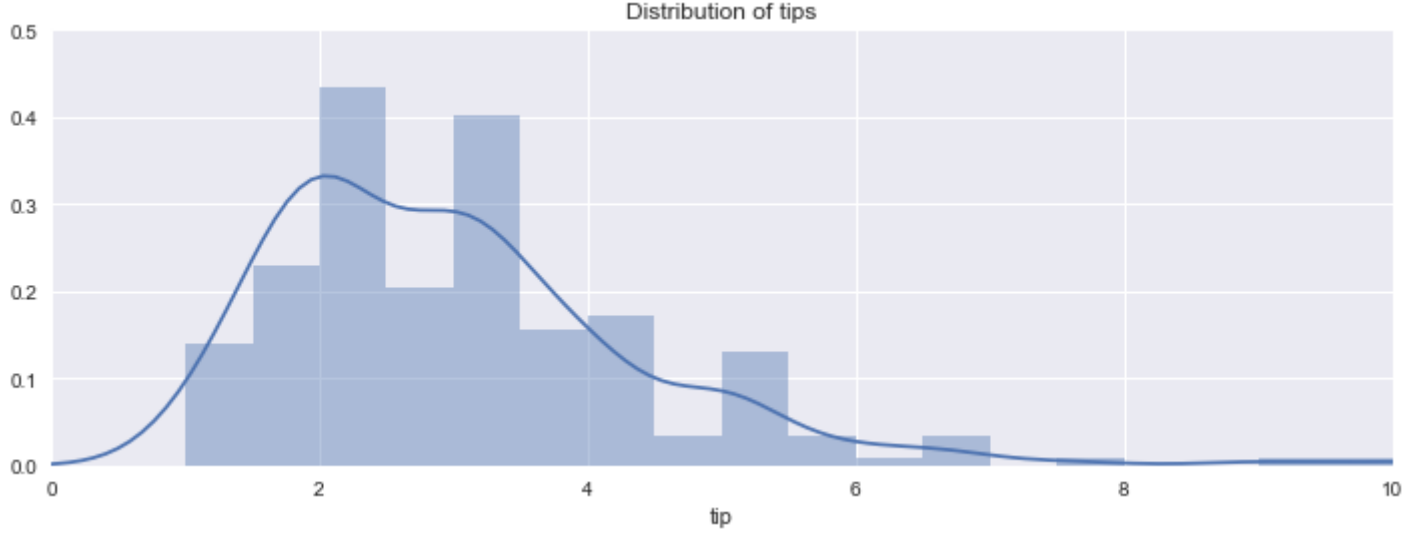
Out[13]:
```
<matplotlib.text.Text at 0x1aa52eafc88>
```



Change bounds for x- and y-axis

In [14]:
```
f,ax = plt.subplots(figsize=(12,4))
sns.distplot(a=tips.tip,
             ax=ax)
ax.set_title('Distribution of tips')

ax.set_xlim(0,10) # set limits for x-axis
ax.set_ylim(0,.5) # set limits for y-axis
```

