Matplotlib and Seaborn

Library for data analysis

- **NumPy** (Numerical Python)
  - Large multidimensional array operations
- **SciPy** (Scientific Python)
  - Many efficient numerical routines such as routines for numerical integration and optimization
- **Pandas**
  - Data manipulation and data visualization
- **Matplotlib**
  - Data exploration and data visualization
- **Seaborn**
  - High-level data visualization library based on Matplotlib
- **Scikit-learn**
  - Machine learning and statistical modeling

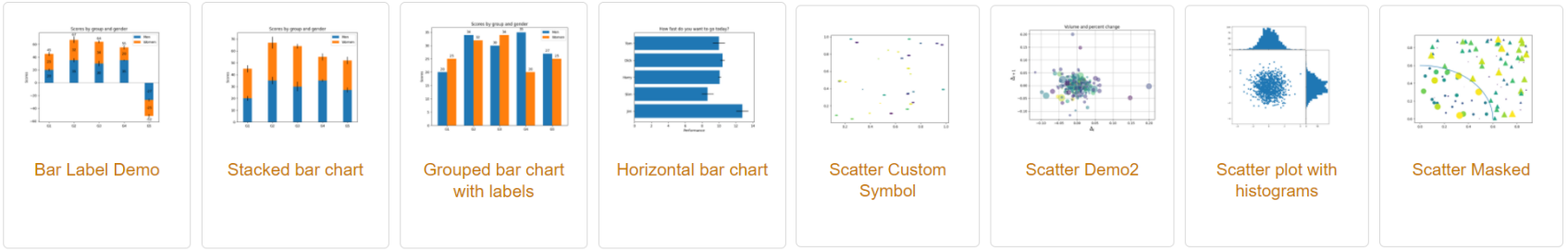
Outline

- Matplotlib
  - Single plot
  - Multiple plot
  - Secondary y-axis

- Seaborn
  - X-axis with categorical data
    - Countplot, barplot, heatmap
  - Numerical data
    - Histogram, scatter plot, joint plot, pair plot
  - Facet Grid

Matplotlib

- **matplotlib**
  - Matplotlib is a low-level data visualization library in python.



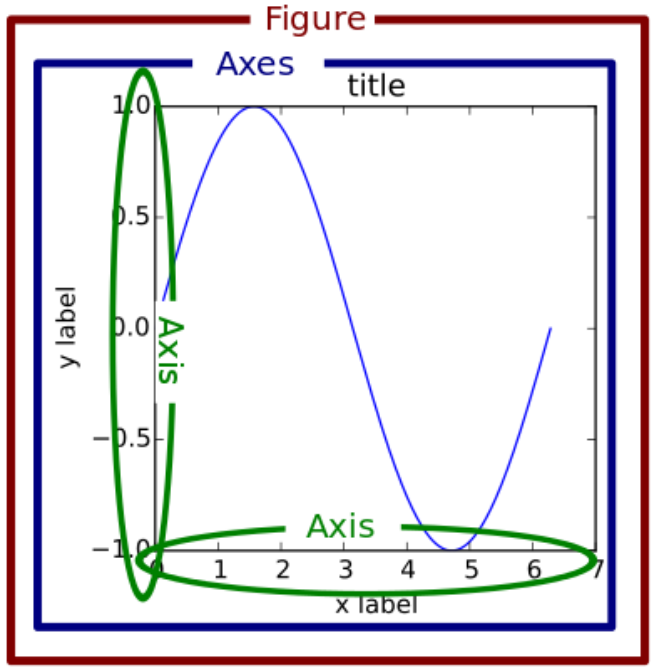
- **matplotlib.pyplot**
  - Pyplot is a subset of matplotlib, which is a collection of the most commonly used plotting functions.

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


https://matplotlib.org/stable/gallery/index.html
https://matplotlib.org/stable/tutorials/introductory/pyplot.html

Matplotlib – figure and axes

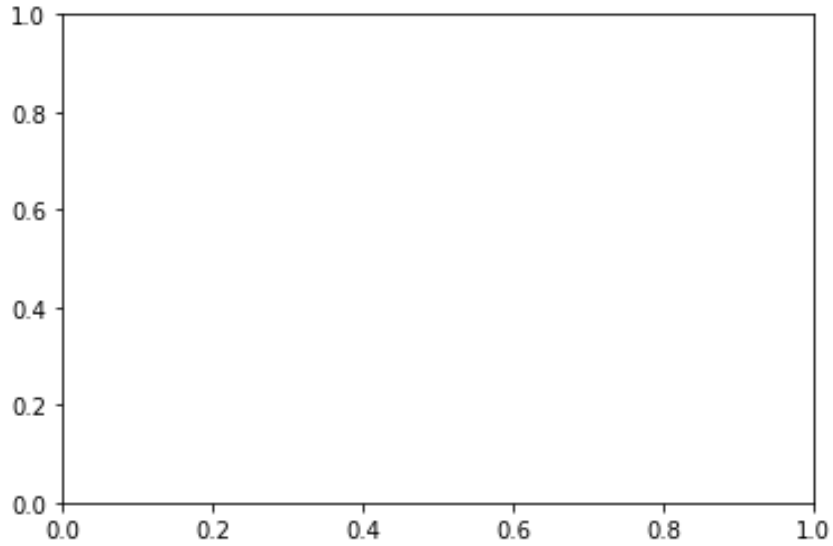
- Figure object: The outermost container for matplotlib plots, which can contain multiple Axes objects.
- Axes object: The axes is the area your plot appears in. (In matplotlib, axes is not the plural form of axis)



Matplotlib – single plot (1/3)

- Step1: Create figure and axes
- Step2: Plot a chart in axes
- Step3: Format the style

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(6, 4))
ax1 = fig.add_subplot()
```




```
type(fig)
```

```
matplotlib.figure.Figure
```

```
type(ax1)
```

```
matplotlib.axes._subplots.AxesSubplot
```

Matplotlib – single plot (2/3)

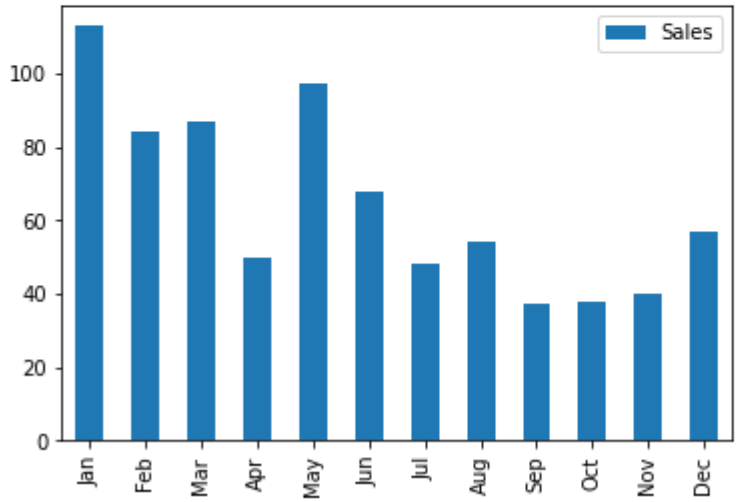
- Step1: Create figure and axes
- Step2: Plot a chart in axes
- Step3: Format the style

	Sales	Cumulative_sales
Jan	113	113
Feb	84	197
Mar	87	284
Apr	50	334
May	97	431
Jun	68	499
Jul	48	547
Aug	54	601
Sep	37	638
Oct	38	676
Nov	40	716
Dec	57	773

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(6, 4))
ax1 = fig.add_subplot()

#step2: Plot a chart in axes
sales_df.plot(kind = "bar", y = "Sales", ax = ax1)
```

```
<AxesSubplot:>
```



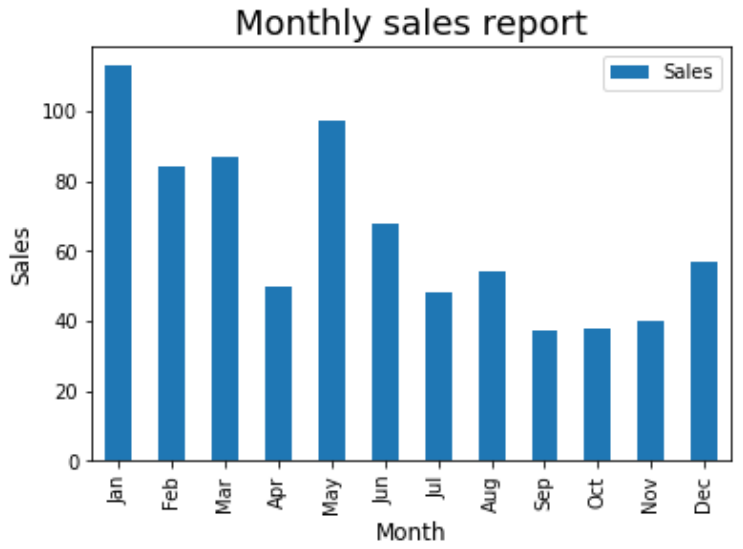
Matplotlib – single plot (3/3)

