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Python for Data Analytics

Matplotlib

Outline

- Data Visualization
- MatplotLib
  - Pyplot Basics
  - Scatter Plot
  - Bar Chart
  - Pie Chart
  - Histogram
  - Box Plot
  - Subplots
- Seaborn
- Plotting in Pandas

Data Visualization

Based on CMU CS15-688 materials

Visualization

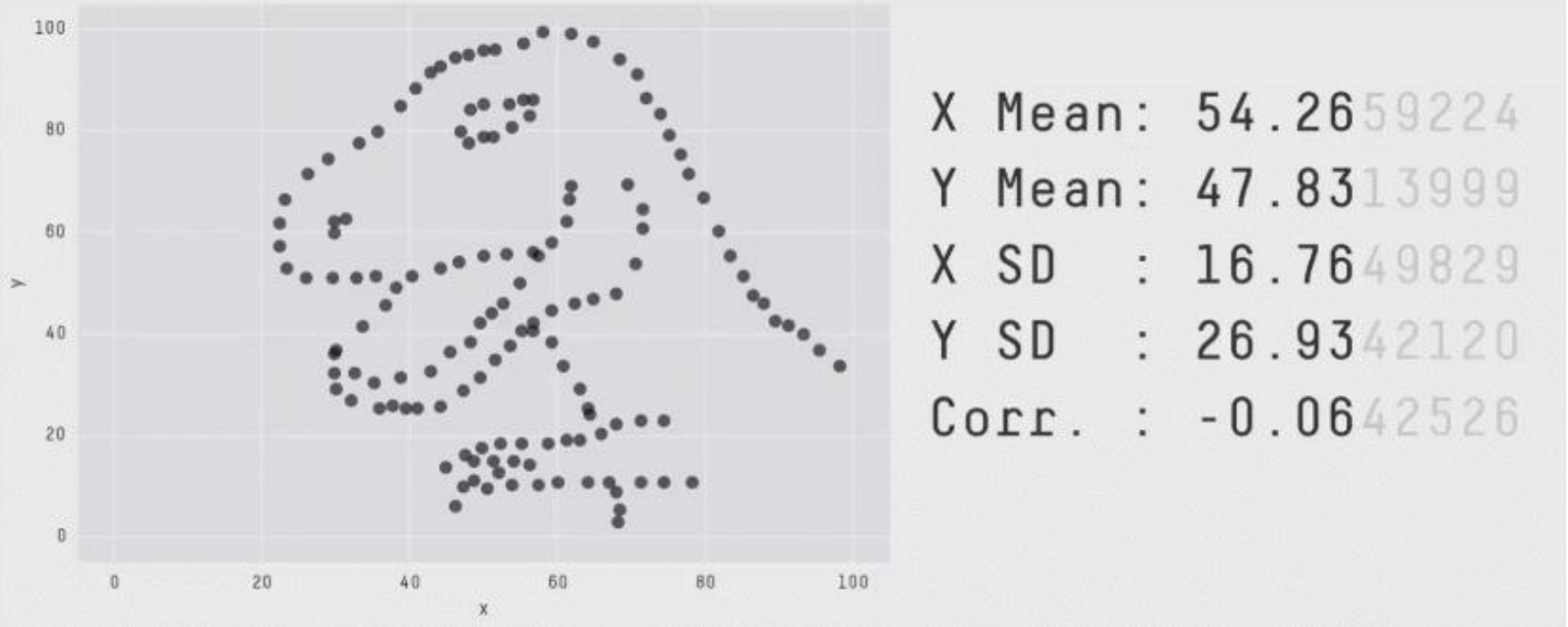
- Data exploration visualization: figuring out what is true
- Data presentation visualization: convincing other people it is true

- Before you run any analysis, build any machine learning system, etc., always visualize your data

- If you can't identify a trend or make a prediction for your dataset, neither will an automated algorithm

Visualization vs. Statistics

- Visualization almost always presents a more informative (though less quantitative) view of your data than statistics
  - This is a mathematical property: *n* data points and *m* equations to satisfy, with *n* > *m*



Source: https://www.autodeskresearch.com/publications/samestats

Data Types

- Nominal
  - Categorical data
  - No quantitative value, no ordering
  - Example – Pet: {dog, cat, rabbit, ...}
  - Operations: =, ≠
- Ordinal
  - Categorical data, with ordering
  - Example – Rating: {1, 2, 3, 4, 5}
  - Operations: =, ≠, ≥, ≤, >, <
- Interval
  - Numerical data
  - Zero has no fixed meaning
  - Example – Temperature Celsius
  - Operations: =, ≠, ≥, ≤, >, <, +, –
- Ratio
  - Numerical data
  - Zero has special meaning
  - Example – Height, Weight, ...
  - Operations: =, ≠, ≥, ≤, >, <, +, –, ×, ÷

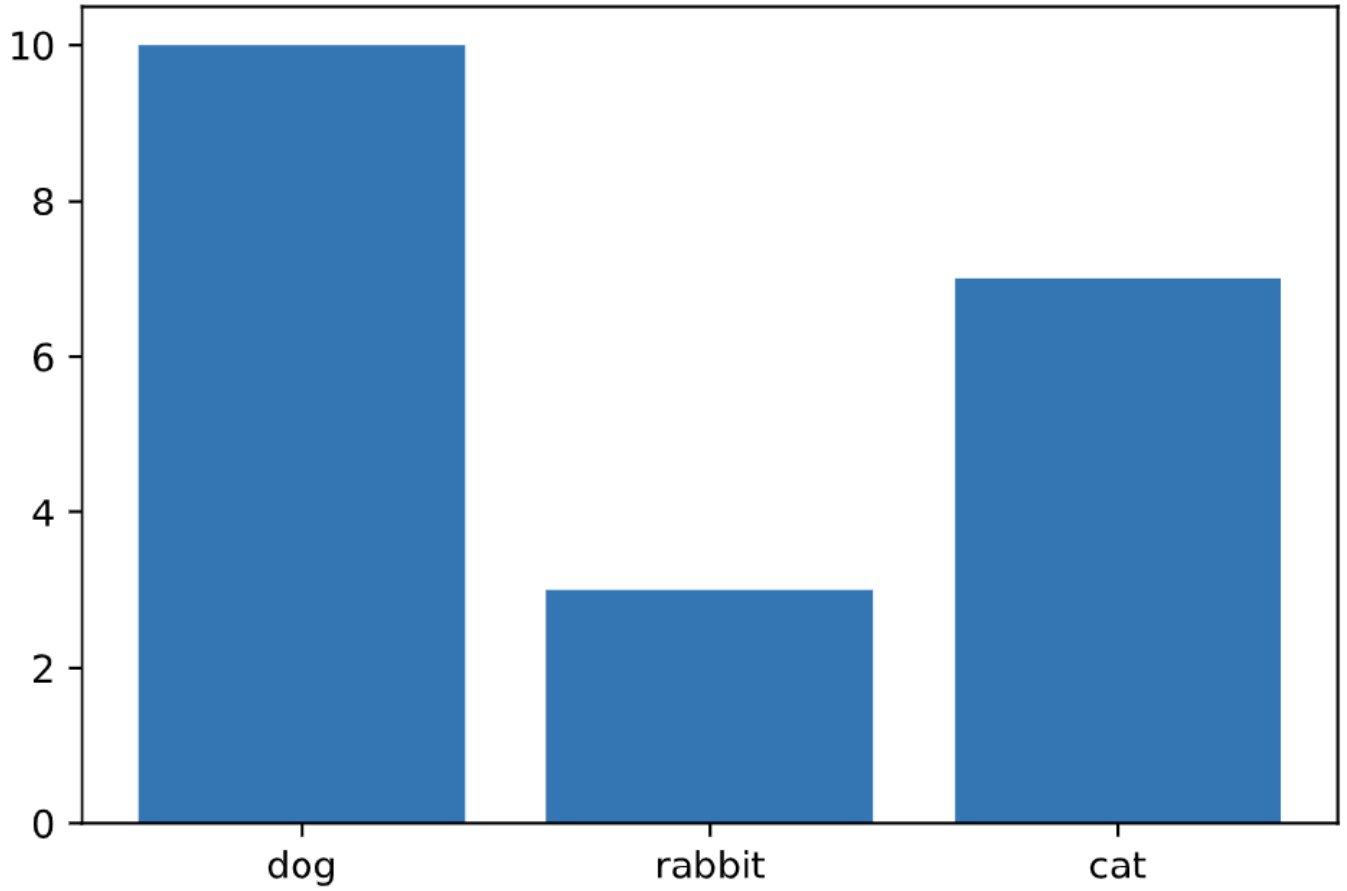
Visualization Types

- 1D
  - Bar chart, pie chart, histogram
- 2D
  - Scatter plot, line plot, box and whisker plot, heatmap
- 3D
  - Scatter matrix, bubble chart

1D: Bar Chart

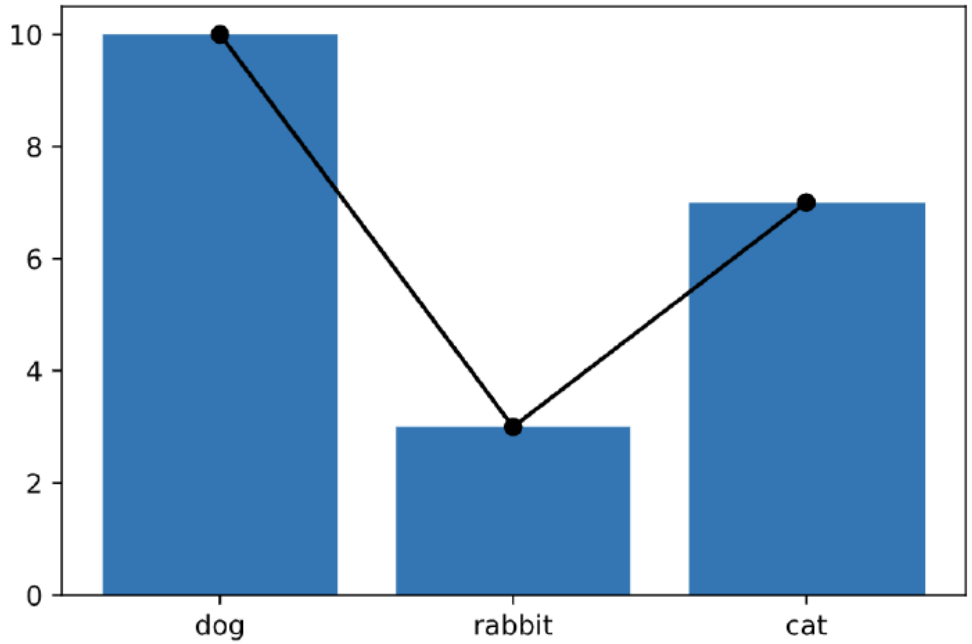
	Data
Nominal	✓
Ordinal	✓
Interval	✗
Ratio	✗

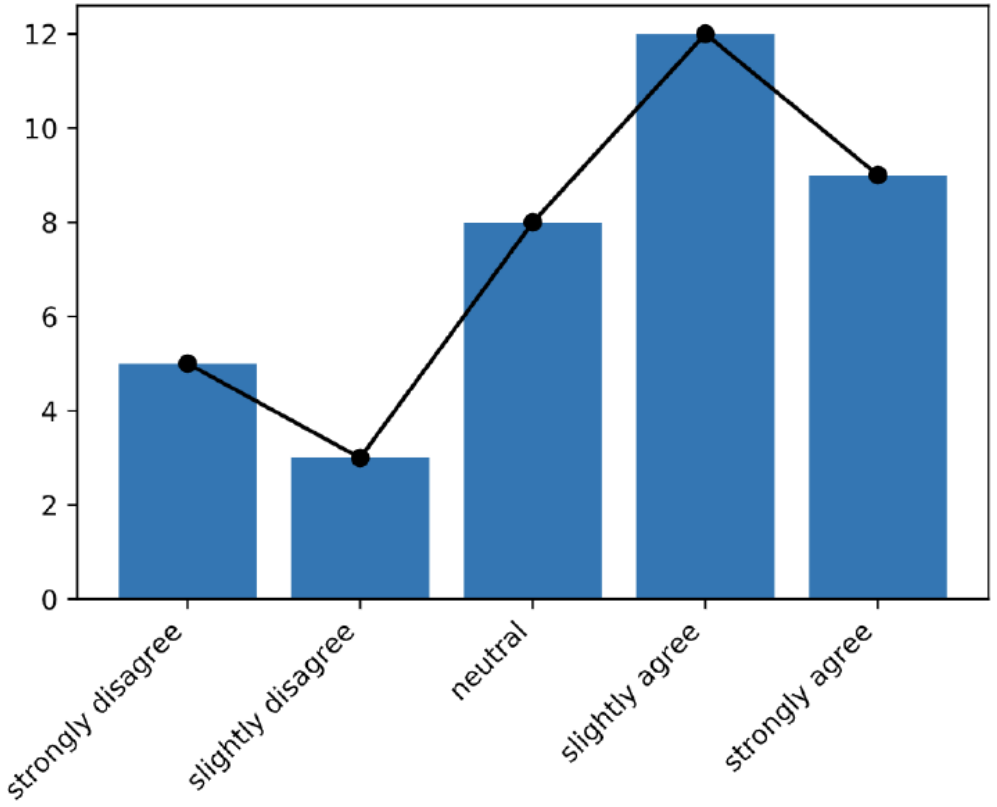
Suggestions, not rules



1D: Bar Chart (bad)

- Don't use lines within a bar chart categorical or ordinal features

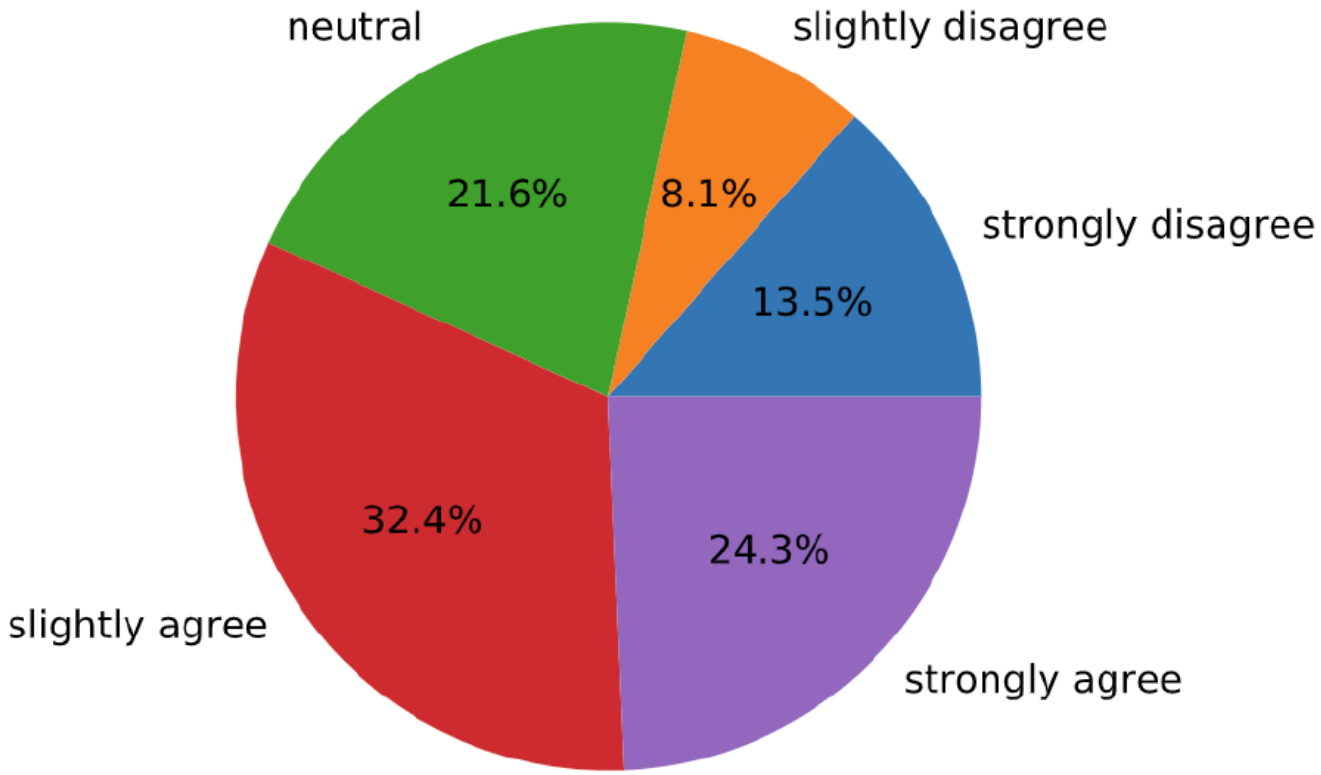




1D: Pie Chart

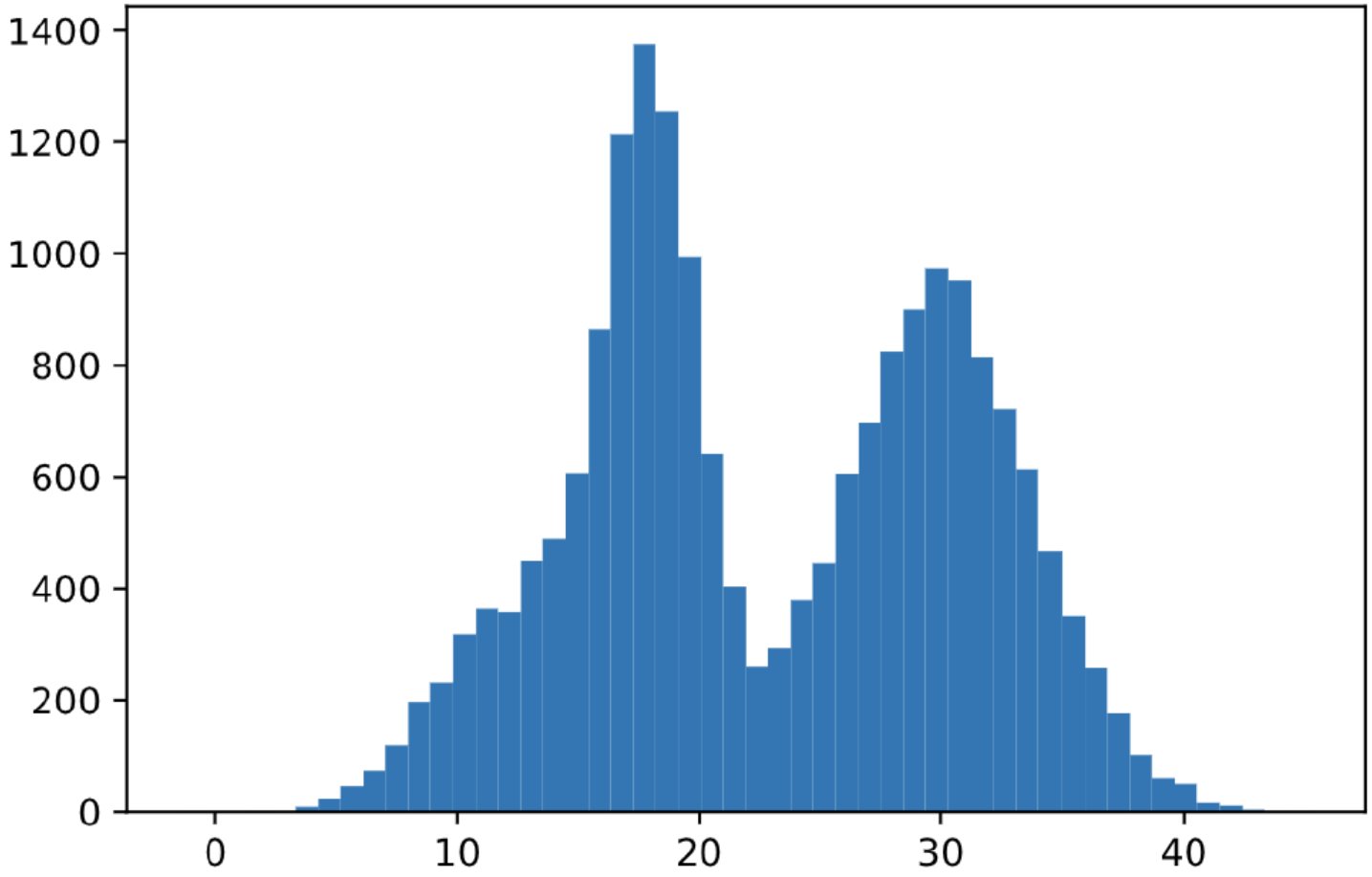
- What's wrong?
  - See "Why you shouldn't use pie charts"

	Data
Nominal	✗
Ordinal	✗
Interval	✗
Ratio	✗



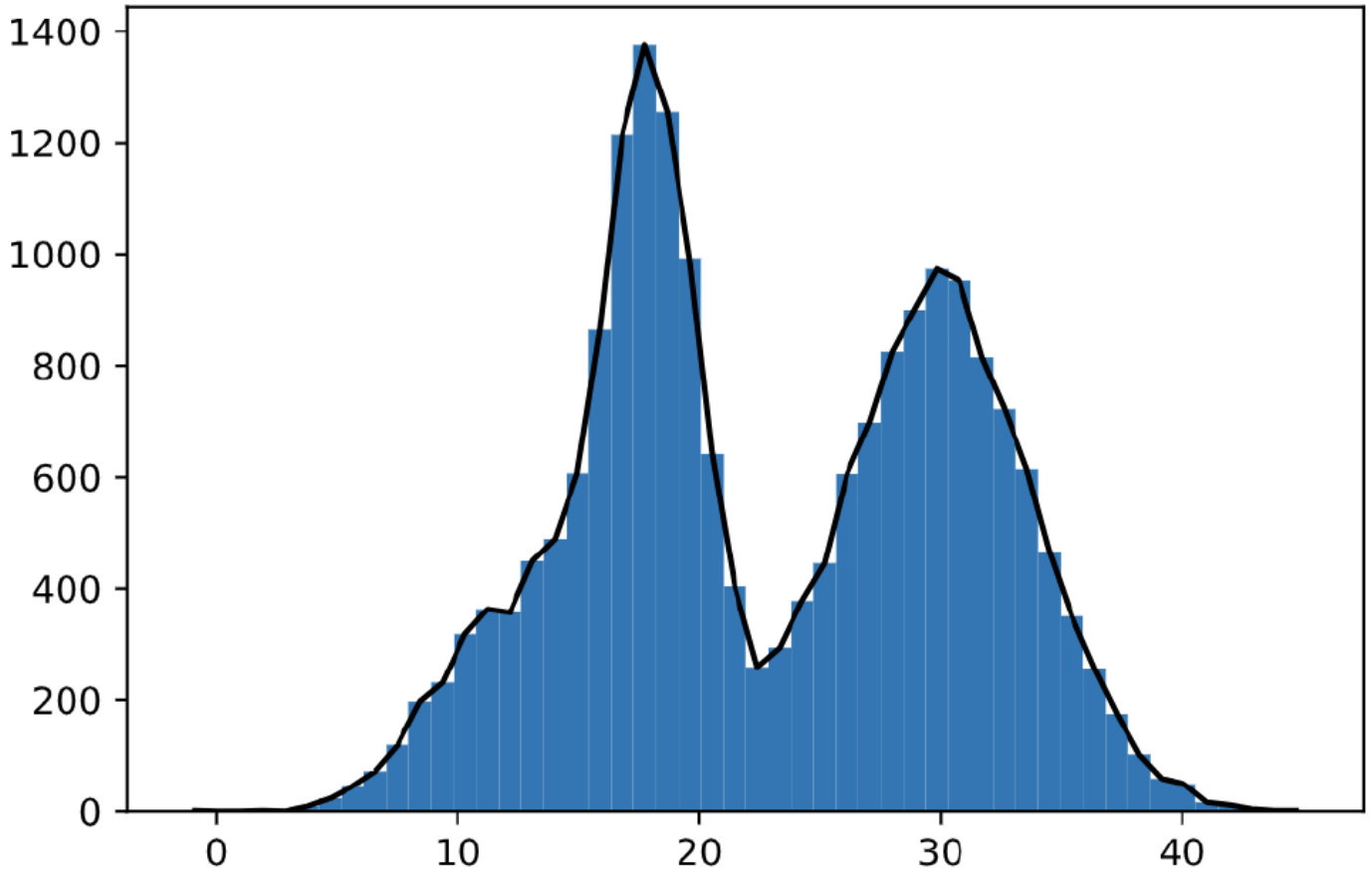
1D: Histogram

	Data
Nominal	✗
Ordinal	✗
Interval	✓
Ratio	✓



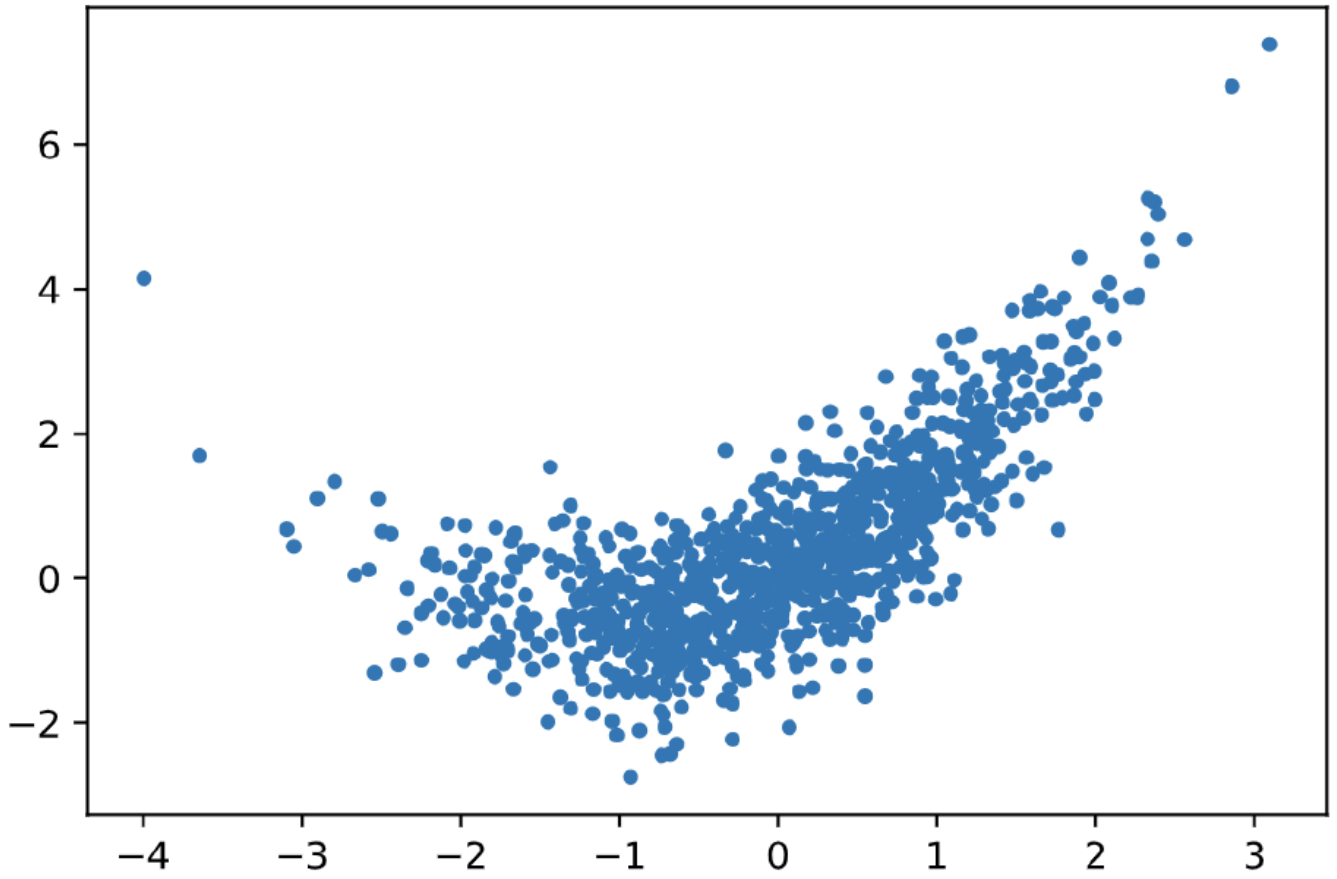
1D: Histogram

- OK to use lines within a histogram (but not very informative)



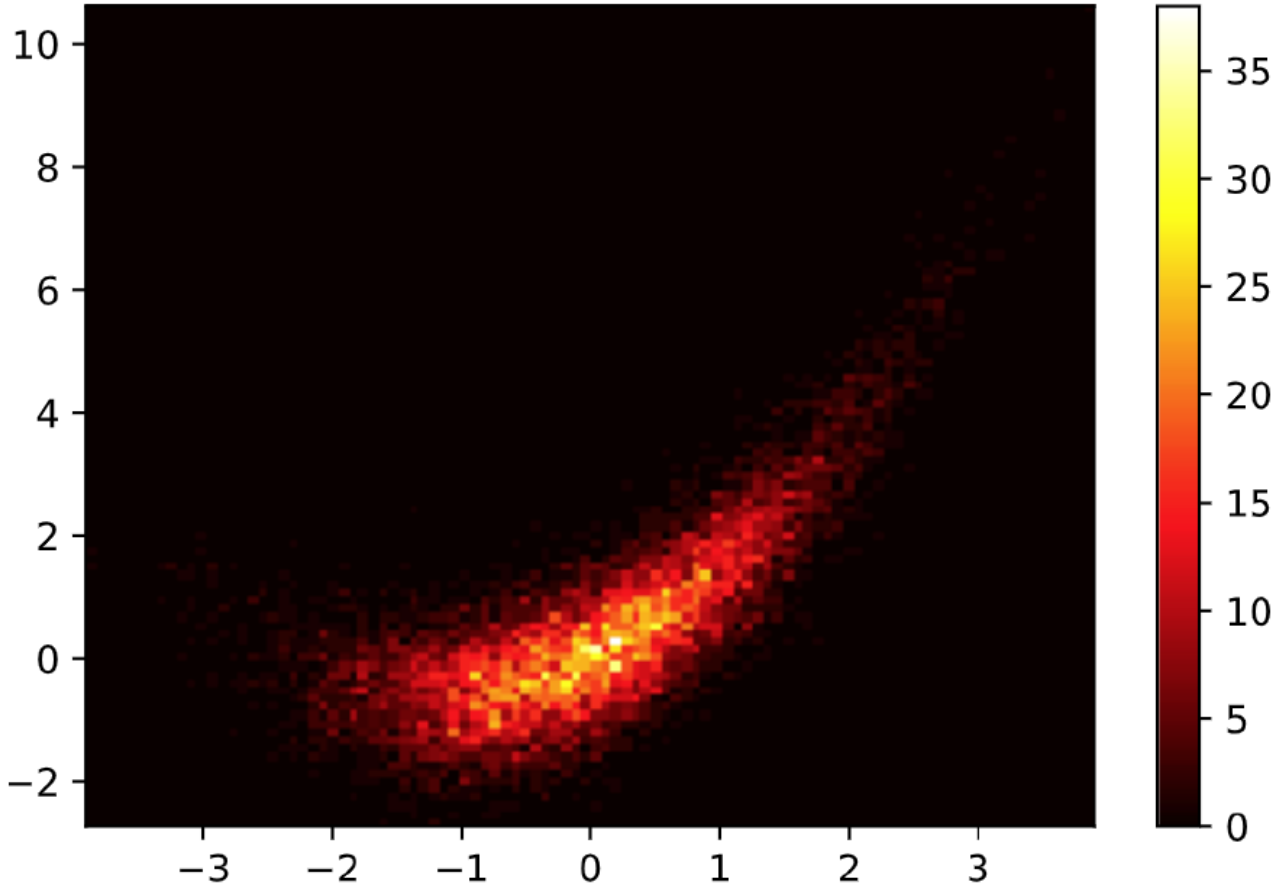
2D: Scatter Plot

	Dim 1	Dim 2
Nominal	✗	✗
Ordinal	✗	✗
Interval	✓	✓
Ratio	✓	✓



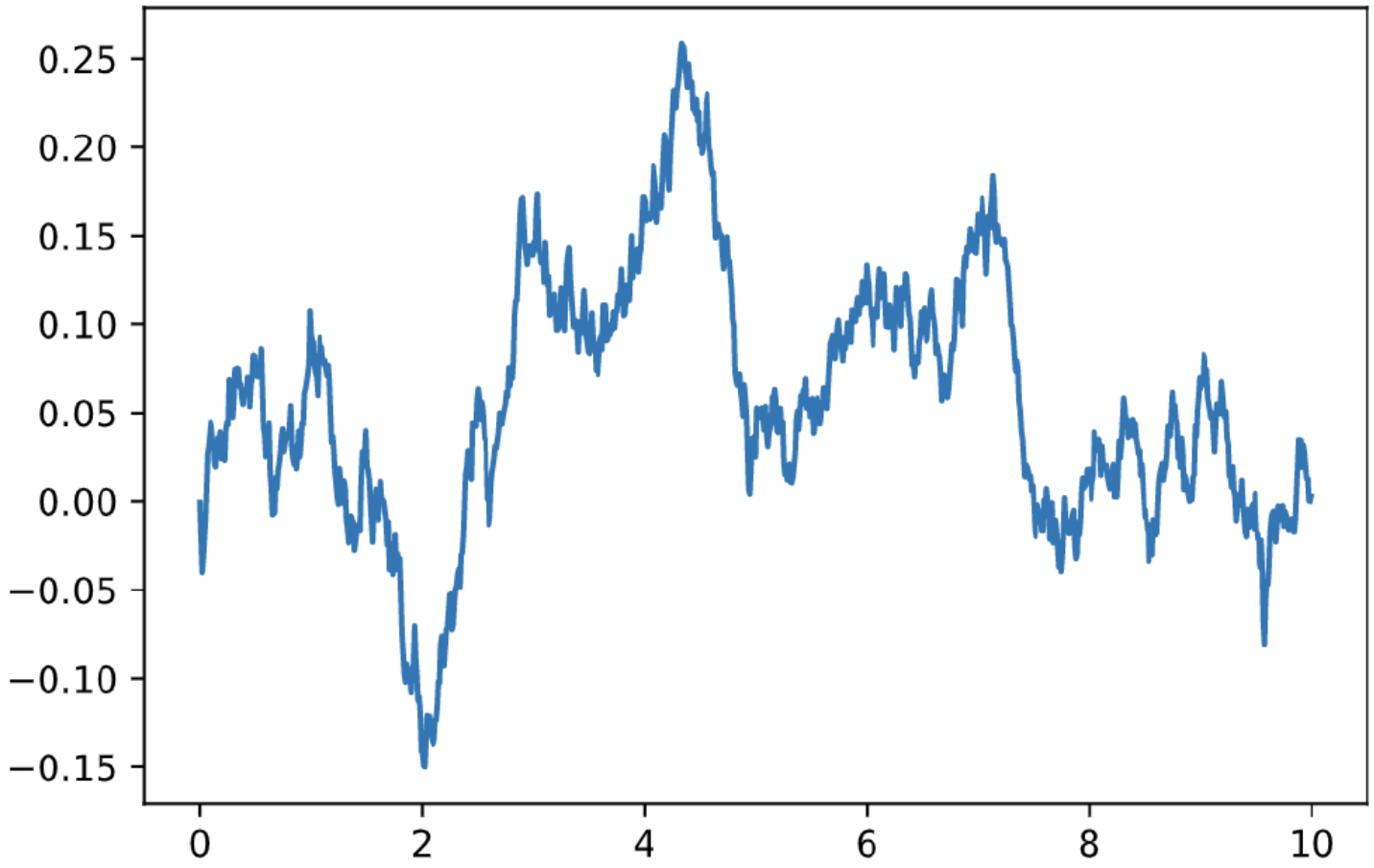
2D: Heatmap (density or 2D histogram)

