Sample solutions

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Since Notebook 8 is an optional assignment, we are releasing these sample solutions concurrently.

Tools for visualizing data

This notebook is a "tour" of just a few of the data visualization capabilities available to you in Python. It focuses on two packages: Bokeh (https://blog.modeanalytics.com/python-data-visualization-libraries/) for creating *interactive* plots and *[Seaborn]* for creating "static" (or non-int The former is really where the ability to develop *programmatic* visualizations, that is, code that generates graphics, really shines. But the latter i printed materials and reports. So, both techniques should be a core part of your toolbox.

With that, let's get started!

> **Note 1.** Since visualizations are not amenable to autograding, this notebook is more of a demo of what you can do. It doesn't require y write any code on your own. However, we strongly encourage you to spend some time experimenting with the basic methods here and generate some variations on your own. Once you start, you'll find it's more than a little fun!
>
> **Note 2.** Though designed for R programs, Hadley Wickham has an excellent description of many of the principles in this notebook (http://r4ds.had.co.nz/data-visualisation.html).

Part 0: Downloading some data to visualize

For the demos in this notebook, we'll need the Iris dataset. The following code cell downloads it for you.

In [1]:
```
import requests
import os
import hashlib
import io

def download(file, url_suffix=None, checksum=None):
    if url_suffix is None:
        url_suffix = file

    if not os.path.exists(file):
        url = 'https://cse6040.gatech.edu/datasets/{}'.format(url_suffix)
        print("Downloading: {} ...".format(url))
        r = requests.get(url)
        with open(file, 'w', encoding=r.encoding) as f:
            f.write(r.text)

    if checksum is not None:
        with io.open(file, 'r', encoding='utf-8', errors='replace') as f:
            body = f.read()
            body_checksum = hashlib.md5(body.encode('utf-8')).hexdigest()
            assert body_checksum == checksum, \
                "Downloaded file '{}' has incorrect checksum: '{}' instead of '{}'".format(file,
ksum, checksum)

    print("'{}' is ready!".format(file))

datasets = {'iris.csv': ('tidy', 'd1175c032e1042bec7f974c91e4a65ae'),
            'tips.csv': ('seaborn-data', 'ee24adf668f8946d4b00d3e28e470c82'),
            'anscombe.csv': ('seaborn-data', '2c824795f5d51593ca7d660986aefb87'),
            'titanic.csv': ('seaborn-data', '56f29cc0b807cb970a914ed075227f94')
           }

for filename, (category, checksum) in datasets.items():
    download(filename, url_suffix='{}/{}'.format(category, filename), checksum=checksum)

print("\n(All data appears to be ready.)")
```

```
'iris.csv' is ready!
'tips.csv' is ready!
'anscombe.csv' is ready!
'titanic.csv' is ready!

(All data appears to be ready.)
```

Part 1: Bokeh and the Grammar of Graphics ("lite")

Part 1: Bokeh and the Grammar of Graphics ("lite")

Let's start with some methods for creating an interactive visualization in Python and Jupyter, based on the Bokeh (https://bokeh.pydata.org/en/ package. It generates JavaScript-based visualizations, which you can then run in a web browser, without you having to know or write any JS yo web-friendly aspect of Bokeh makes it an especially good package for creating interactive visualizations in a Jupyter notebook, since it's also b based.

The design and use of Bokeh is based on Leland Wilkinson's Grammar of Graphics (GoG).

> If you've encountered GoG ideas before, it was probably when using the best known implementation of GoG, namely, Hadley Wickham package, ggplot2 (http://ggplot2.org/).

Setup

Here are the modules we'll need for this notebook:

In [2]:
```
from IPython.display import display, Markdown
import pandas as pd
import bokeh
```

Bokeh is designed to output HTML, which you can then embed in any website. To embed Bokeh output into a Jupyter notebook, we need to d following:

In [3]:
```
from bokeh.io import output_notebook
from bokeh.io import show
output_notebook ()
```

(https://bokeh.pydata.org)

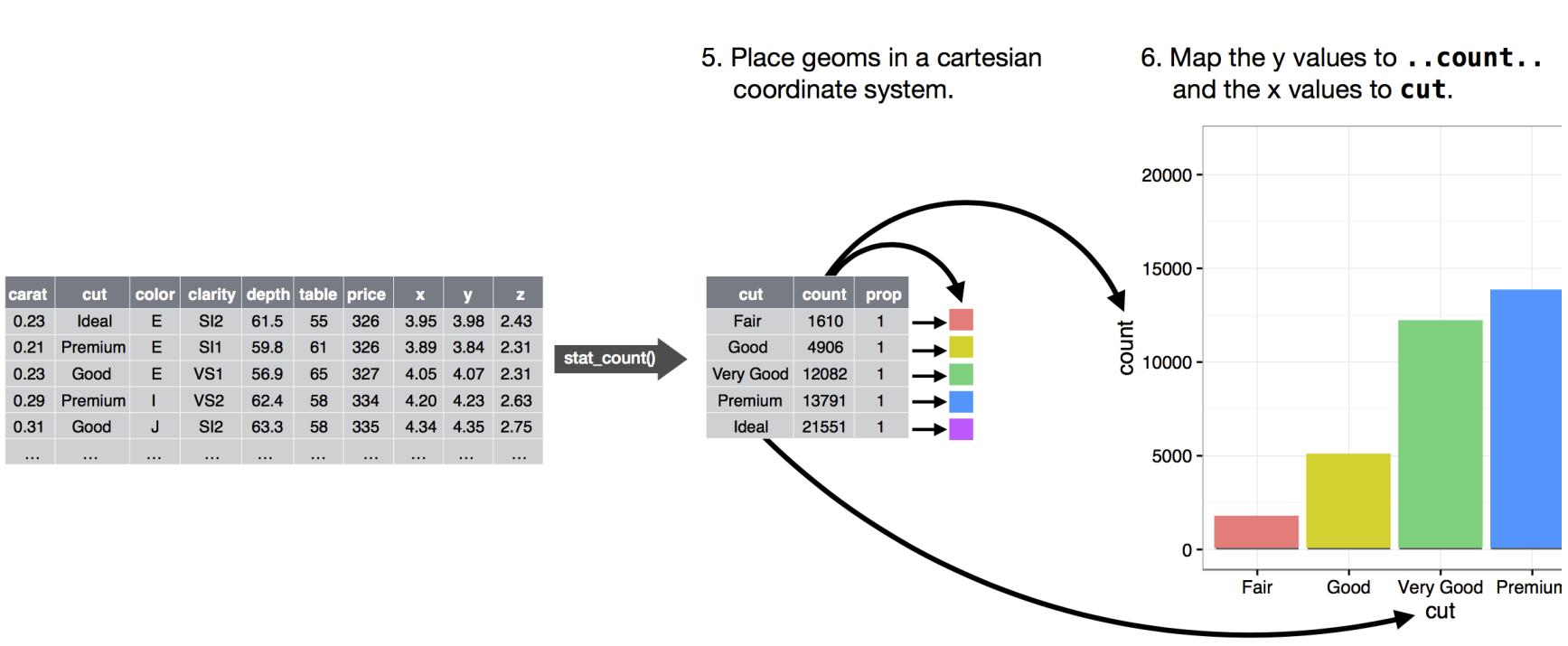
Philosophy: Grammar of Graphics

The Grammar of Graphics (http://www.springer.com.prx.library.gatech.edu/us/book/9780387245447) is an idea of Leland Wilkinson. Its basic ic way most people think about visualizing data is ad hoc and unsystematic, whereas there exists in fact a "formal language" for describing visual

The reason why this idea is important and powerful in the context of our course is that it makes visualization more systematic, thereby making i create those visualizations through code.