- Step1: Create figure and axes
- Step2: Plot a chart in axes
- Step3: Format the style

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(6, 4))
ax1 = fig.add_subplot()

#step2: Plot a chart in axes
sales_df.plot(kind = "bar", y = "Sales", ax = ax1)

#step3: Format the style
ax1.set_title("Monthly sales report", fontsize=18)
ax1.set_xlabel("Month", fontsize=12)
ax1.set_ylabel("Sales", fontsize=12);
```



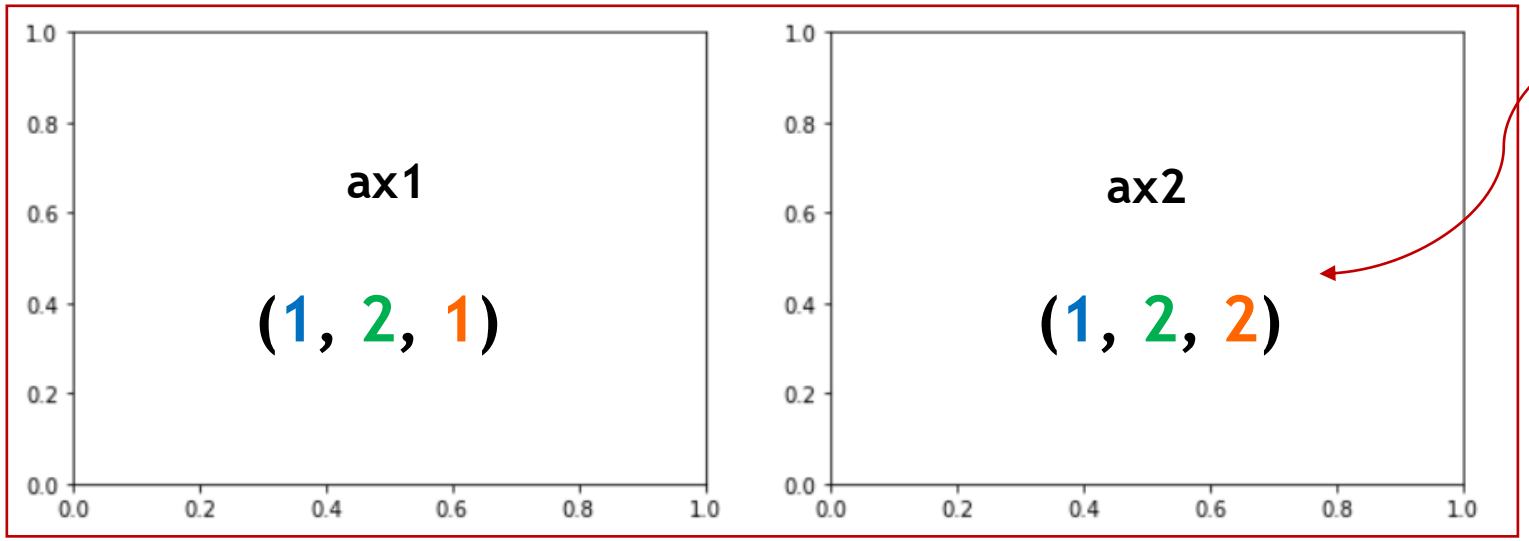
https://matplotlib.org/stable/api/axes_api.html

Matplotlib – multiple plots

- Use three integers (nrows, ncols, index) to describe the positions.
- The subplot will take the index position on a grid with nrows rows and ncols columns. index starts at 1 in the upper left corner and increases to the right.

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(12,4))
ax1 = fig.add_subplot(1,2,1)
ax2 = fig.add_subplot(1,2,2)
```

fig



1 x 2 grid

1 (1,2,1)	2 (1,2,2)

2 x 3 grid

1 (2,3,1)	2 (2,3,2)	3 (2,3,3)
4 (2,3,4)	5 (2,3,5)	6 (2,3,6)

https://matplotlib.org/stable/api/_as_gen/matplotlib.pyplot.subplot.html

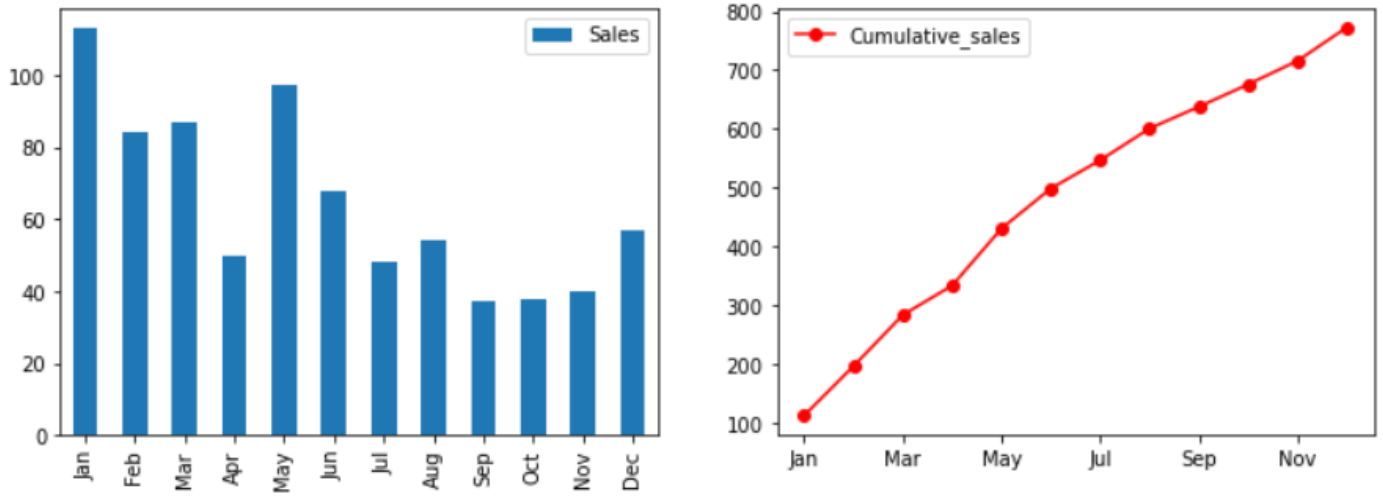
Matplotlib – multiple plots

- Assign axes by the argument `ax`.

	Sales	Cumulative_sales
Jan	113	113
Feb	84	197
Mar	87	284
Apr	50	334
May	97	431
Jun	68	499
Jul	48	547
Aug	54	601
Sep	37	638
Oct	38	676
Nov	40	716
Dec	57	773