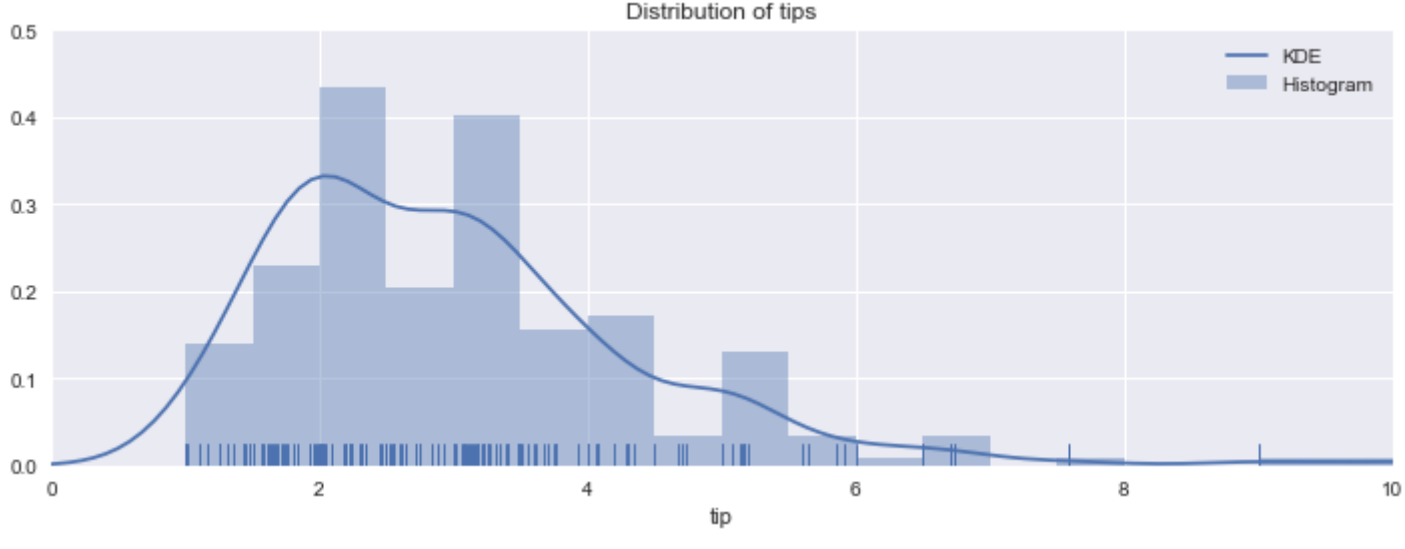
Out[14]:
```
(0, 0.5)
```



Add observation rug and legend

In [15]:
```
f,ax = plt.subplots(figsize=(12,4))
sns.distplot(a=tips.tip,
             ax=ax,
             rug=True,
             kde_kws={'label': 'KDE'}, # label for KDE plot
             hist_kws={'label': 'Histogram'}) # label for histogram
ax.set_title('Distribution of tips')
ax.set_xlim(0,10)
ax.set_ylim(0,.5)
```

Out[15]:
```
(0, 0.5)
```



Set font sizes

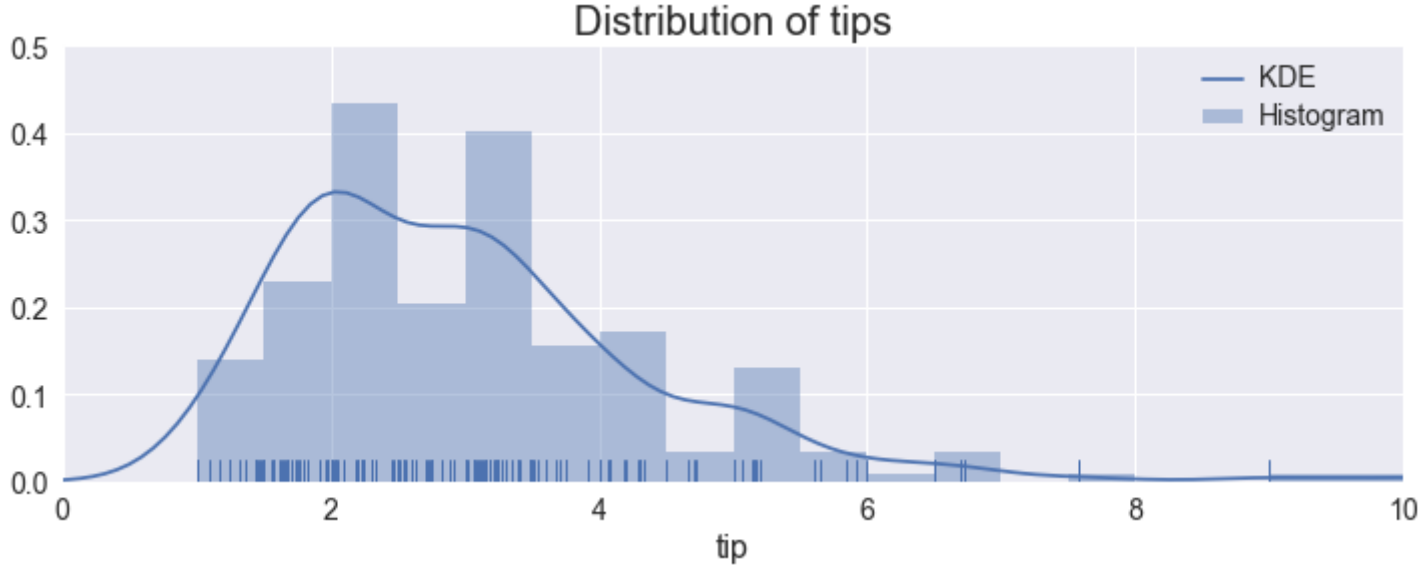
In [18]:
```
f,ax = plt.subplots(figsize=(12,4))
sns.distplot(a=tips.tip, ax=ax, rug=True,
             kde_kws={'label': 'KDE'},
             hist_kws={'label': 'Histogram'})
ax.set_title('Distribution of tips')
ax.set_xlim(0,10)
ax.set_ylim(0,.5)


ax.title.set_fontsize(20) # title
ax.xaxis.label.set_fontsize(16) # xaxis label
tick_labels = ax.get_yticklabels()+ax.get_xticklabels()

# set font sizes
ax.title.set_fontsize(20) # title
ax.xaxis.label.set_fontsize(16)  #xaxis label
tick_labels = ax.get_yticklabels()+ax.get_xticklabels()
for item in tick_labels: # axis tickers
    item.set_fontsize(14)

legends = plt.gca().get_legend().get_texts()# legend labels
plt.setp(legends, fontsize='14') # set size of legend labels
```

Out[18]:
```
[None, None, None, None]
```

The final plot

In [48]:
```
f
```

Out[48]:



Explanation for the final plot

In [ ]:
```
f,ax = plt.subplots(figsize=(12,4)) # set the plot size
sns.distplot(a=tips.tip,
             ax=ax, # use matplotlib defined plot for size
             rug=True, # include raw count
             kde_kws={'label': 'KDE'}, # label for KDE plot
             hist_kws={'label': 'Histogram'}) # label for histogram
ax.set_title('Distribution of tips') # set title
ax.set_xlim(0,10) # set x limits
ax.set_ylim(0,.5) # set x limits

# set font sizes
ax.title.set_fontsize(20) # title
ax.xaxis.label.set_fontsize(16)  #xaxis label
for item in ax.get_yticklabels()+ax.get_xticklabels(): # xaxis tickers
    item.set_fontsize(14)
plt.setp(plt.gca().get_legend().get_texts(), fontsize='14') # legend labels
```

Exporting our final plot

In [69]:
```
f.figure.savefig('my_histogram.pdf')
```

Out[69]:
```
<bound method Figure.savefig of <matplotlib.figure.Figure object at 0x000001AA58115F6
0>>
```

Setting - standard plot size

In [26]:
```
plt.rcParams['figure.figsize'] = 12,5 # set default size of plots
```

Univariate categorical data

What if we have categorical data?

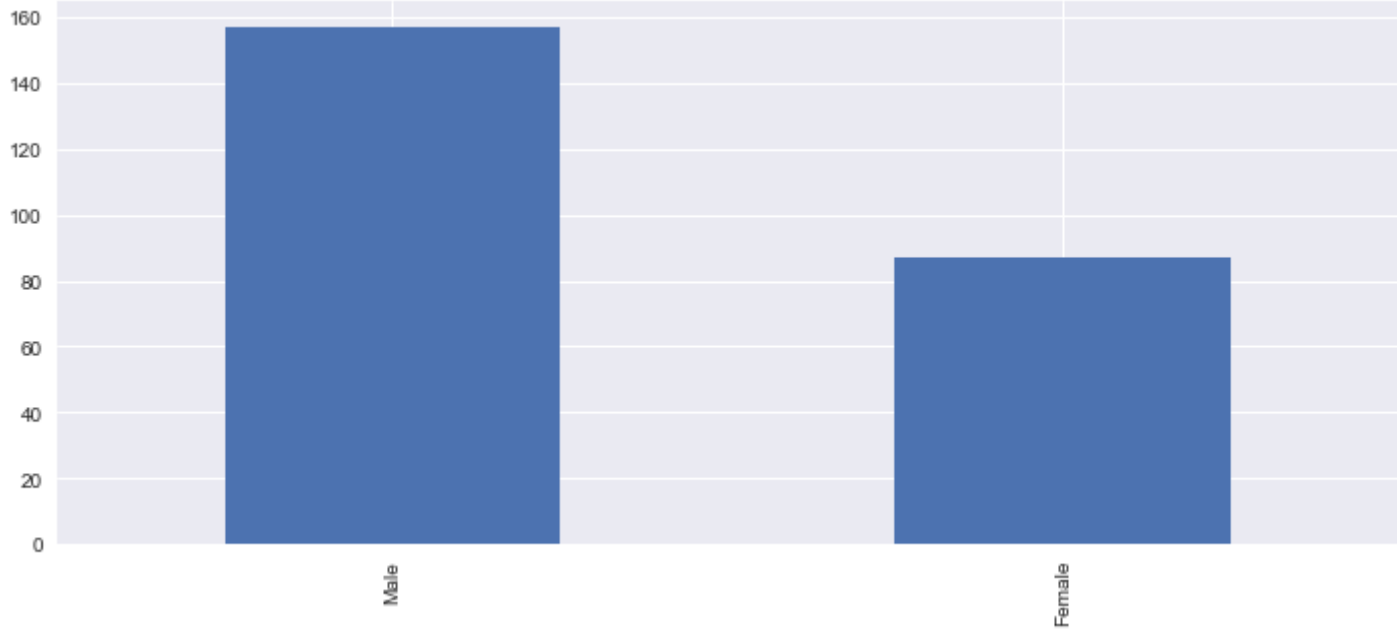
What is categorical data? Example gender count:

In [ ]:
```
count_sex = tips.sex.value_counts()
```

Let's plot this with bars:

In [28]:
```
count_sex.plot.bar()
```

Out[28]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa53b5c9e8>
```



Let's plot this as a pie:

In [ ]:
```
count_sex.plot.pie()
```

Univariate series plots

Simulating data

Let's create some data

In [29]:
```
np.random.seed(123) # set seed - then we get same random data

ts = np.random.normal(0,1,[1000,3]) # time series with no slope

dates = pd.date_range(start='20170801', periods=1000, freq='D') # 1000 daily observation
s beginning Aug 1, 17
```

Simulating data (2)

We use our data to create a DataFrame with a time series index.

In [30]:
```
df_norm = pd.DataFrame(data=ts, # our data
                       index=dates, # our date indices
                       columns=['A', 'B', "C"]) # column names
```

In [34]:
```
df = df_norm.cumsum() # use cumulative sum
```

In [36]:
```
df['A'] += np.arange(0,60,.06) # add-to 'A' a linear trend with .06 increments
df['B'] += np.arange(0,30,.03) # add-to 'B' a linear trend with .03 increments
```

Quiz: is our data in long or wide format?

Power of Pandas

Why is pandas used in fin-tech so much?

Example: Plotting time series for one variable (e.g. GDP, inflation)

In [38]:
```
df['A'].plot()
```

Out[38]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa53e672b0>
```