	Dim 1	Dim 2
Nominal	✗	✗
Ordinal	✗	✗
Interval	✓	✓
Ratio	✓	✓



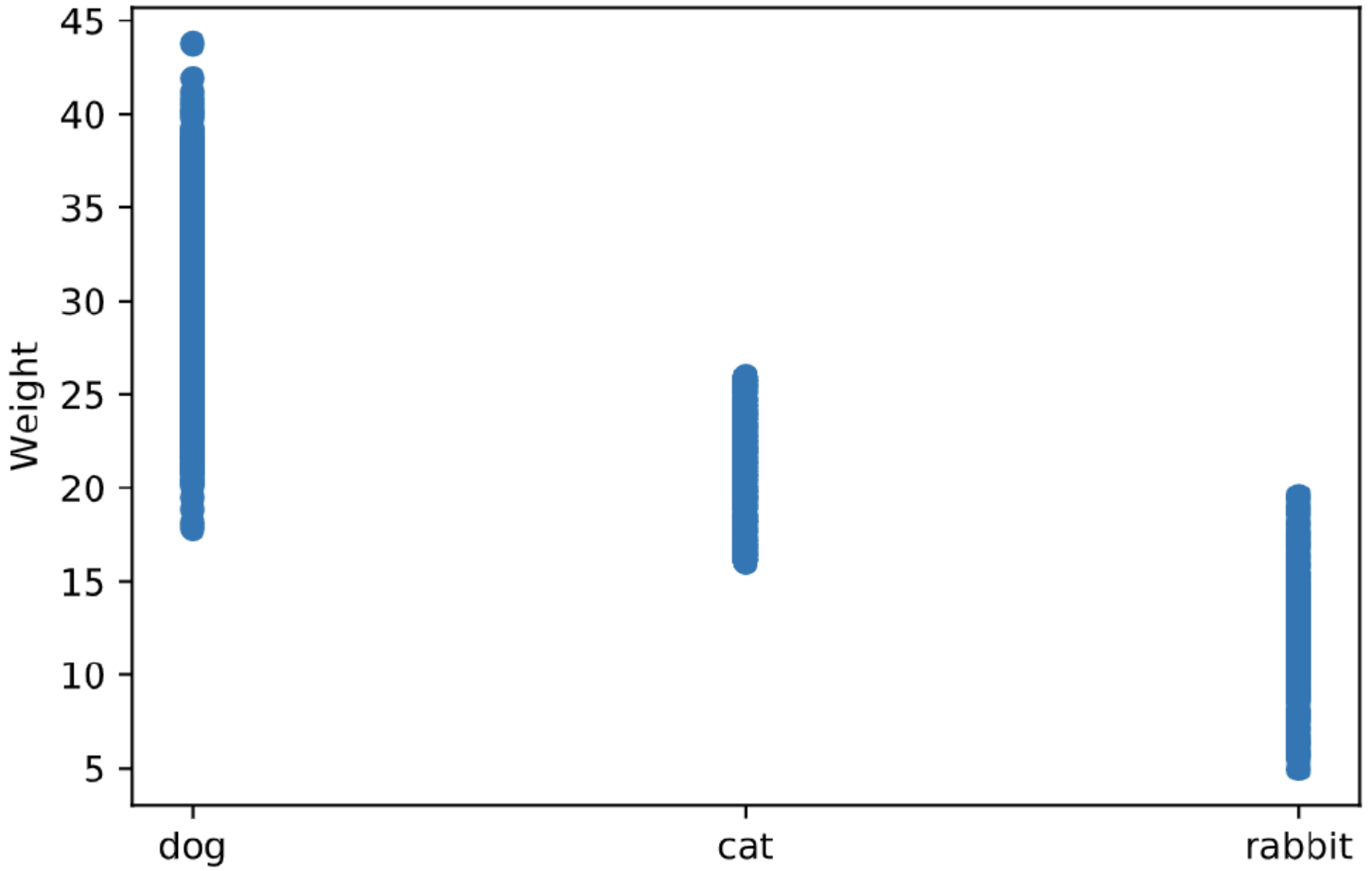
2D: Line Plot

	Dim 1	Dim 2
Nominal	✗	✗
Ordinal	✗	✗
Interval	✓	✓
Ratio	✓	✓



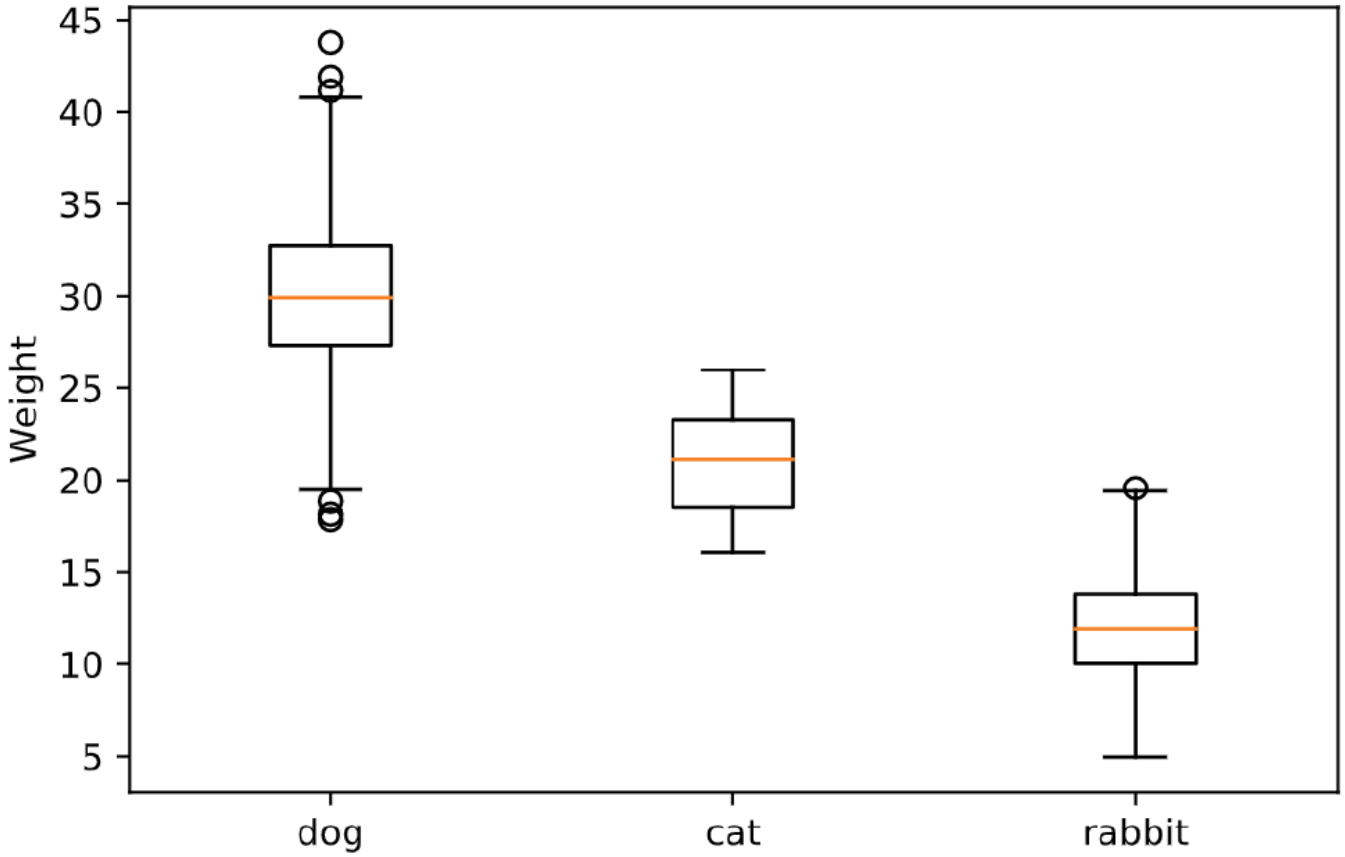
2D: Scatter Plot (bad)

	Dim 1	Dim 2
Nominal	✗	✗
Ordinal	✗	✗
Interval	✓	✓
Ratio	✓	✓



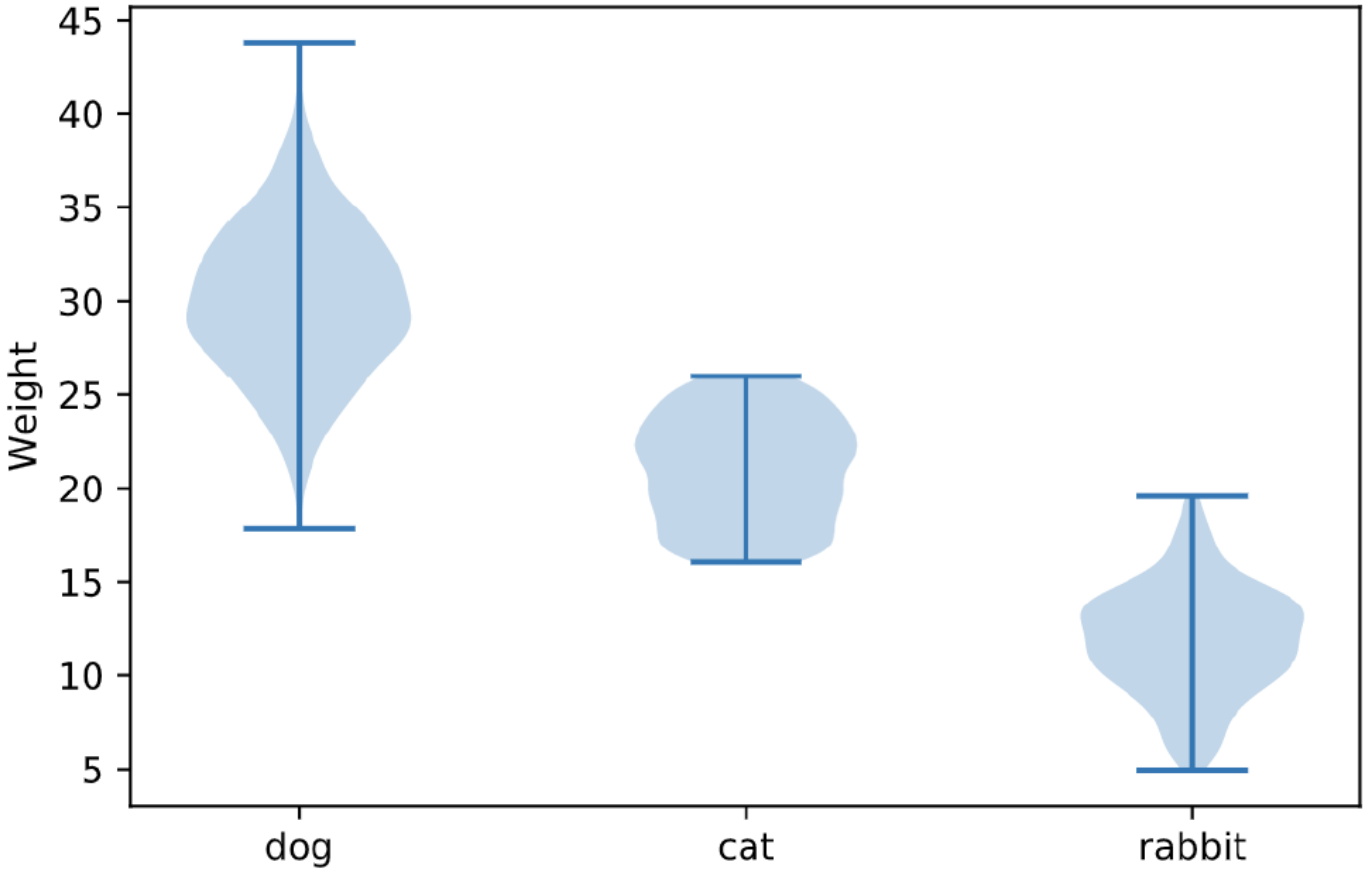
2D: Box and Whiskers

	Dim 1	Dim 2
Nominal	✓	✗
Ordinal	✓	✗
Interval	✗	✓
Ratio	✗	✓



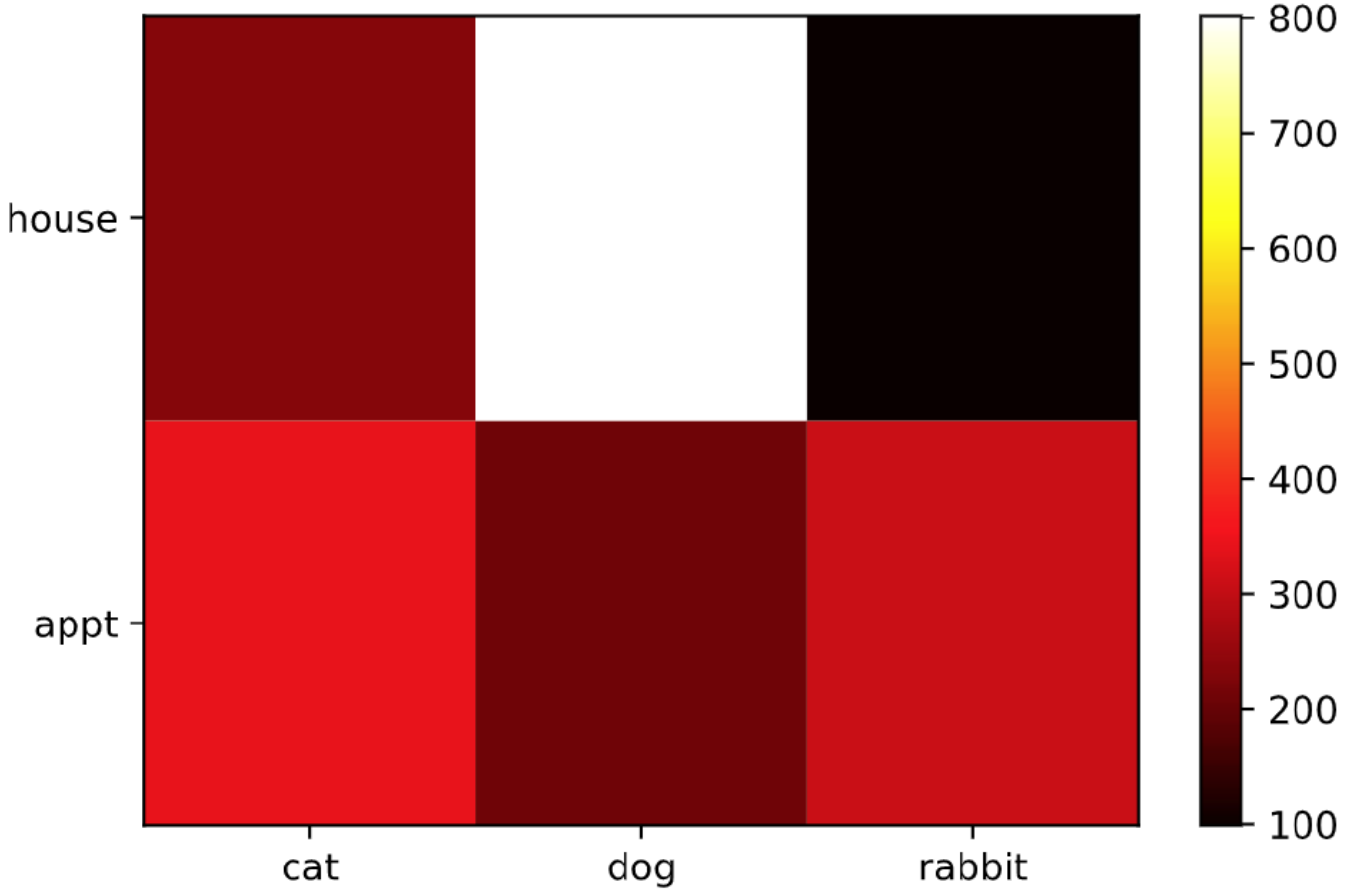
2D:Violin Plot

	Dim 1	Dim 2
Nominal	✓	✗
Ordinal	✓	✗
Interval	✗	✓
Ratio	✗	✓



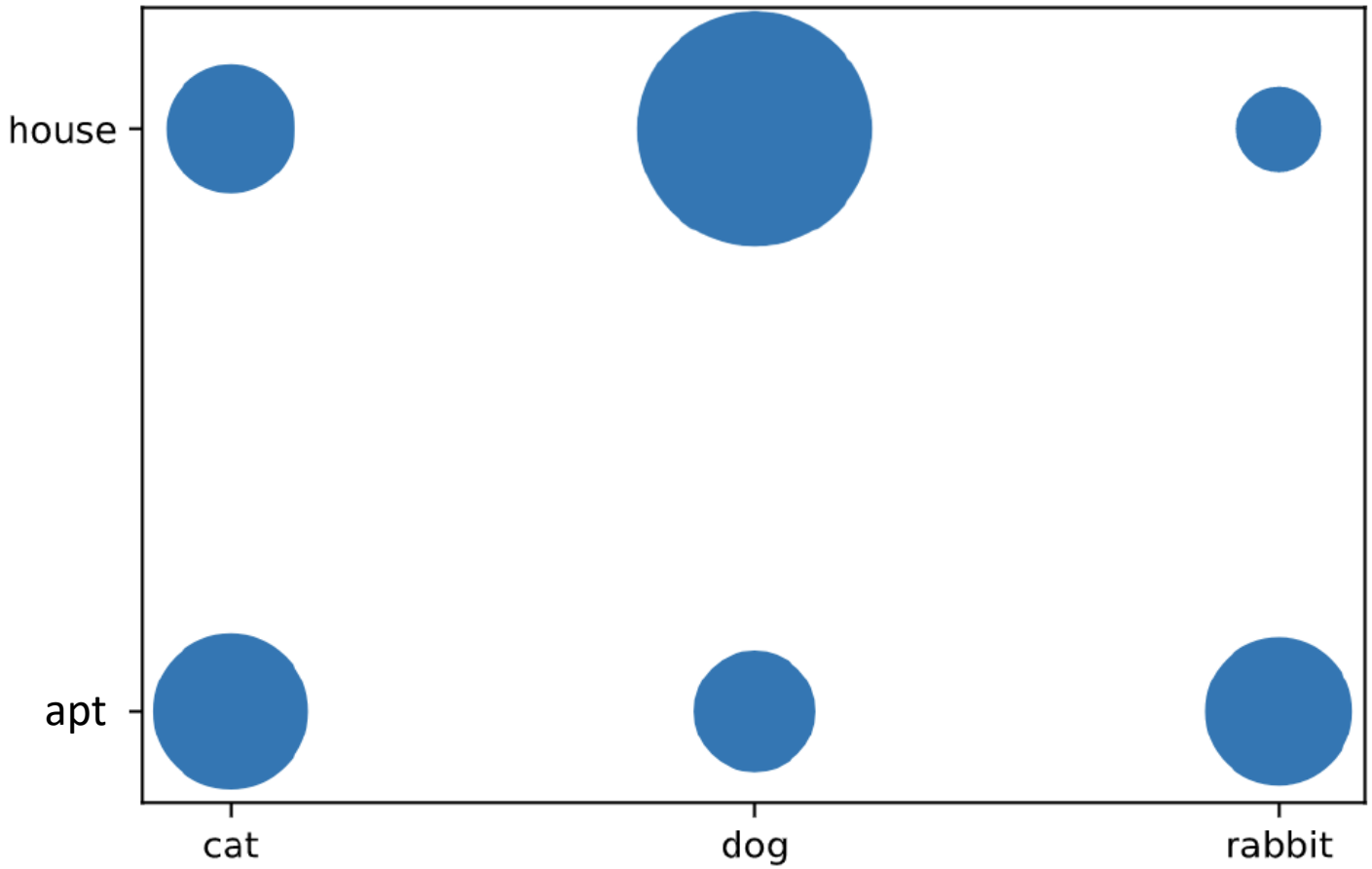
2D: Heatmap (matrix)

	Dim 1	Dim 2
Nominal	✓	✓
Ordinal	✓	✓
Interval	✗	✗
Ratio	✗	✗



2D: Bubble Plot

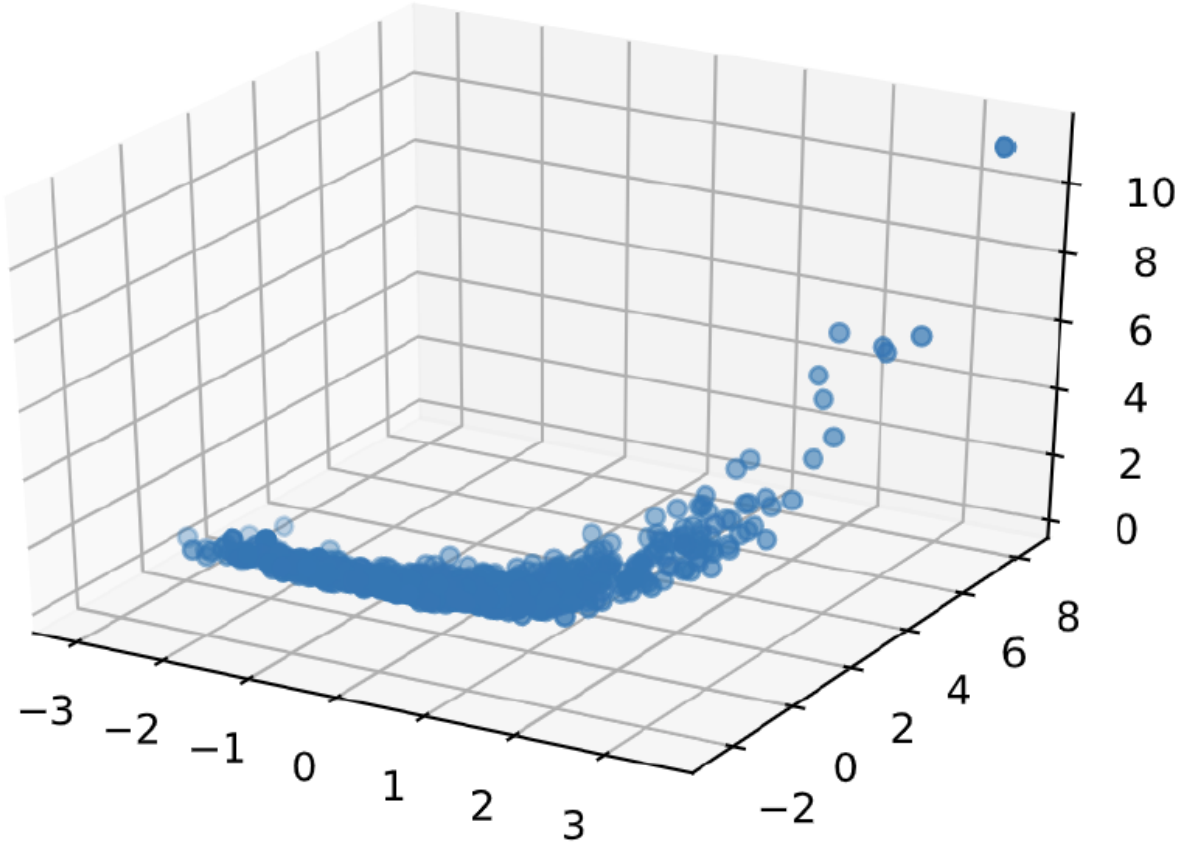
	Dim 1	Dim 2
Nominal		
Ordinal		
Interval	X	X
Ratio	X	X



3D+: 3D Scatter Plot

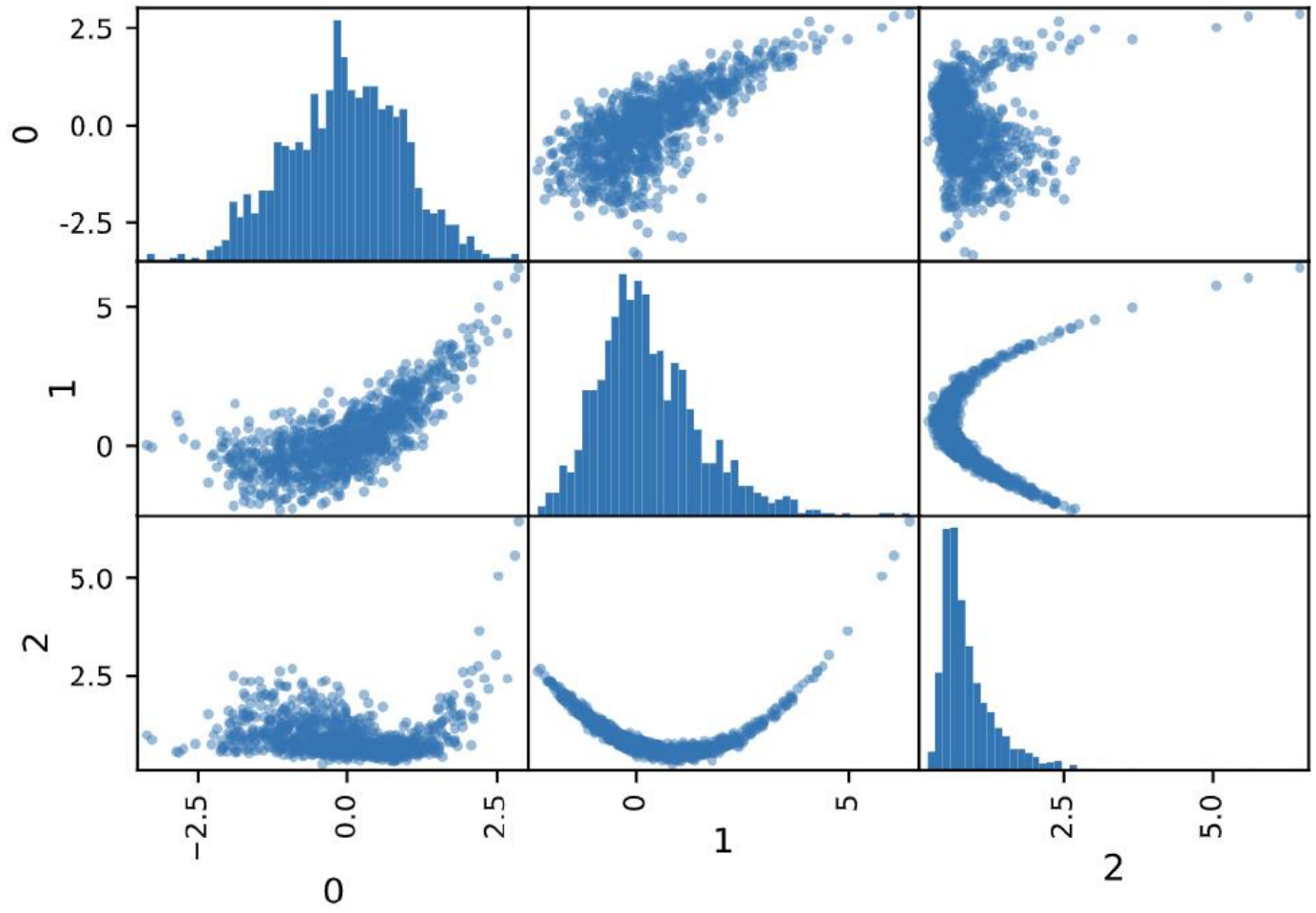
- What's wrong?

	Dim 1	Dim 2	Dim 3
Nominal	✗	✗	✗
Ordinal	✗	✗	✗
Interval	✗	✗	✗
Ratio	✗	✗	✗



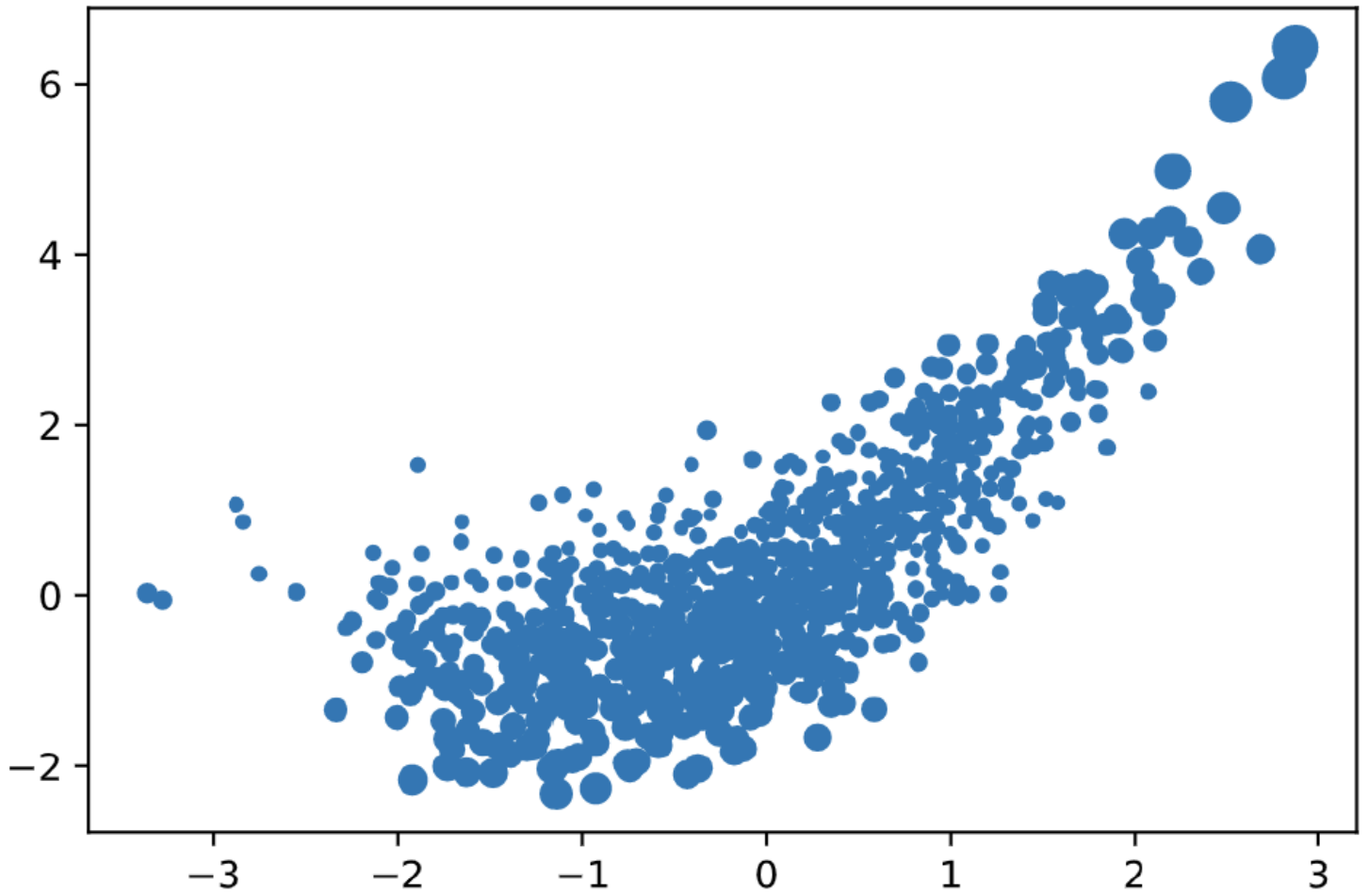
3D+: Scatter Plot Matrix

	Dim 1	Dim 2	Dim 3
Nominal	✗	✗	✗
Ordinal	✗	✗	✗
Interval	✓	✓	✓
Ratio	✓	✓	✓



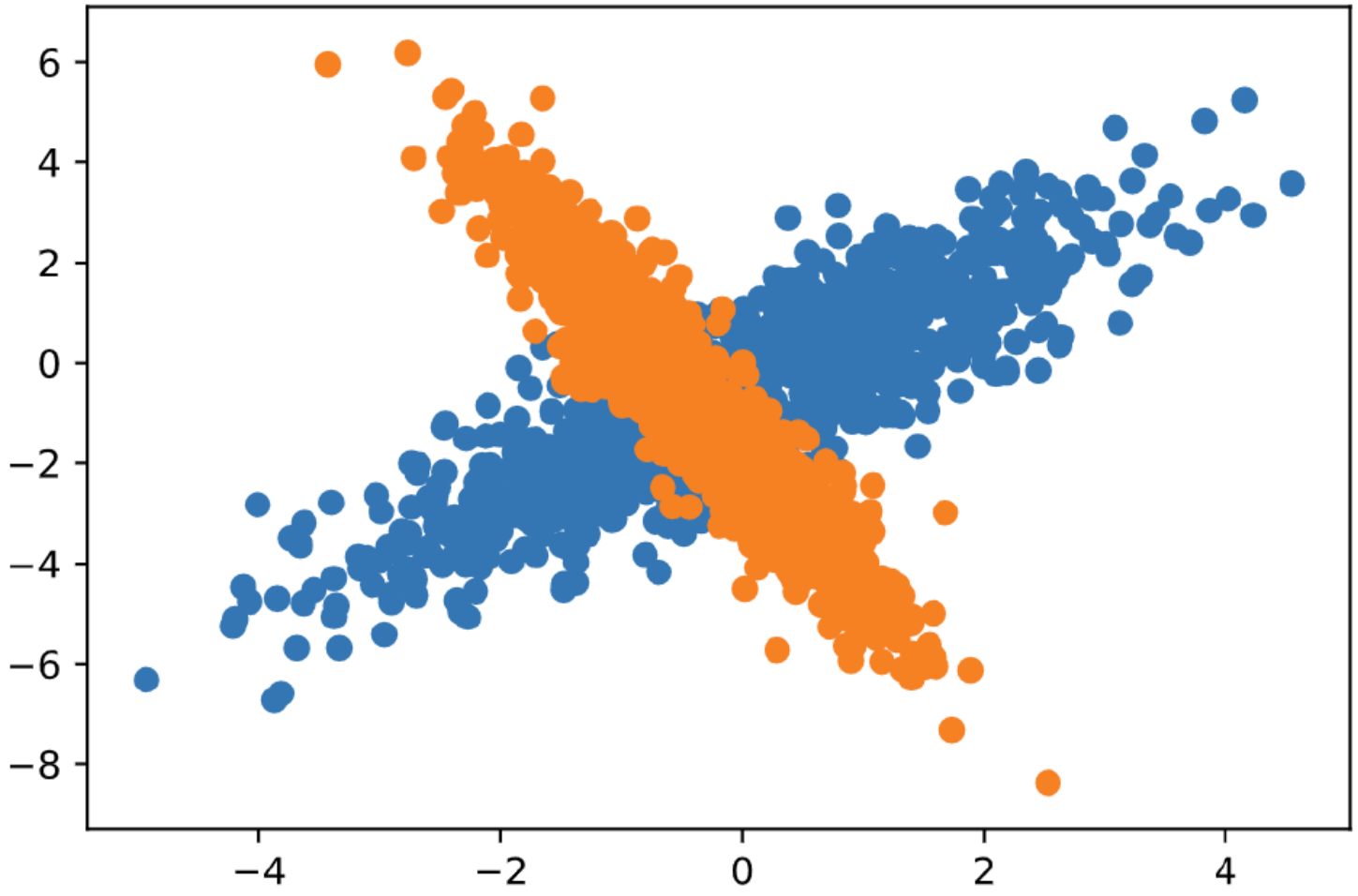
3D+: Bubble Plot

	Dim 1	Dim 2	Dim 3
Nominal	✗	✗	✗
Ordinal	✗	✗	✗
Interval	✓	✓	✓
Ratio	✓	✓	✓



3D+: Color Scatter Plot

	Dim 1	Dim 2	Dim 3
Nominal	✗	✗	✓
Ordinal	✗	✗	✓
Interval	✓	✓	✗
Ratio	✓	✓	✗



MatplotLib

Matplotlib

- The most popular plotting library for Python
  - Based on NumPy
- MATLAB-style plotting interface with hierarchical organized elements
  - pyplot module: provides state-machine environment at the top of hierarchy
- Open source (http://matplotlib.org)
  - Original author: John D. Hunter (2003) → Michael Droettboom (2012)
- pyplot tutorials
  - https://matplotlib.org/users/pyplot_tutorial.html