The high-level concept is simple:

1. Start with a (tidy) data set.
2. Transform it into a new (tidy) data set.
3. Map variables to geometric objects (e.g., bars, points, lines) or other aesthetic "flourishes" (e.g., color).
4. Rescale or transform the visual coordinate system.
5. Render and enjoy!



> This image is "liberated" from: http://r4ds.had.co.nz/data-visualisation.html (http://r4ds.had.co.nz/data-visualisation.html)

HoloViews

Before seeing Bokeh directly, let's start with an easier way to take advantage of Bokeh, which is through a higher-level interface known as Holo (http://holoviews.org/). HoloViews provides a simplified interface suitable for "canned" charts.

To see it in action, let's load the Iris data set and study relationships among its variables, such as petal length vs. petal width.

The cells below demonstrate histograms, simple scatter plots, and box plots. However, there is a much larger gallery of options: http://holoviews.org/reference/index.html (http://holoviews.org/reference/index.html)

In [4]:
```
flora = pd.read_csv ('iris.csv')
display (flora.head ())
```

	sepal length	sepal width	petal length	petal width	species
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

In [5]:
```
from bokeh.io import show
import holoviews as hv
import numpy as np
hv.extension('bokeh')
```

1. Histogram

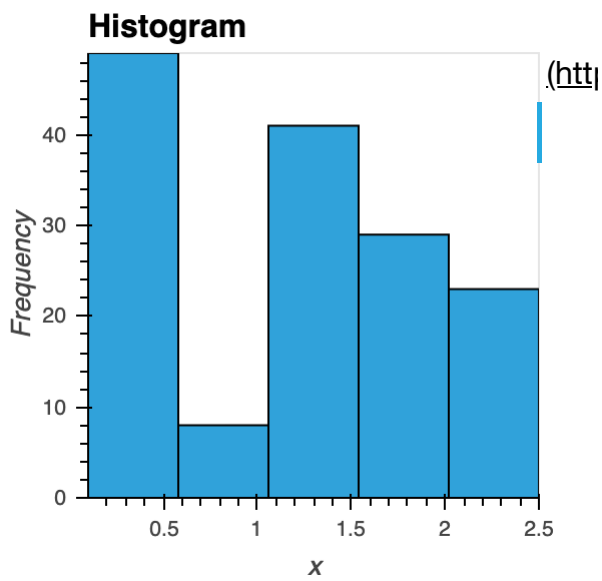
- The Histogram(f, e) can takes two arguments, frequencies and edges (bin boundaries).
- These can easily be created using numpy's histogram function as illustrated below.
- The plot is interactive and comes with a bunch of tools. You can customize these tools as well; for your many options, see http://bokeh.pydata.org/en/latest/docs/user_guide/tools.html (http://bokeh.pydata.org/en/latest/docs/user_guide/tools.html).

> You may see some warnings appear in a pink-shaded box. You can ignore these. They are caused by some slightly older version of the library that is running on Vocareum.

In [6]:
```
frequencies, edges = np.histogram(flora['petal width'], bins = 5)
hv.Histogram(frequencies, edges, label = 'Histogram')
```

```
WARNING:root:Histogram: Histogram edges should be supplied as a tuple along with the values, pas
edges will be deprecated in holoviews 2.0.
/usr/local/lib/python3.6/site-packages/bokeh/core/json_encoder.py:80: FutureWarning: Conversion
cond argument of issubdtype from `float` to `np.floating` is deprecated. In future, it will be t
`np.float64 == np.dtype(float).type`.
  elif np.issubdtype(type(obj), np.float):
```

Out[6]:



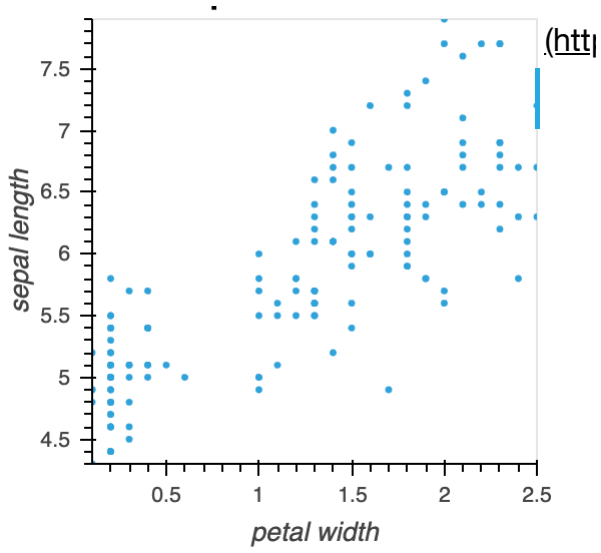
A user can interact with the chart above using the tools shown on the right-hand side. Indeed, you can select or customize these tools! You'll s below.

2. ScatterPlot

In [7]:
```
hv.Scatter(flora[['petal width','sepal length']],label = 'Scatter plot')
```

Out[7]:

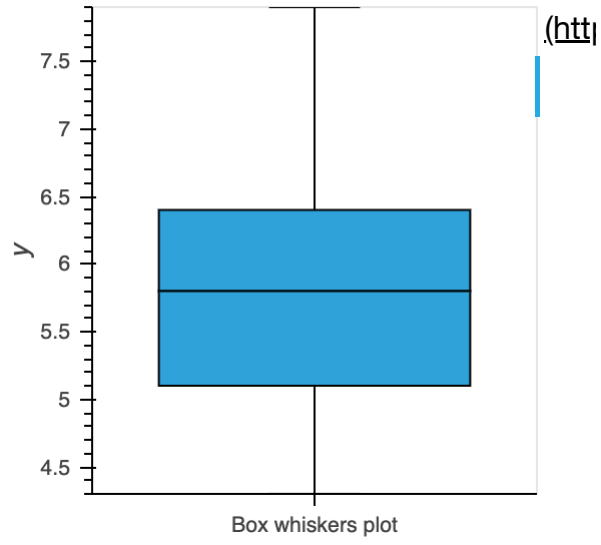
Scatter plot



3. BoxPlot

In [8]:
```
hv.BoxWhisker(flora['sepal length'], label = "Box whiskers plot")
```

Out[8]:



Mid-level charts: the Plotting interface

Beyond the canned methods above, Bokeh provides a "mid-level" interface that more directly exposes the grammar of graphics methodology f constructing visual displays.