Scatter and related plots

Raw distribution of two numeric variables

Pandas scatter plot

In [39]:
```
df.plot.scatter('A','B')
```

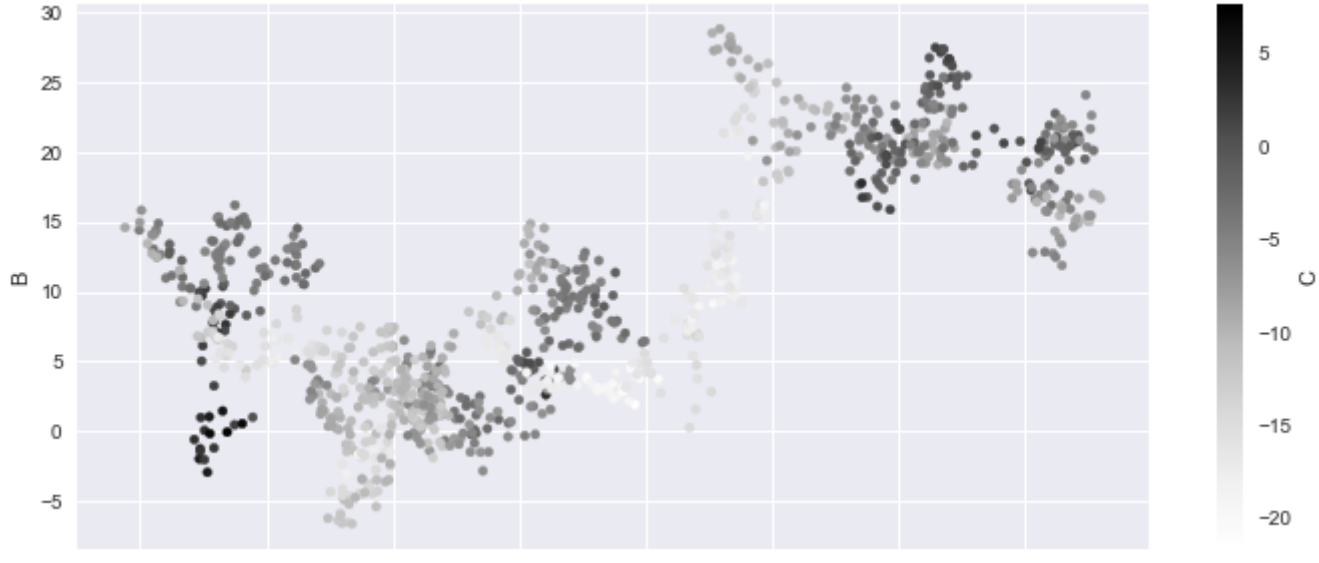
Out[39]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa53efbeb8>
```

Quiz: How might we alter the scatter plot?

- Let's try to change the colors of the dots:

In [40]:
```
df.plot.scatter(x='A', y='B', c='C')
```

Out[40]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa53cb9160>
```