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(12,4))
ax1 = fig.add_subplot(1,2,1)
ax2 = fig.add_subplot(1,2,2)
#step2: Plot a chart in axes
sales_df.plot(kind = "bar", y = "Sales", ax = ax1)
sales_df.plot(kind = "line", y = "Cumulative_sales", ax = ax2, color = "red", marker = "o")
```

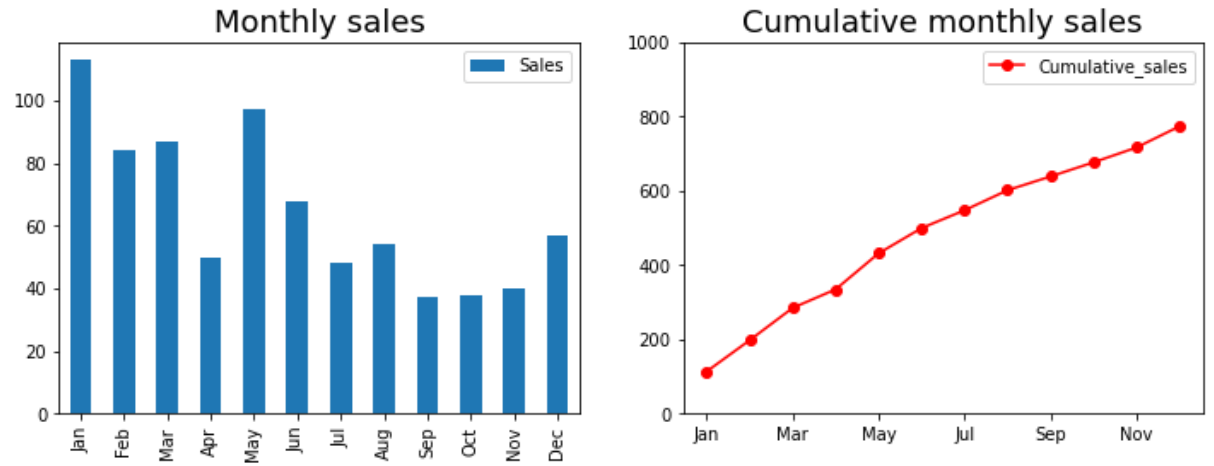
```
<AxesSubplot:>
```



Matplotlib – multiple plots

- Plot charts in axes and format the charts

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(12,4))
ax1 = fig.add_subplot(1,2,1)
ax2 = fig.add_subplot(1,2,2)
#step2: Plot a chart in axes
sales_df.plot(kind = "bar", y = "Sales", ax=ax1)
sales_df.plot(kind = "line", y = "Cumulative_sales", ax=ax2, color = "red", marker = "o")
#step3: Format the style
ax1.set_title("Monthly sales", fontsize = 18)
ax2.set_title("Cumulative monthly sales", fontsize = 18)
ax2.set_ylim([0,1000]);
```

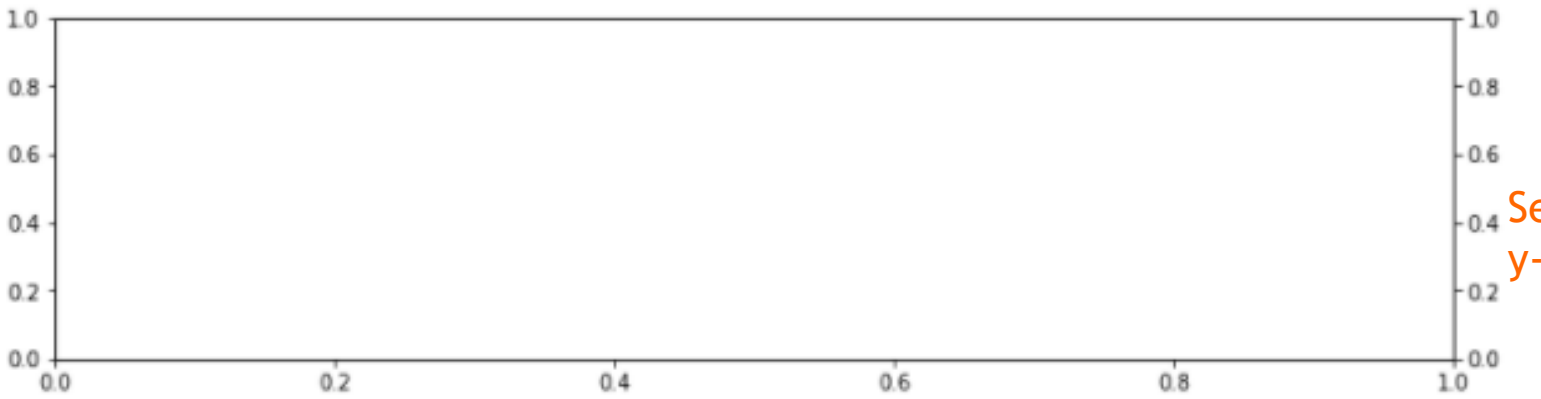


Matplotlib – Single plot with secondary y-axis

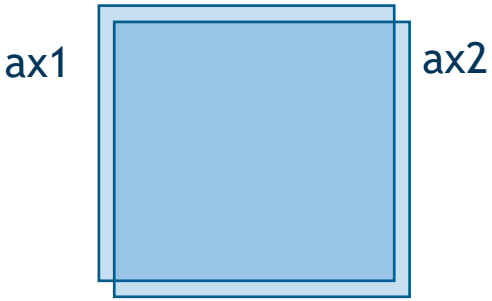
- In some cases, we need the secondary y-axis: it allows you to use the same X axis with two different sets of Y-axis data with two different scales.

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(12,3))
ax1 = fig.add_subplot()
ax2 = ax1.twinx()
```

Share the same x-axis as ax1

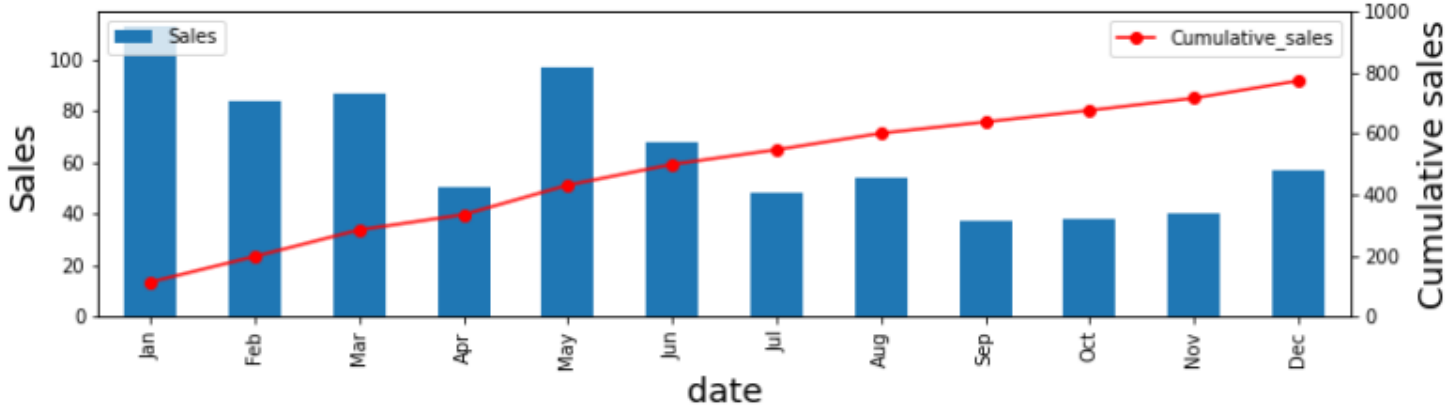


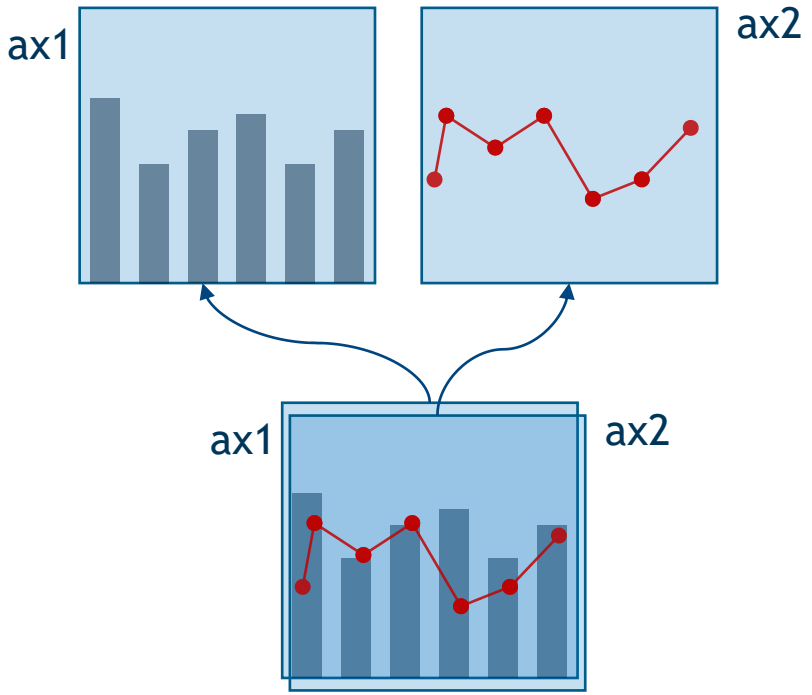
Secondary y-axis



Matplotlib – Single plot with secondary y-axis