The basic procedure is

- Create a blank canvas by calling `bokeh.plotting.figure`
- Add glyphs, which are geometric shapes.

> For a full list of glyphs, refer to the methods of `bokeh.plotting.figure`: http://bokeh.pydata.org/en/latest/docs/reference/plotting.h (http://bokeh.pydata.org/en/latest/docs/reference/plotting.html)

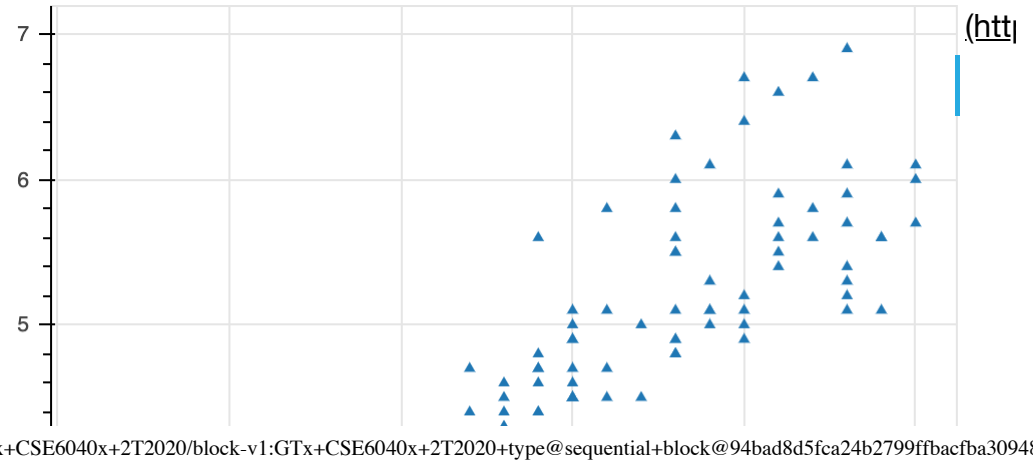
In [9]:
```
from bokeh.plotting import figure

# Create a canvas with a specific set of tools for the user:
TOOLS = 'pan,box_zoom,wheel_zoom,lasso_select,save,reset,help'
p = figure(width=500, height=500, tools=TOOLS)
print(p)
```

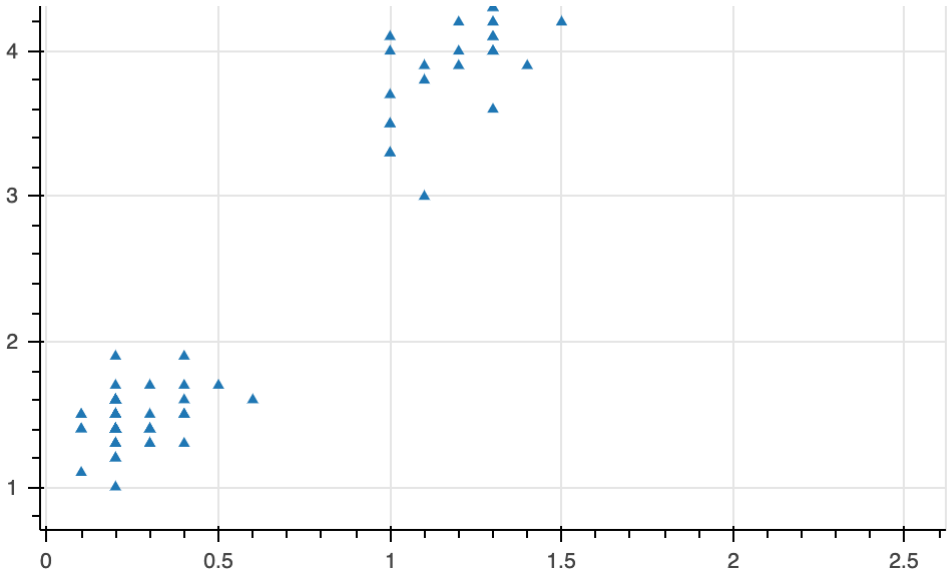
```
Figure(id='8a49e441-503c-445b-a571-5360eab653ed', ...)
```

In [10]:
```
# Add one or more glyphs
p.triangle(x=flora['petal width'], y=flora['petal length'])
```

Out[10]: **GlyphRenderer**(id = '0686e0d3-4f1c-4e31-828a-570095c61fe6', ...)