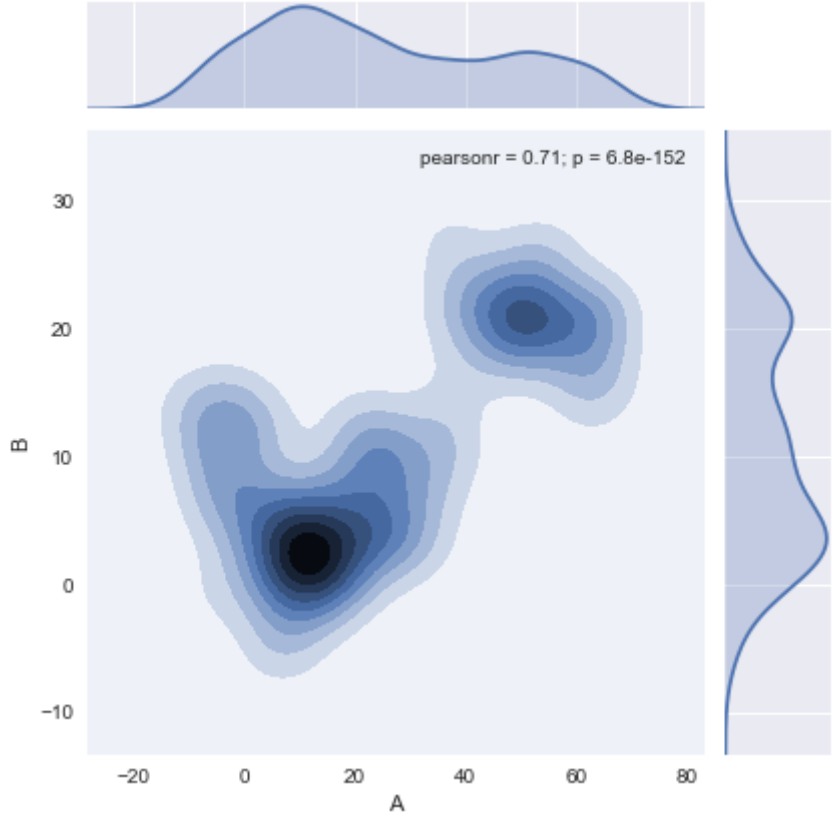


Seaborn for scatter and related

The jointplot for scatter

In [43]:
```
sns.jointplot(x='A',y='B', data=df, kind='kde')
```

Out[43]:
```
<seaborn.axisgrid.JointGrid at 0x1aa543a40f0>
```

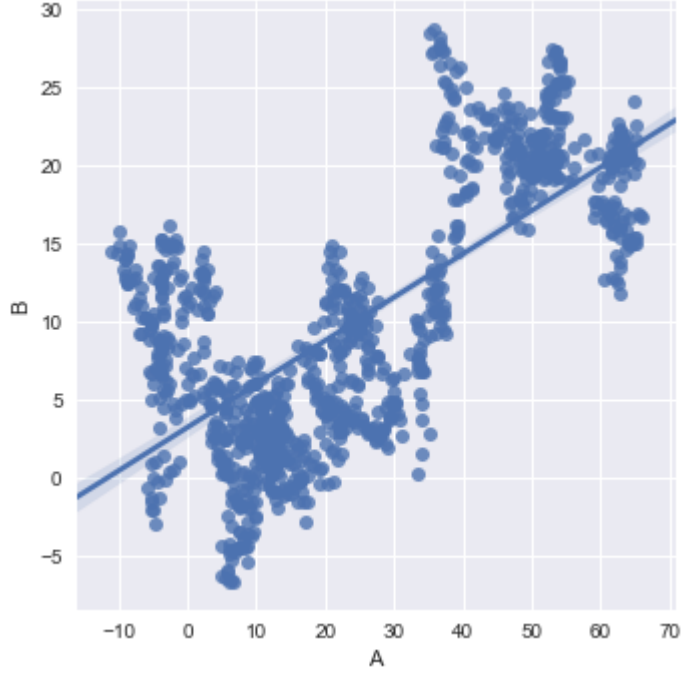


How can we modify this? KDE, hexbin?

- The regression plot

In [44]:
```
sns.lmplot('A', 'B', data=df)
```

Out[44]:
```
<seaborn.axisgrid.FacetGrid at 0x1aa55711278>
```



- Multiple scatterplots (correlation matrix style)

Plotting multiple variables

Wide formatting

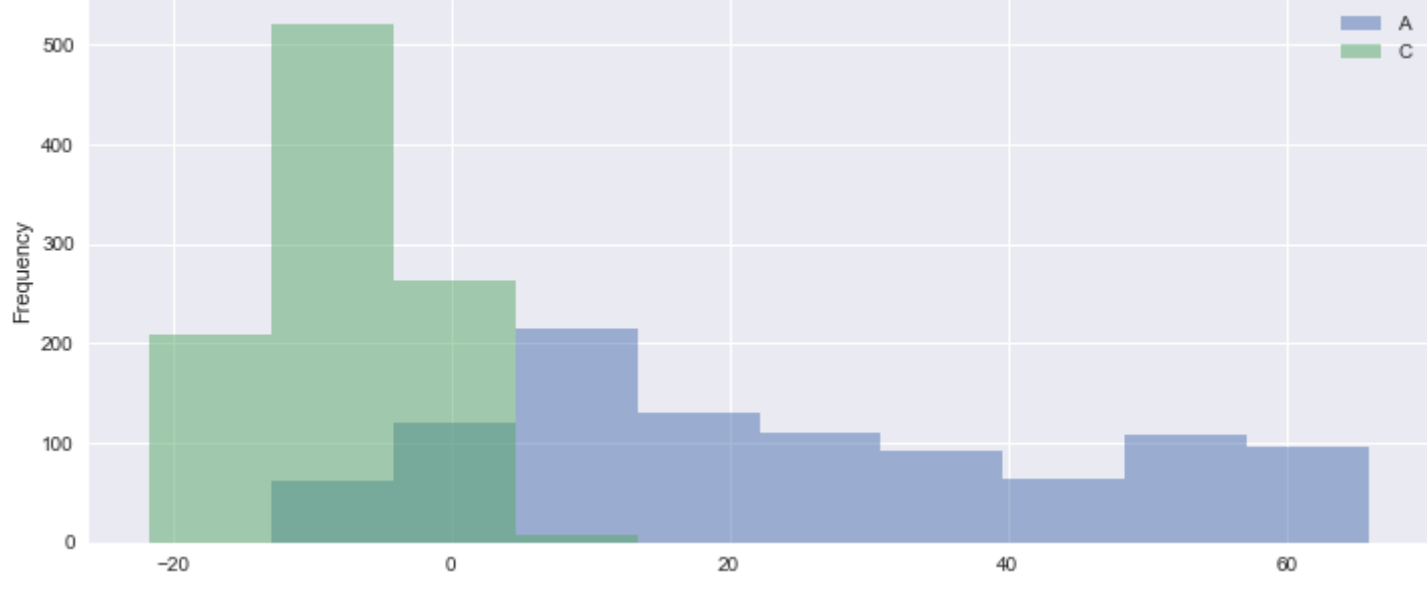
Which tool should we pick for wide data?