```
#step1: Create a figure and axes
fig = plt.figure(figsize=(12,3))
ax1 = fig.add_subplot()
ax2 = ax1.twinx()
#step2: Plot a chart in axes
sales_df.plot(kind = "bar", y = "Sales", ax=ax1)
sales_df.plot(kind = "line", y = "Cumulative_sales", ax=ax2, color = "red", marker = "o")
#step3: Format the style
ax1.set_xlabel("date", fontsize = 18)
ax1.set_ylabel("Sales", fontsize = 18)
ax1.legend(loc="upper left")
ax2.set_ylabel("Cumulative sales", fontsize = 18)
ax2.set_ylim([0,1000])
ax2.legend(loc="upper right");
```





Exercise

(A.1) Given the synthetic dataset above, each column represents the quarterly sales of products A, B, and C. Create a figure with three bar charts to show the sales data of each product.

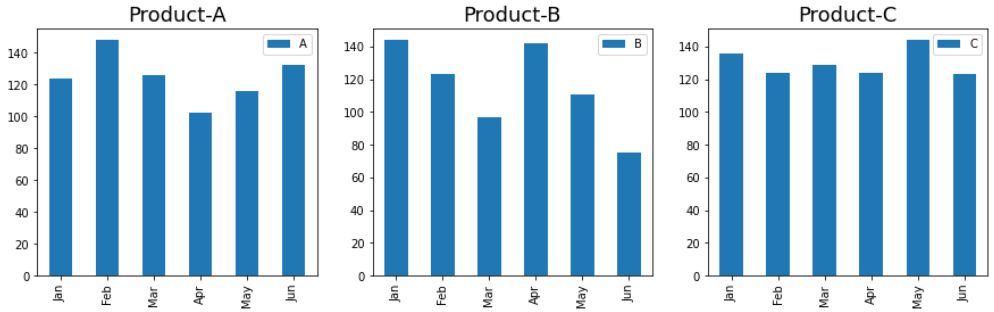
Setting: `figsize = (15,4)`

```
#step1: Create a figure and axes

#step2: Plot a chart in axes

#step3: Format the style
```

	A	B	C
Jan	124	144	136
Feb	148	123	124
Mar	126	97	129
Apr	102	142	124
May	116	111	144
Jun	132	75	123



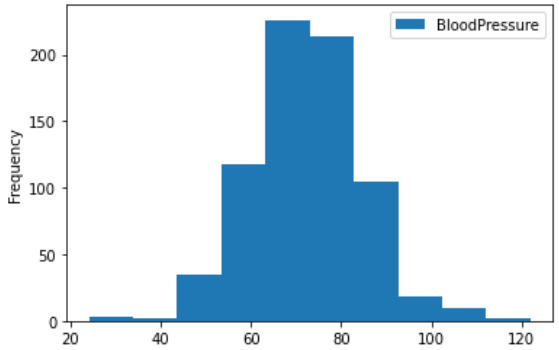
1 x 3 grid

1 (1,3,1)	2 (1,3,2)	3 (1,3,3)

Different plotting methods

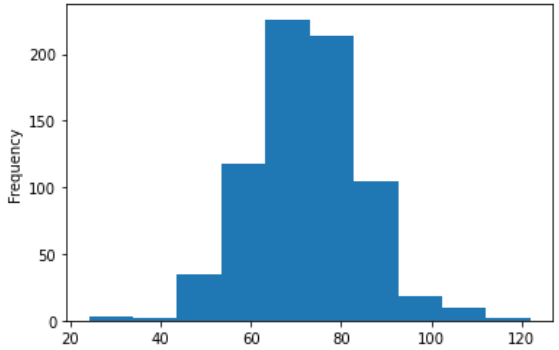
Pandas

```
diabetes_df.plot(kind = "hist", y = "BloodPressure");
```



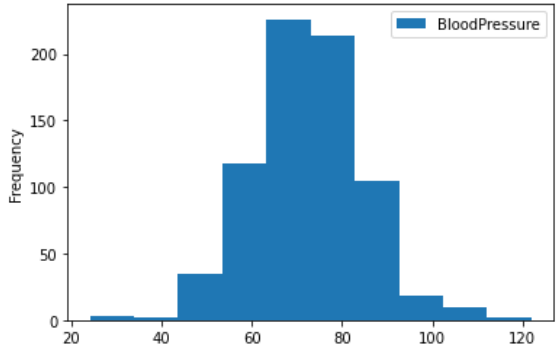
Matplotlib

```
plt.hist(diabetes_df.BloodPressure)
plt.ylabel('Frequency')
plt.show()
```



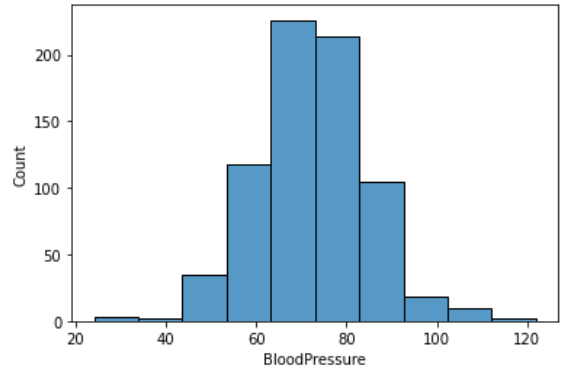
Matplotlib
(Create a container)
Pandas
(plot)

```
fig = plt.figure(figsize=(6, 4))
ax1 = fig.add_subplot()
diabetes_df.plot(kind = "hist", y = "BloodPressure", ax=ax1);
```



Seaborn

```
sns.histplot(data = diabetes_df, x = "BloodPressure", bins = 10);
```



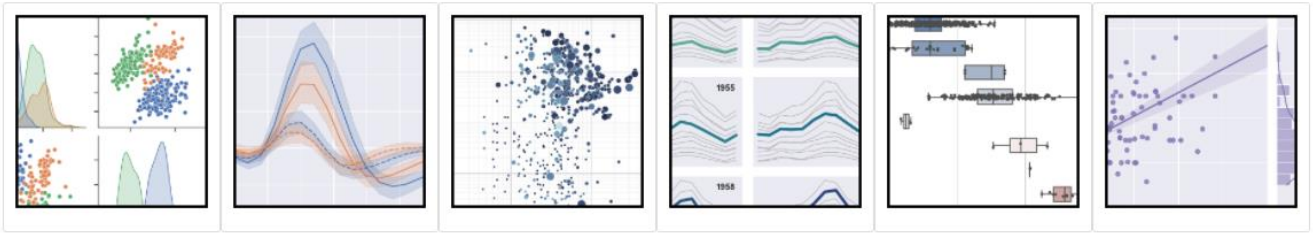
Outline

- Matplotlib
  - Single plot
  - Multiple plot
  - Secondary y-axis

- Seaborn
  - X-axis with categorical data
    - Countplot, barplot, heatmap
  - Numerical data
    - Histogram, scatter plot, joint plot, pair plot
  - Facet Grid

Seaborn

- Seaborn is a package that provides many types of insightful plots. You can write simple code to visualize complex graphics.



- Data structures accepted by seaborn
  - Objects from pandas or numpy
  - Long-form and wide-form
- Installation