Overview

- matplotlib submodules
  - pyplot: provides MATLAB-like plotting framework
    - Closely related with actual plotting functionality
  - image: image loading, rescaling and display operations
  - colors: converting numbers or color arguments to RGB or RGBA
  - cm(colormap): provides function for color mapping functionality
  - collections: for efficient drawing of large collections

- We'll focus on pyplot module because it is in charge of creating plotting

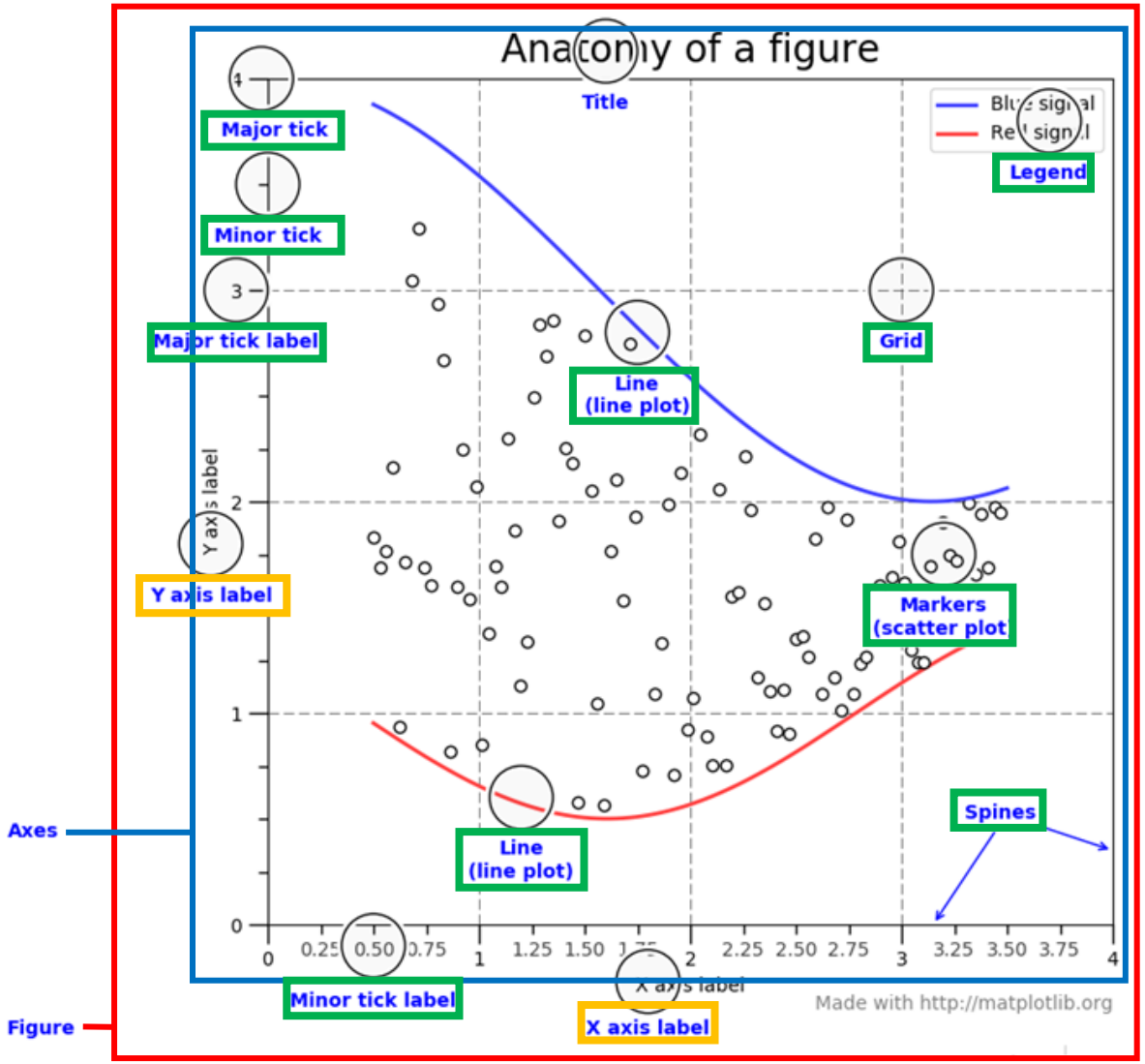
- Other submodules support better plotting environment

Matplotlib Submodule List

matplotlib.afm
matplotlib.animation
matplotlib.artist
matplotlib.axes
matplotlib.axis
matplotlib.backend_bases
matplotlib.backend_managers
matplotlib.backend_tools
matplotlib.backends.backend_agg
matplotlib.backends.backend_cairo
matplotlib.backends.backend_mixed
matplotlib.backends.backend_nbagg
matplotlib.backends.backend_pdf
matplotlib.backends.backend_pgf
matplotlib.backends.backend_ps
matplotlib.backends.backend_svg
matplotlib.backends.backend_tkagg
matplotlib.blocking_input
matplotlib.category
matplotlib.cbook
matplotlib.cm
matplotlib.collections
matplotlib.colorbar
matplotlib.colors
matplotlib.container
matplotlib.contour
matplotlib.dates
matplotlib.dviread
matplotlib.figure
matplotlib.font_manager
matplotlib.fontconfig_pattern
matplotlib.gridspec
matplotlib.image
matplotlib.legend
matplotlib.legend_handler
matplotlib.lines
matplotlib.markers
matplotlib.mathtext
matplotlib.mlab
matplotlib.offsetbox
matplotlib.patches
matplotlib.path
matplotlib.patheffects
matplotlib.projections
matplotlib.projections.polar
matplotlib.pyplot
matplotlib.rcsetup
matplotlib.sankey
matplotlib.scale
matplotlib.sphinxext.plot_di
matplotlib.spines
matplotlib.style
matplotlib.table
matplotlib.testing
matplotlib.testing.compare
matplotlib.testing.decorators
matplotlib.testing.disable_internet
ma exceptions
ma
ma
ma
ma yout
matplotlib.transforms
matplotlib.tri
matplotlib.type1font
matplotlib.units
matplotlib.widgets

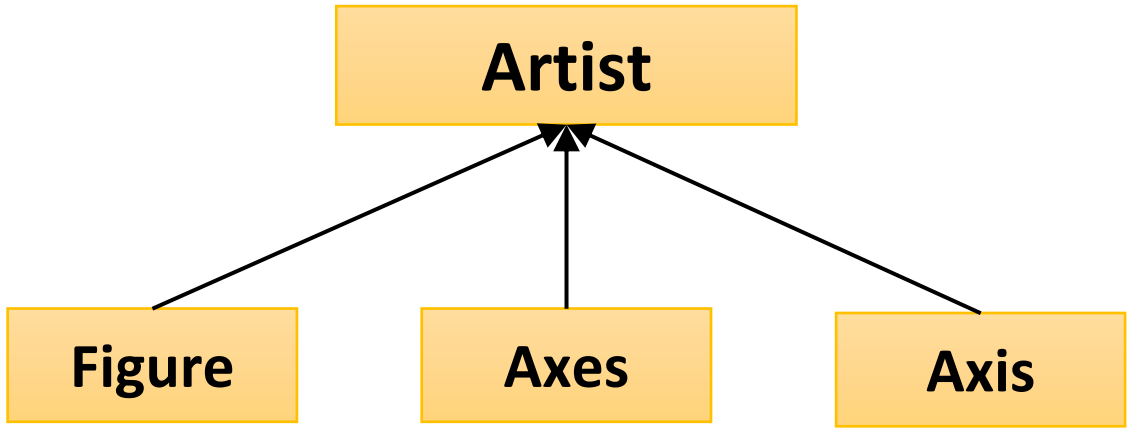
plot()
bar()
hist()
boxplot()
subplot()
...

Pyplot Plotting Example



Matplotlib Classes

- 4 important classes in matplotlib



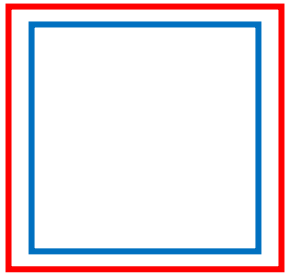
- Artist
  - Basically everything you can see on the figure
- Figure
  - Consider as a window
  - A figure may contain several child Axes and keep track of them
  - Several figures can be created
- Axes: region of an image or a plot
- Axis: strings labeling ticks

Using Pyplot

For old jupyter notebook:
plot graphs without show()

- Import library

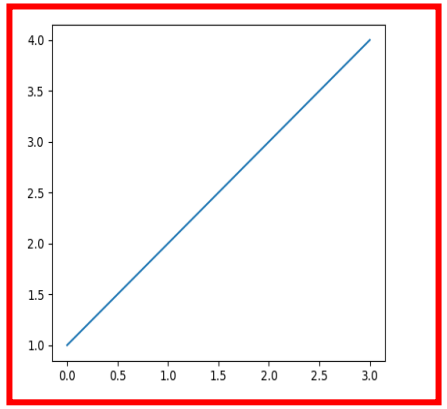
```
%matplotlib inline
import matplotlib.pyplot as plt
%config InlineBackend.figure_format = 'svg'
```



  - Pyplot uses 1 Figure with 1 Axes by default and use it as current Axes
  - Each object can be added as needed

- Plot on current Axes

```
plt.plot([1, 2, 3, 4])
```



  - Automatically set the x, y ranges and tick labels

- Display figure

```
plt.show()
```

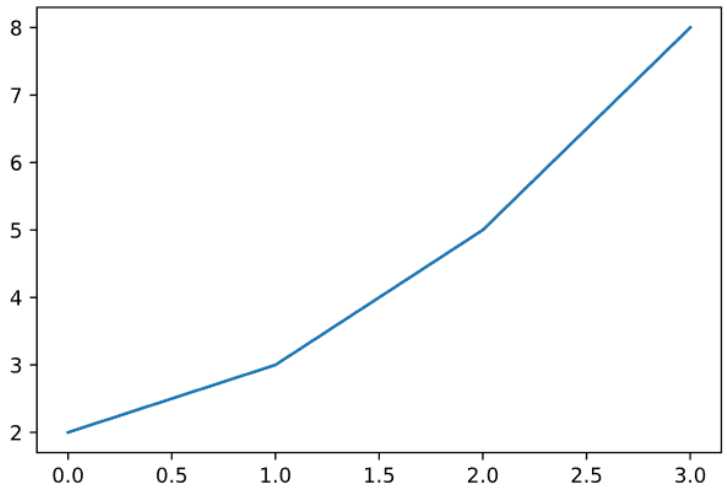
  - For actual display of figures in pyplot, additional statement is necessary

Pyplot Basics

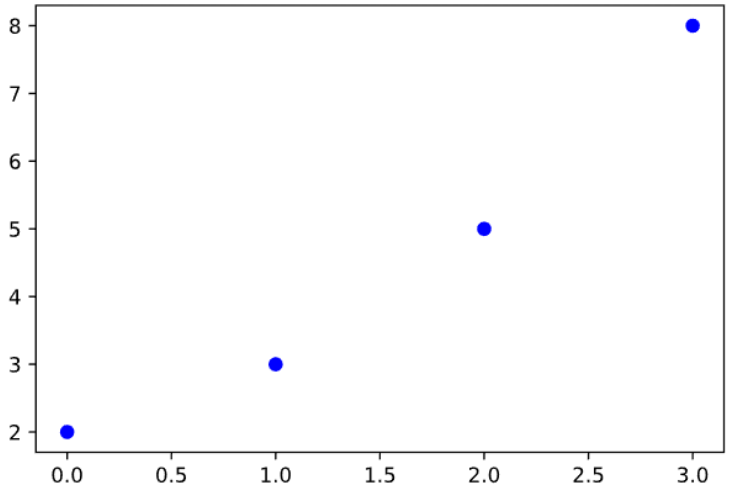
Line and Scatter Plot

- *plt*.`plot`([*x*], *y*, [*fmt*], [*x2*], *y2*, [*fmt2*], ...)
  - The coordinates of the points or line nodes given by *x*, *y*
  - If *x* is omitted, index array [0, 1, ..., *N*-1] is used as *x*
  - *fmt*: defines basic formatting like color, marker and linestyle (default: blue line graph)

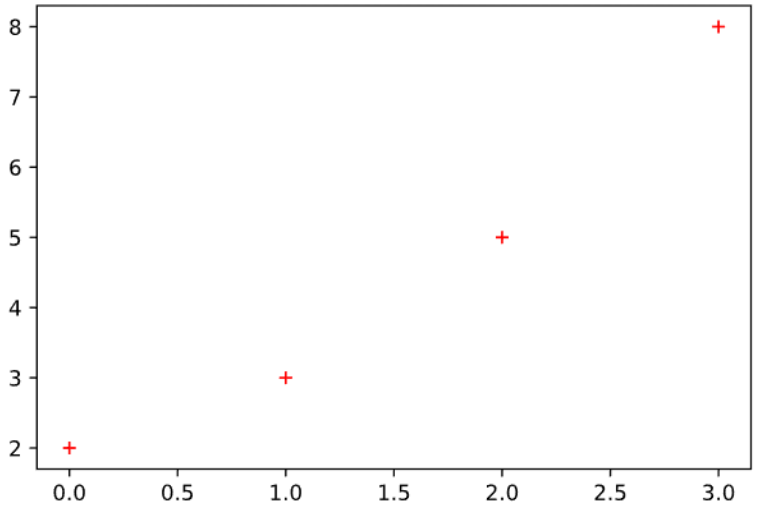
```
plt.plot([2,3,5,8])
```




```
plt.plot([2,3,5,8], 'bo')
```




```
plt.plot([2,3,5,8], 'r+')
```



Markers

'.'	point marker	's'	square marker
','	pixel marker	'p'	pentagon marker
'o'	circle marker	'*'	star marker
'v'	triangle_down marker	'h'	hexagon1 marker
'^'	triangle_up marker	'H'	hexagon2 marker
'<'	triangle_left marker	'+'	plus marker
'>'	triangle_right marker	'x'	x marker
'1'	tri_down marker	'D'	diamond marker
'2'	tri_up marker	'd'	thin_diamond marker
'3'	tri_left marker	'|'	vline marker
'4'	tri_right marker	'_'	hline marker

Line Styles and Colors

'-'	solid line style
'--'	dashed line style
'-.'	dash-dot line style
':'	dotted line style

'b'	blue
'g'	green
'r'	red
'c'	cyan
'm'	magenta
'y'	yellow
'k'	black
'w'	white

```
fmt = '[marker][line][color]'
```

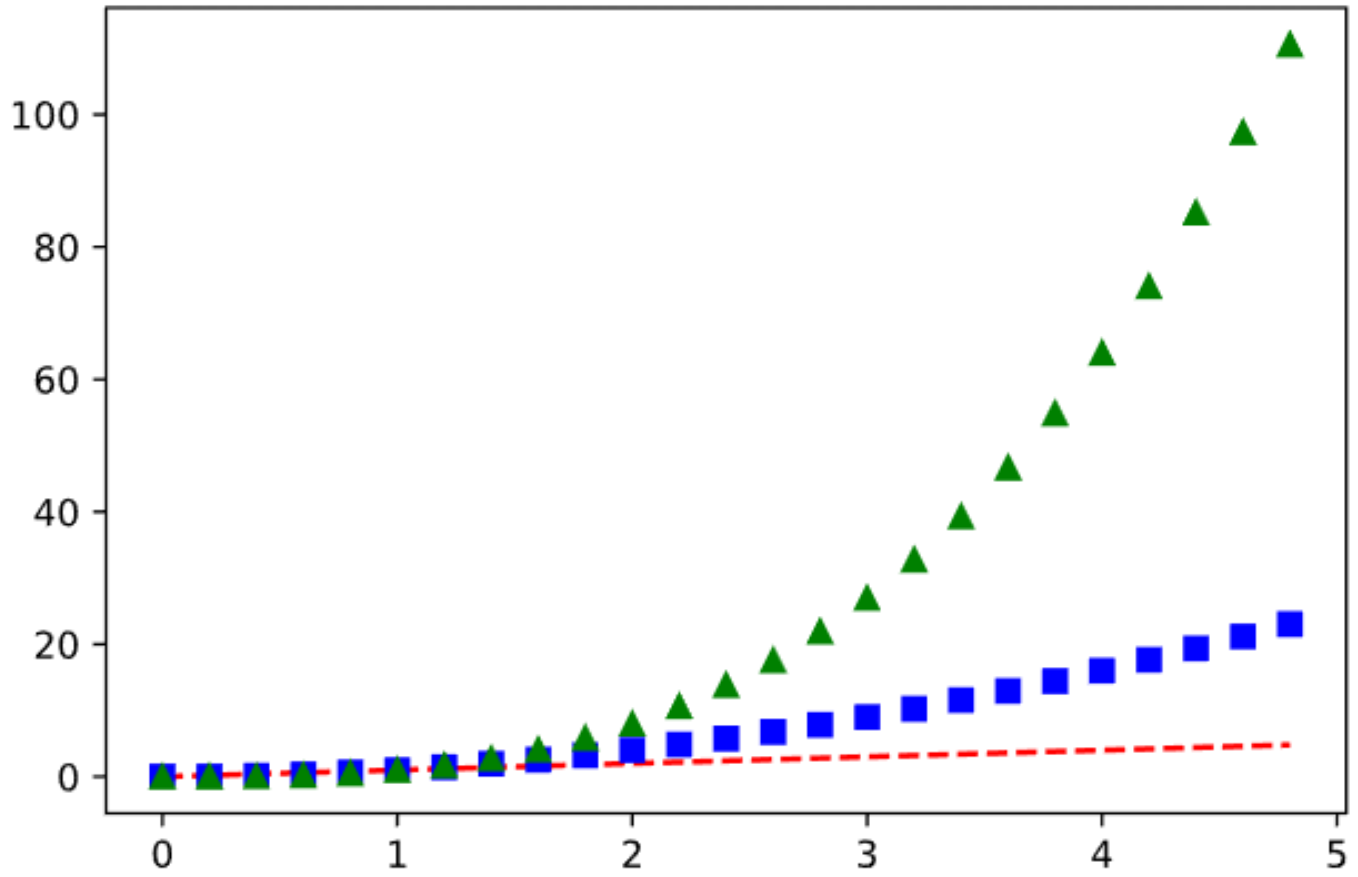
(Same color for line and marker)

Plotting Multiple Graphs

- Plotting 3 different data at once

```
t = np.arange(0.0, 5.0, 0.2)
plt.plot(t, t, 'r--',
         t, t**2, 'bs',
         t, t**3, 'g^')
```

- `'r--'`: red dashed
- `'bs'`: blue square
- `'g^'`: green triangle

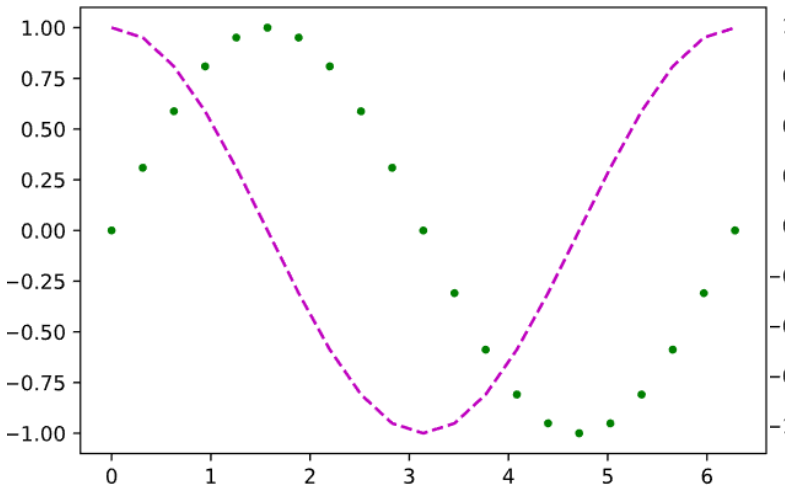


More Examples

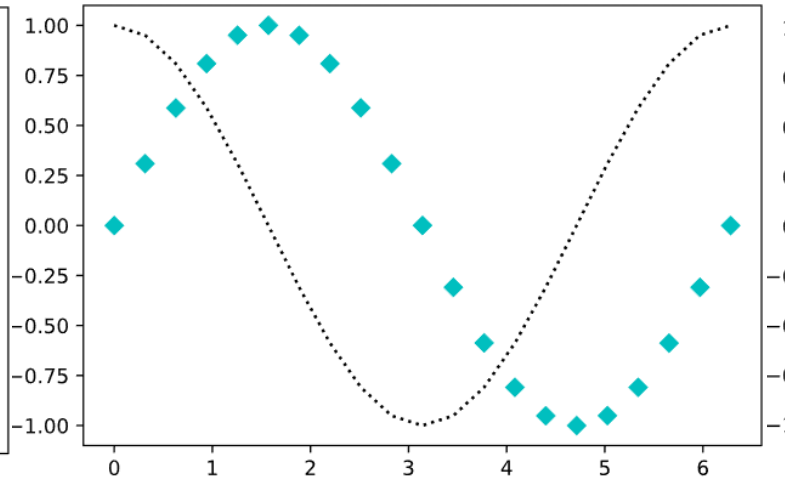
```
x = np.linspace(0, 2*np.pi, 21)
y = np.sin(x)
y2 = np.cos(x)
```

Choose colors automatically

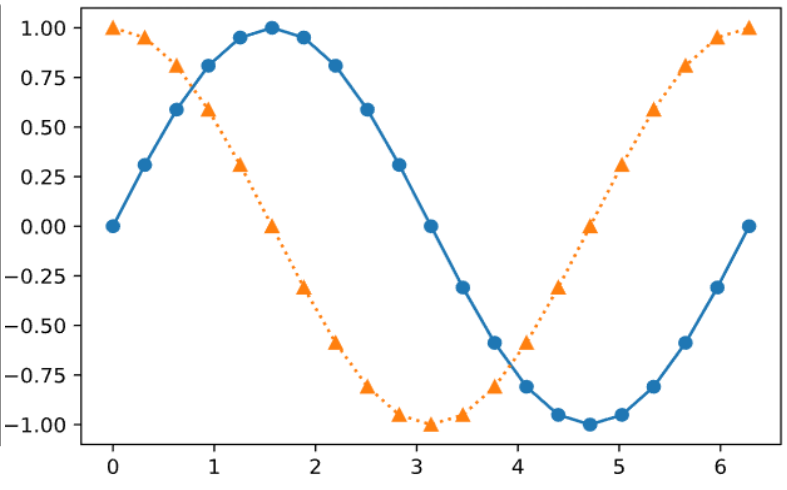
```
plt.plot
(x, y, 'g.', x, y2, 'm--')
```




```
plt.plot
(x, y, 'cD', x, y2, 'k-.')
```



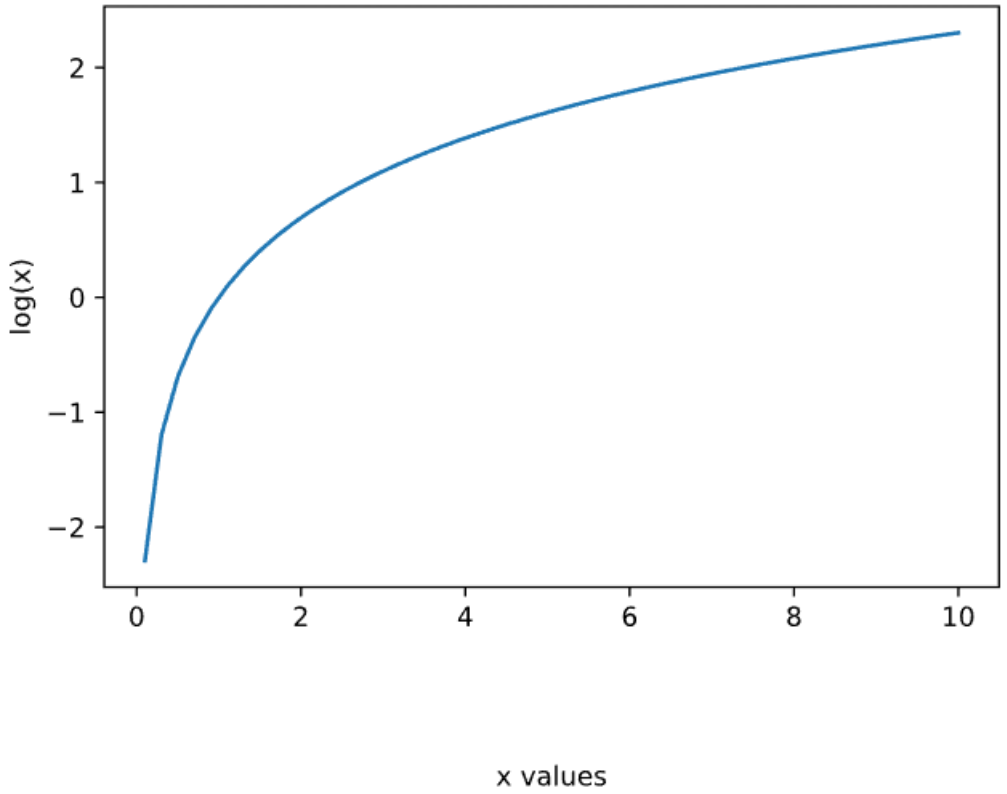

```
plt.plot
(x, y, '-o', x, y2, '^:')
```



Axis Labels

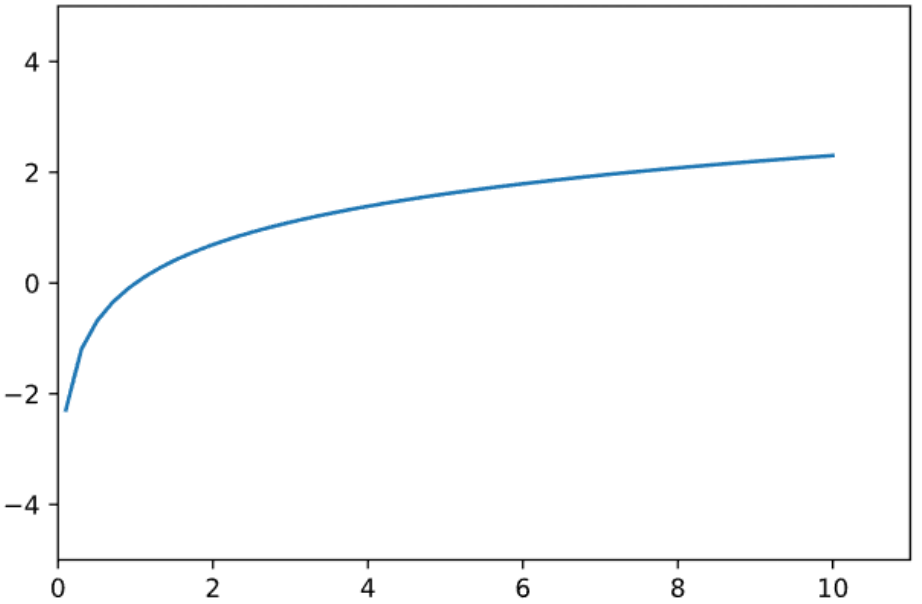
- *plt*.`xlabel`(*xlabel*, [*labelpad*], ...)
- *plt*.`ylabel`(*ylabel*, [*labelpad*], ...)
  - Set the label for the x-axis (or y-axis)
  - *xlabel*, *ylabel*: string for the label
  - *labelpad*: spacing in points from the axes bounding box including ticks and tick labels

```
x = np.linspace(0.1, 10, 100)
y = np.log(x)
plt.xlabel('x values', labelpad=50)
plt.ylabel('log(x)')
plt.plot(x, y)
```

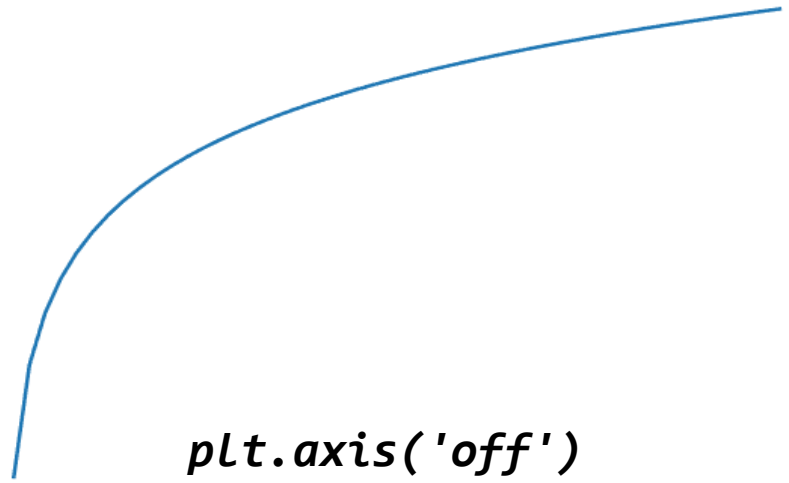


Axis

- *plt.*`axis`*(limits, ...)*
  - Set (or get) some axis properties
  - *limits*: a list with the axis limits to be set.
    `[xmin, xmax, ymin, ymax]`
  - Use `'off'` to hide all the axes




```
x = np.linspace(0.1, 10, 100)
y = np.log(x)
plt.axis([0, 11, -5, 5])
# plt.axis('off')
plt.plot(x, y)
```

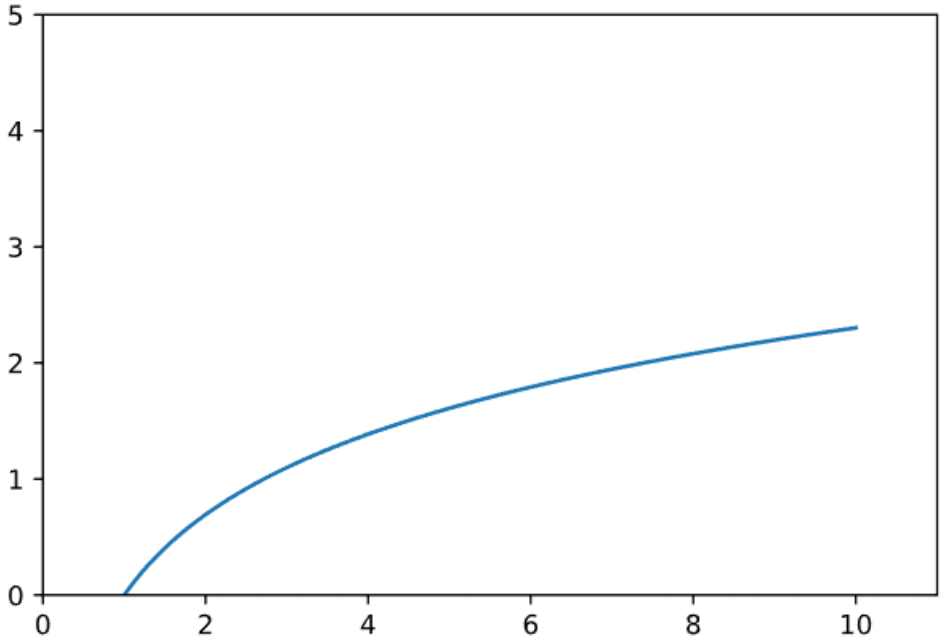


plt.axis('off')

Axis Limit

- *plt*.`xlim`(*left*, *right*)
- *plt*.`ylim`(*bottom*, *top*)
  - Set (or get) the x-limits (or y-limits) of the current axes
  - *left*, *right*: x-limits
  - *bottom*, *top*: y-limits

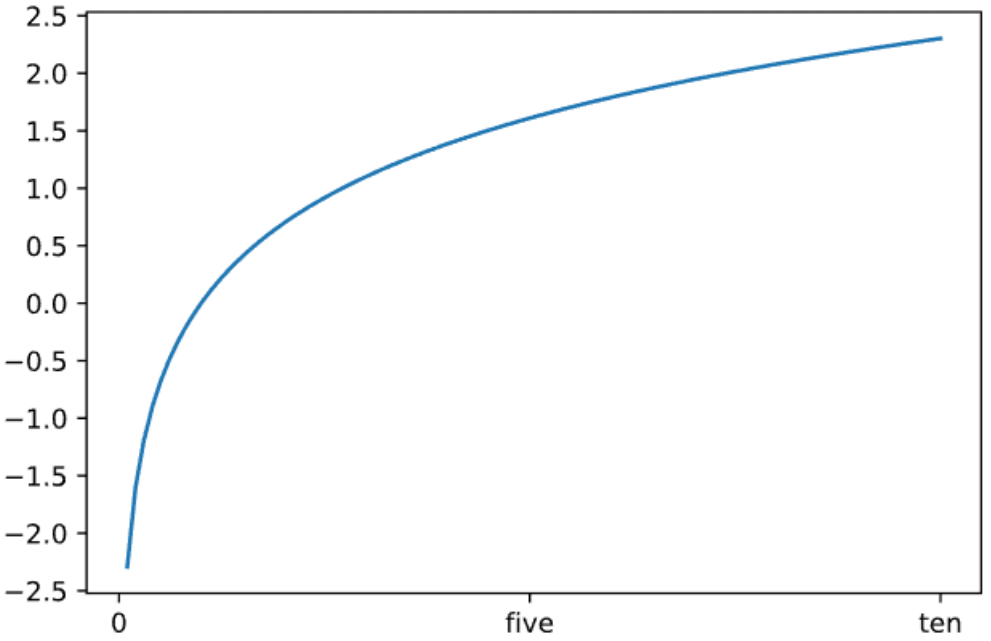
```
x = np.linspace(0.1, 10, 100)
plt.xlim(0, 11)
plt.ylim(top=5)
plt.plot(x, np.log(x))
```