Pandas!

Histogram

In [48]:
```
df[['A','C']].plot.hist(alpha=.5)
```

Out[48]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa558667b8>
```



Time series plot

In [49]:
```
df.plot()
```

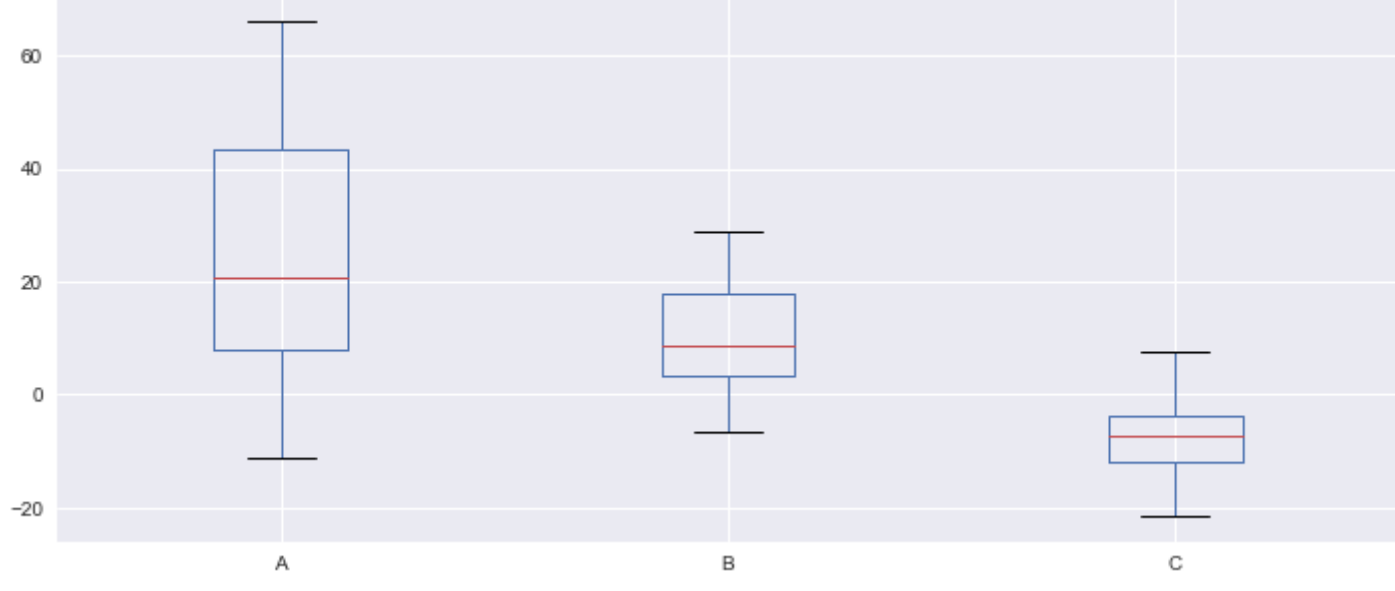
Out[49]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa563b8940>
```

The boxplot

Measure: median + top,bottom for quartiles and deciles.