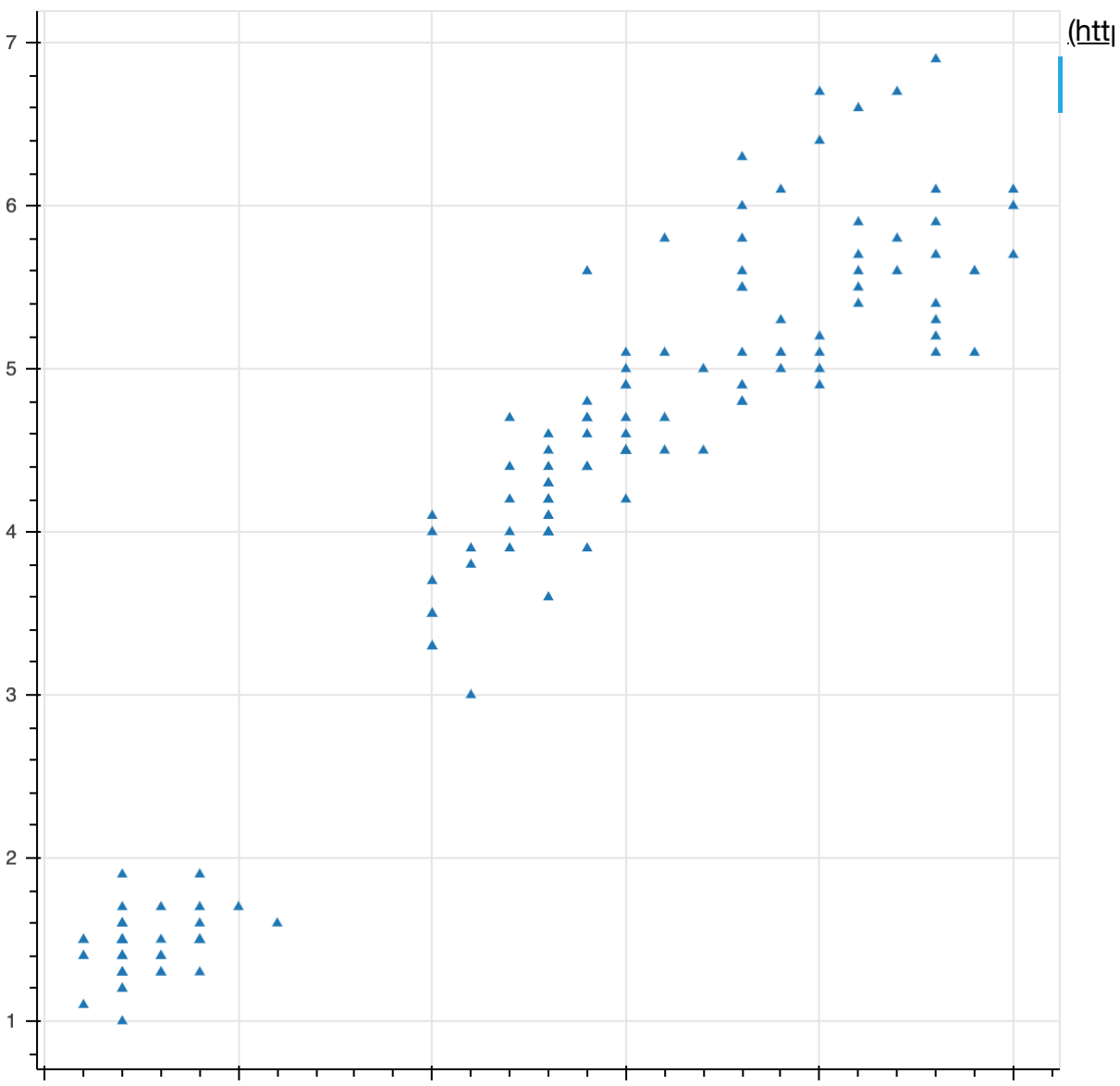
In [11]:
```
show(p)
```





Using data from Pandas. Here is another way to do the same thing, but using a Pandas data frame as input.

In [12]:
```
from bokeh.models import ColumnDataSource

data=ColumnDataSource(flora)
p=figure()
p.triangle(source=data, x='petal width', y='petal length')
show(p)
```



Color maps. Let's make a map that assigns each unique species its own color. Incidentally, there are many choices of colors!
http://bokeh.pydata.org/en/latest/docs/reference/palettes.html (http://bokeh.pydata.org/en/latest/docs/reference/palettes.html)

In [13]:
```
# Determine the unique species
unique_species = flora['species'].unique()
print(unique_species)
```

```
['Iris-setosa' 'Iris-versicolor' 'Iris-virginica']
```

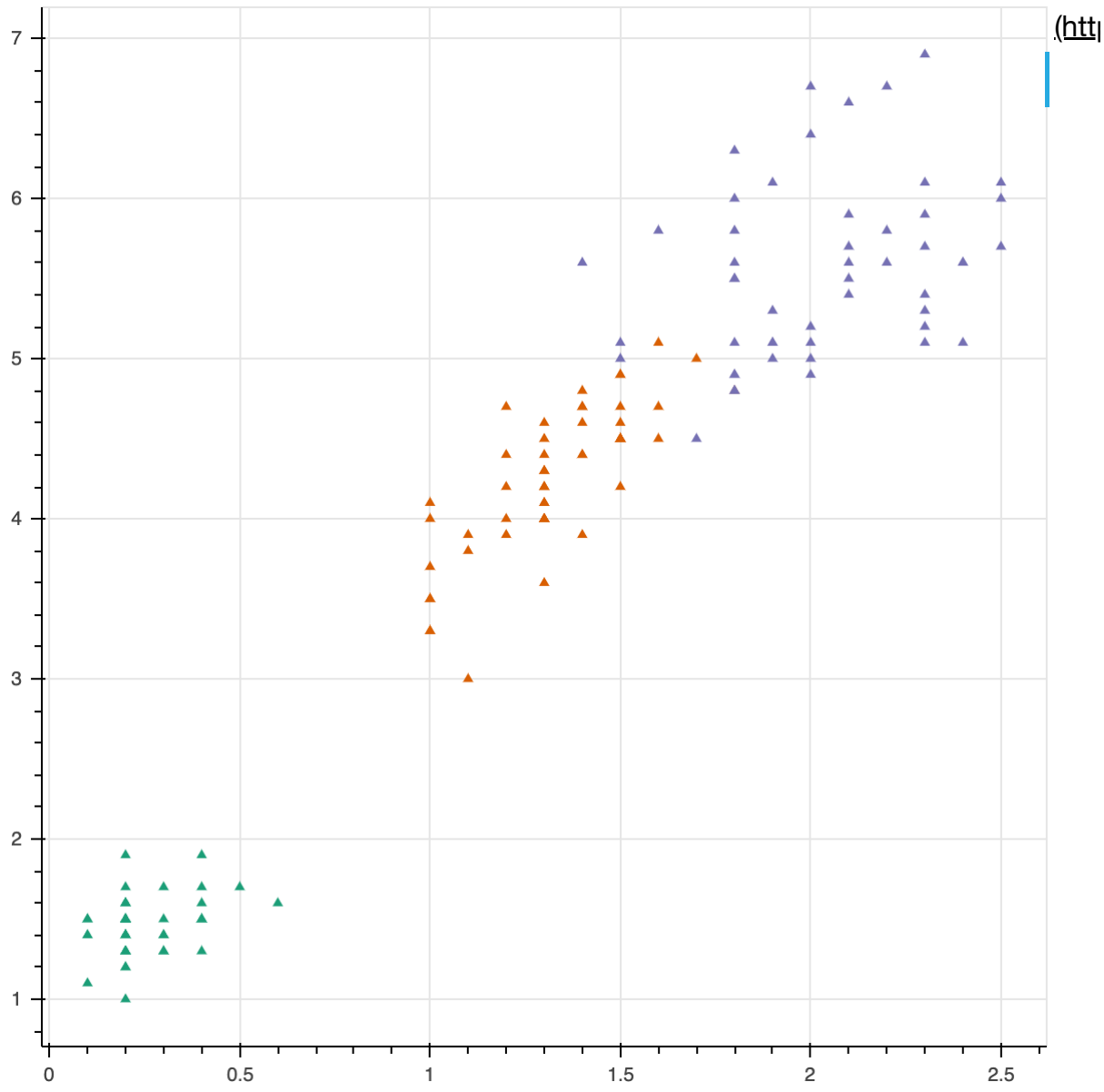
In [14]:
```
# Map each species with a unique color
from bokeh.palettes import brewer
color_map = dict(zip(unique_species, brewer['Dark2'][len(unique_species)]))
print(color_map)
```

```
{'Iris-setosa': '#1b9e77', 'Iris-versicolor': '#d95f02', 'Iris-virginica': '#7570b3'}
```

In [15]:
```
# Create data sources for each species
data_sources = {}
for s in unique_species:
    data_sources[s] = ColumnDataSource(flora[flora['species']==s])
```

Now we can more programmatically generate the same plot as above, but use a unique color for each species.

In [16]:
```
p = figure()
for s in unique_species:
    p.triangle(source=data_sources[s], x='petal width', y='petal length', color=color_map[s])
show(p)
```



That's just a quick tour of what you can do with Bokeh. We will incorporate it into some of our future labs. At this point, we'd encourage you to with the code cells above and try generating your own variations!

Part 2: Static visualizations using Seaborn

Parts of this lab are taken from publicly available Seaborn tutorials. http://seaborn.pydata.org/tutorial/distributions.html (http://seaborn.pydata.org/tutorial/distributions.html)

They were adapted for use in this notebook by Shang-Tse Chen at Georgia Tech (https://www.cc.gatech.edu/~schen351).