Ticks

- *plt*.`xticks`(*ticks*, [*labels*], ...)
- *plt*.`yticks`(*ticks*, [*labels*], ...)
  - Set the current tick locations and labels of the x-axis (or y-axis)
  - *ticks*: A list of positions ticks should be placed
  - *labels*: A list of explicit labels to place at the given locations

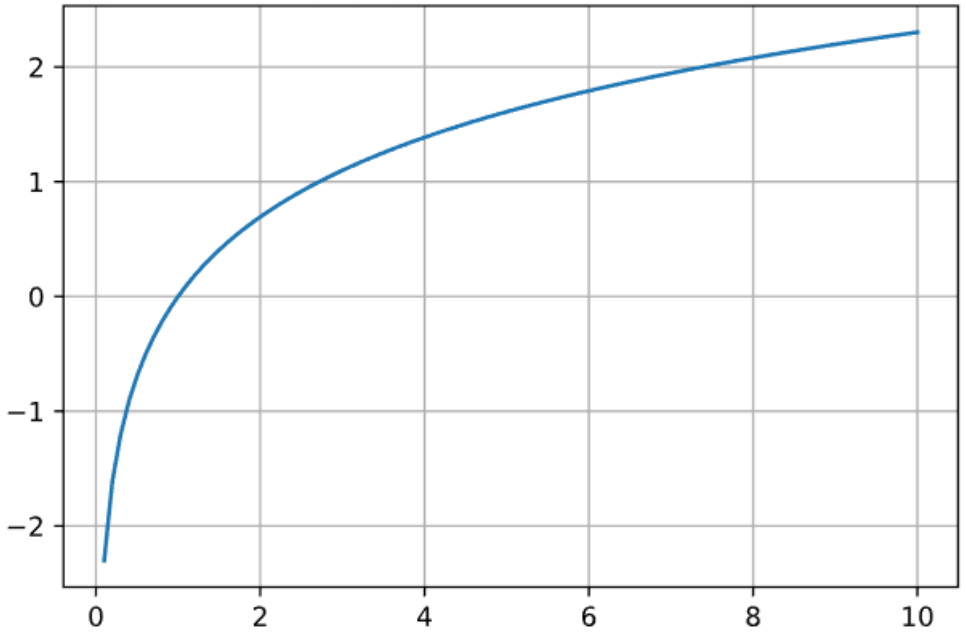
```
x = np.linspace(0.1, 10, 100)
plt.xticks(np.arange(0, 11, 5),
    ('0', 'five', 'ten'))
plt.yticks(np.arange(-3, 3, 0.5))
plt.plot(x, np.log(x))
```



Grids

- *plt*.`grid`([*b*], [*which*], [*axis*], ...)
  - Configure the grid lines
  - *b*: if True, show the grid lines (toggle if no argument given)
  - *which*: the grid lines to apply the changes on ('major', 'minor', or 'both)
  - *axis*: the axis to apply ('x', 'y', or 'both')

```
x = np.linspace(0.1, 10, 100)
plt.grid()
plt.plot(x, np.log(x))
```

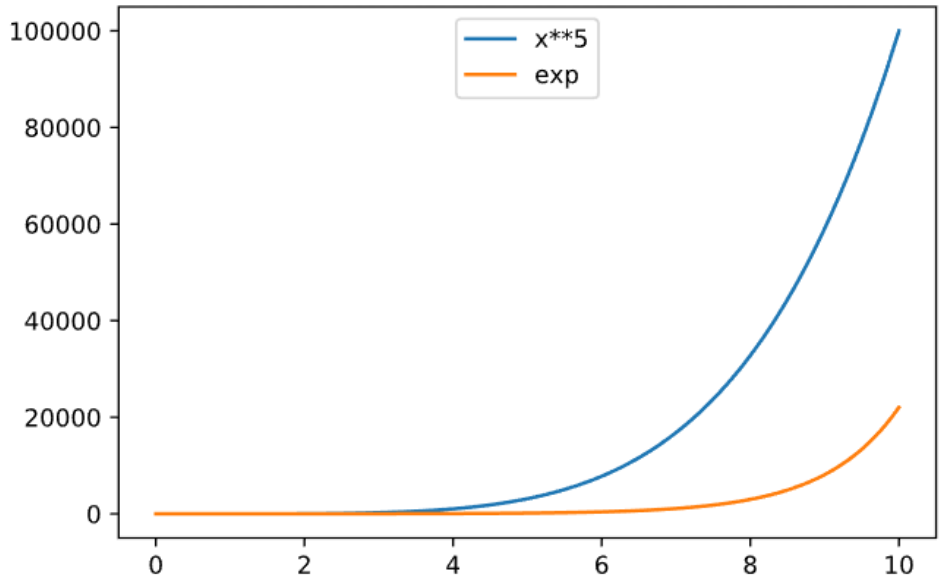


Legend

- *plt*.`legend`([*loc*], [*ncol*], ...)
  - Place a legend on the axes
  - If no argument is given, automatically determine and show the legend
  - *loc*: the location of the legend (default: 'best')
  - *ncol*: the number of columns (default: 1)

Location String	Location Code
'best'	0
'upper right'	1
'upper left'	2
'lower left'	3
'lower right'	4
'right'	5
'center left'	6
'center right'	7
'lower center'	8
'upper center'	9
'center'	10

```
x = np.linspace(0, 10, 100)
plt.plot(x, x**5, label='x**5')
plt.plot(x, np.exp(x), label='exp')
plt.legend(loc='upper center')
```

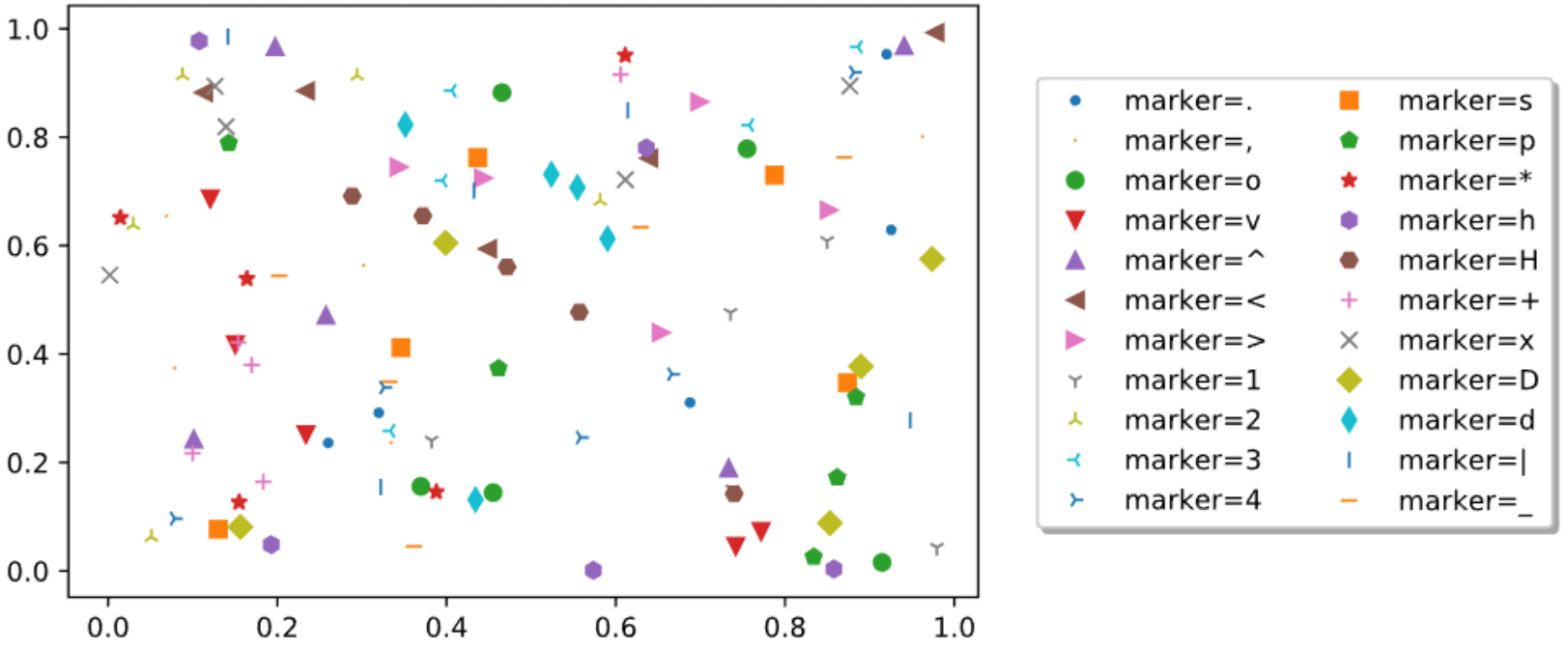


Legend: More Options

- *plt*.`legend`(...)
  - *bbox_to_anchor*: box that is used to position the legend in the arbitrary location with the form (x, y) or (x, y, width, height)
  - *frameon*: control whether the legend should be drawn on a frame (default: True)
  - *fancybox*: control whether round edges should be enabled (default: True)
  - *shadow*: control whether to draw a shadow behind the legend (default: False)
  - *fontsize*: control the font size of the legend
  - *title*: the legend's title
  - *markerscale*: the relative size of legend markers compared
  - *markerfirst*: if True, legend marker is placed to the left (default: True)
  - ...

Legend: Example

```
markers = '.,ov^<>1234sp*hH+xDd|_'
for m in markers:
    plt.plot(np.random.rand(5), np.random.rand(5), m, label=f'marker={m}')
plt.legend(ncol=2, bbox_to_anchor=(1.05, 0.9), shadow=True)
```



Texts

- *plt*.`title`(*label*, [*loc*], [*pad*], ...)
  - *label*: text to use for the title
  - *loc*: which title to set ('center', 'left', or 'right')
  - *pad*: the offset from the top of the axes
- *plt*.`text`(*x*, *y*, *s*, [*loc*], [*pad*], ...)
  - *x*, *y*: the position to place the text
  - *s*: the text to display
- *plt*.`annotate`(*s*, [*xy*], [*xytext*], ...)
  - *s*: the text to display
  - *xy*: the point to annotate
  - *xytext*: the position to place the text at

```
x = np.linspace(0.1, 10, 100)
plt.plot(x, np.log(x))
plt.title("The log(x) graph")
plt.text(6, -1, 'matplotlib rules!')
plt.annotate('log(1) = 0', xy=(1,0),
    xytext=(2,-0.1),
    arrowprops=dict(facecolor='pink',
    shrink=0.05))
```

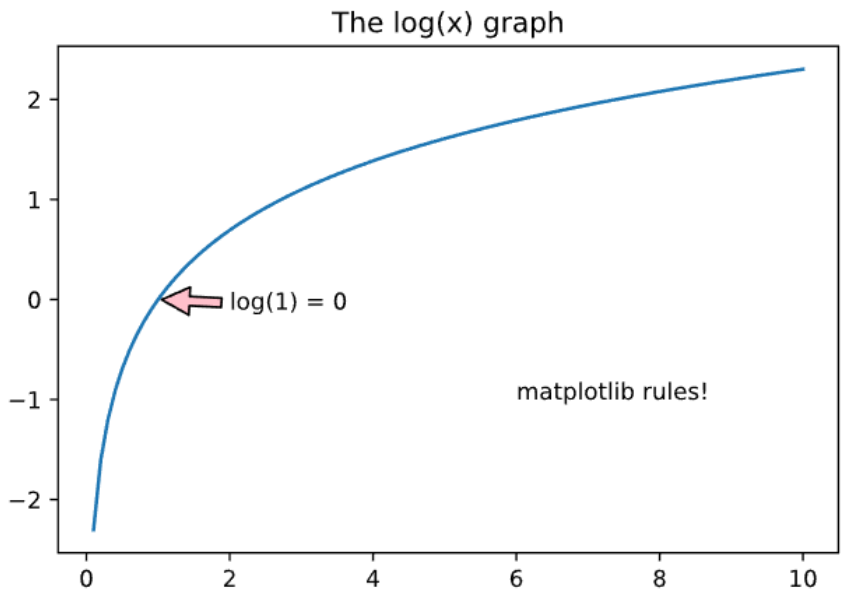
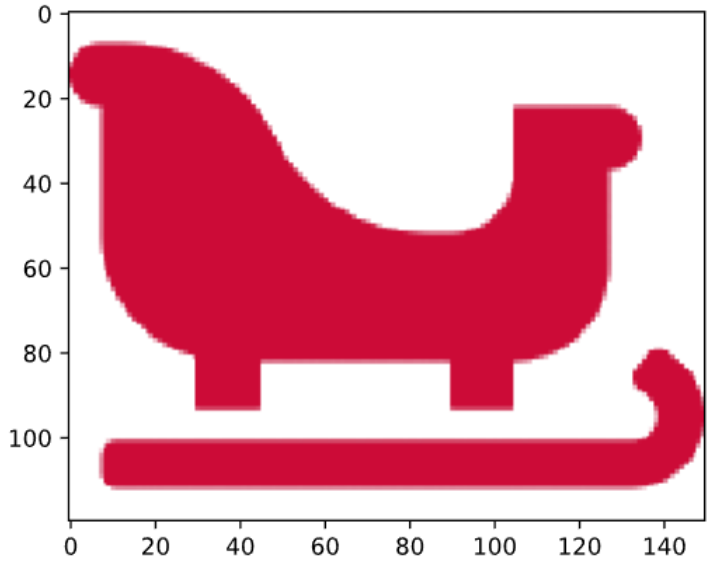
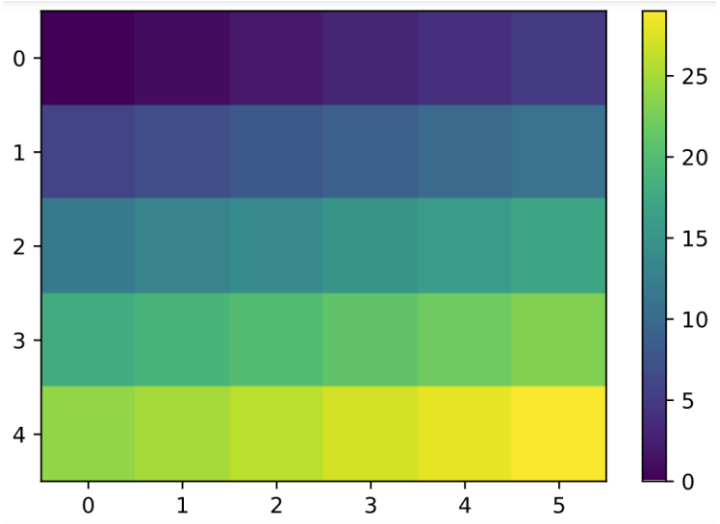


Image Submodule

```
import matplotlib.pyplot as plt
import matplotlib.image as mpimg

img = mpimg.imread('sleds.png')
plt.imshow(img)
```




```
a = np.arange(0,30).reshape(5,6)
plt.imshow(a)
plt.colorbar()
```



Saving Plots

- *plt.*`savefig`(*fname*, [*format*], [*dpi*], [*transparent*], ...)
  - Save the current figure
  - *fname*: file name to save. If format is not given, the output format is inferred from the extension of the fname
  - *format*: the file format (e.g., 'png', 'pdf', 'svg', 'jpg', ...)
  - *dpi*: the resolution in dots per inch
  - *transparent*: if True, make the plot transparent (default: False)

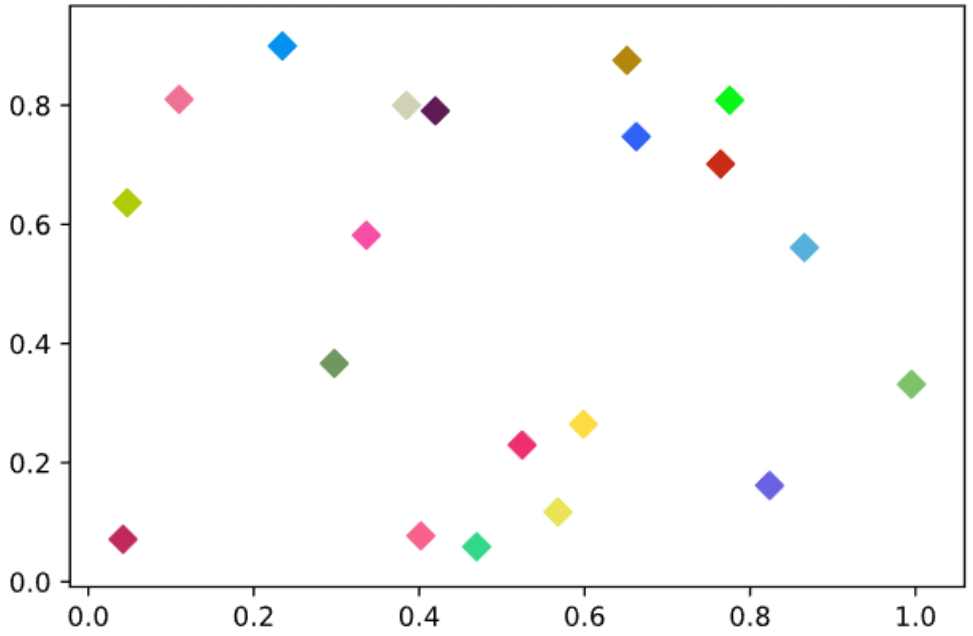
```
x = np.linspace(0.1, 10, 100)
plt.plot(x, np.log(x))
plt.savefig('log.png', dpi=300, transparent=True)
```

Scatter Plot

scatter()

- *plt*.`scatter`(*x*, *y*, [*s*], [*c*], [*marker*], [*alpha*], ...)
  - A scatter plot of y vs. x with varying marker size and/or color
  - *x*, *y*: data positions
  - *s*, *c*: the marker size (in points**2) and its color
  - *marker*: the marker style
  - *alpha*: the alpha blending value (0: transparent ~ 1: opaque)

```
x = np.random.rand(20)
y = np.random.rand(20)
colors=[f'#{np.random.randint(256**3):06x}'
    for _ in range(20)]
plt.scatter(x, y, s=50, c=colors, marker='D')
```



plot() vs. scatter()

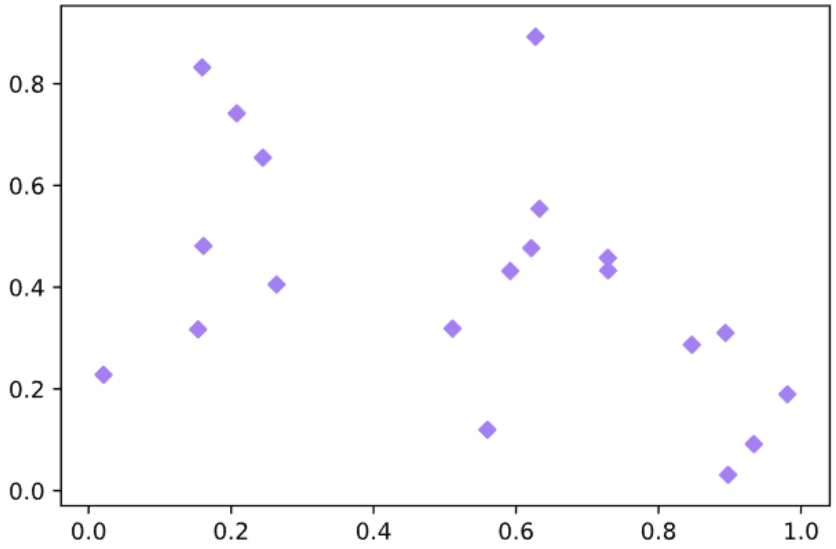
- *plt*.`plot()`

```
np.random.seed(1010)
N = 20
x = np.random.rand(N)
y = np.random.rand(N)
plt.plot(x,y,'D',c='#a37ff1',markersize=5)
```

- *plt*.`scatter()`

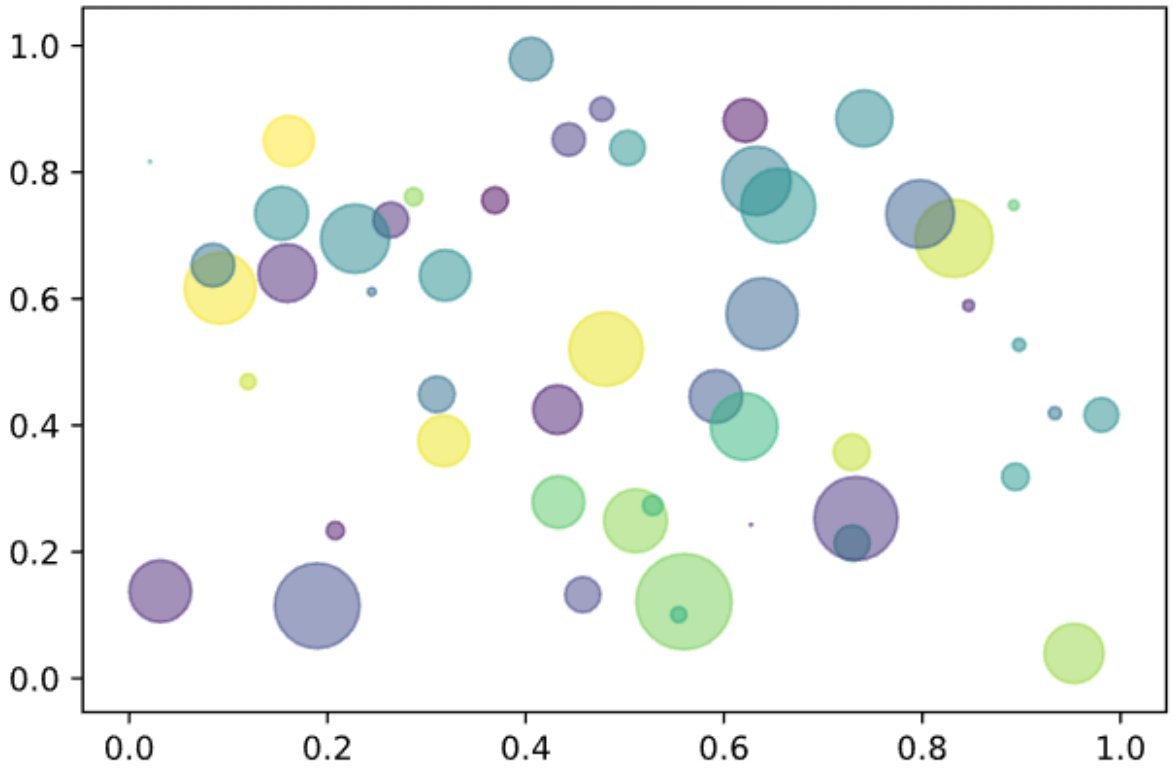
```
np.random.seed(1010)
N = 20
x = np.random.rand(N)
y = np.random.rand(N)
plt.scatter(x,y,s=25,c='#a37ff1',marker='D')
```

- Both can be used for simple cases
  ➔ same result
- `scatter()` is more comfortable to configure each data point
- `plot()` allows to plot the lines connecting data points



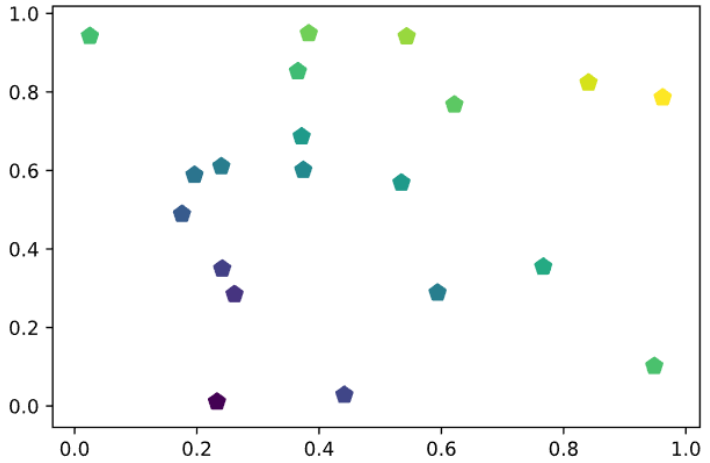
Scatter Plot with Different Marker Sizes

```
np.random.seed(20200101)

N = 50
x = np.random.rand(N)
y = np.random.rand(N)
colors = np.random.rand(N)
area=(30 * np.random.rand(N))**2

plt.scatter(x, y, s=area, c=colors, alpha=0.5)
```



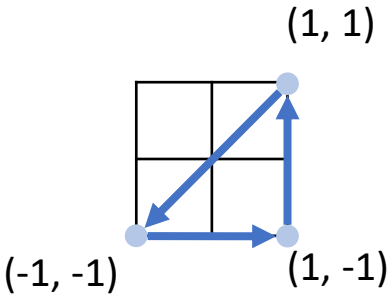
Scatter Plot with Polygon Symbols

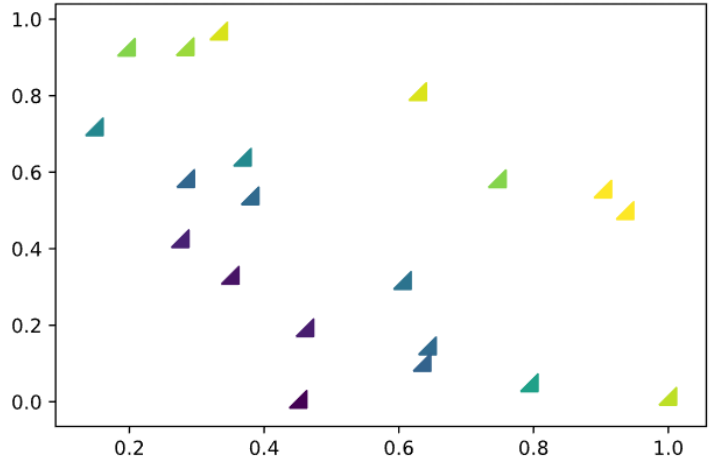
- Marker = (numsides, style, angle)
  - *numsides*: number of sides
  - *style*: regular polygon(0), star-like symbol(1), asterisk(2), circle(3)
  - *angle*: angle of rotation



- User-defined marker:
  - A list of (x, y) describing a symbol with center = (0, 0)

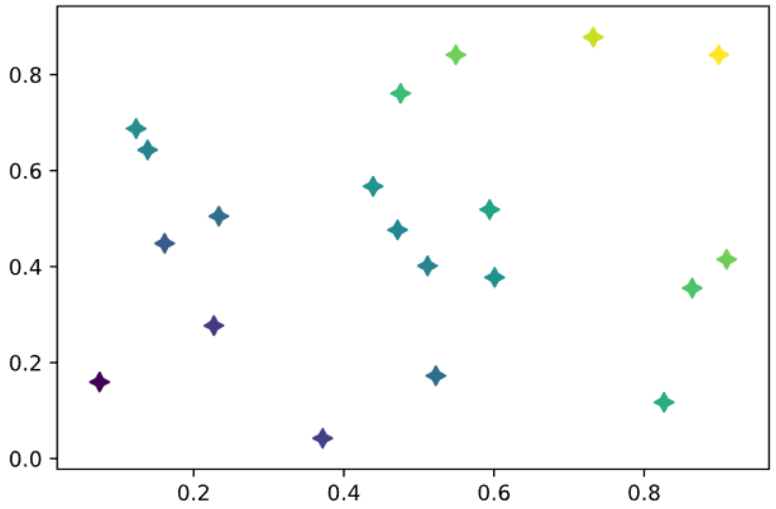
```
x = np.random.rand(20)
y = np.random.rand(20)
z = np.sqrt(x**2 + y**2)
plt.scatter(x, y, s=80, c=z, marker=(5,0))
v = np.array([[-1,-1],[1,-1],[1,1],[-1,-1]])
plt.scatter(x, y, s=80, c=z, marker=v)
```

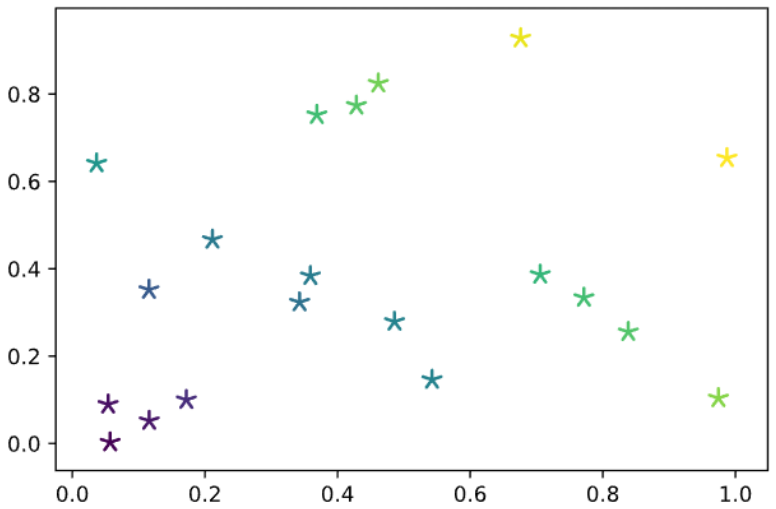




Scatter Plot with Stars and Asterisks

```
x = np.random.rand(20)
y = np.random.rand(20)
z = np.sqrt(x**2 + y**2)

# with 4-side star
plt.scatter(x, y, s=80, c=z, marker=(4,1))

# with 5-side asterisk
plt.scatter(x, y, s=80, c=z, marker=(5,2))
```

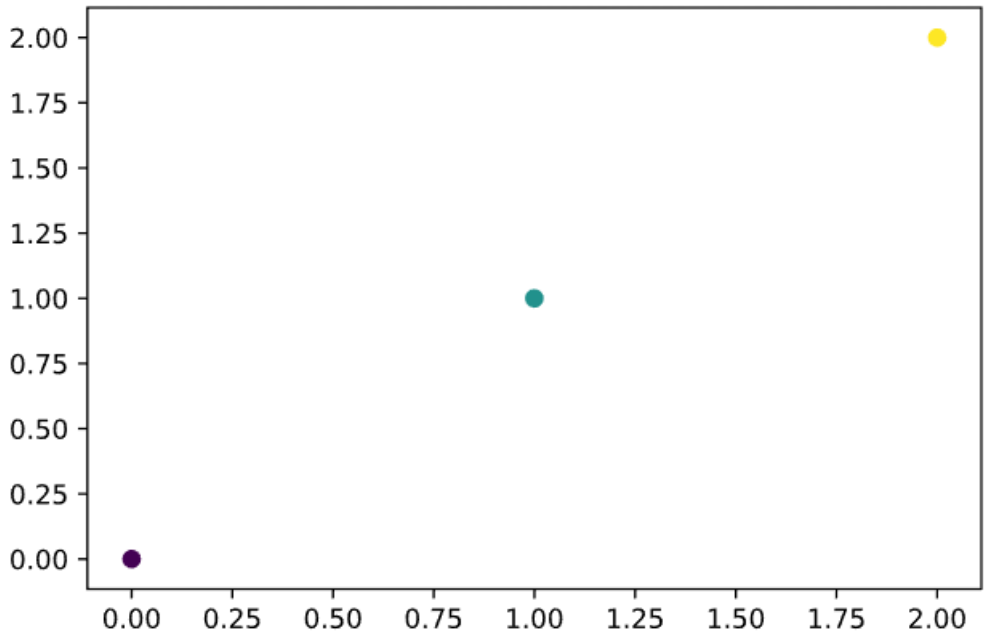




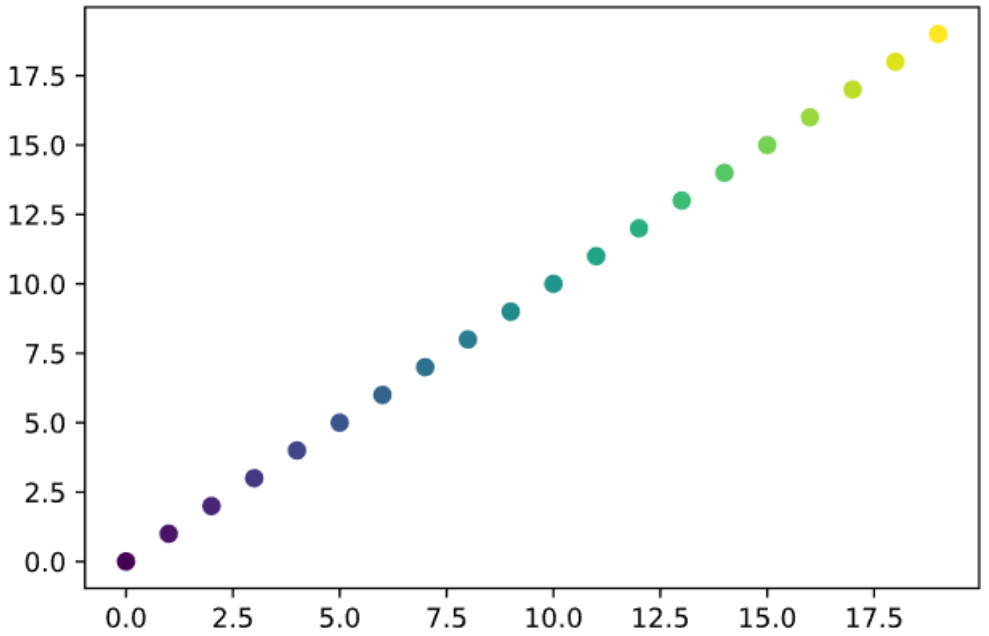
Default Color Map

- 'viridis':


```
x = np.arange(3)
plt.scatter(x, x, c=x)
```

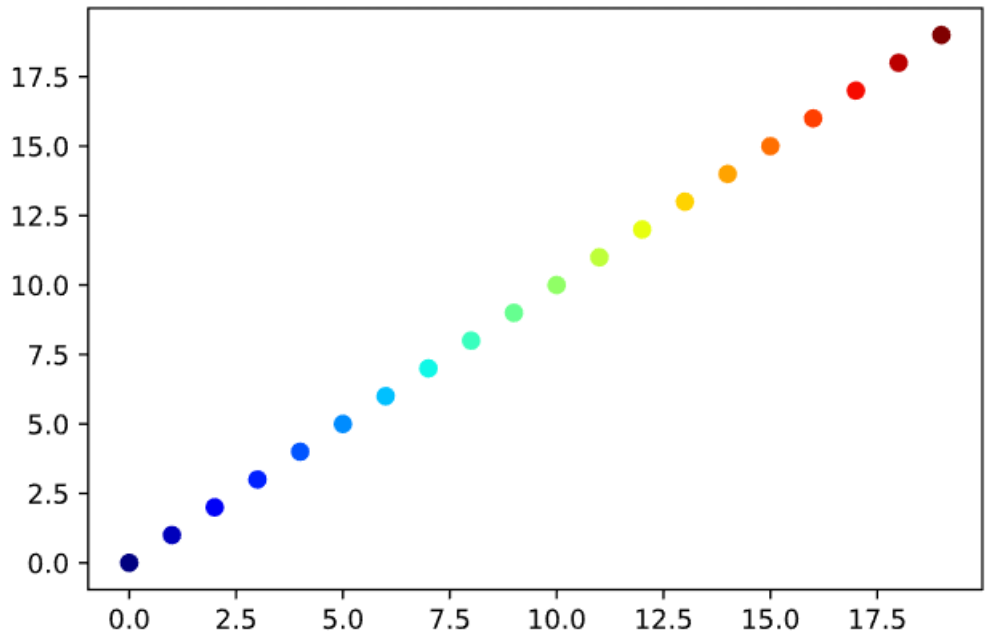



```
x = np.arange(20)
plt.scatter(x, x, c=x)
```