In [51]:
```
df.plot.box()
```

Out[51]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa575d8630>
```



Plotting multiple variables

Using long format

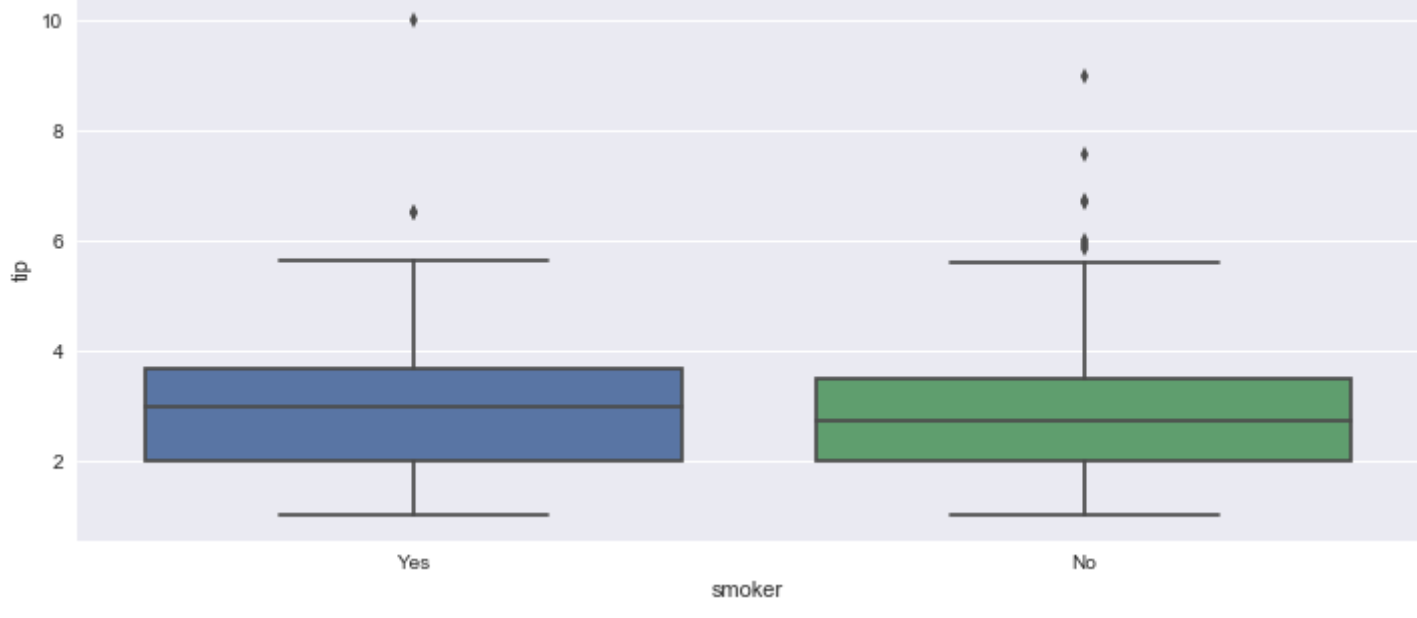
What was long format? (one row per observation)

What columns can we use as extra info? Categorical variables?

Let's make a boxplot of tips - distinguish by smoker:

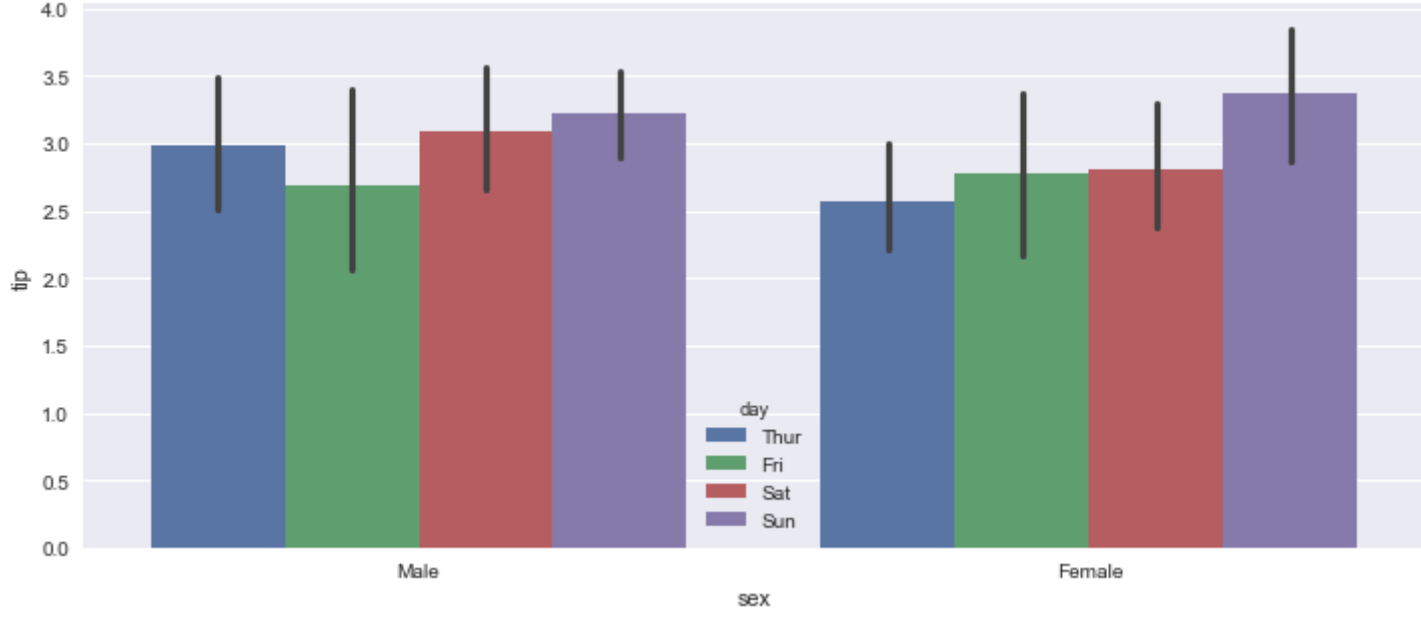
In [52]:
```
sns.boxplot(y='tip', x='smoker', data=tips)
```

Out[52]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x1aa577885c0>
```