In [17]:
```
import seaborn as sns

# The following Jupyter "magic" command forces plots to appear inline
# within the notebook.
%matplotlib inline
```

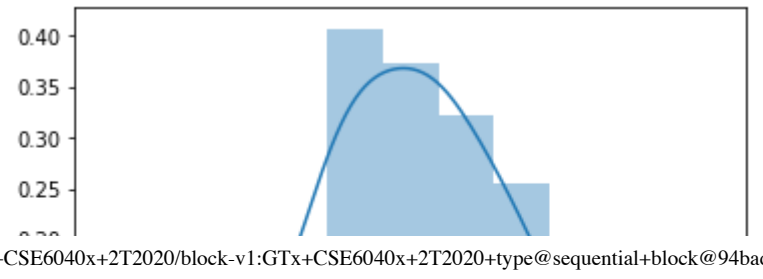
When dealing with a set of data, often the first thing we want to do is get a sense for how the variables are distributed. Here, we will look at sor in seborn for examining univariate and bivariate distributions.

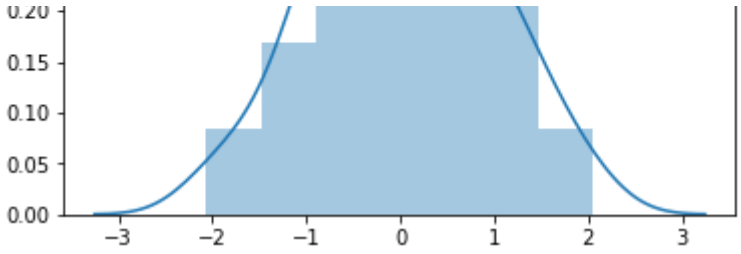
Plotting univariate distributions

distplot() function will draw a histogram and fit a kernel density estimate

In [18]:
```
import numpy as np
x = np.random.normal(size=100)
sns.distplot(x)
```

Out[18]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fb1baf902b0>
```





Plotting bivariate distributions

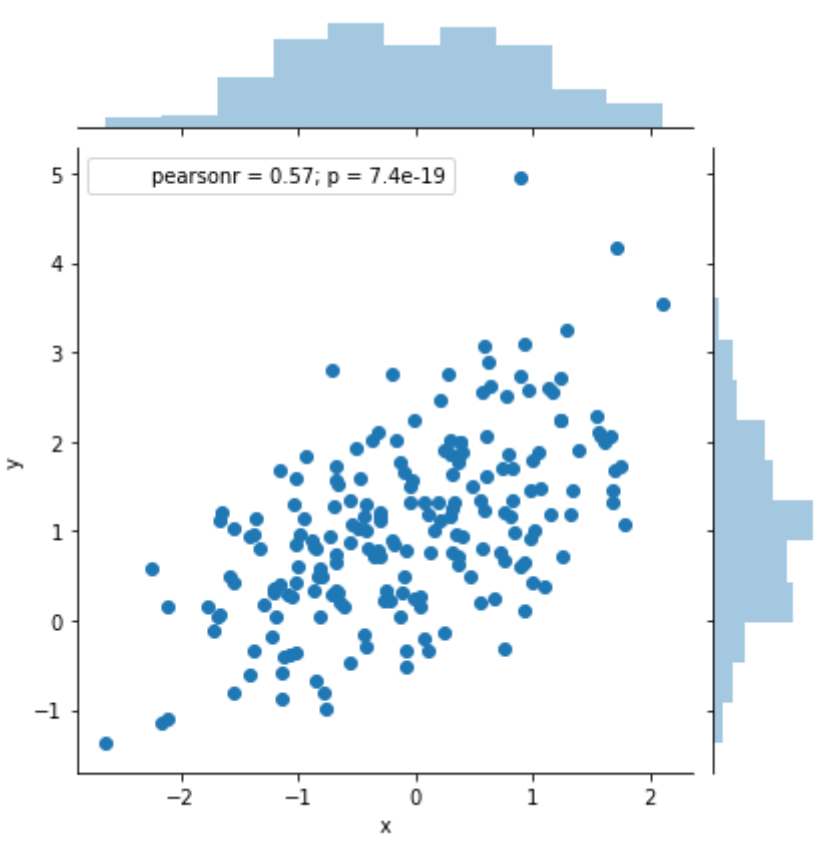
The easiest way to visualize a bivariate distribution in seaborn is to use the jointplot() function, which creates a multi-panel figure that shows bo bivariate (or joint) relationship between two variables along with the univariate (or marginal) distribution of each on separate axes.

In [19]:
```
mean, cov = [0, 1], [(1, .5), (.5, 1)]
data = np.random.multivariate_normal(mean, cov, 200)
df = pd.DataFrame(data, columns=["x", "y"])
```

Basic scatter plots. The most familiar way to visualize a bivariate distribution is a scatterplot, where each observation is shown with point at th values. You can draw a scatterplot with the matplotlib plt.scatter function, and it is also the default kind of plot shown by the jointplot() function

In [20]:
```
sns.jointplot(x="x", y="y", data=df)
```

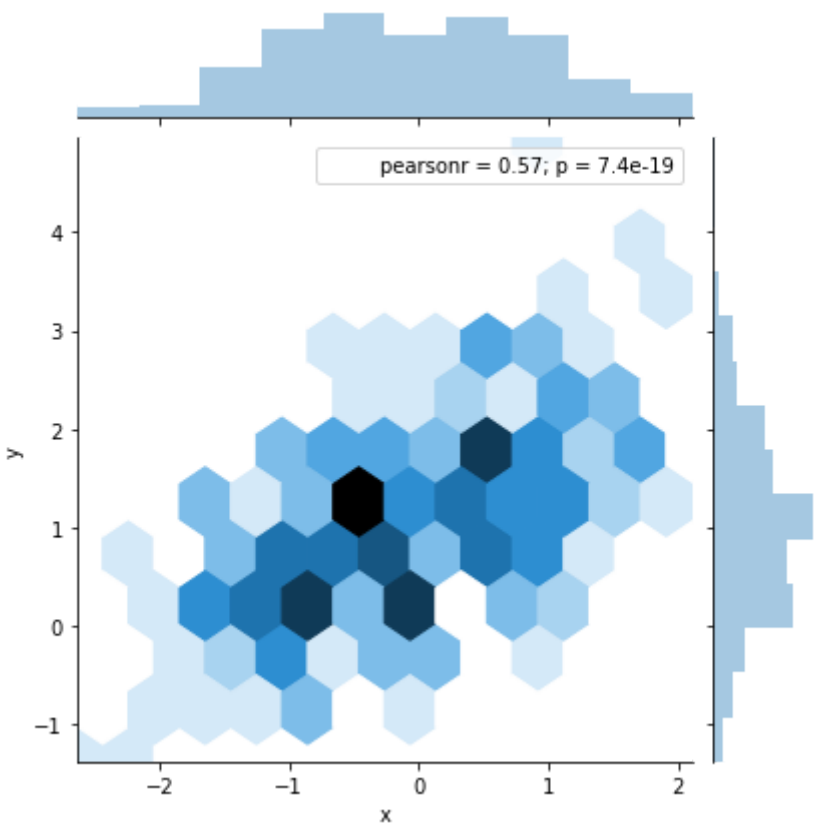
Out[20]: <seaborn.axisgrid.JointGrid at 0x7fb1b8f321d0>



Hexbin plots. The bivariate analogue of a histogram is known as a “hexbin” plot, because it shows the counts of observations that fall within h This plot works best with relatively large datasets. It’s availible through the matplotlib plt.hexbin function and as a style in jointplot()

In [21]:
```
sns.jointplot(x="x", y="y", data=df, kind="hex")
```

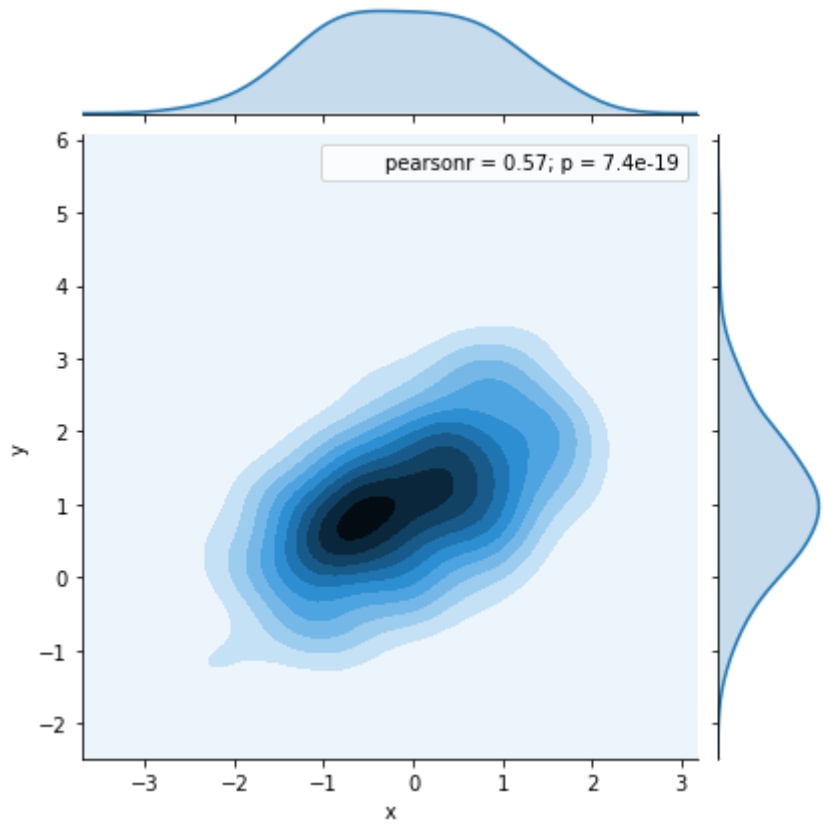
Out[21]: <seaborn.axisgrid.JointGrid at 0x7fb1b8dda6d8>



Kernel density estimation. It is also posible to use the kernel density estimation procedure described above to visualize a bivariate distributio this kind of plot is shown with a contour plot and is available as a style in jointplot()