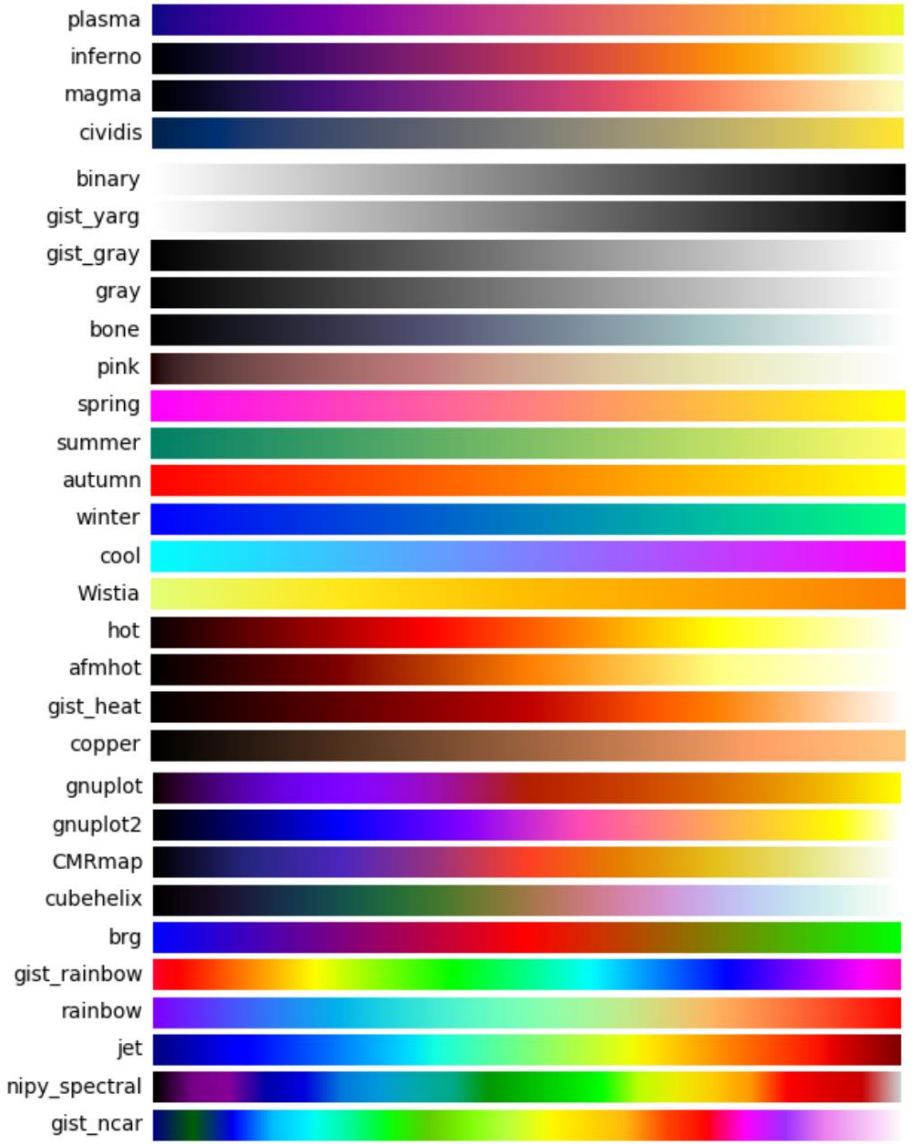


Changing a Color Map

```
plt.rc('image', cmap='jet')
x = np.arange(20)
plt.scatter(x, x, c=x)
```



For other colormaps, visit
https://matplotlib.org/tutorials/colors/colormaps.html

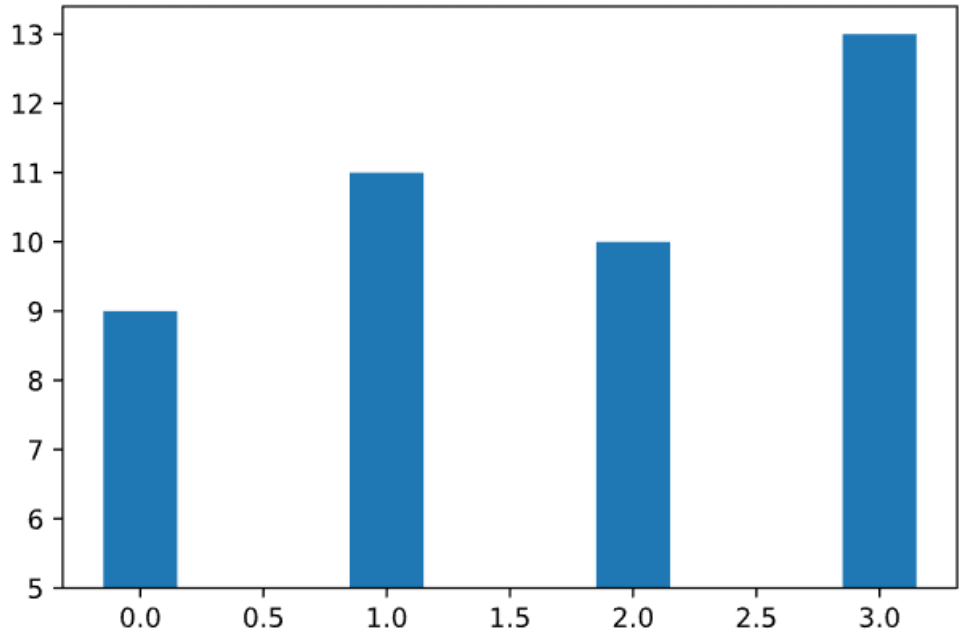


Bar Chart

bar()

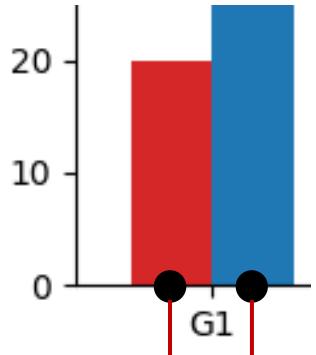
- *plt.*bar(*x, height,* [*width*], [*bottom*], [*align*], ...)
  - Make a bar plot
  - *x*, *height*: data points
  - *width*: the width(s) of the bars (default: 0.8)
  - *bottom*: the y coordinate(s) of the bars bases
  - *align*: alignment of the bars to the x coordinates -- 'center' (default) or 'edge'

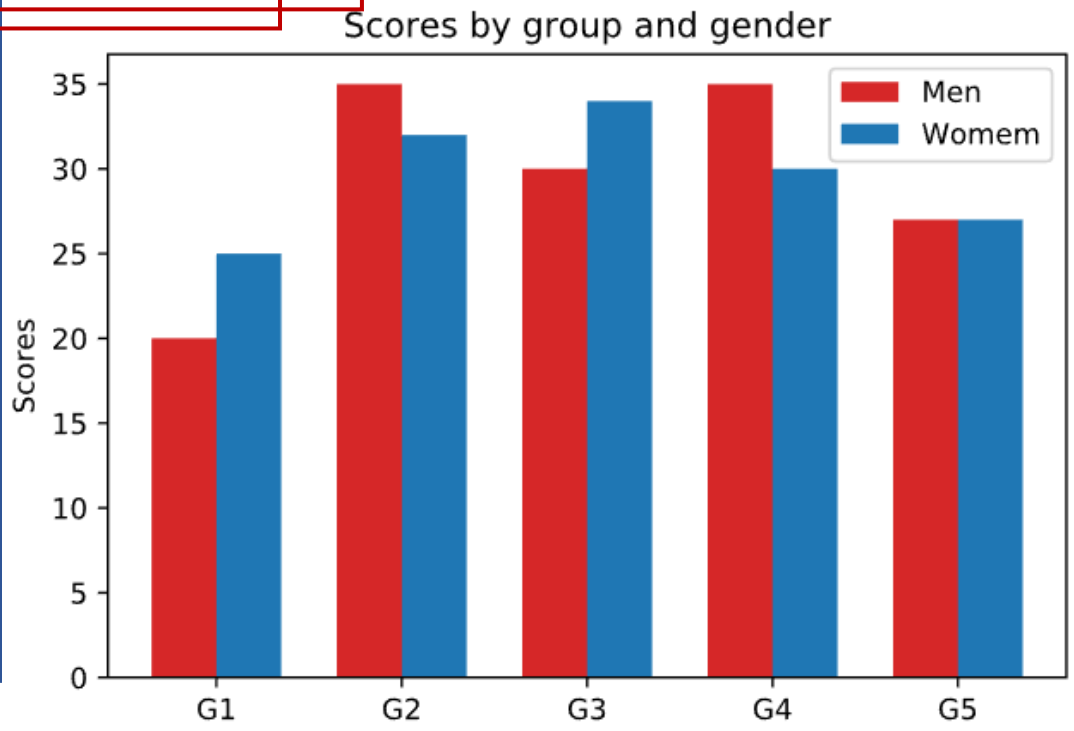
```
x = np.arange(4)
y = [4, 6, 5, 8]
plt.bar(x, y, width=0.3, bottom=5)
```



Side-by-Side Bar Chart

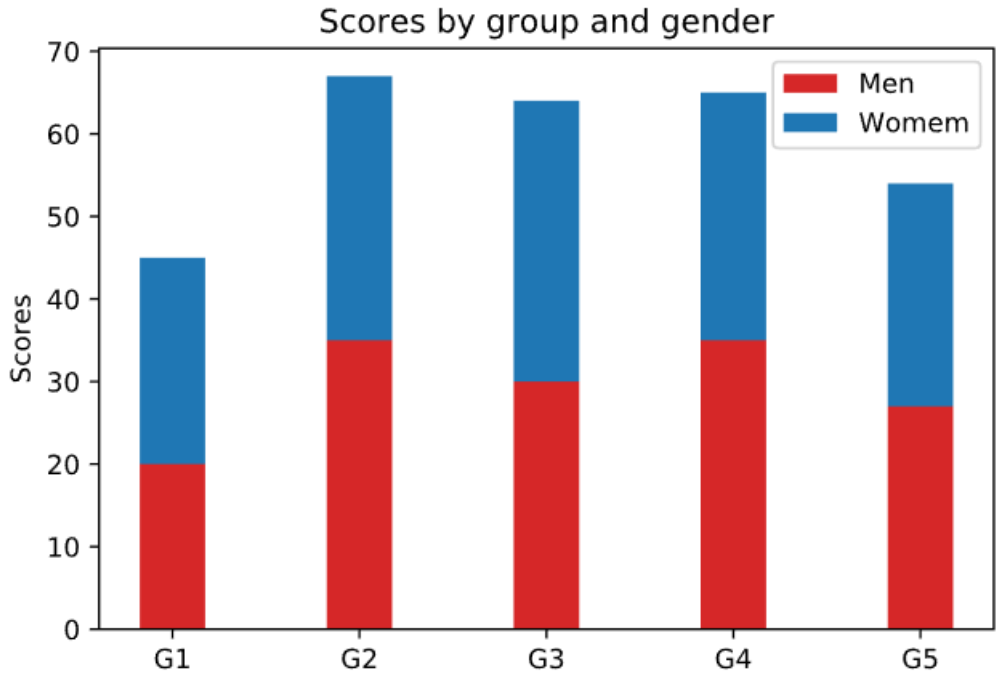
```
N = 5

m = (20, 35, 30, 35, 27)
w = (25, 32, 34, 30, 27)
x = np.arange(N)
width=0.35

plt.bar(x-width/2, m, width, color='#d62728')
plt.bar(x+width/2, w, width)

plt.xticks(x, ('G1','G2','G3','G4','G5'))
plt.ylabel('Scores')
plt.title('Scores by group and gender')
plt.legend(('Men', 'Womem'))
```





Stacked Bar Chart

```
N = 5

m = (20, 35, 30, 35, 27)
w = (25, 32, 34, 30, 27)
x = np.arange(N)
width=0.35

plt.bar(x, m, width, color='#d62728')
plt.bar(x, w, width, bottom=m)

plt.xticks(x, ('G1','G2','G3','G4','G5'))
plt.ylabel('Scores')
plt.title('Scores by group and gender')
plt.legend(('Men', 'Womem'))
```

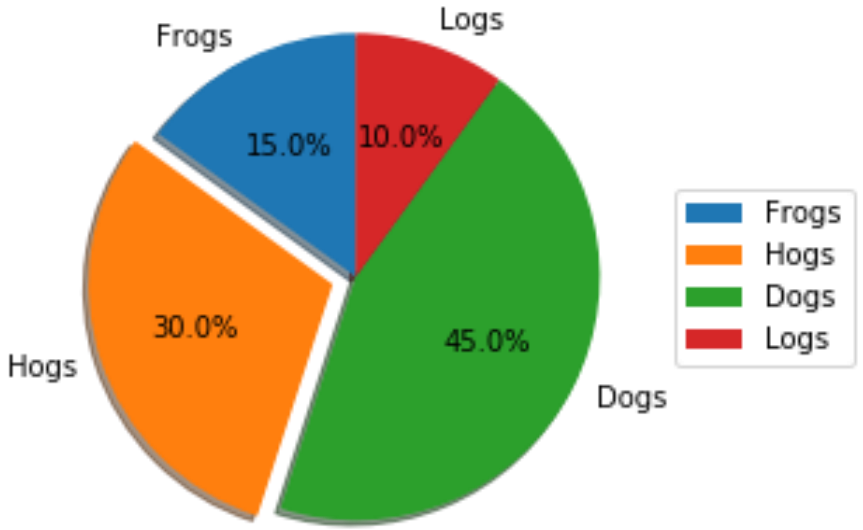


Pie Chart

pie()

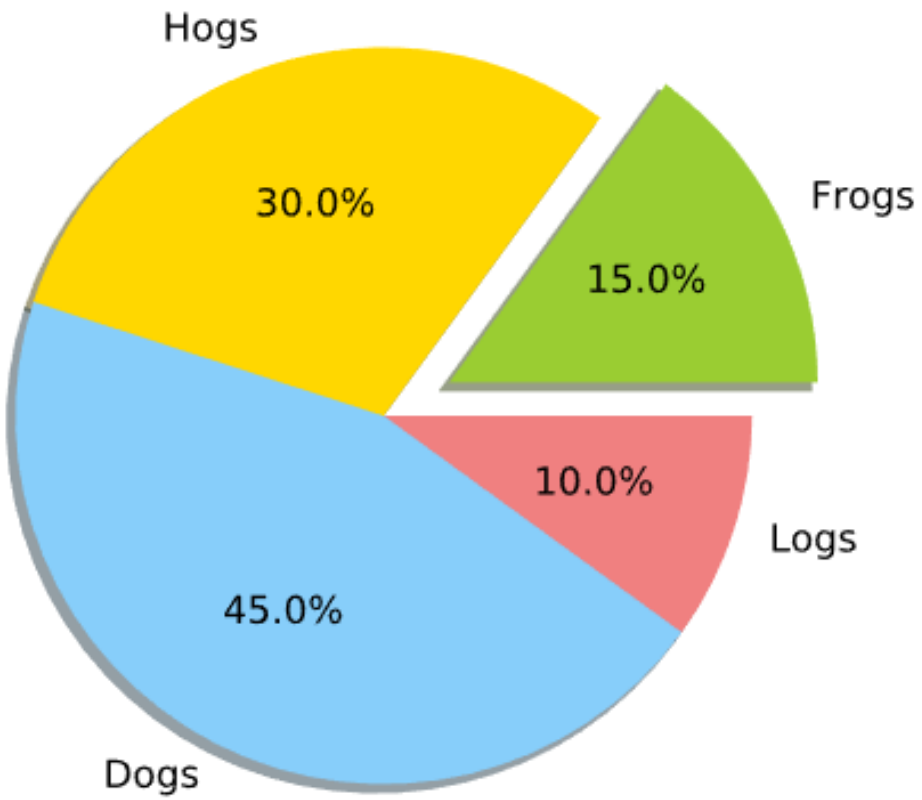
- *plt.*`pie`(*x*, [*labels*], [*colors*], [*explode*], [*startangle*], [*autopct*], ...)
  - Plot a pie chart
  - *x*: the wedge sizes
  - *labels*: a sequence of labels
  - *colors*: a sequence of colors
  - *explode*: the fraction of the radius with which to offset each wedge
  - *startangle*: start pie chart with this degree
  - *autopct*: label wedges with numeric value

```
labels = ['Frogs', 'Hogs', 'Dogs', 'Logs']
sizes = [15, 30, 45, 10]
ex = (0, 0.1, 0, 0)
plt.pie(sizes, explode=ex, labels=labels,
   autopct='%.1f%%', shadow=True, startangle=90)
plt.legend(loc='center right',
   bbox_to_anchor=(1.4, 0.5))
```



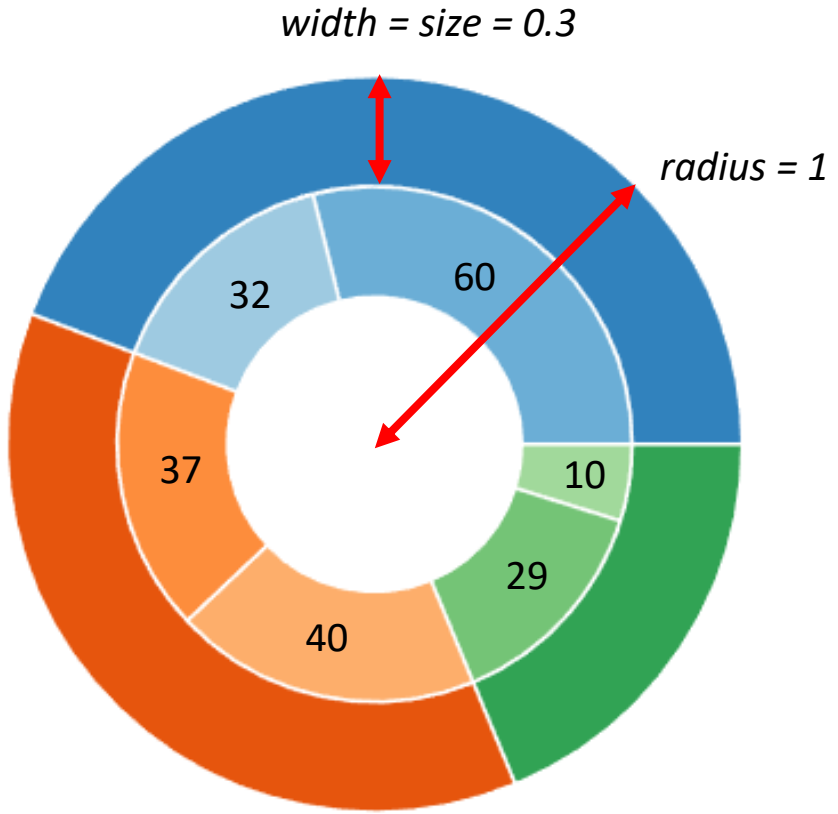
Using Specific Colors

```
labels = ['Frogs','Hogs','Dogs','Logs']
sizes = [15, 30, 45, 10]
ex = (0.2, 0, 0, 0)
c = ['yellowgreen', 'gold',
     'lightskyblue', 'lightcoral']

plt.pie(sizes, explode=ex, labels=labels,
    colors=c, autopct='%.1f%%',
    shadow=True, startangle=0)

plt.axis('equal')
```



Nested Pie Chart

```
size = 0.3
vals = np.array([[60.,32.],[37.,40.],[29.,10.]])

cmap = plt.get_cmap('tab20c')
outer_colors = cmap(np.arange(3)*4)
inner_colors = cmap(np.array([1,2,5,6,9,10]))

plt.pie(vals.sum(axis=1), radius=1,
    colors=outer_colors,
    wedgeprops={'width':size, 'edgecolor':'w'})
plt.pie(vals.flatten(), radius=1-size,
    colors=inner_colors,
    wedgeprops={'width':size, 'edgecolor':'w'})
plt.axis('equal')
```

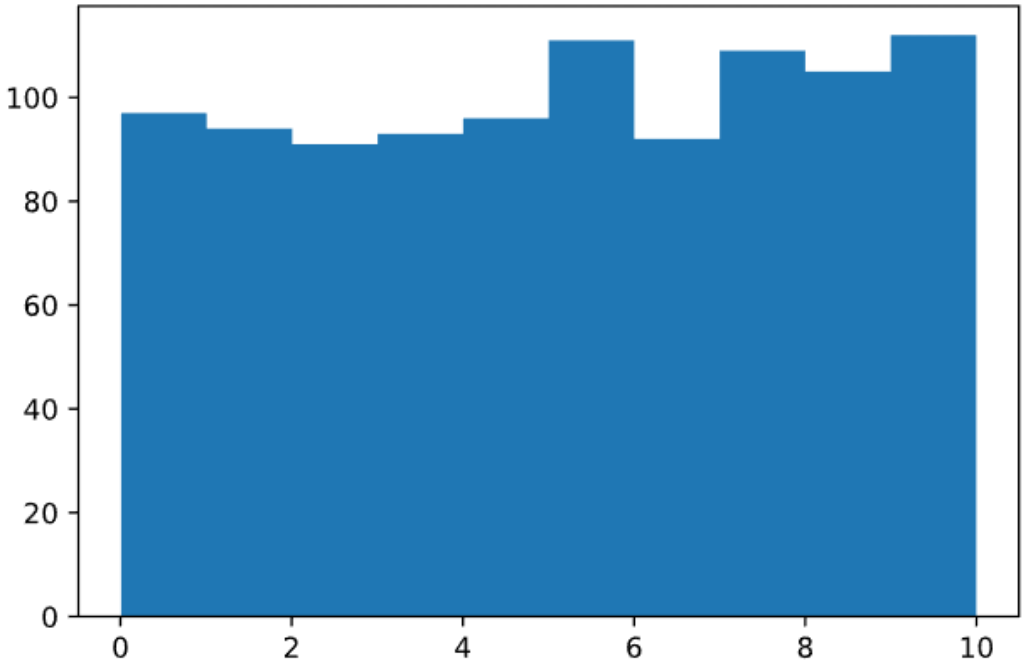


Histogram

hist()

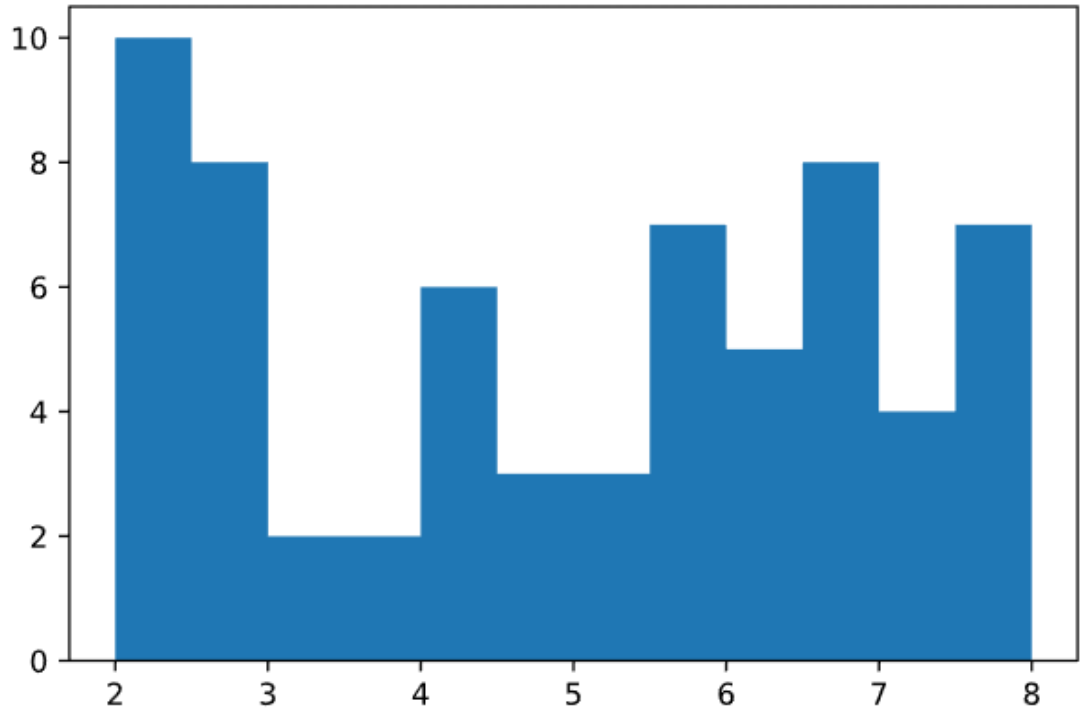
- *plt.*`hist`(*x*, [*bins*], [*range*], [*cumulative*], [*bottom*], ...)
  - Plot a histogram
  - *x*: input values
  - *bins*: number of bins (default: 10)
  - *range*: the lower and upper range of the bins
  - *cumulative*: if True, shows the cumulative sum
  - *bottom*: the baseline of each bin

```
x = np.random.uniform(0., 10., 1000)
plt.hist(x)
```



Range and Bins

```
x = np.random.uniform(0., 10., 100)
plt.hist(x, range=[2., 8.], bins=12)
```



Split [2.0, 8.0] into 12 bins:

bin *0* has the count of $2. \le x < 2.5$
bin *1* has the count of $2.5 \le x < 3.0$

bin *i* has the count of $2.+0.5i \le x < 2.5+0.5i$

bin *11* has the count of $7.5 \le x < 8.0$

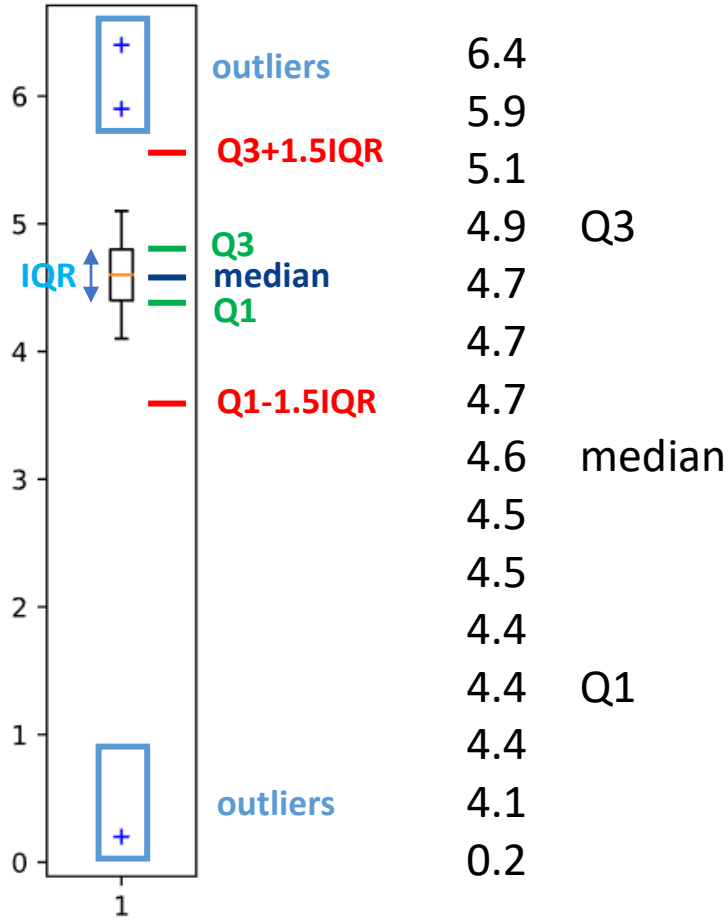
Box Plot

boxplot()

- *plt*.boxplot(*x*, [*notch*], [*sym*], [*vert*], [*whis*], ...)
  - Make a box and whisker plot
  - *x*: input data
  - *notch*: If True, produce a notched box plot (default: False)
  - *sym*: the symbol for outliers
  - *vert*: If True, make the boxes vertical (default: True)
  - *whis*: the reach of the whiskers (default: 1.5)

(cf.) IQR = InterQuartile Range

```
x = [0.2, 4.1, 4.4, 4.4, 4.4, 4.5, 4.5, 4.6,
     4.7, 4.7, 4.7, 4.9, 5.1, 5.9, 6.4]
plt.boxplot(x, sym='b+')
```

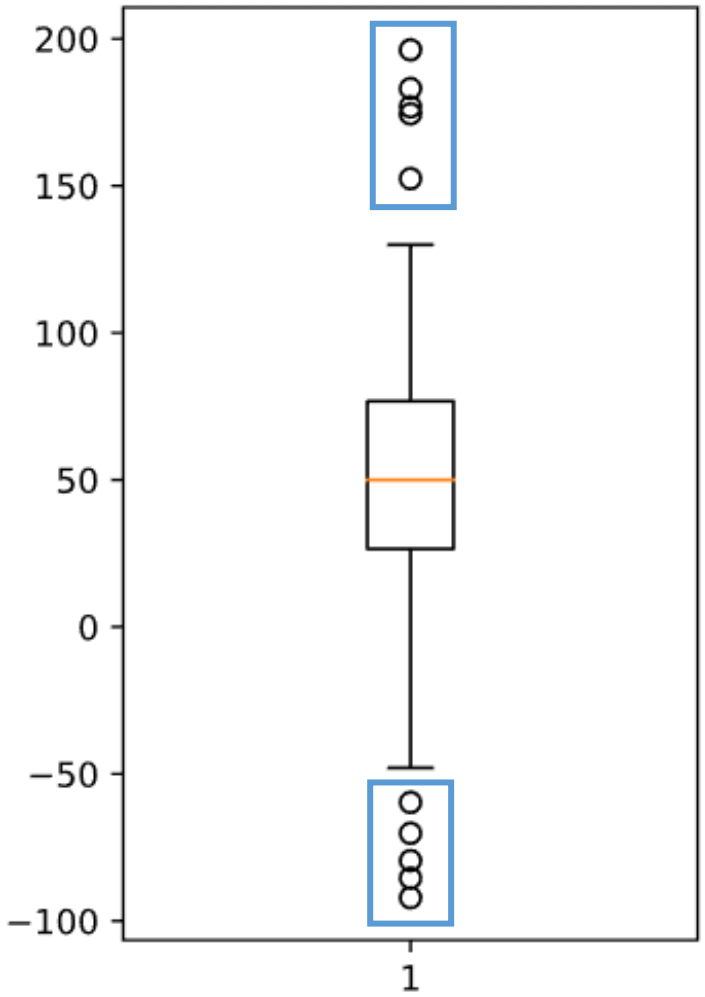


6.4	
5.9	
5.1	
4.9	Q3
4.7	
4.7	
4.7	
4.6	median
4.5	
4.5	
4.4	
4.4	Q1
4.4	
4.1	
0.2	

IQR = Q3 – Q1 = 4.9 - 4.4 = 0.5
Q1 - 1.5IQR = 4.4 – 1.5*0.5 = 3.65
Q3 + 1.5IQR = 4.9 + 1.5*0.5 = 5.65

Box Plot Example

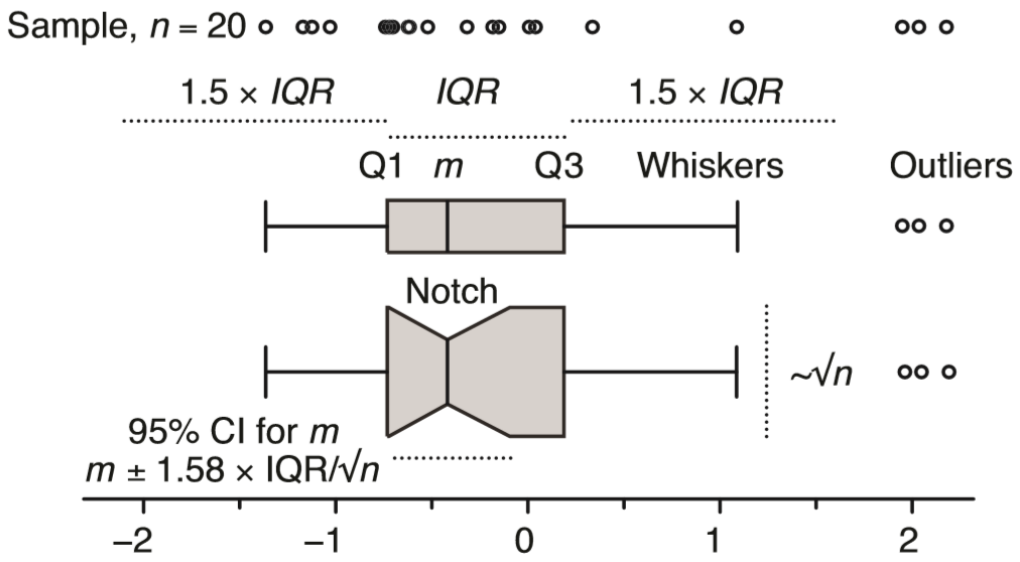
```
spread = np.random.rand(50)*100
center = np.ones(25)*50
high = np.random.rand(10)*100+100
low = np.random.rand(10)*(-100)

data = np.concatenate((spread, center, high, low), 0)
plt.figure(figsize=(3, 5))  # fig size in inches
plt.boxplot(data)
```

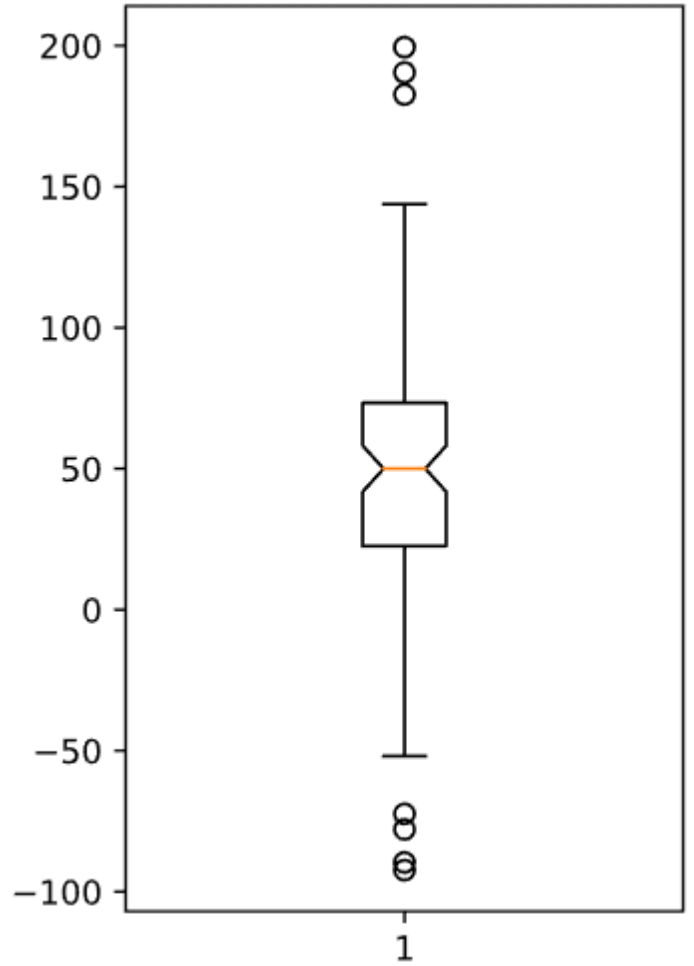


- spread: 50 numbers in [0, 100)
- center: 25 numbers with the value 50.0
- high: 10 numbers in [100, 200)
- low: 10 numbers in (-100, 0]