```
pip install seaborn
```

```
import seaborn as sns
```

https://seaborn.pydata.org/
https://seaborn.pydata.org/tutorial/data_structure.html
sns: https://en.wikipedia.org/wiki/Sam_Seaborn

Countplot

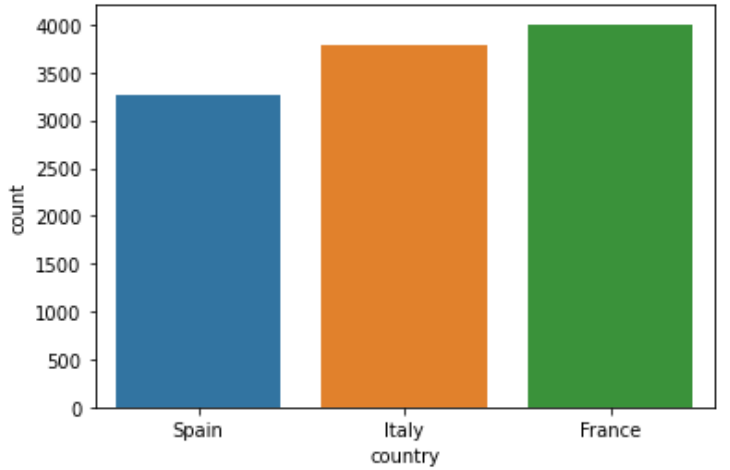
- Use `countplot()` to show the counts of observations in each bar.
- Pass arguments: `data`, `x`

	country	description	designation	points	price	province	region_1	region_2	variety	winery
51	France	This structured, complex Chardonnay is packed ...	NaN	90	68.0	Burgundy	Chassagne-Montrachet	NaN	Chardonnay	Chartron et Trébuchet
53	France	With its light color and cool feel, this well-...	L'Inédit	90	28.0	Loire Valley	Coteaux du Giennois	NaN	Pinot Noir	Clement et Florian Berthier
63	France	L'Homme Mort is a northern extension of the Fo...	L'Homme Mort Premier Cru	91	45.0	Burgundy	Chablis	NaN	Chardonnay	Domaine Chenevières
66	France	The steely character of a young Chablis is ver...	Fourchaume Premier Cru	91	38.0	Burgundy	Chablis	NaN	Chardonnay	Louis Max
76	France	This wine is bone-dry, although with some age ...	Le Nombre d'Or Brut Nature	91	85.0	Champagne	Champagne	NaN	Chardonnay	Aubry
...	...	...	...	...	...	...	...	...	...	...
150908	France	Another premier cru from Michel Gros, this one...	Aux Brulees	90	65.0	Burgundy	Vosne-Romanée	NaN	Pinot Noir	Michel Gros
150909	France	This is a lovely, fragrant Burgundy, with a sm...	Clos dea Argillieres	89	52.0	Burgundy	Nuits-St.-Georges	NaN	Pinot Noir	Daniel Rion
150910	France	Scents of graham cracker and malted milk choco...	NaN	89	38.0	Burgundy	Chambolle-Musigny	NaN	Pinot Noir	Michel Gros
150911	France	This needs a good bit of breathing time, then ...	Les Chaliots	87	37.0	Burgundy	Nuits-St.-Georges	NaN	Pinot Noir	Michel Gros
150912	France	The nose is dominated by the attractive scents...	Les Charmes	87	65.0	Burgundy	Chambolle-Musigny	NaN	Pinot Noir	Daniel Rion

4580 rows × 10 columns

```
sns.countplot(data = wine_df, x = "country")
```

```
<AxesSubplot:xlabel='country', ylabel='count'>
```



The bar height is the number of wines of each country.

No need to group data in advance

```
wine_df.groupby("country").size()
```

```
country
France    4004
Italy     3783
Spain     3258
dtype: int64
```

Understand the data behind the chart

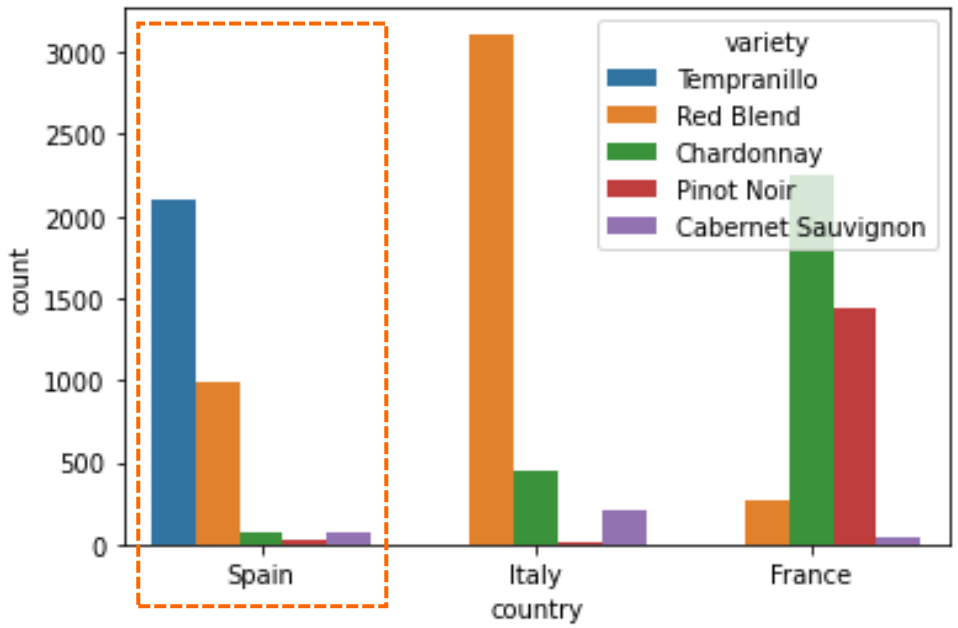
https://seaborn.pydata.org/generated/seaborn.countplot.html

Countplot

- Use the argument hue to specify the categorical variable used for color encoding.

```
sns.countplot(data = wine_df, x = "country", hue = "variety")
```

```
<AxesSubplot:xlabel='country', ylabel='count'>
```




```
wine_df.groupby(["country","variety"]).size()
```

```
country  variety
France   Cabernet Sauvignon      44
         Chardonnay            2247
         Pinot Noir            1446
         Red Blend              267
Italy    Cabernet Sauvignon      214
         Chardonnay              450
         Pinot Noir                7
         Red Blend              3111
         Tempranillo               1
Spain    Cabernet Sauvignon       74
         Chardonnay               67
         Pinot Noir               31
         Red Blend               987
         Tempranillo            2099
dtype: int64
```

Understand the data behind the chart

Barplot

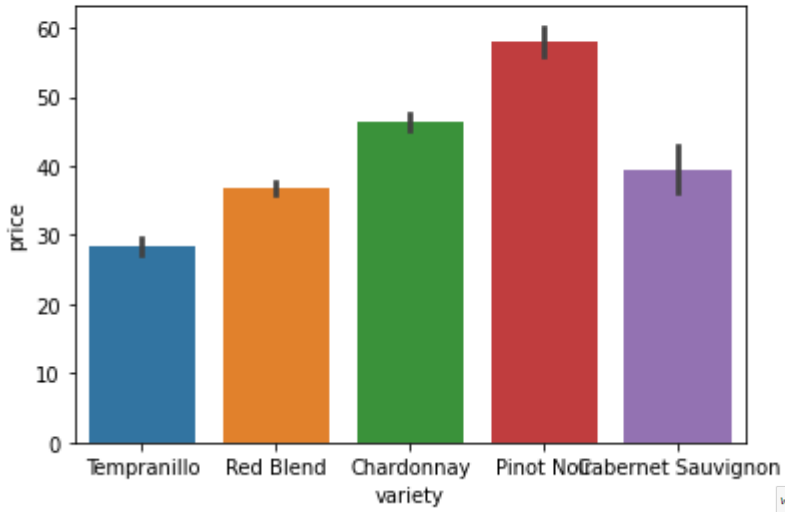
- Use `barplot()` to draw a bar chart grouped by a categorical variable.
- A bar plot shows the mean (or other estimator) value.

	country	description	designation	points	price	province	region_1	region_2	variety	winery
51	France	This structured, complex Chardonnay is packed ...	NaN	90	68.0	Burgundy	Chassagne-Montrachet	NaN	Chardonnay	Chartron et Trébuchet
53	France	With its light color and cool feel, this well-...	L'Inédit	90	28.0	Loire Valley	Coteaux du Giennois	NaN	Pinot Noir	Clement et Florian Berthier
63	France	L'Homme Mort is a northern extension of the Fo...	L'Homme Mort Premier Cru	91	45.0	Burgundy	Chablis	NaN	Chardonnay	Domaine Chenevières
66	France	The steely character of a young Chablis is ver...	Fourchaume Premier Cru	91	38.0	Burgundy	Chablis	NaN	Chardonnay	Louis Max
76	France	This wine is bone-dry, although with some age ...	Le Nombre d'Or Brut Nature	91	85.0	Champagne	Champagne	NaN	Chardonnay	Aubry
...	...	...	...	...	...	...	...	...	...	...
150908	France	Another premier cru from Michel Gros, this one...	Aux Brulees	90	65.0	Burgundy	Vosne-Romanée	NaN	Pinot Noir	Michel Gros
150909	France	This is a lovely, fragrant Burgundy, with a sm...	Clos dea Argillieres	89	52.0	Burgundy	Nuits-St.-Georges	NaN	Pinot Noir	Daniel Rion
150910	France	Scents of graham cracker and malted milk choco...	NaN	89	38.0	Burgundy	Chambolle-Musigny	NaN	Pinot Noir	Michel Gros
150911	France	This needs a good bit of breathing time, then ...	Les Chaliots	87	37.0	Burgundy	Nuits-St.-Georges	NaN	Pinot Noir	Michel Gros
150912	France	The nose is dominated by the attractive scents...	Les Charmes	87	65.0	Burgundy	Chambolle-Musigny	NaN	Pinot Noir	Daniel Rion

4580 rows × 10 columns

```
sns.barplot(data = wine_df, x = "variety", y = "price")
```

```
<AxesSubplot:xlabel='variety', ylabel='price'>
```



The bar height is the average price of each grape variety.