```
In [22]: sns.jointplot(x="x", y="y", data=df, kind="kde")
```

```
Out[22]: <seaborn.axisgrid.JointGrid at 0x7fb1b8d8b898>
```

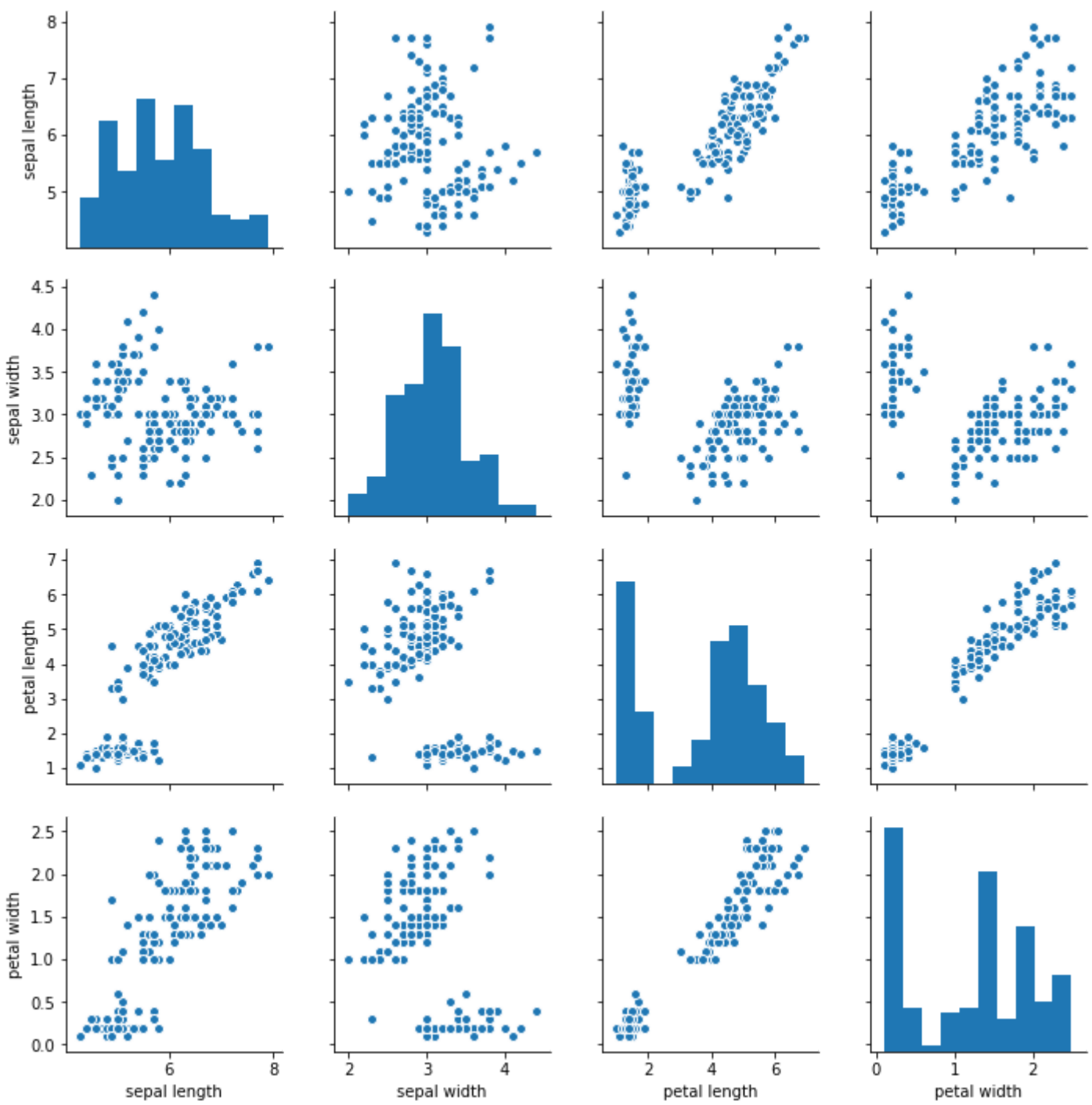


Visualizing pairwise relationships in a dataset

To plot multiple pairwise bivariate distributions in a dataset, you can use the pairplot() function. This creates a matrix of axes and shows the rela each pair of columns in a DataFrame. by default, it also draws the univariate distribution of each variable on the diagonal Axes:

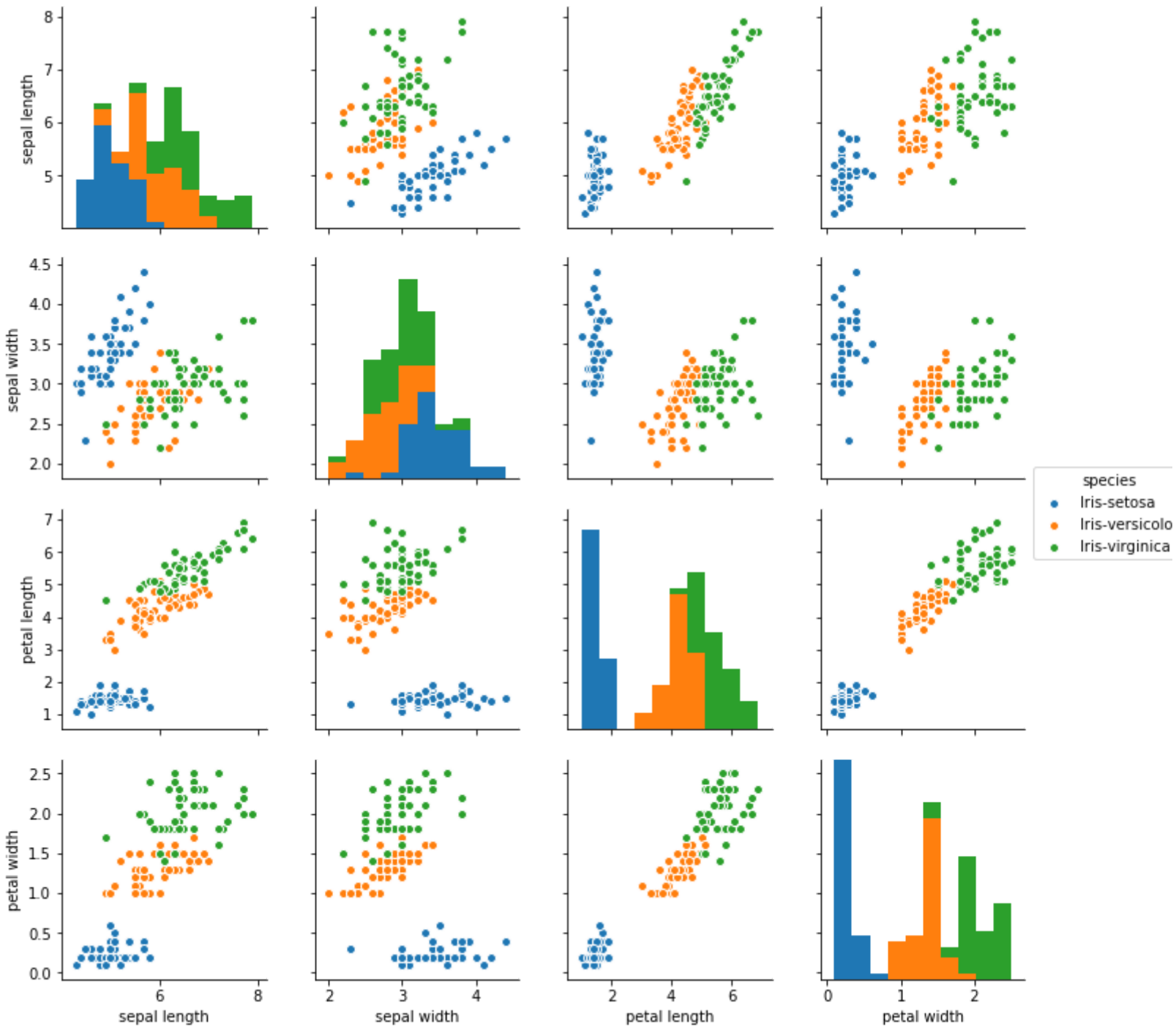
```
In [23]: sns.pairplot(flora)
```

```
Out[23]: <seaborn.axisgrid.PairGrid at 0x7fb1b8b58748>
```



In [24]:
```