Notched Box Plot

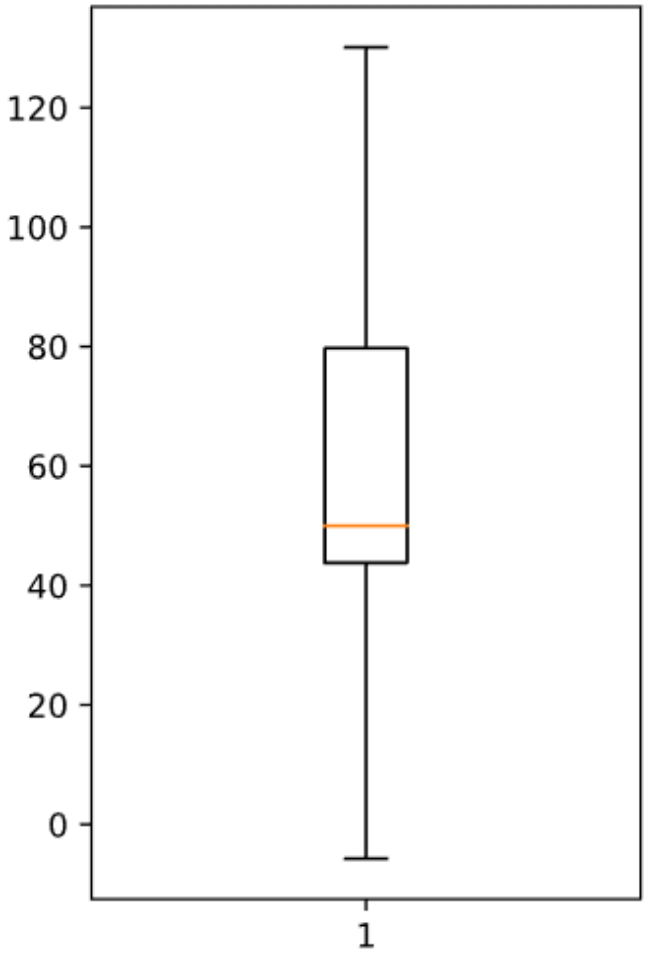
```
spread = np.random.rand(50)*100
center = np.ones(25)*50
high = np.random.rand(10)*100+100
low = np.random.rand(10)*(-100)
data = np.concatenate((spread, center, high, low), 0)
plt.figure(figsize=(3, 5))  # fig size in inches
plt.boxplot(data, notch=True)
```





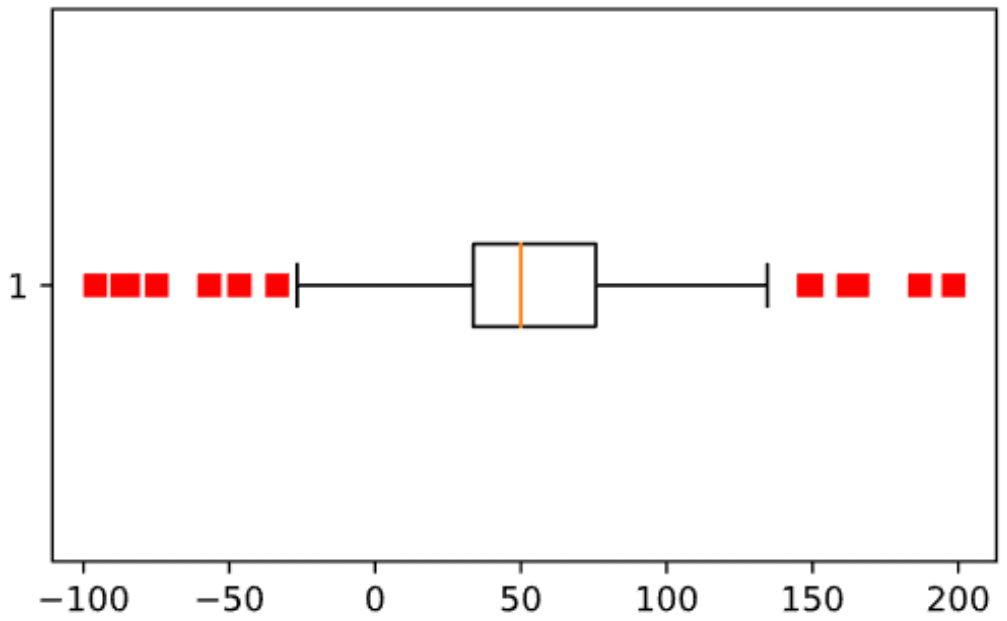
Removing Outliers

```
spread = np.random.rand(50)*100
center = np.ones(25)*50
high = np.random.rand(10)*100+100
low = np.random.rand(10)*(-100)
data = np.concatenate((spread, center, high, low), 0)

plt.figure(figsize=(3, 5))  # fig size in inches
plt.boxplot(data, sym=' ')
```



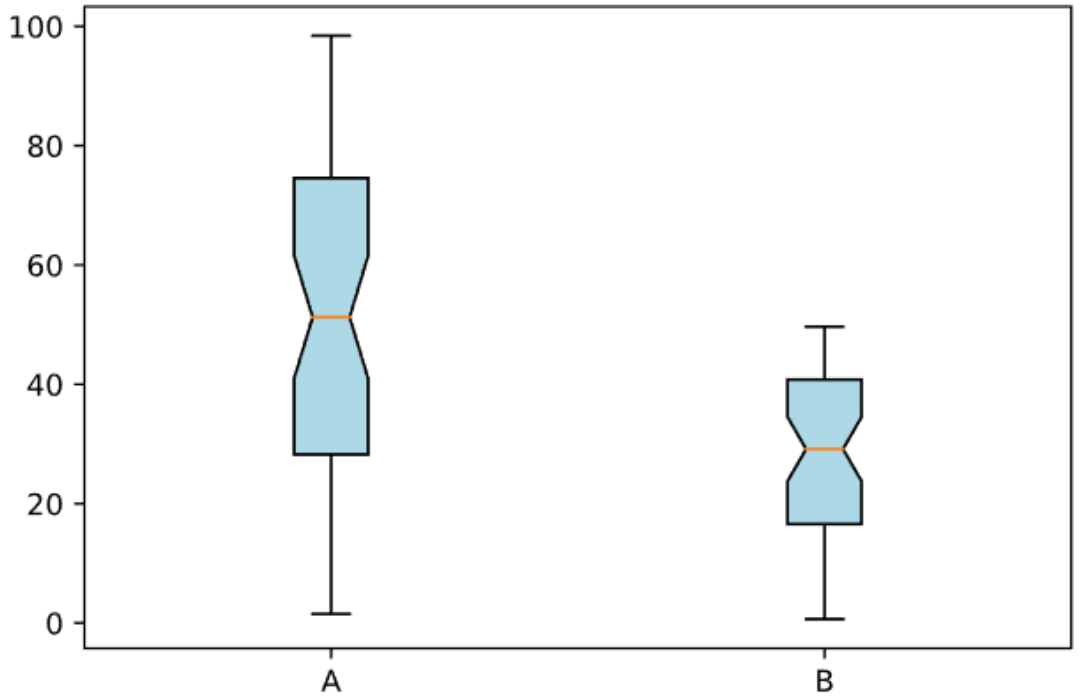
Horizontal Box Plot

```
spread = np.random.rand(50)*100
center = np.ones(25)*50
high = np.random.rand(10)*100+100
low = np.random.rand(10)*(-100)
data = np.concatenate((spread, center,
    high, low), 0)

plt.figure(figsize=(5, 3))
plt.boxplot(data, vert=False, sym='rs')
```



Multiple Box Plots

```
p1 = np.random.rand(50)*100
p2 = np.random.rand(50)*50
data = [p1, p2]

plt.boxplot(data, notch=True,
    patch_artist=True,
    boxprops={'facecolor':'lightblue'},
    labels=['A', 'B'])
```



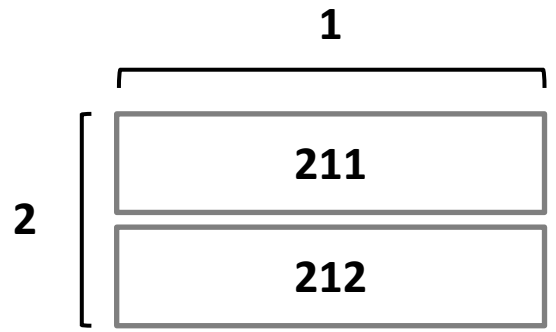
Subplots

figure()

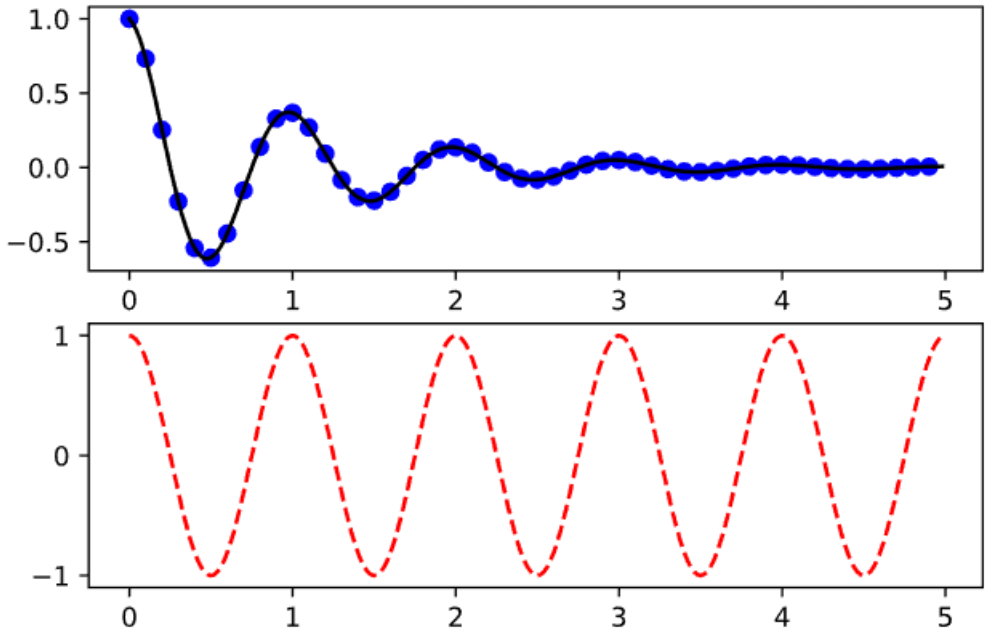
- *plt.*`figure`([*num*], [*figsize*], [*facecolor*], [*edgecolor*], [*frameon*], ...)
  - Create a new figure
  - *num*: If not provided, a new figure will be created with the figure number incremented. If provided, a figure with this id is created
  - *figsize*: (width, height) in inches
  - *facecolor*: the background color
  - *edgecolor*: the border color
  - *frameon*: If True, draw the figure frame (default: True)

subplot()

- *plt*.`subplot`([*pos*], ...)
  - Add a subplot to the current figure
  - *pos*: a three digit integer denoting the number of rows, the number of columns, and the index of the subplot
  - Returns the axes of the subplot

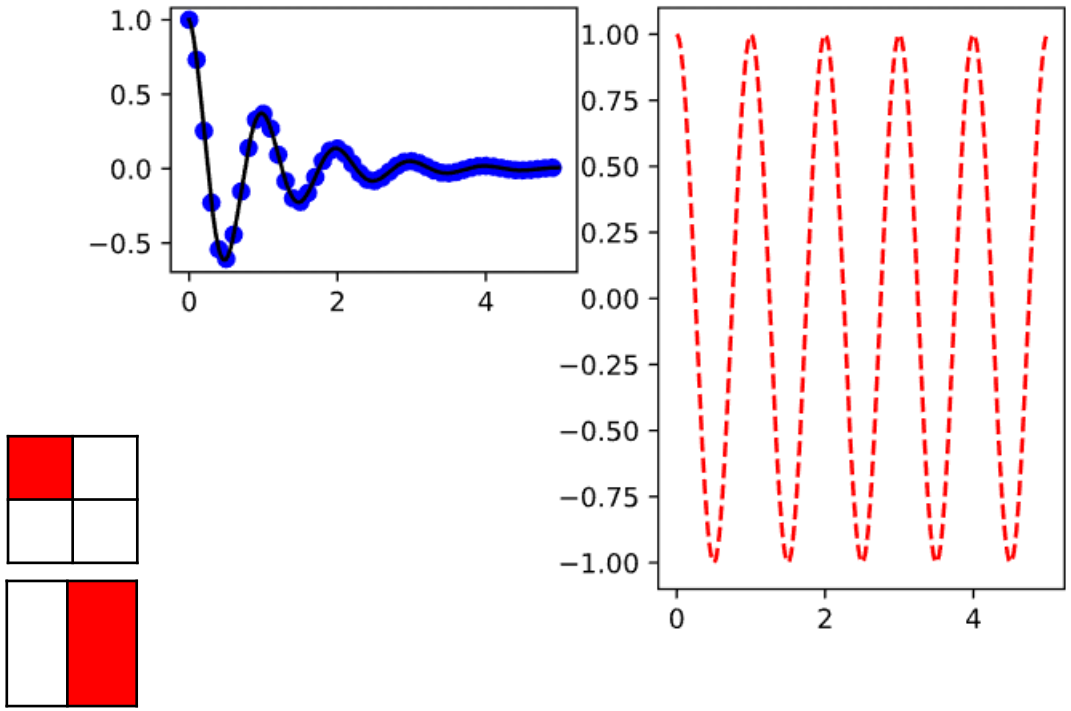



```
def f(t):
    return np.exp(-t)*np.cos(2*np.pi*t)
t1 = np.arange(0.0, 5.0, 0.1)
t2 = np.arange(0.0, 5.0, 0.02)
# plt.figure(1)
plt.subplot(211)
plt.plot(t1, f(t1), 'bo', t2, f(t2), 'k')
plt.subplot(212)
plt.plot(t2, np.cos(2*np.pi*t2), 'r--')
```

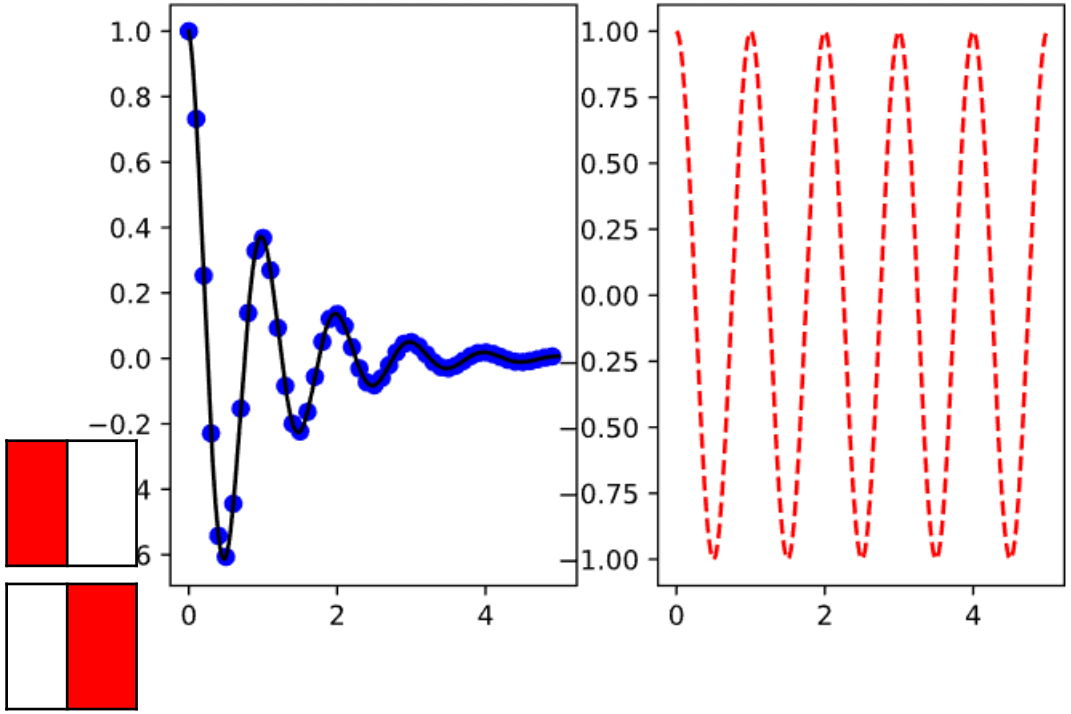


Subplot Examples

```
plt.subplot(221)
plt.plot(t1, f(t1), 'bo', t2, f(t2), 'k')
plt.subplot(122)
plt.plot(t2, np.cos(2*np.pi*t2), 'r--')
```



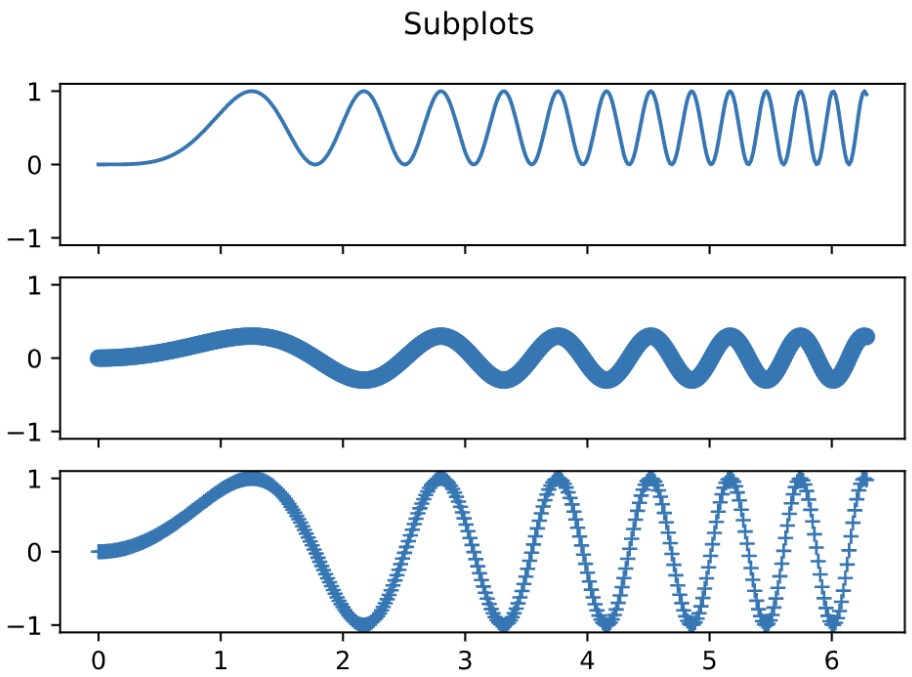

```
plt.subplot(121)
plt.plot(t1, f(t1), 'bo', t2, f(t2), 'k')
plt.subplot(122)
plt.plot(t2, np.cos(2*np.pi*t2), 'r--')
```



subplots()

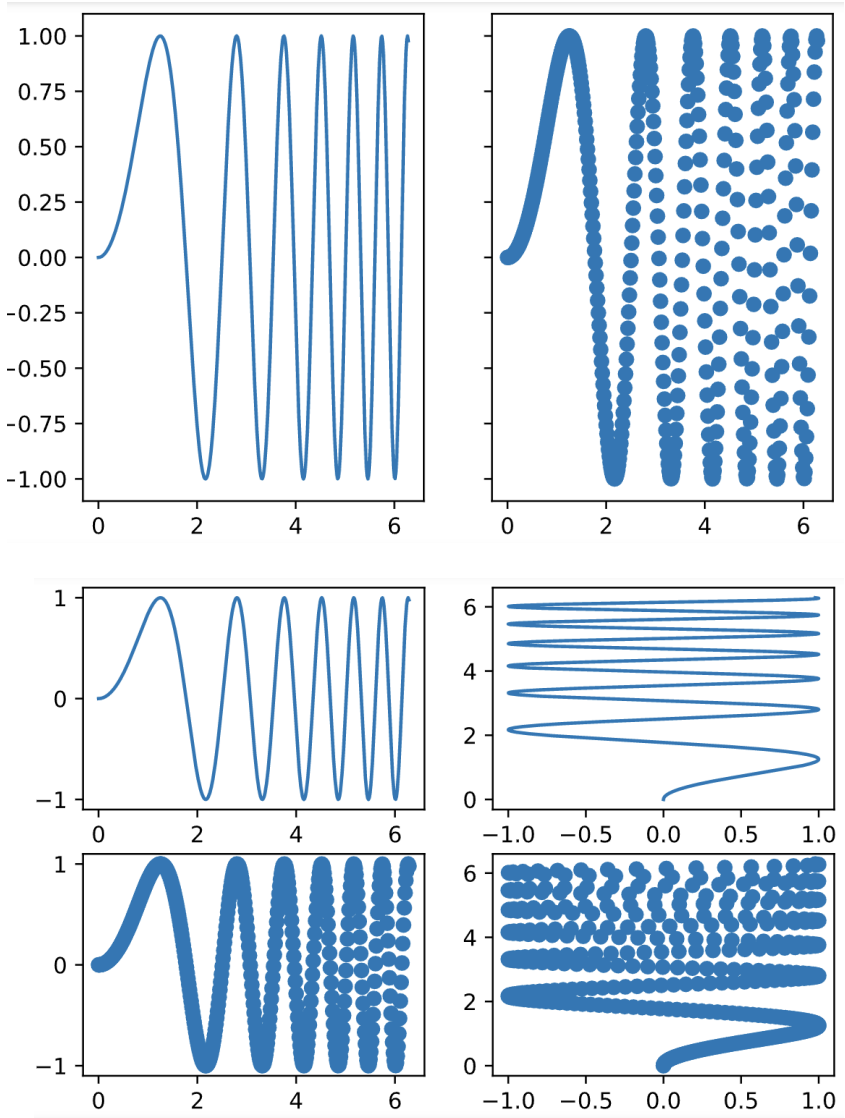
- *plt*.`subplots`([*nrows*], [*ncols*], [*sharex*], [*sharey*], ...)
  - Create a figure and a set of subplots
  - *nrows, ncols*: number of rows/columns of the subplot grid
  - *sharex, sharey:* if True, x- or y- axis will be shared among all subplots (default: False)
  - Return figure and ax (or array of axes)

```
x = np.linspace(0, 2*np.pi, 400)
y = np.sin(x**2)

fig, axs = plt.subplots(3, 1,
                sharex=True, sharey=True)
fig.suptitle('Subplots')
axs[0].plot(x, y**2)
axs[1].plot(x, 0.3*y, 'o')
axs[2].plot(x, y, '+')
```



subplots(): More Examples

```
x = np.linspace(0, 2*np.pi, 400)
y = np.sin(x**2)

# Create two subplots
f, (ax1, ax2) = plt.subplots(1, 2, sharey=True)
ax1.plot(x, y)
ax2.scatter(x, y)

# Create four subplots
_, axs = plt.subplots(2, 2)   # axs: 2D ndarray
axs[0, 0].plot(x, y)
axs[0, 1].plot(y, x)
axs[1, 0].scatter(x, y)
axs[1, 1].scatter(y, x)
```



Seaborn

Seaborn

- Python visualization library based on matplotlib
  - More attractive and informative statistical graphics
  - Wrapper of matplotlib which improved the default styles
  - Even if plotting using only matplotlib.pyplot, importing seaborn will make nicer plots
- Dependency
  - Data structures: NumPy, Pandas
  - Statistical routines: SciPy
- Open source
  - https://seaborn.pydata.org

```
>>> import seaborn as sns
```

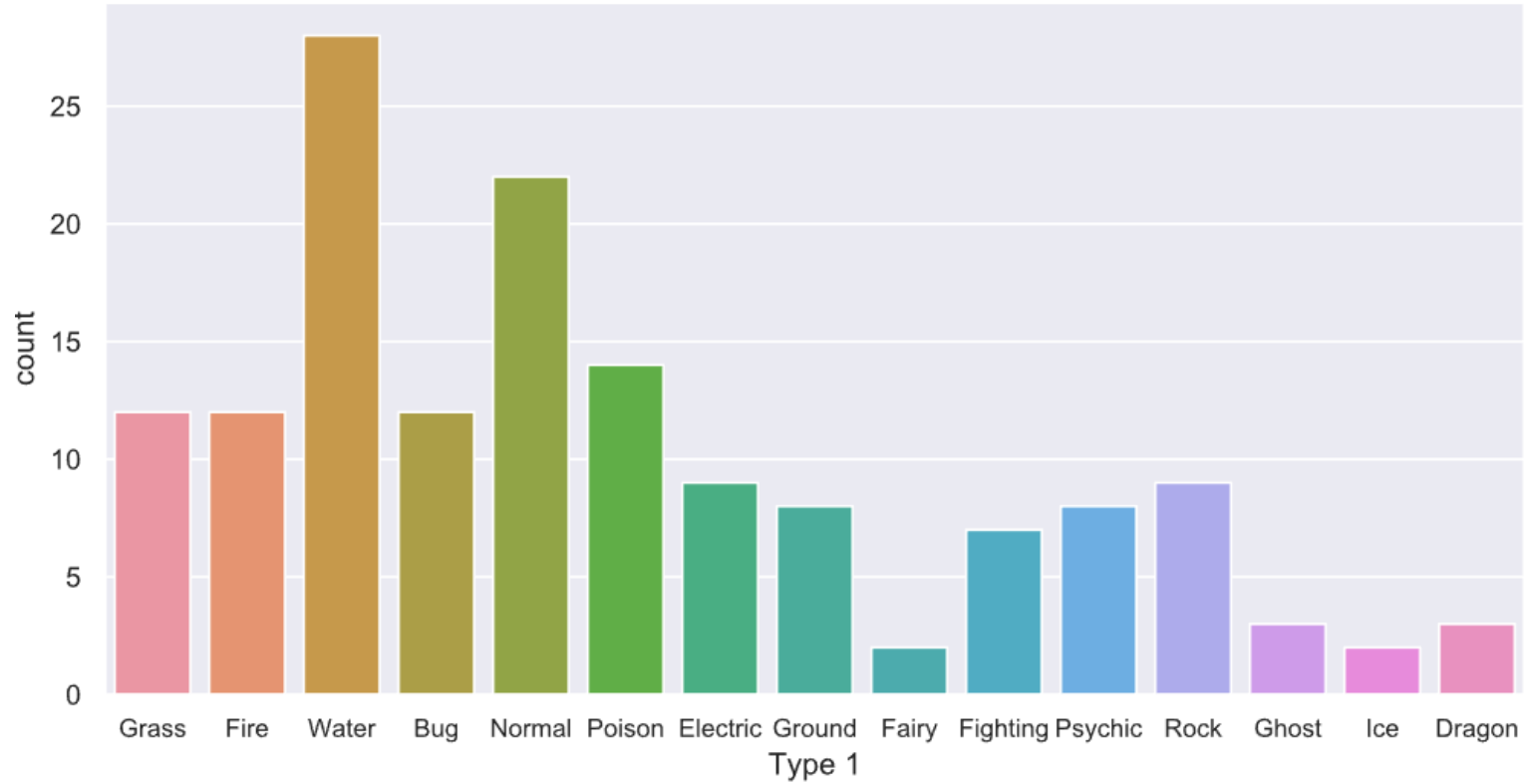
Pokemon Dataset

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
df = pd.read_csv('pokemon.csv', index_col=0)
df.head()
```

#	Name	Type 1	Type 2	Total	HP	Attack	Defense	Sp. Atk	Sp. Def	Speed	Stage	Legendary
1	Bulbasaur	Grass	Poison	318	45	49	49	65	65	45	1	False
2	Ivysaur	Grass	Poison	405	60	62	63	80	80	60	2	False
3	Venusaur	Grass	Poison	525	80	82	83	100	100	80	3	False
4	Charmander	Fire	NaN	309	39	52	43	60	50	65	1	False
5	Charmeleon	Fire	NaN	405	58	64	58	80	65	80	2	False

Count Plot

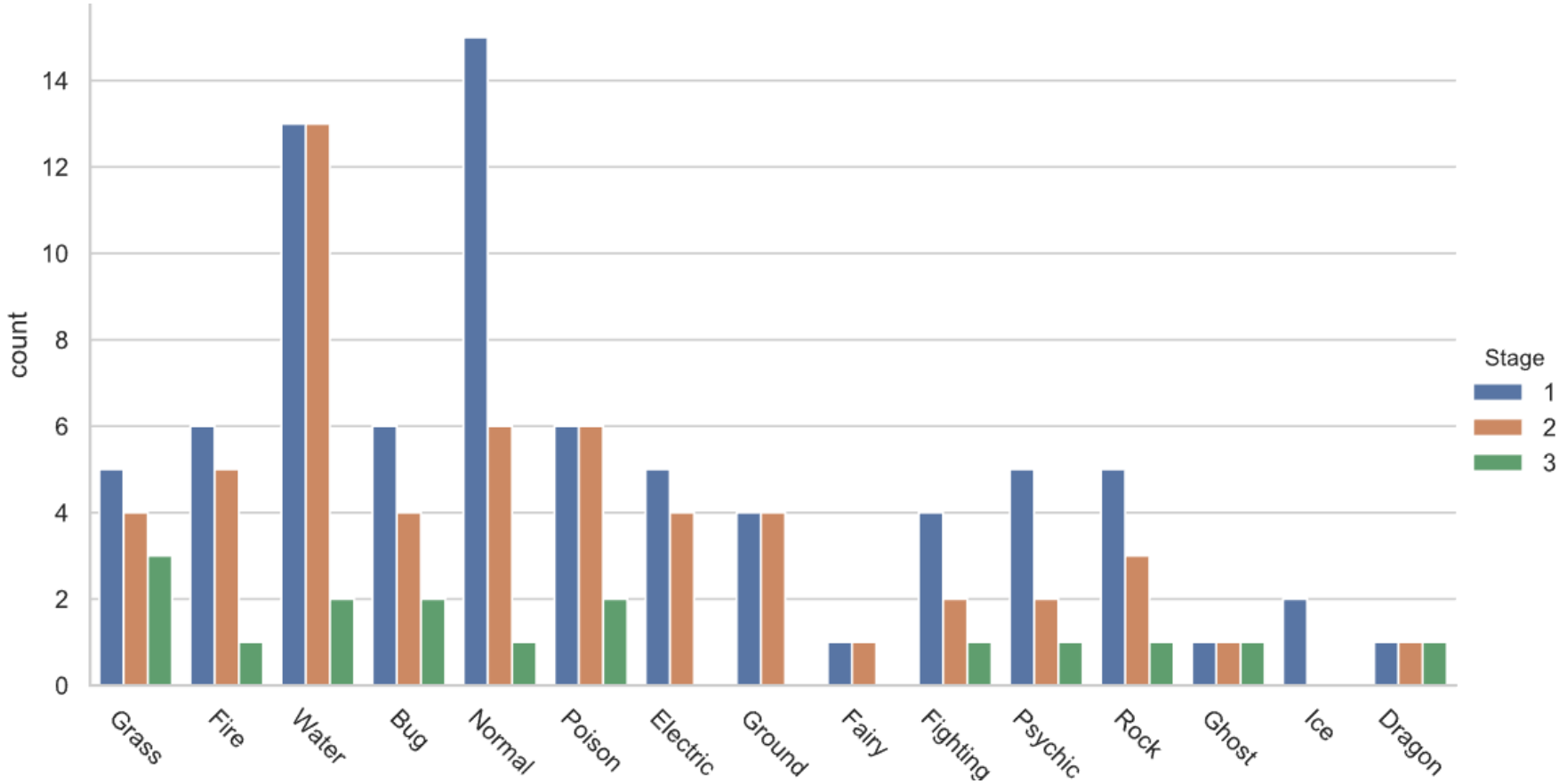
```
sns.set(style='darkgrid')
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10)
sns.countplot(x='Type 1', data=df)
```



Categorical Plot

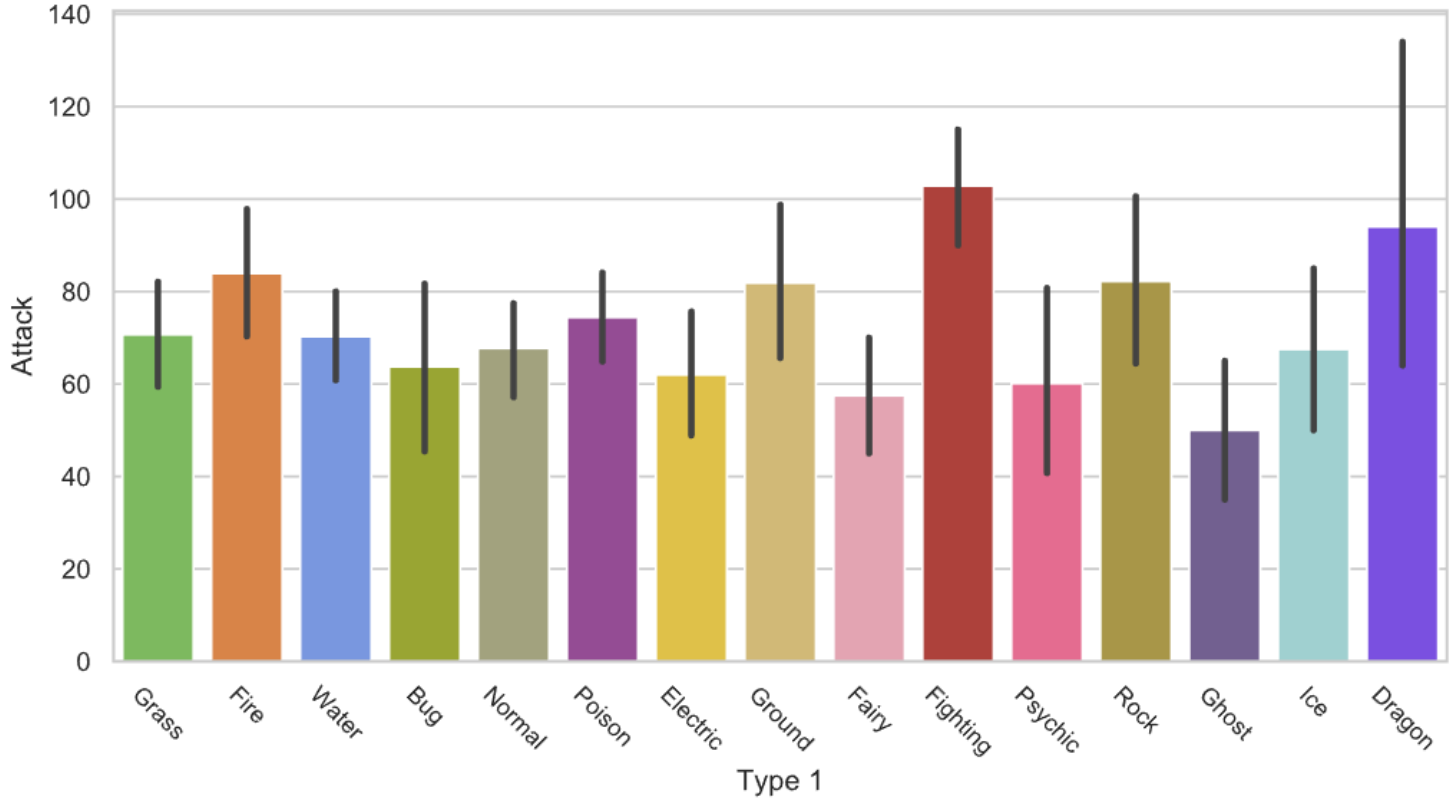
Group data