Let's try a barplot of tips. Distinguish in addition by gender:

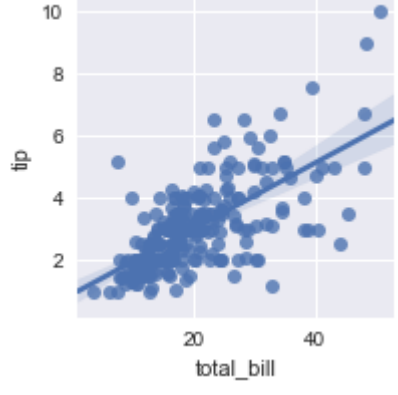
In [66]:
```
f = sns.barplot(x='sex', y='tip', hue='day',data=tips)
f.figure.savefig('tip_gender_day.png')
```



Data exploration

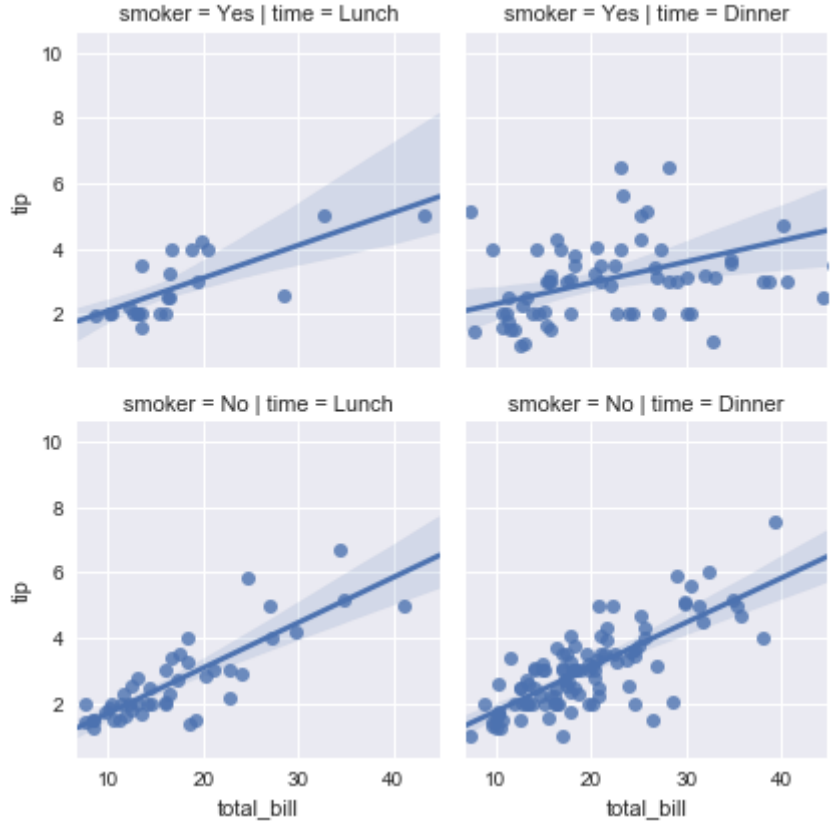
The FacetGrid

In [57]:
```
g = sns.FacetGrid(tips)
g = g.map(sns.regplot, 'total_bill', 'tip')
```



Let's try to add gender distinctive slopes

In [63]:
```
g = sns.FacetGrid(tips, row = 'smoker', col='time')
g = g.map(sns.regplot, 'total_bill', 'tip')
```



Let's try to further add seperate estimates for smoking status

In [ ]:
```
g = sns.FacetGrid(tips, col = 'smoker')
g = g.map(sns.regplot, 'total_bill', 'tip')
```

Can we say anything about smokers tipping behavior?

Summing up

Exploratory analysis

- We learned how we could leverage Pandas:
  - data in wide format
  - time series data
- We learned that Seaborn:
  - makes great, first visualization
  - powerful for exploring data patterns

Explanatory plots

- Customization is time consuming.
- Matplotlib must be configured.

If you want to learn more

Other useful plots can be found in the tutorials of Seaborn (https://seaborn.pydata.org/).

To master plot making in python the tweaking with matplotlib (https://matplotlib.org/) is essential. Worth looking into are:

- a general tutorial can be found here (https://matplotlib.org/users/pyplot_tutorial.html);
- subplots (https://matplotlib.org/examples/pylab_examples/subplots_demo.html) for multiple figures (with for loops);
- color palettes (https://matplotlib.org/users/colormaps.html) for styling figures;

Plotting network and geographic data has other types of plots - see readings (https://abjer.github.io/sds/readings/) for references to NetworkX and GeoPandas.