```
wine_df.groupby("variety").mean().price
```

```
variety
Cabernet Sauvignon    39.490964
Chardonnay            46.447540
Pinot Noir            58.053908
Red Blend             36.891409
Tempranillo           28.294762
Name: price, dtype: float64
```

http://seaborn.pydata.org/generated/seaborn.barplot.html#seaborn.barplot

Heatmap

- A heatmap is a two-dimensional visual representation of data using colors, where the colors all represent different values.

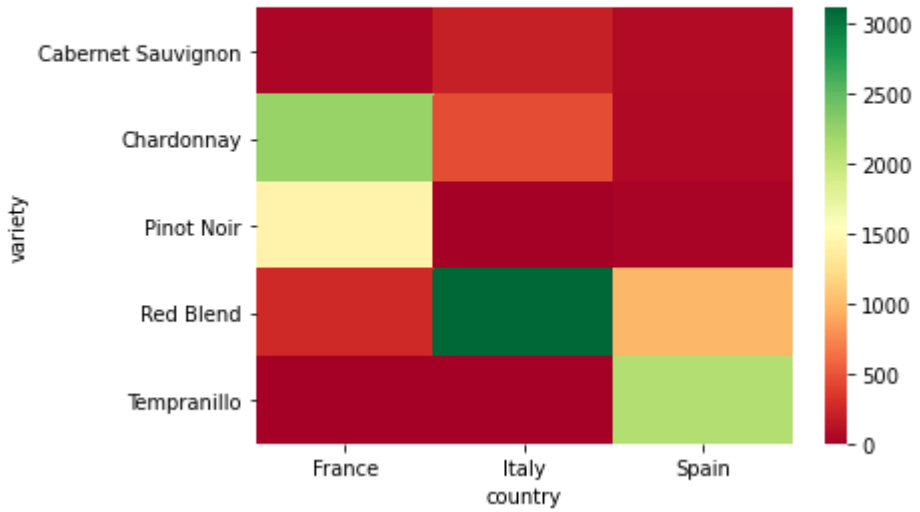
```
# data preparation
heatmap_data = pd.crosstab(wine_df["variety"],wine_df["country"])
heatmap_data
```

variety \ country	France	Italy	Spain
Cabernet Sauvignon	44	214	74
Chardonnay	2247	450	67
Pinot Noir	1446	7	31
Red Blend	267	3111	987
Tempranillo	0	1	2099

Use crosstab() to get a cross table of two categorical variables.

```
sns.heatmap(data = heatmap_data, cmap = "RdYlGn")
```

```
<AxesSubplot:xlabel='country', ylabel='variety'>
```



BI

- https://seaborn.pydata.org/generated/seaborn.heatmap.html
- A cross table is a frequency table that shows the frequency of the combination of values of two categorical variables. https://pandas.pydata.org/docs/reference/api/pandas.crosstab.html

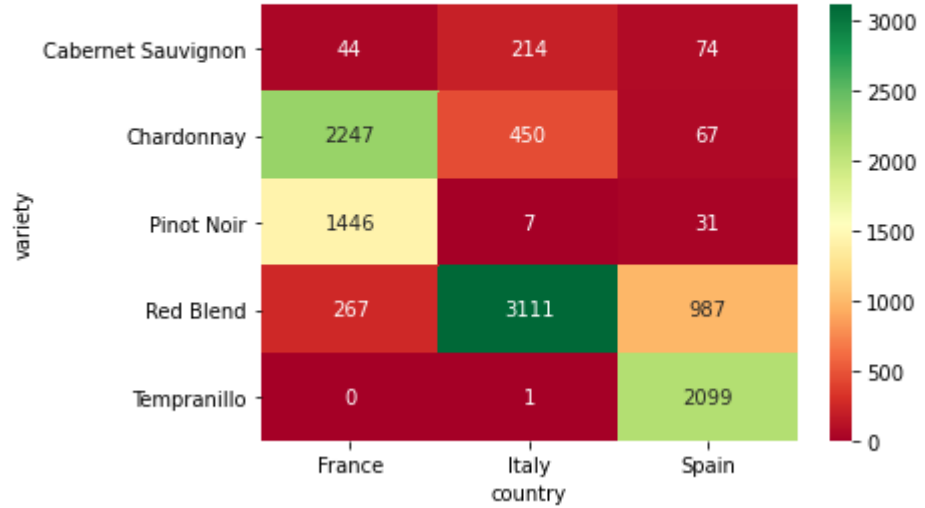
Heatmap

- Custom style
  - `annot`: If True, show the data value in each cell.
  - `fmt`: String formatting code to use when adding annotations.

country variety	France	Italy	Spain
Cabernet Sauvignon	44	214	74
Chardonnay	2247	450	67
Pinot Noir	1446	7	31
Red Blend	267	3111	987
Tempranillo	0	1	2099

```
sns.heatmap(data = heatmap_data, annot = True, fmt = "d", cmap = "RdYlGn")
```

```
<AxesSubplot:xlabel='country', ylabel='variety'>
```



Exercise

Exercise.B

```
titanic_df = sns.load_dataset("titanic", dtype = {"survived": object, "pclass":object})
```

(B.1) Show the first 10 rows of the dataset.

(B.2) Use a count plot to display the number of male and female passengers.

(B.3) Use a count plot to display the number of male and female passengers, and use the column `survived` to divide the data into two subgroups.
Hint: `hue`

(B.4) Create a cross table based on the columns `pclass` and `survived`.
Hint: `pd.crosstab()`

(B.5) Use the result obtained in (B.4) to draw a heatmap.
Setting: `cmap = "coolwarm"`

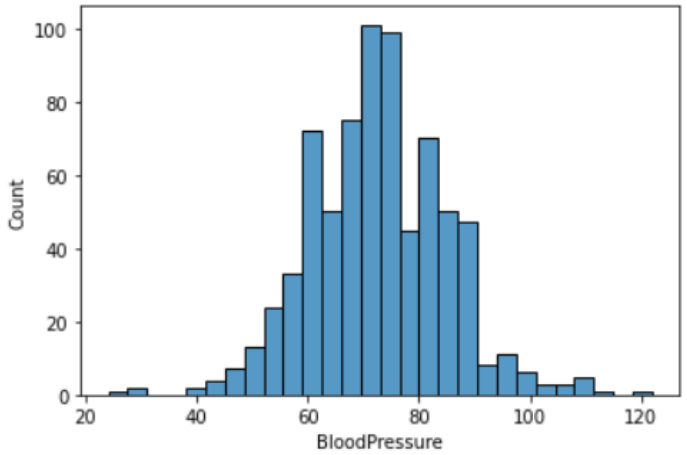
- https://seaborn.pydata.org/generated/seaborn.load_dataset.html
- `sns.get_dataset_names()`

Histogram

- Use `histplot()` to get the histogram.
- Use `hue` to show the distribution of each category.

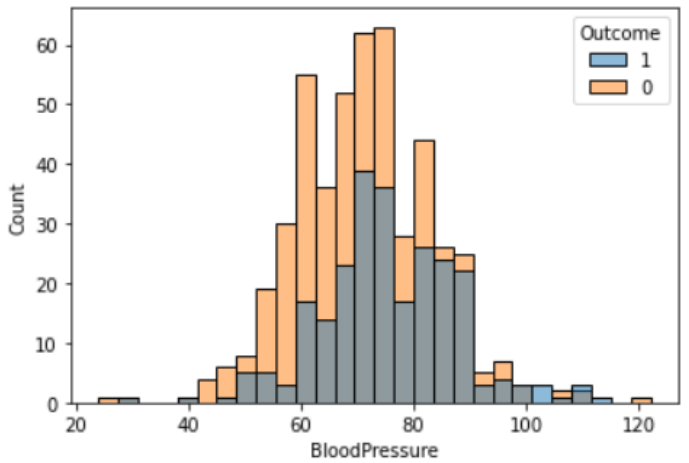
```
sns.histplot(data = diabetes_df, x = "BloodPressure")
```