```
sns.catplot(x='Type 1', kind='count', hue='Stage', data=df, aspect=1.8)
plt.xticks(rotation=-45)
```



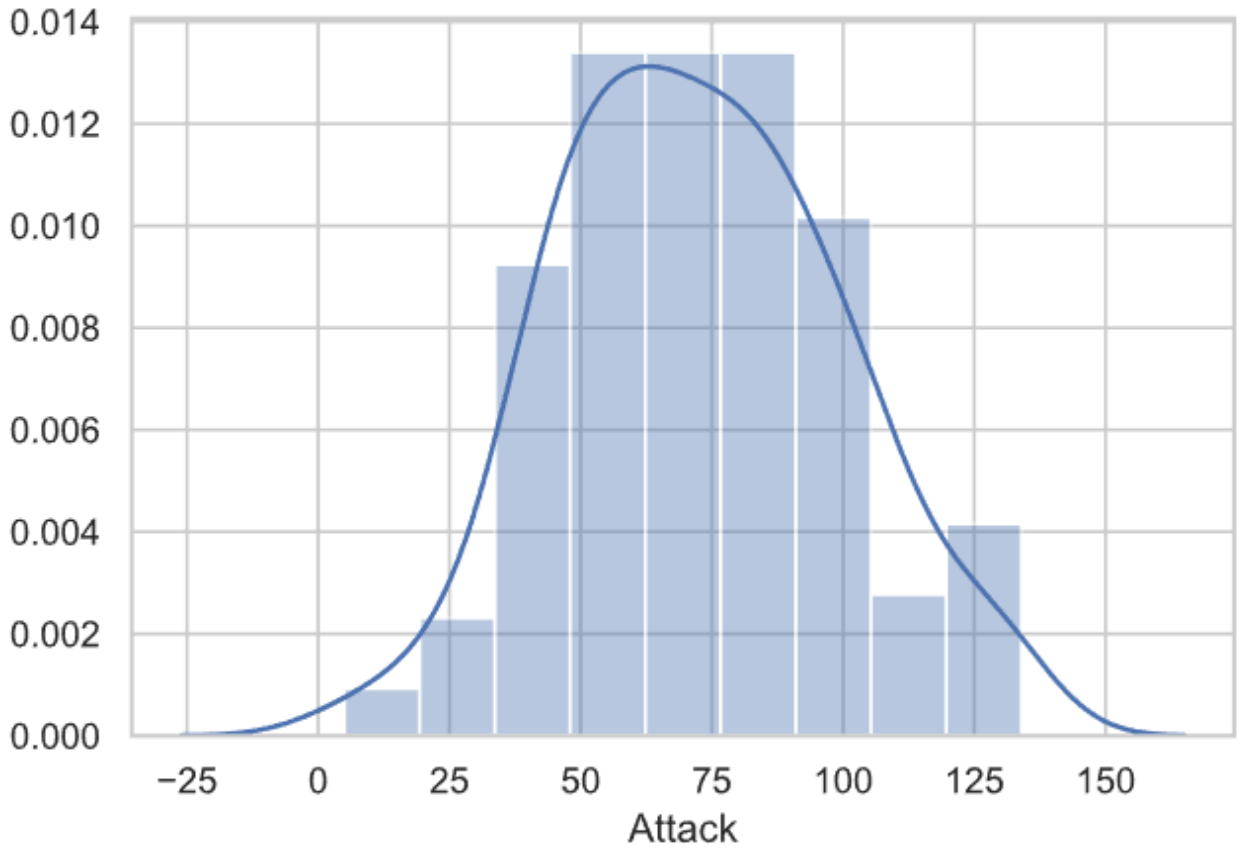
Bar Plot

```
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10, rotation=-45)
sns.barplot(x='Type 1', y='Attack', data=df, palette=poke_colors)
```



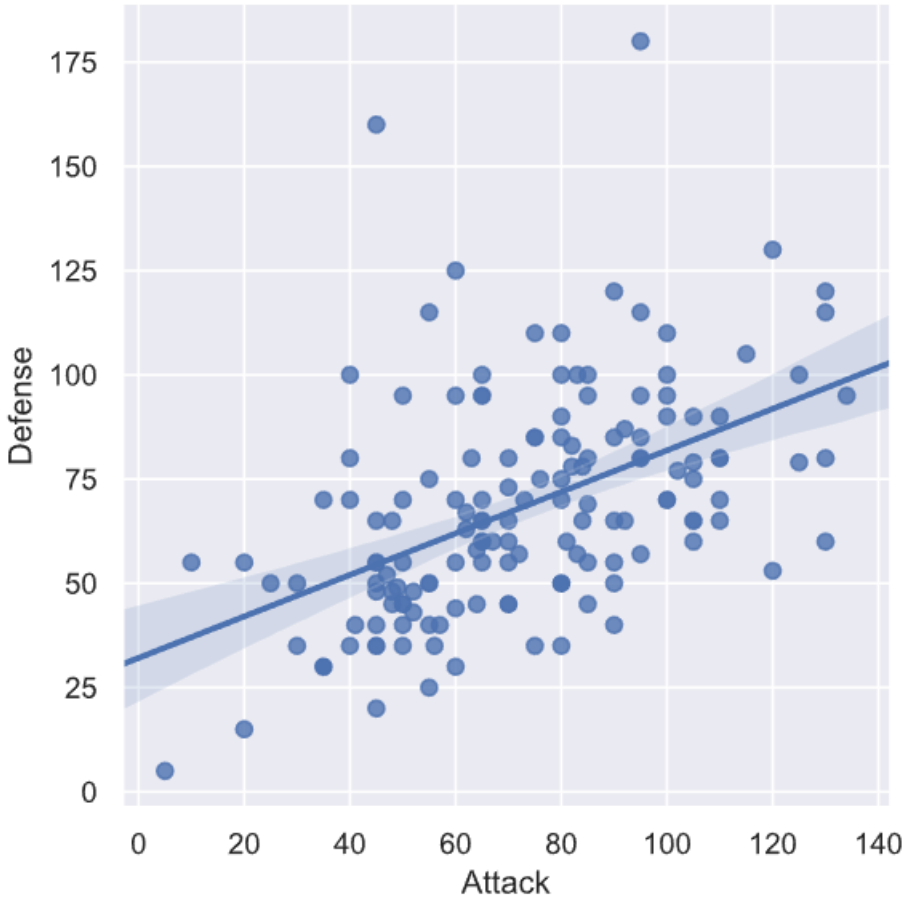
Histogram

```
sns.distplot(df.Attack)
```

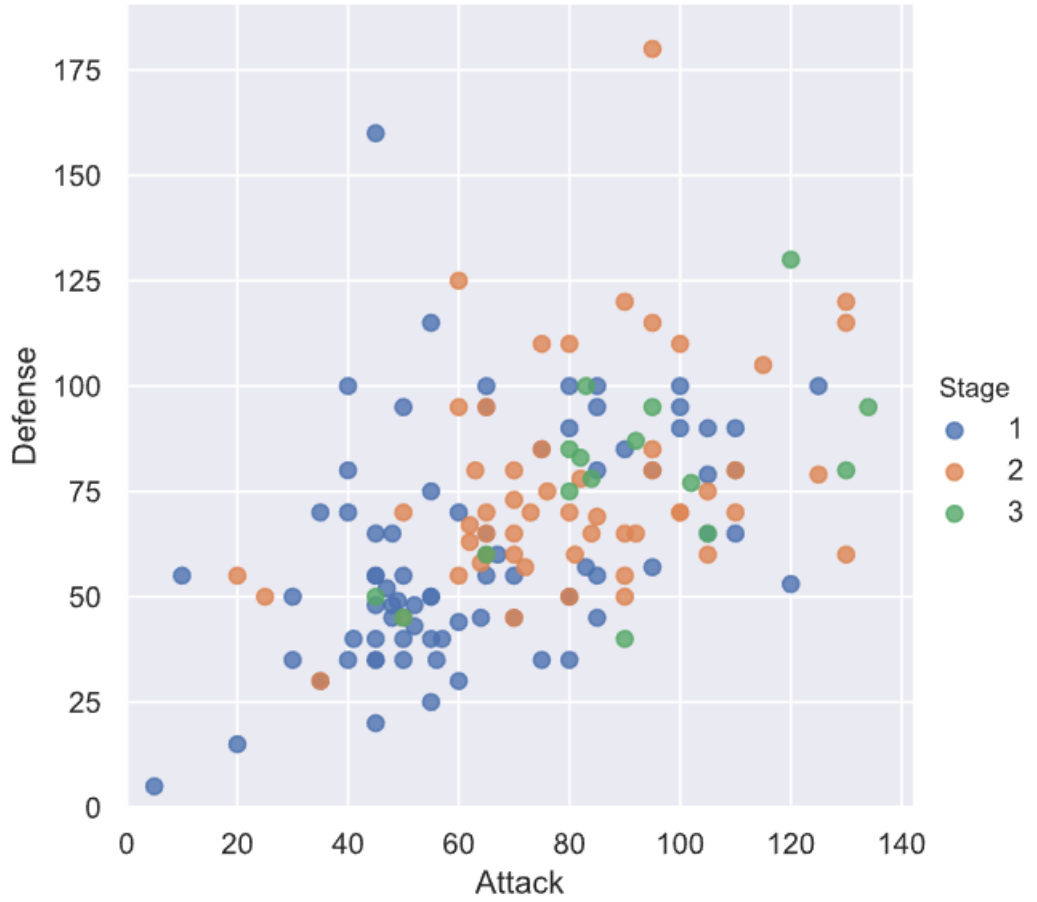


Scatter Plot

```
sns.regplot(x='Attack', y='Defense', data=df)
```

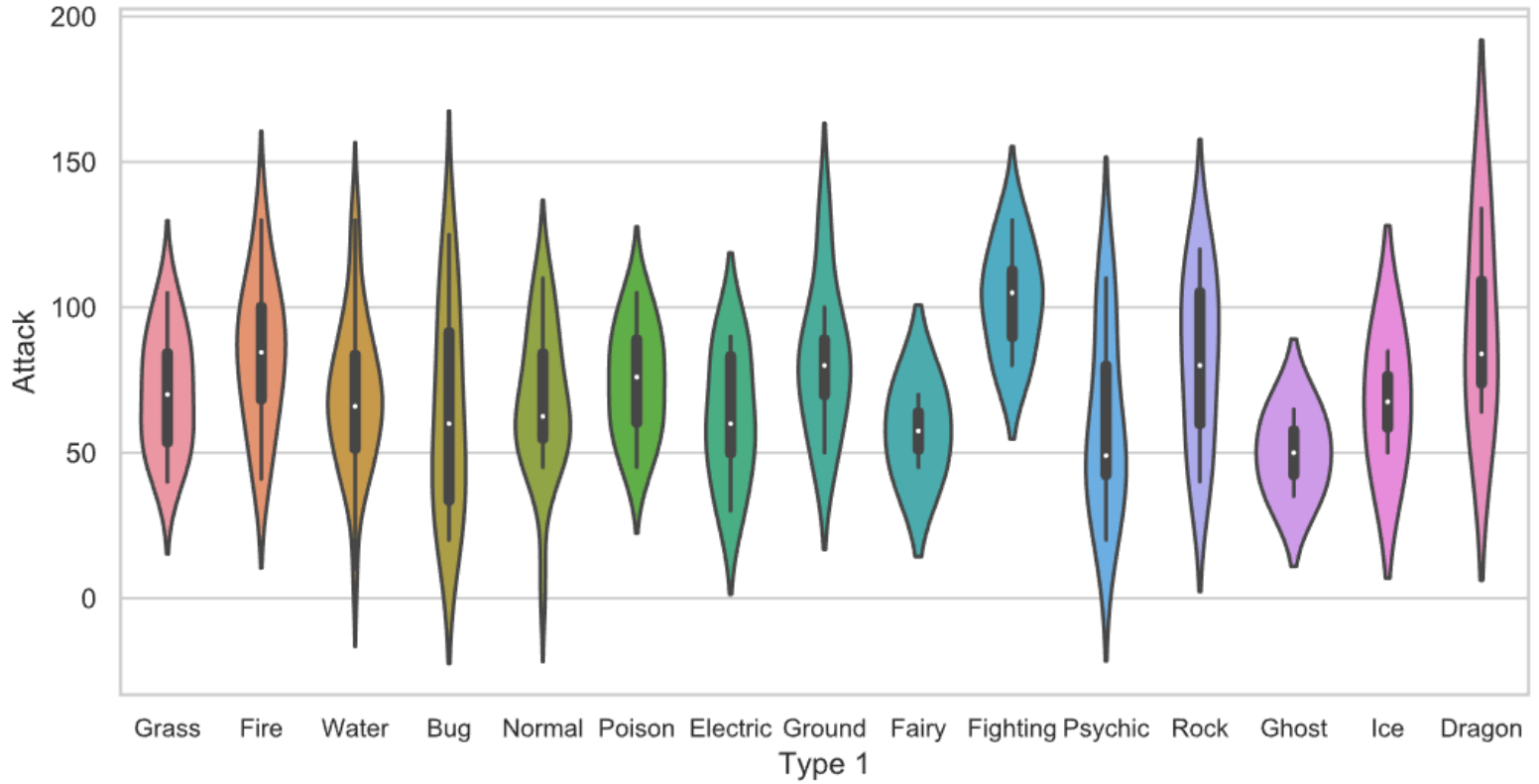



```
sns.lmplot(x='Attack', y='Defense',
    fit_reg=False, hue='Stage', data=df)
```



Violin Plot

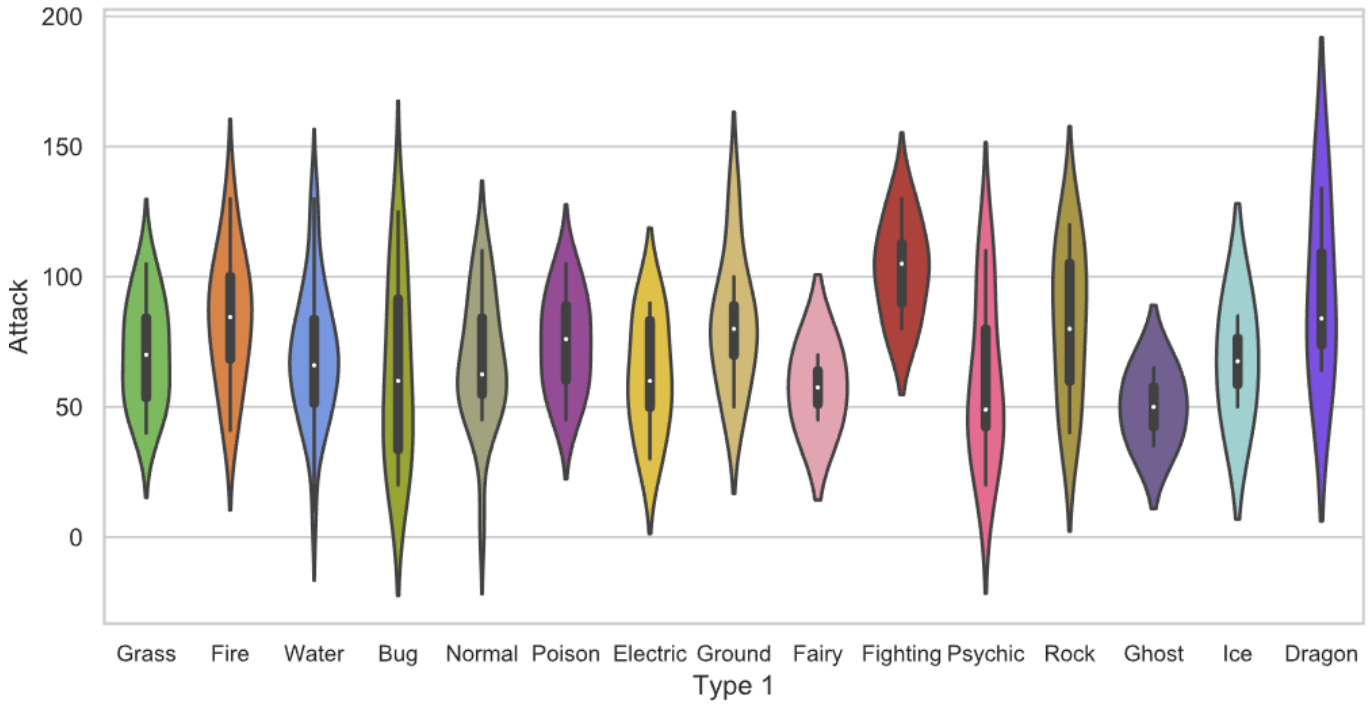
```
sns.set_style('whitegrid')
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10)
sns.violinplot(x='Type 1', y='Attack', data=df)
```



Violin Plot (with Customized Colors)

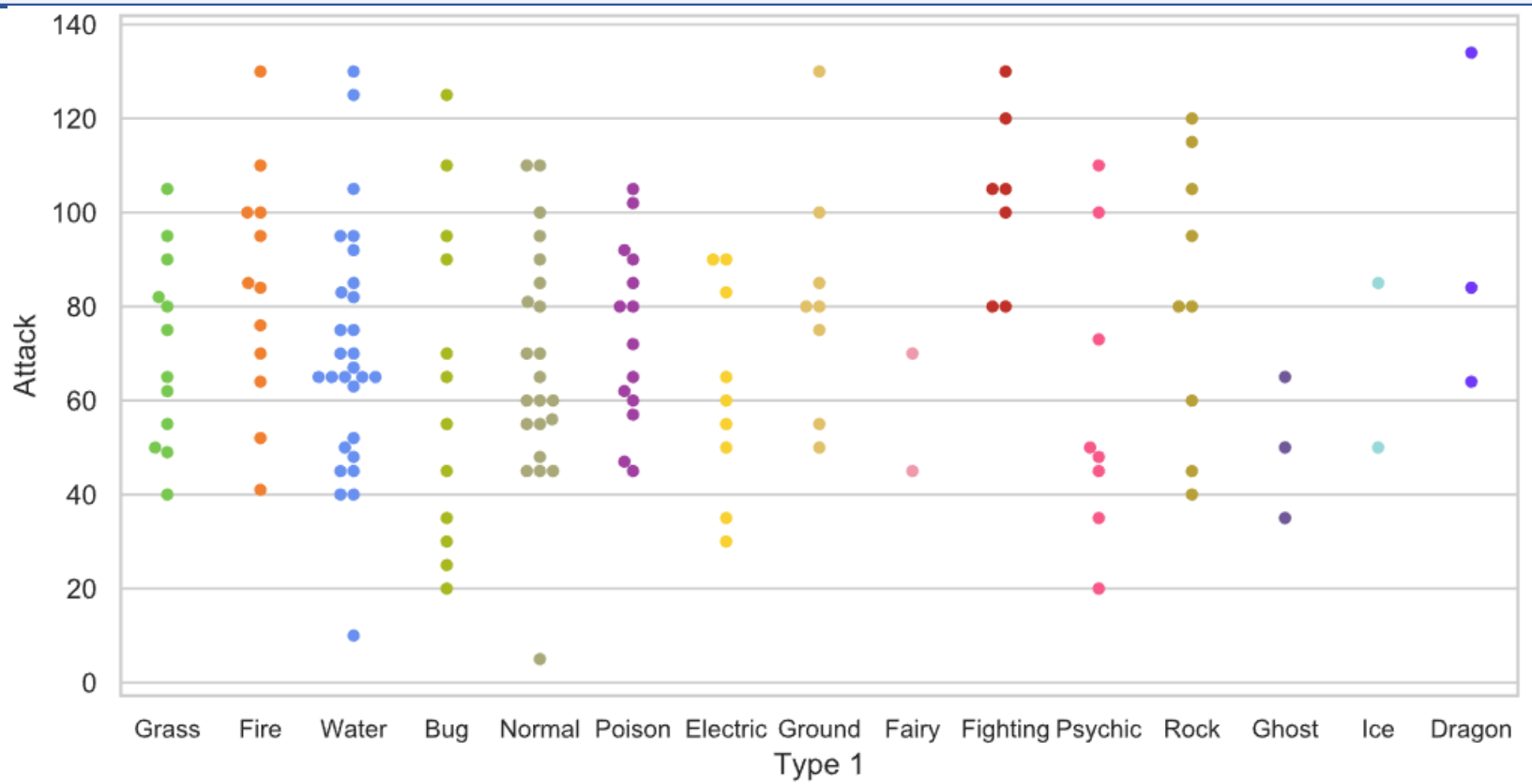
```
poke_colors = ['#78C850',  # Grass
               '#F08030',  # Fire
               '#6890F0',  # Water
               '#A8B820',  # Bug
               '#A8A878',  # Normal
               '#A040A0',  # Poison
               '#F8D030',  # Electric
               '#E0C068',  # Ground
               '#EE99AC',  # Fairy
               '#C03028',  # Fighting
               '#F85888',  # Psychic
               '#B8A038',  # Rock
               '#705898',  # Ghost
               '#98D8D8',  # Ice
               '#7038F8',  # Dragon
              ]
```

```
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10)
sns.violinplot(x='Type 1', y='Attack', data=df,
    palette=poke_colors)
```



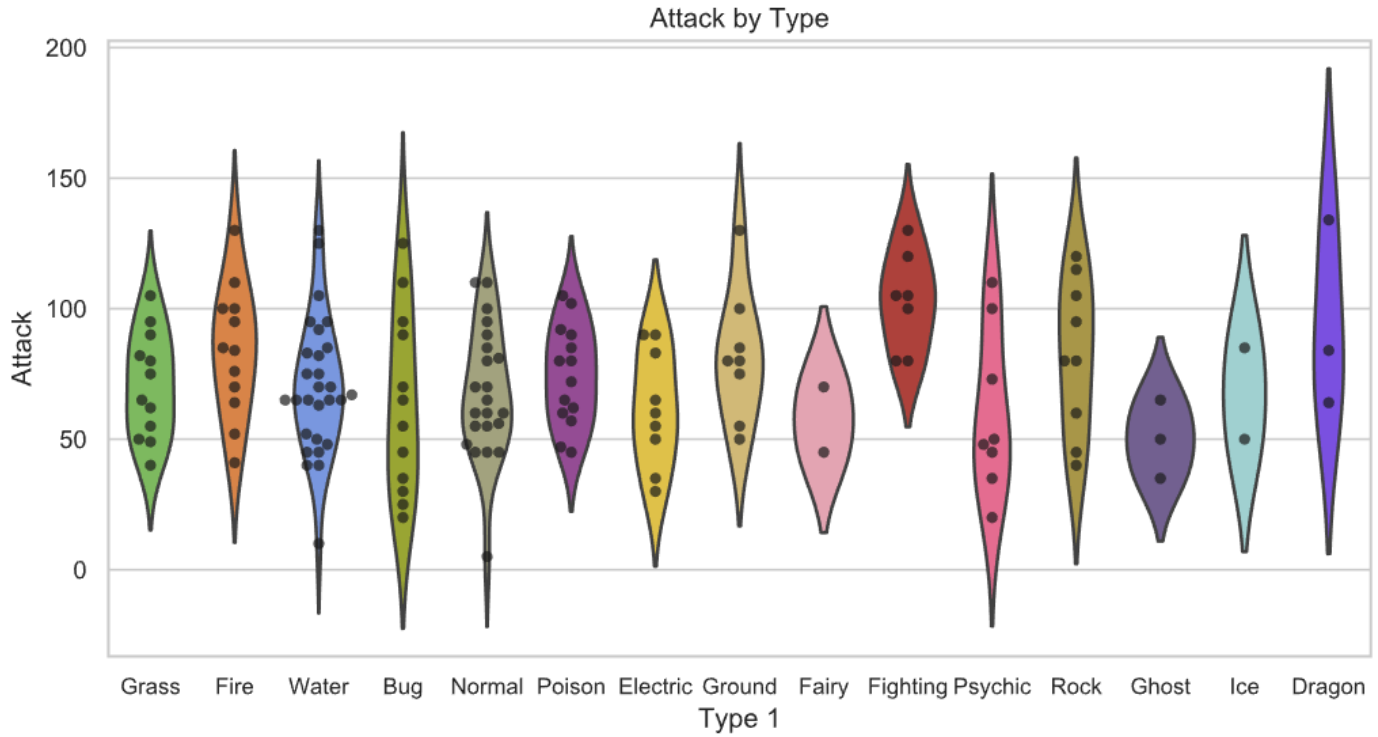
Swarm Plot

```
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10)
sns.swarmplot(x='Type 1', y='Attack', data=df, palette=poke_colors)
```



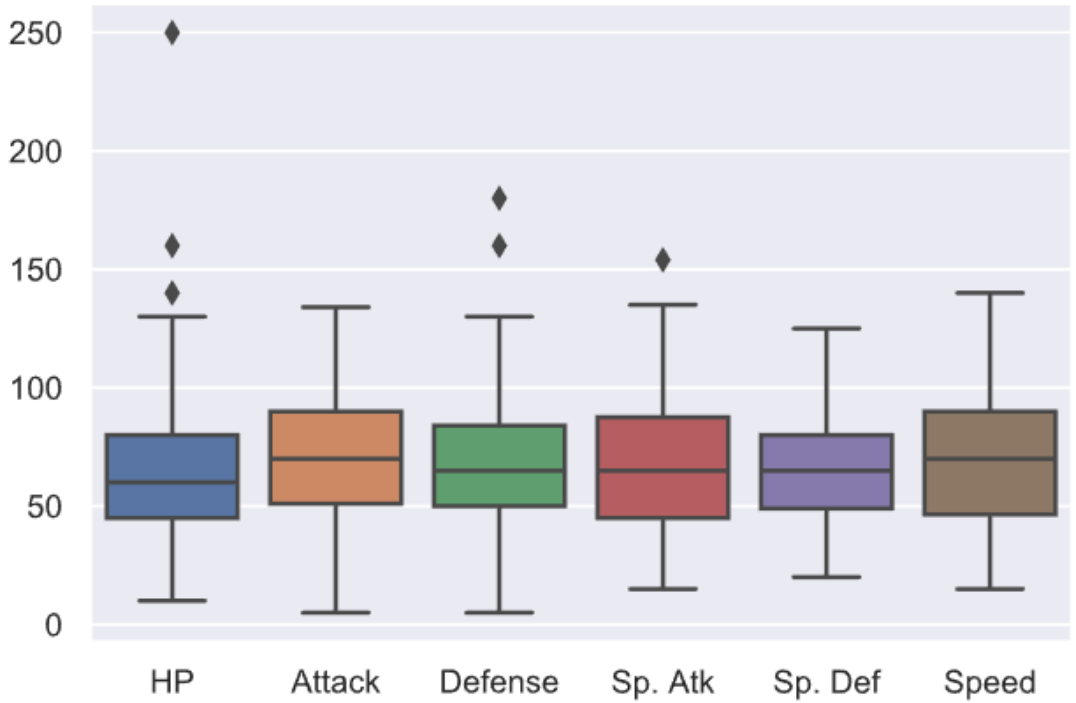
Violin + Swarm Plot

```
plt.figure(figsize=(10, 5))
plt.xticks(fontsize=10)
sns.violinplot(x='Type 1', y='Attack', data=df, palette=poke_colors, inner=None)
sns.swarmplot(x='Type 1', y='Attack', data=df, color='k', alpha=0.7)
plt.title('Attack by Type')
```

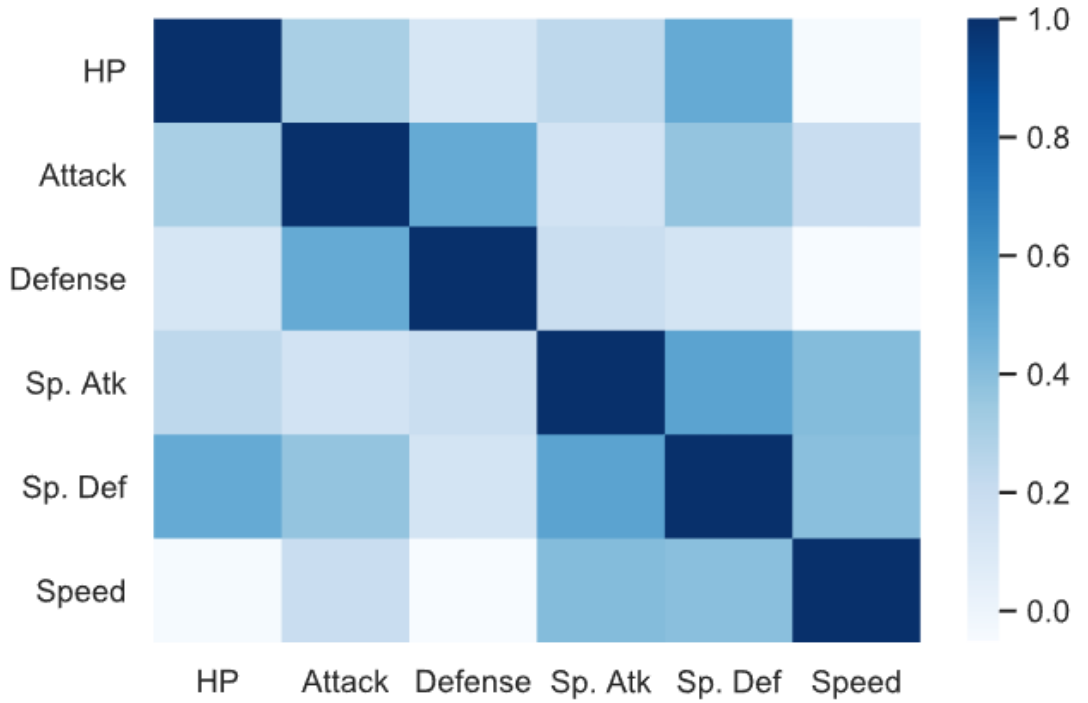


Box Plot and Heatmap

```
stats_df = df.drop(['Total', 'Stage',
                    'Legendary'], axis=1)
sns.boxplot(data=stats_df)
```

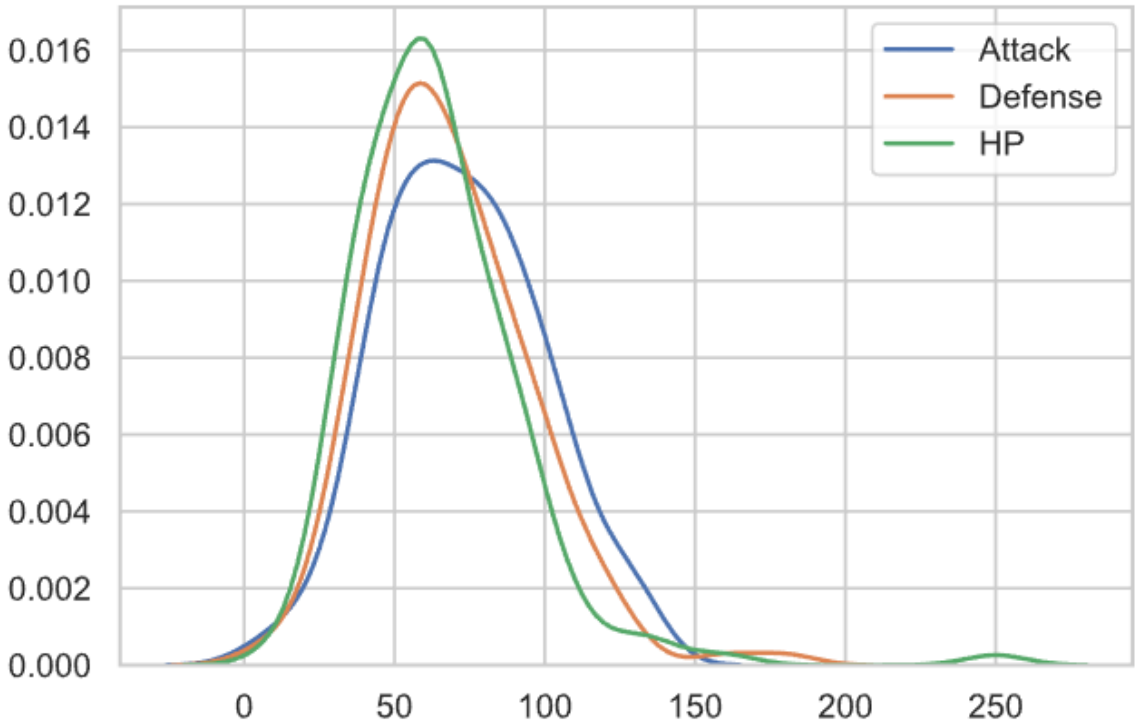



```
corr = stats_df.corr()
sns.heatmap(corr, cmap='Blues')
```

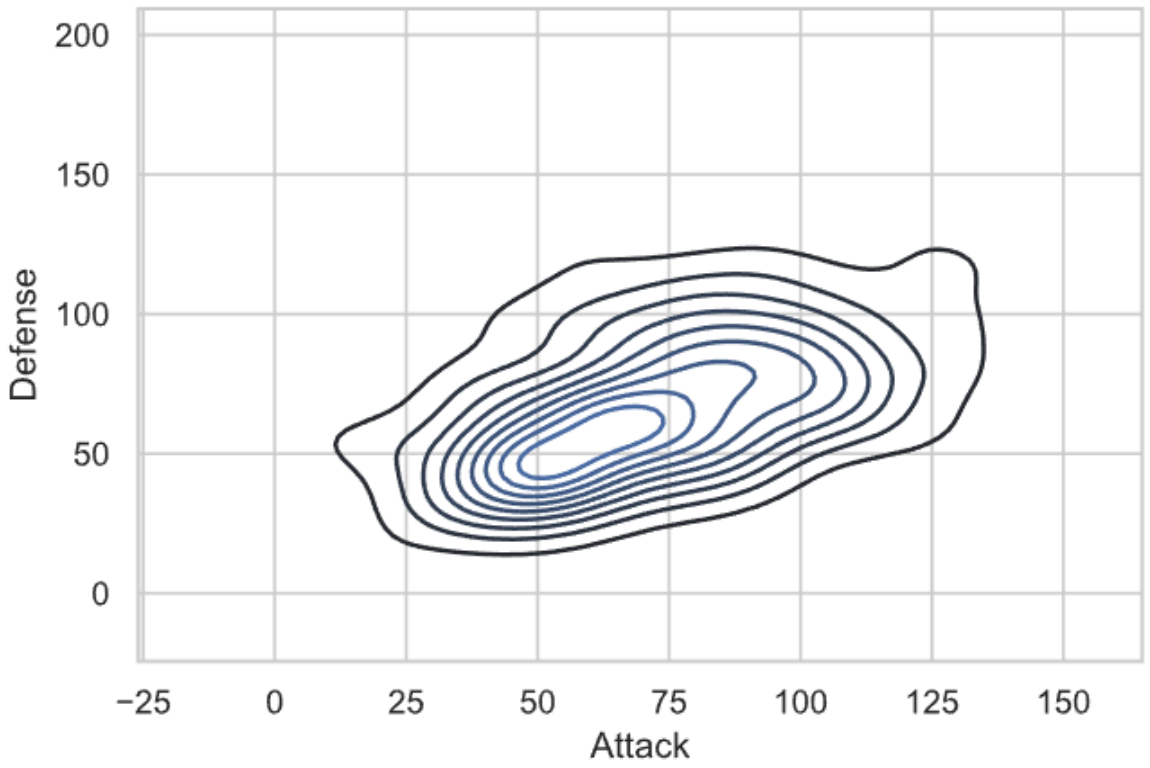


KDE Plot