# We can add colors to different species
sns.pairplot(flora, hue="species")
```

Out[24]: <seaborn.axisgrid.PairGrid at 0x7fb1b842b278>



Visualizing linear relationships

In [25]:
```
tips = pd.read_csv("tips.csv")
tips.head()
```

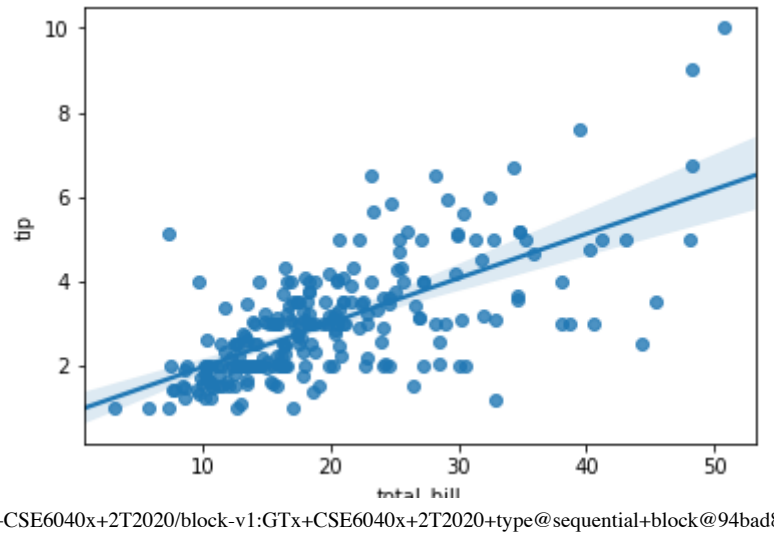
Out[25]:

	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

We can use the function `regplot` to show the linear relationship between total_bill and tip. It also shows the 95% confidence interval.

In [26]:
```
sns.regplot(x="total_bill", y="tip", data=tips)
```

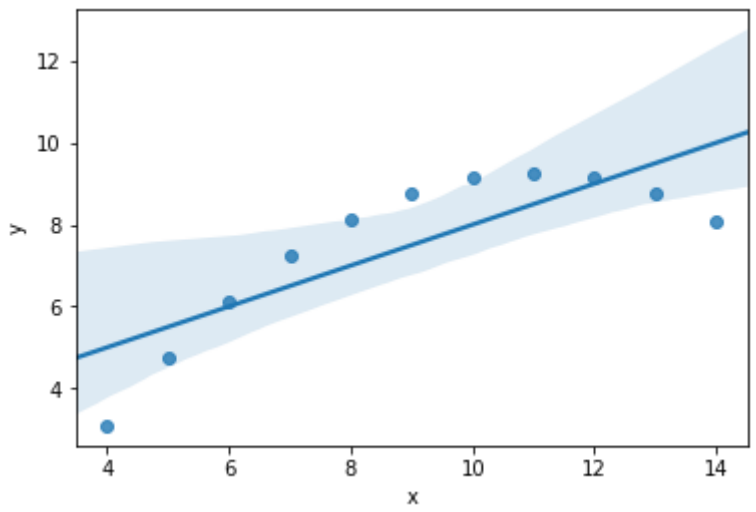
Out[26]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7d43080>



Visualizing higher order relationships