```
<AxesSubplot:xlabel='BloodPressure', ylabel='Count'>
```




```
sns.histplot(data = diabetes_df, x = "BloodPressure", hue = "Outcome")
```

```
<AxesSubplot:xlabel='BloodPressure', ylabel='Count'>
```



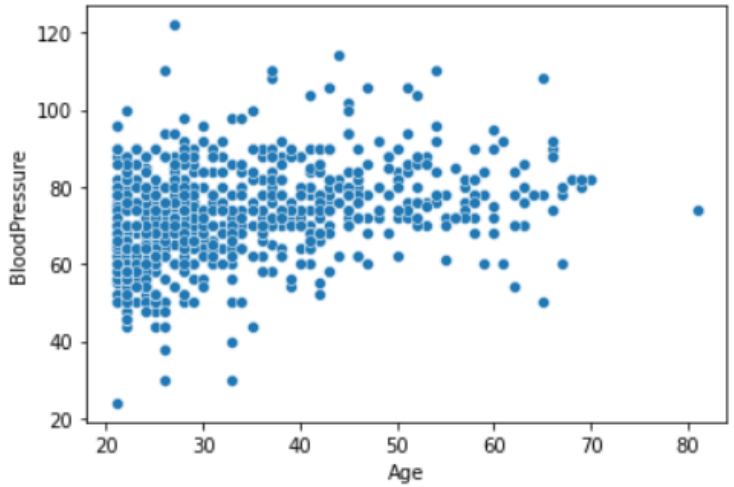
https://seaborn.pydata.org/generated/seaborn.histplot.html

Scatter plot

- Use `scatterplot()` to show the relationship between two variables.
- Use `hue` to show the scatter plot for each category.

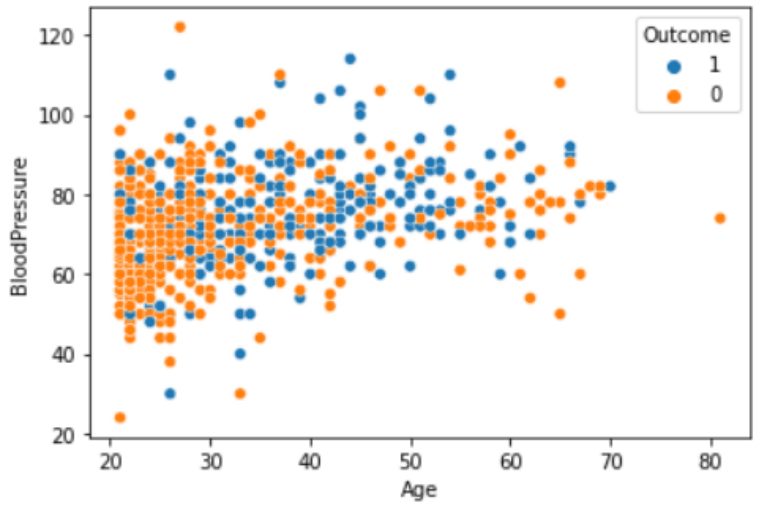
```
sns.scatterplot(data = diabetes_df, x = "Age", y = "BloodPressure")
```

```
<AxesSubplot:xlabel='Age', ylabel='BloodPressure'>
```




```
sns.scatterplot(data = diabetes_df, x = "Age", y = "BloodPressure",
                hue = "Outcome")
```

```
<AxesSubplot:xlabel='Age', ylabel='BloodPressure'>
```



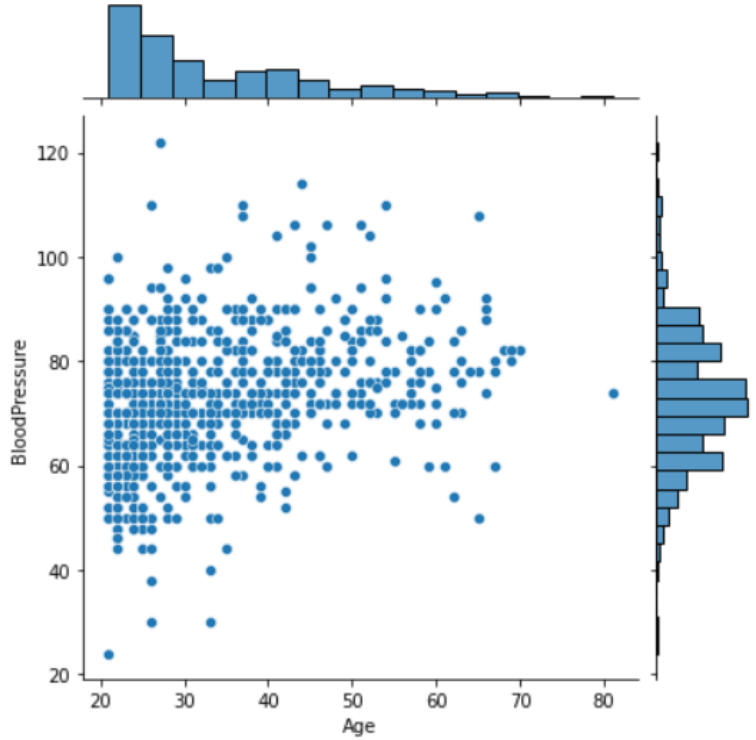
https://seaborn.pydata.org/generated/seaborn.scatterplot.html

Jointplot

- Use `jointplot()` to show the individual distribution and the relationship between two variables.

```
sns.jointplot(data = diabetes_df, x = "Age", y = "BloodPressure")
```

```
<seaborn.axisgrid.JointGrid at 0x19793e56640>
```



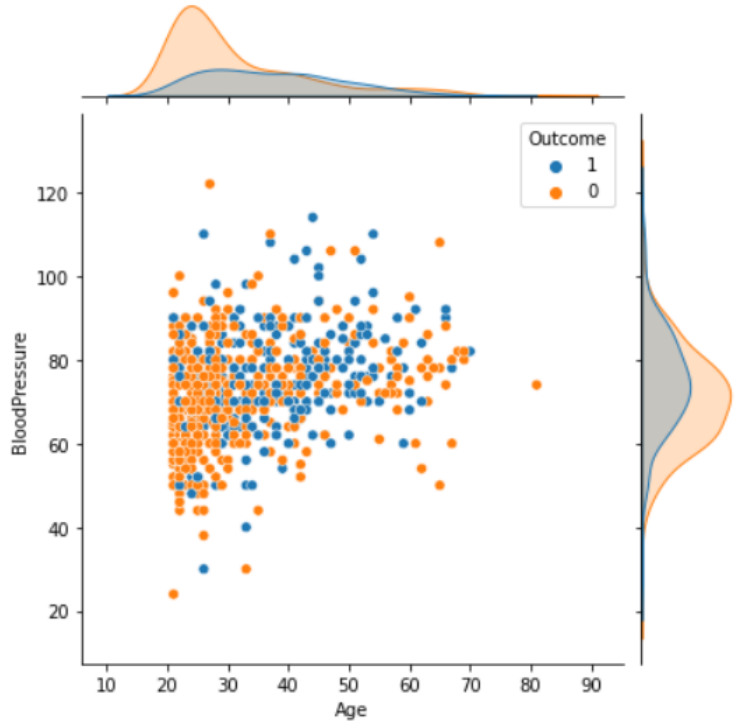
https://seaborn.pydata.org/generated/seaborn.jointplot.html

Jointplot

- Use the argument hue to specify the categorical variable used for color encoding.

```
sns.jointplot(data = diabetes_df, x = "Age", y = "BloodPressure", hue = "Outcome")
```