```
In [27]: anscombe = pd.read_csv("anscombe.csv")
         sns.regplot(x="x", y="y", data=anscombe[anscombe["dataset"] == "II"])
```

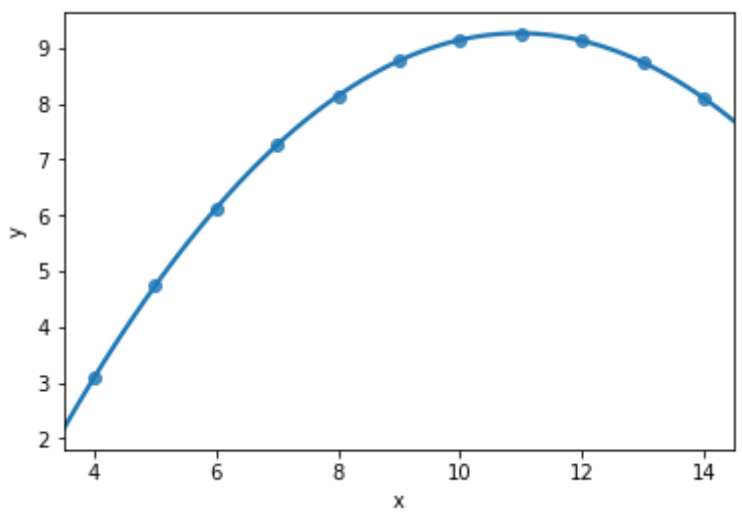
```
Out[27]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7cc9dd8>
```



The plot clearly shows that this is not a good model. Let's try to fit a polynomial regression model with degree 2.

```
In [28]: sns.regplot(x="x", y="y", data=anscombe[anscombe["dataset"] == "II"], order=2)
```

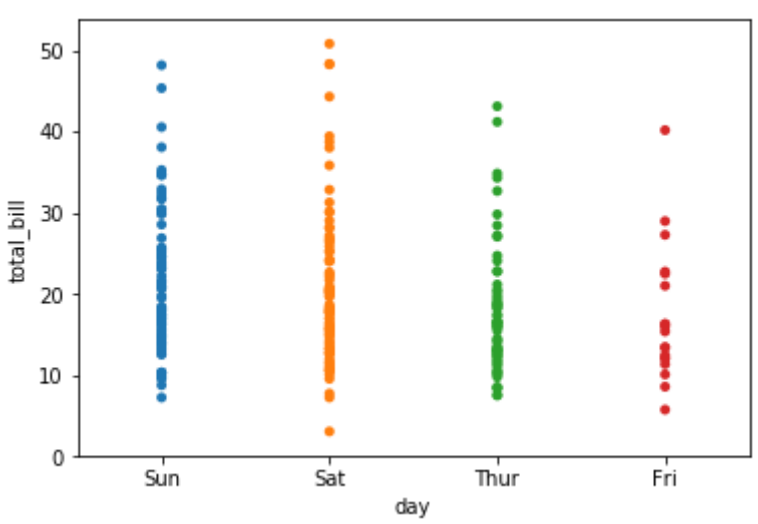
```
Out[28]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7c29da0>
```



Strip plots. This is similar to scatter plot but used when one variable is categorical.

```
In [29]: sns.stripplot(x="day", y="total_bill", data=tips)
```

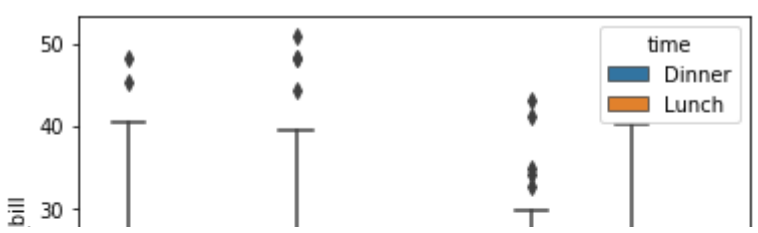
```
Out[29]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7c50358>
```

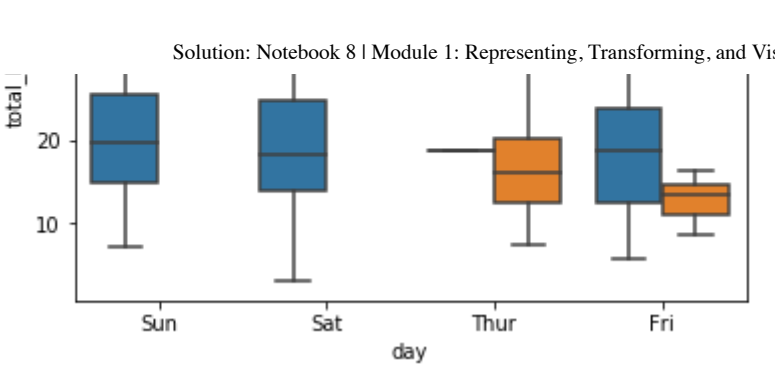


Box plots.

```
In [30]: sns.boxplot(x="day", y="total_bill", hue="time", data=tips)
```

```
Out[30]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7c03940>
```

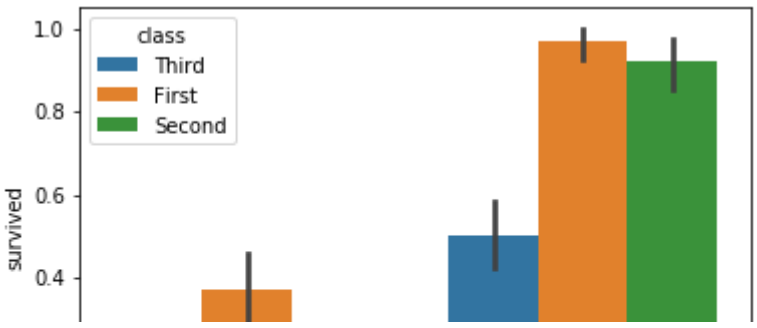




Bar plots.

In [31]:
```
titanic = pd.read_csv("titanic.csv")
sns.barplot(x="sex", y="survived", hue="class", data=titanic)
```

Out[31]: <matplotlib.axes._subplots.AxesSubplot at 0x7fb1b7accf98>



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