```
<seaborn.axisgrid.JointGrid at 0x19793df2e20>
```



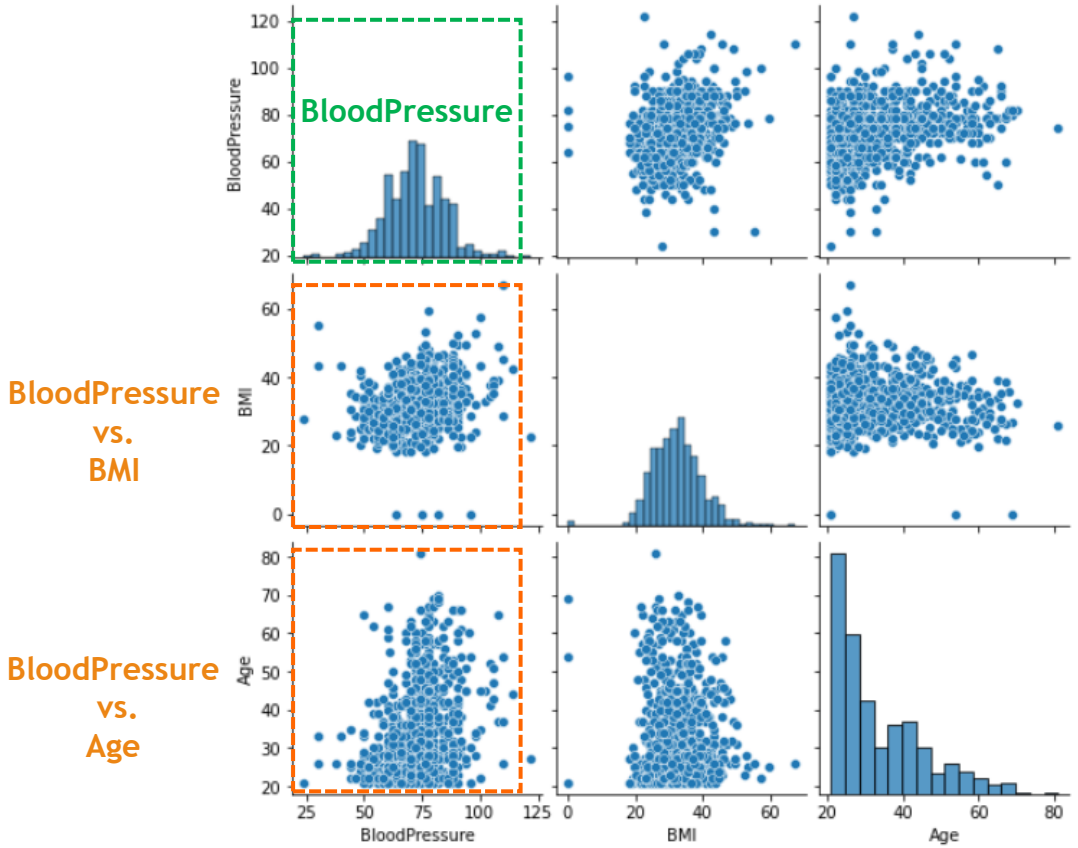
Pair plot

- Use `Pairplot()` to plot pairwise relationships in a dataset.

- The diagonal plots are univariate distribution plot (histogram) of the data in each column.

```
sns.pairplot(data = diabetes_df.loc[:,["BloodPressure","BMI", "Age"]])
```

```
<seaborn.axisgrid.PairGrid at 0x1de936fda30>
```



https://seaborn.pydata.org/generated/seaborn.pairplot.html

Exercise

Exercise.C

```
diamond_df = sns.load_dataset("diamonds")
```

(C.1) Show the first 5 rows of the dataset.

(C.2) Show the distribution of the price.
Hint: `histplot()`

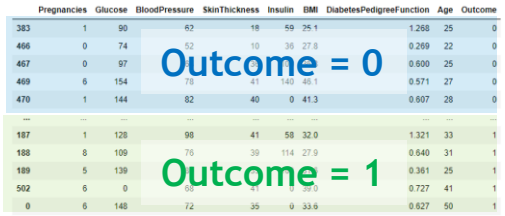
(C.3) Use a scatter plot to show the relathionship between `carat` and `price` of the best clarity diamonds.
Hint: Select a subset by using `diamond_df.clarity == "IF"`

(C.4) Use a join plot to show the relathionship between `carat` and `price` of the best clarity diamonds.

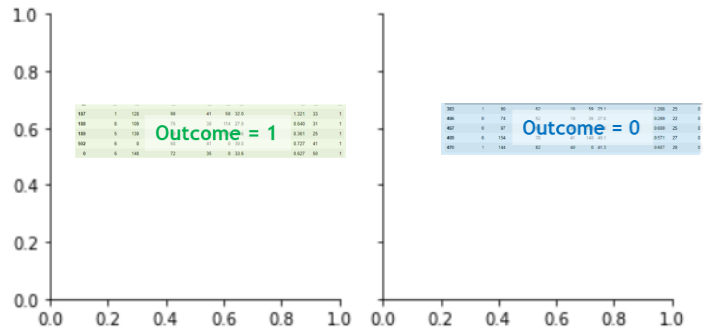
FacetGrid

- FacetGrid is basically a grid of subplots.
- The method `FacetGrid()` return a `FacetGrid` object which stores some information on how you want to break down your data visualization.

Step1: Initialize the grid




```
fig =  sns.FacetGrid(data = diabetes_df, col = "Outcome")
```




```
type(fig)
```

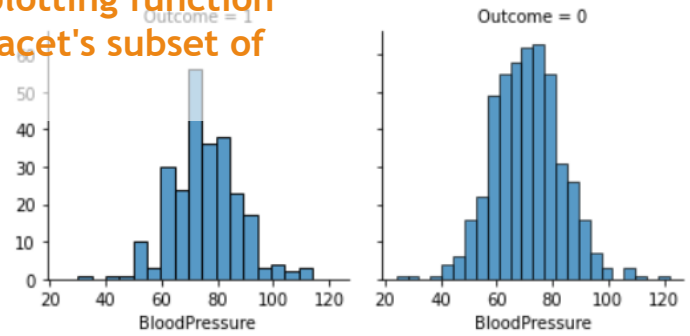
```
seaborn.axisgrid.FacetGrid
```

Step2: Draw a plot on every facet

```
fig = sns.FacetGrid(data =diabetes_df, col="Outcome")
fig.map(sns.histplot, "BloodPressure")
```

```
<seaborn.axisgrid.FacetGrid at 0x25650e88730>
```

Apply a plotting function to each facet's subset of the data.



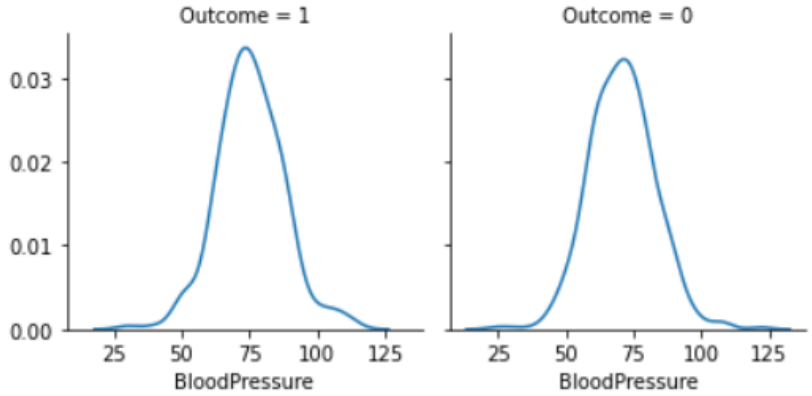
https://seaborn.pydata.org/generated/seaborn.FacetGrid.html
https://seaborn.pydata.org/generated/seaborn.PairGrid.html

FacetGrid

- Change chart type

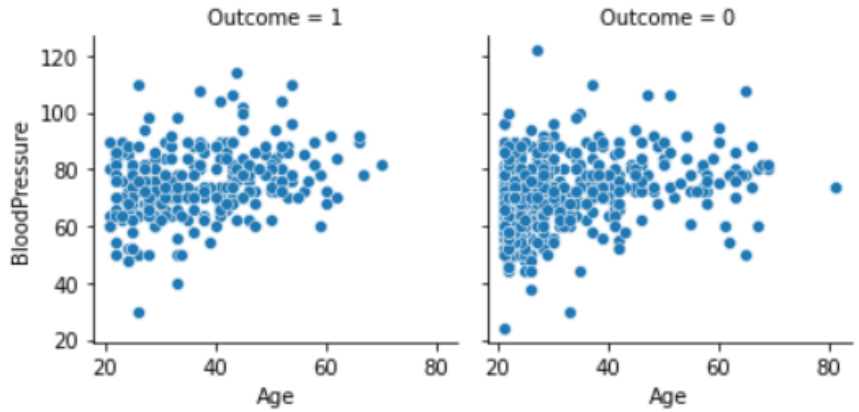
```
fig = sns.FacetGrid(data = diabetes_df, col="Outcome")
fig.map(sns.kdeplot, "BloodPressure")
```

```
<seaborn.axisgrid.FacetGrid at 0x25650c48e80>
```




```
fig = sns.FacetGrid(data = diabetes_df, col = "Outcome")
fig.map(sns.scatterplot, "Age", "BloodPressure")
```

```
<seaborn.axisgrid.FacetGrid at 0x25650d6ac10>
```



A kernel density estimate (KDE) plot is a method for visualizing the distribution of observations in a dataset, analagous to a histogram. https://seaborn.pydata.org/generated/seaborn.kdeplot.html

Exercise

Exercise.D

(D.1) Use the dataframe `diamond_df` in (C.1). Draw a price histogram for each `cut` category.
Hint: `col="cut"`