```
sns.kdeplot(df.Attack)
sns.kdeplot(df.Defense)
sns.kdeplot(df.HP)
```

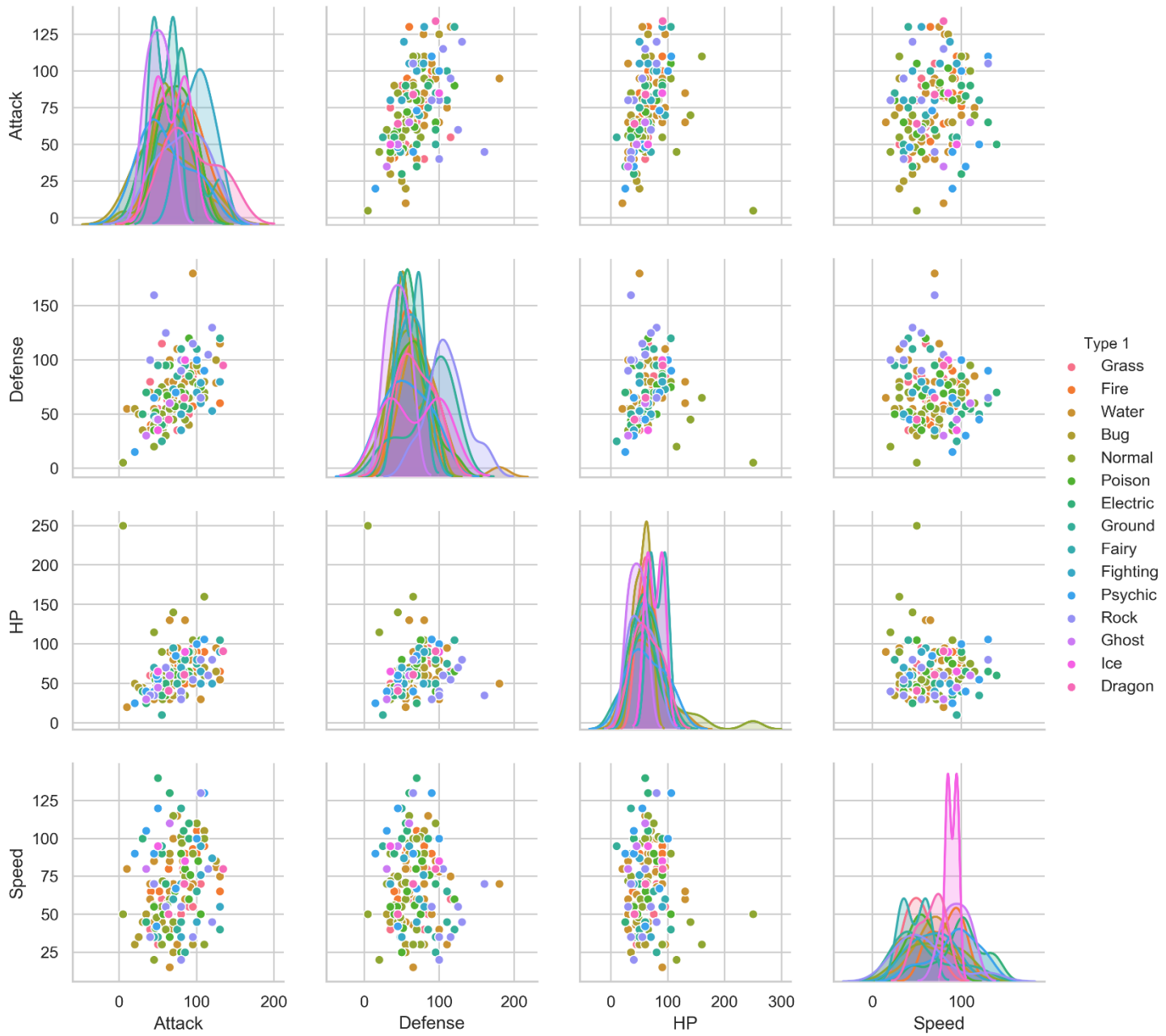



```
sns.kdeplot(df.Attack, df.Defense)
```



Pairplot

```
s.pairplot(df[['Type 1',
               'Attack',
               'Defense',
               'HP',
               'Speed']],
           hue='Type 1')
```



Plotting in Pandas

Pandas plot()

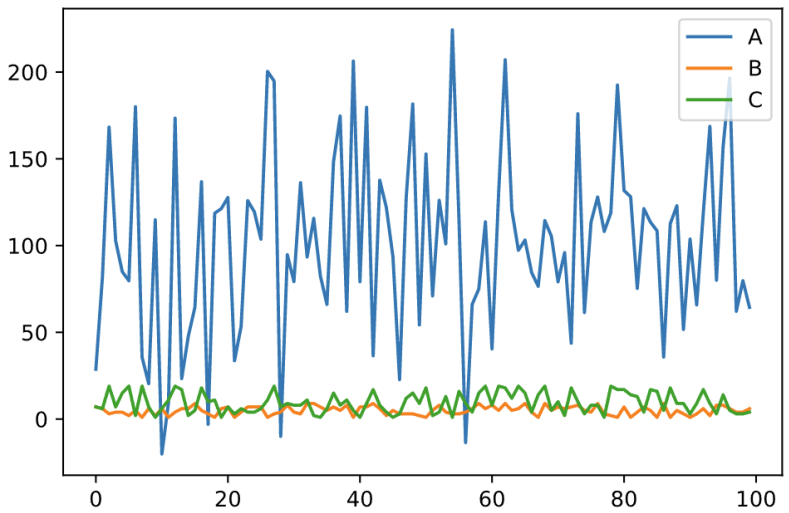
- *df*.`plot`(*args, **kwargs) or *series*.`plot` (*args, **kwargs)
  - Make plots of DataFrame or Series

plot(kind=str)	subfunction	Graph produced
`'line'`	`plot.line()`	Line plot (default)
`'bar'`	`plot.bar()`	Vertical bar plot
`'barh'`	`plot.barh()`	Horizontal bar plot
`'hist'`	`plot.hist()`	Histogram
`'box'`	`plot.box()`	Box plot
`'kde'` or `'density'`	`plot.kde()`	Kernel Density Estimation plot
`'area'`	`plot.area()`	Area plot
`'pie'`	`plot.pie()`	Pie plot
`'scatter'`	`plot.scatter()`	Scatter plot (DataFrame only)

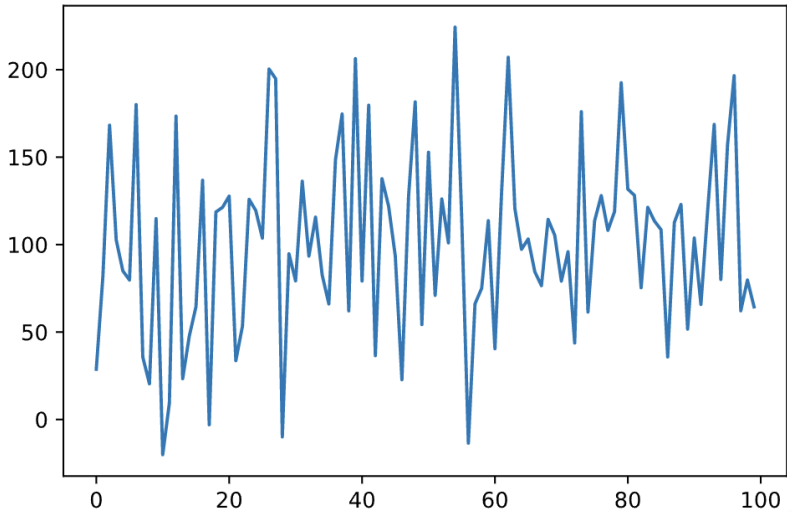
Line Plot

```
df = pd.DataFrame({'A': np.random.normal(100, 50, 100),
                   'B': np.random.randint(1, 10, size=100),
                   'C': np.random.randint(1, 20, size=100)})
```

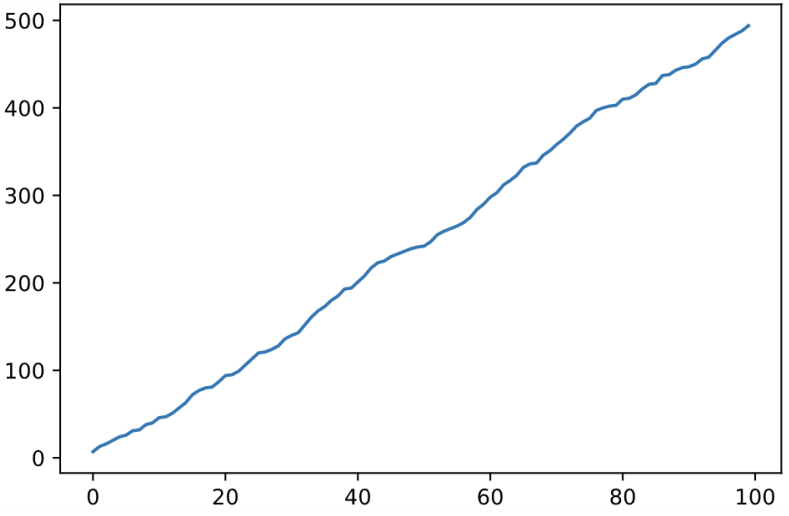
```
df.plot()
```




```
df.A.plot()
```




```
df.B.cumsum().plot()
```

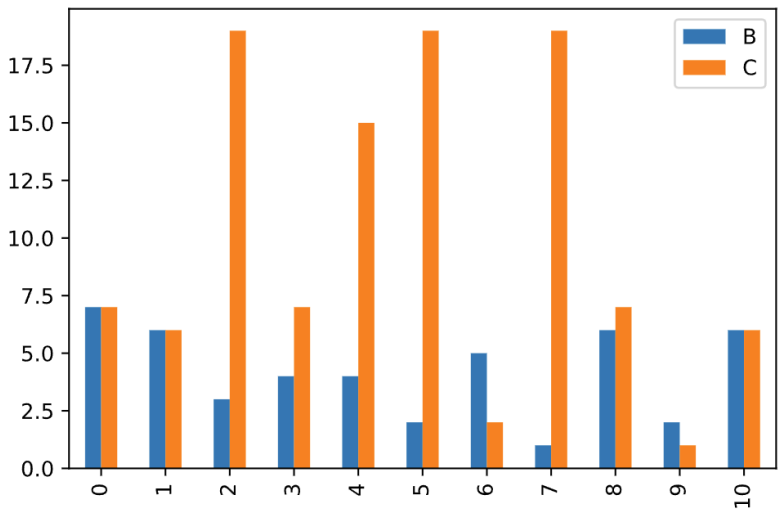


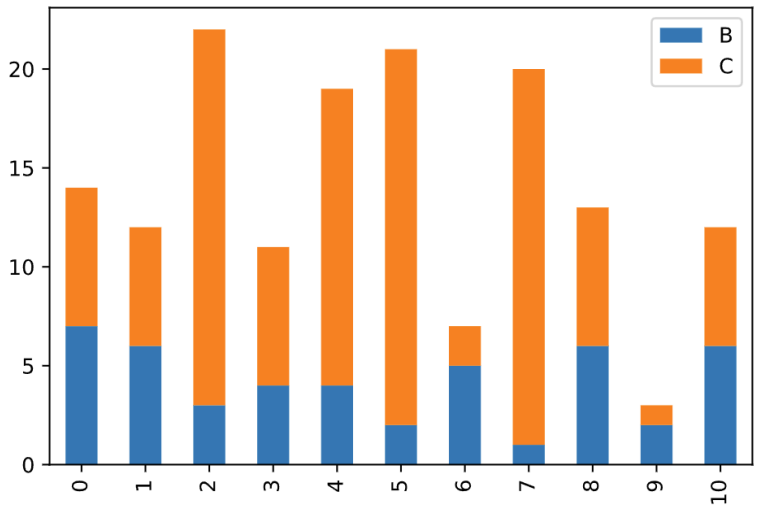
Bar Plot

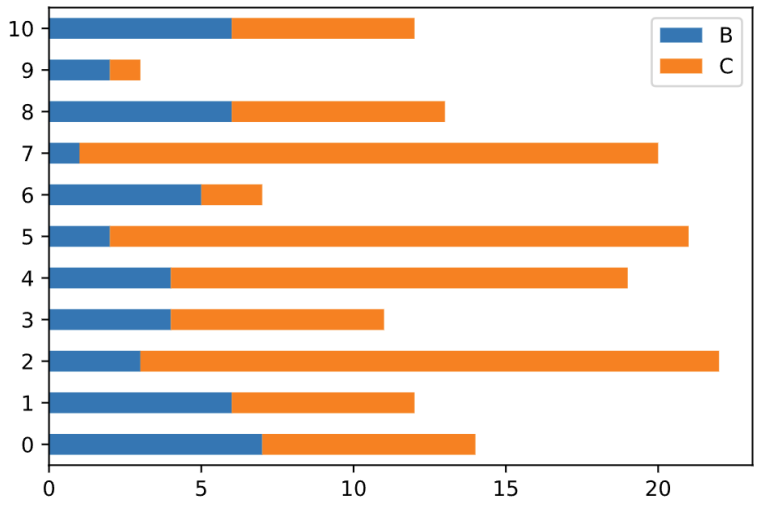
```
df.loc[:10, ['B','C']].plot.bar()
```

```
df.loc[:10, ['B','C']].plot.bar(stacked=True)
```

```
df.loc[:10, ['B','C']].plot.barh(stacked=True)
```

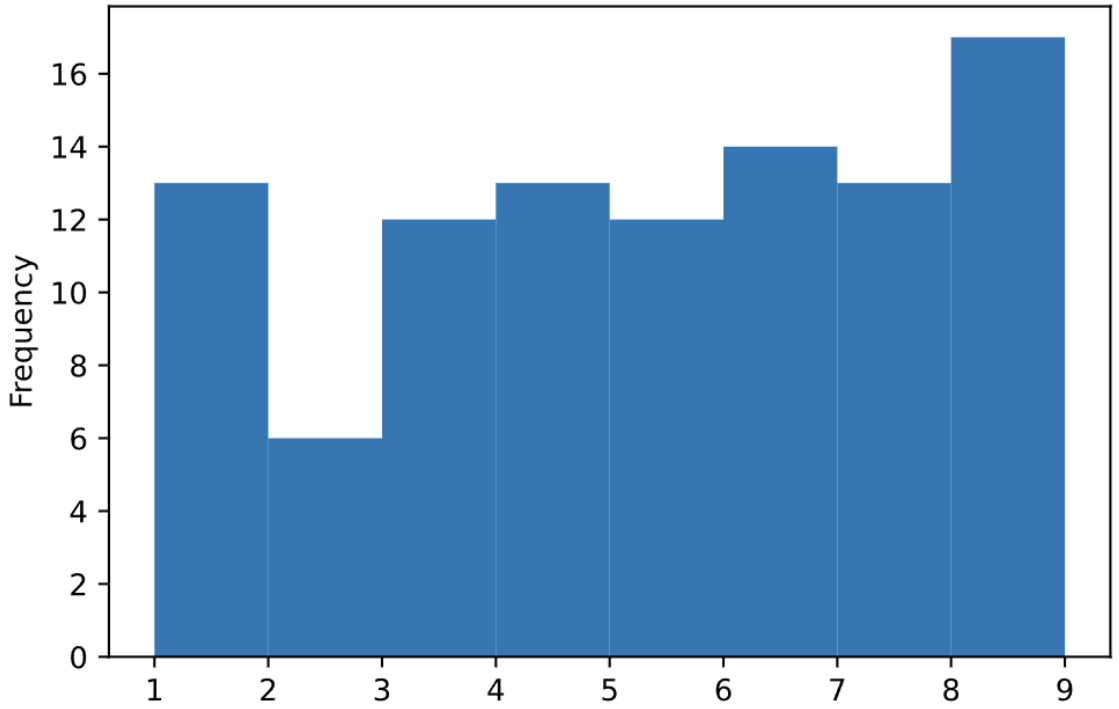




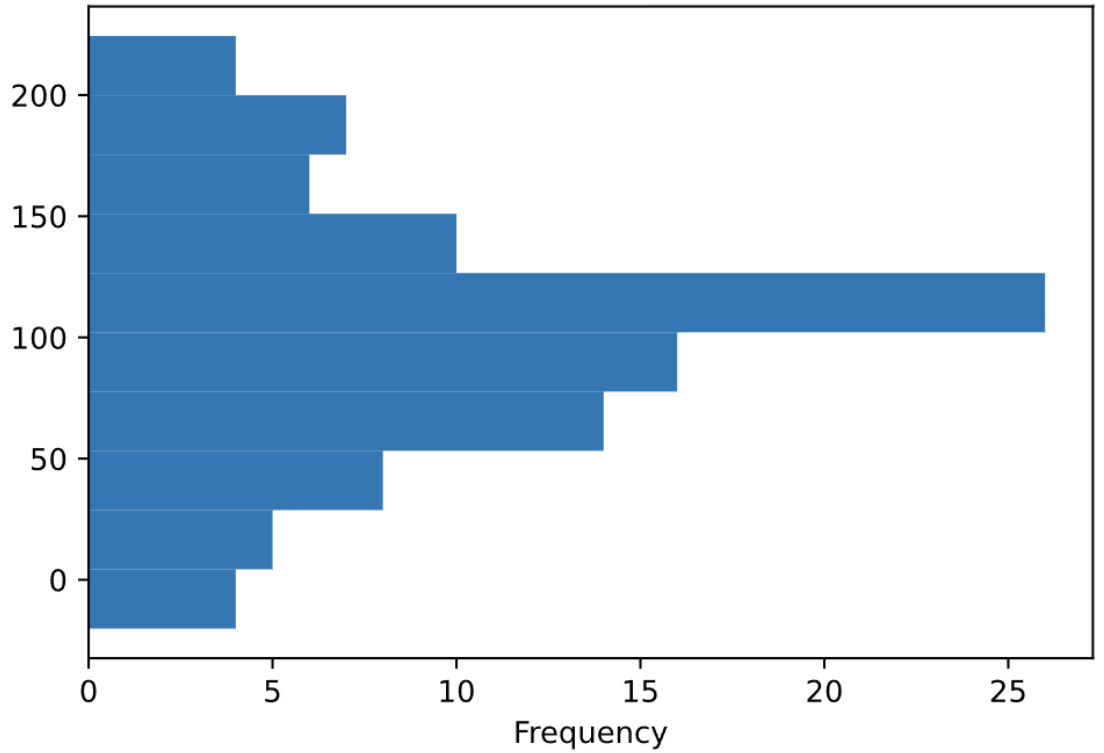


Histogram

```
df.B.plot(kind='hist', bins=8)
```

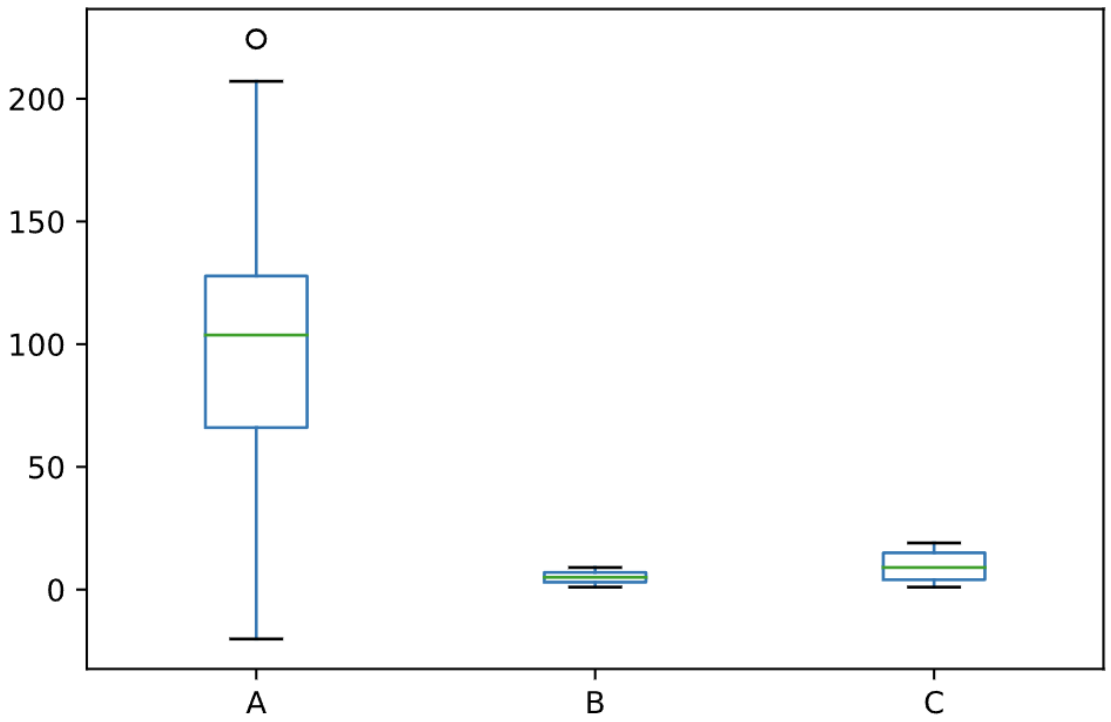



```
df.A.plot.hist(orientation='horizontal')
```

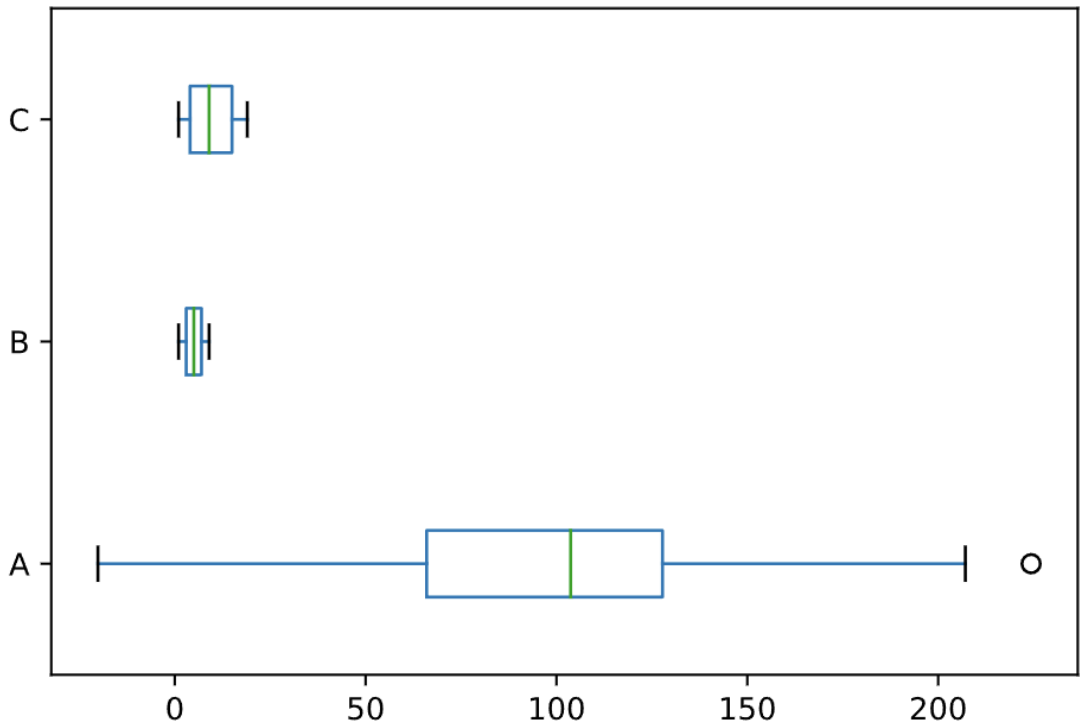


Box Plot

```
df.plot.box()
```

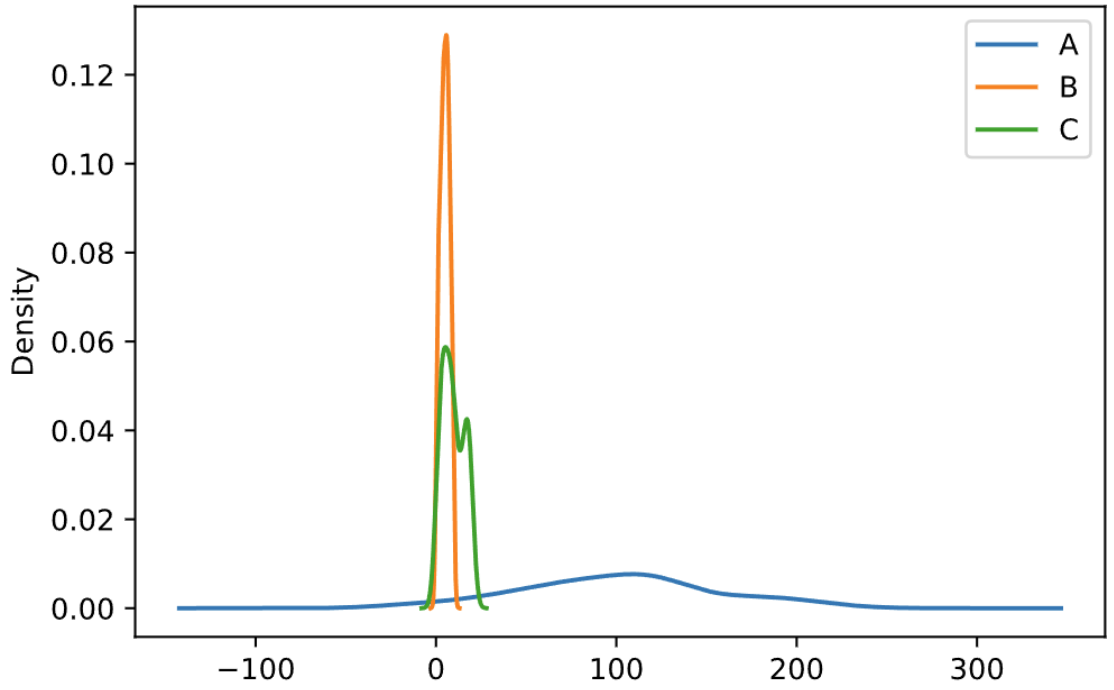



```
df.plot.box(vert=False)
```

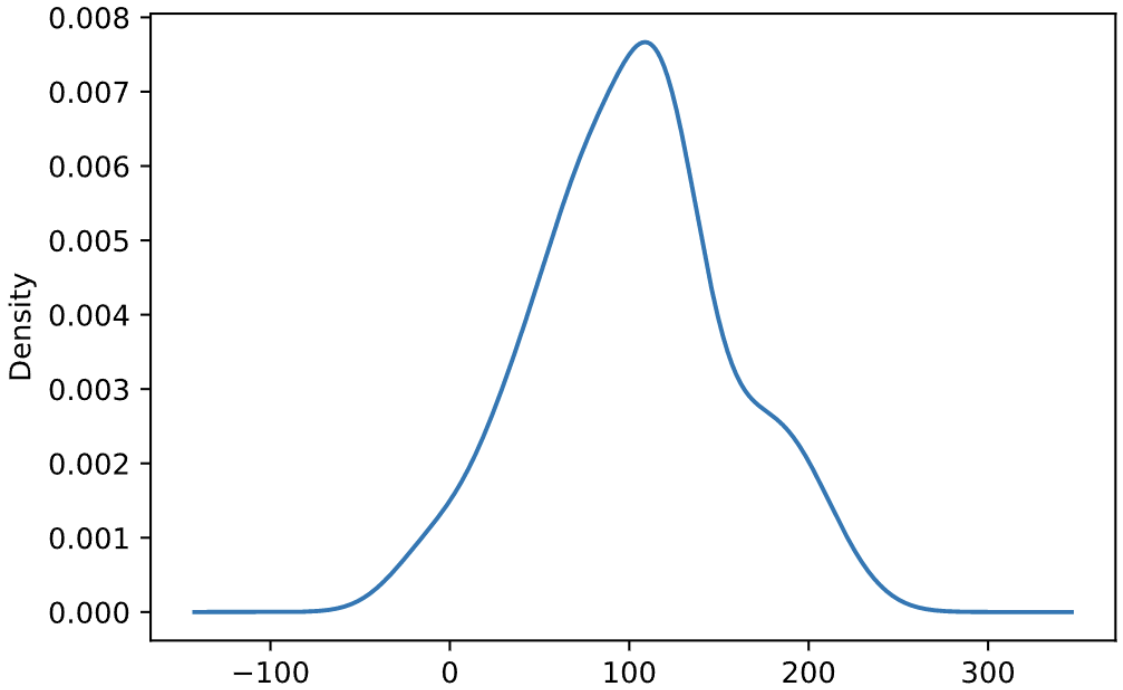


KDE Plot

```
df.plot.kde()
```

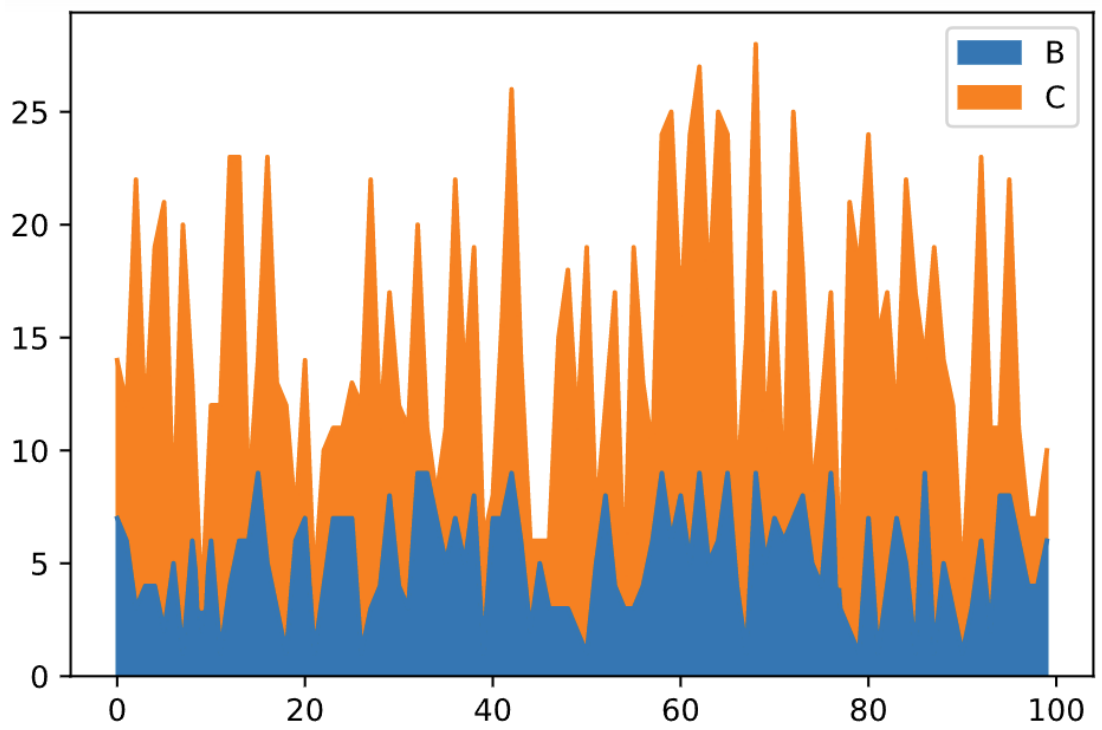



```
df.A.plot.kde()
```

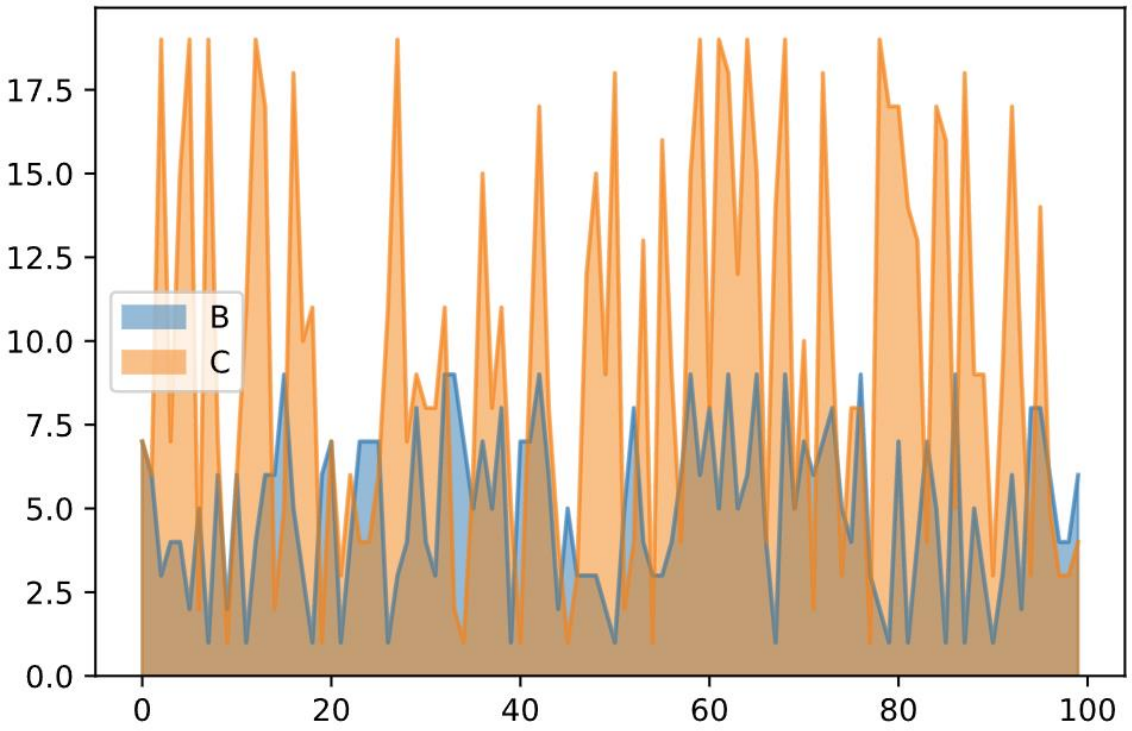


Area Plot

```
df[['B','C']].plot.area()
```

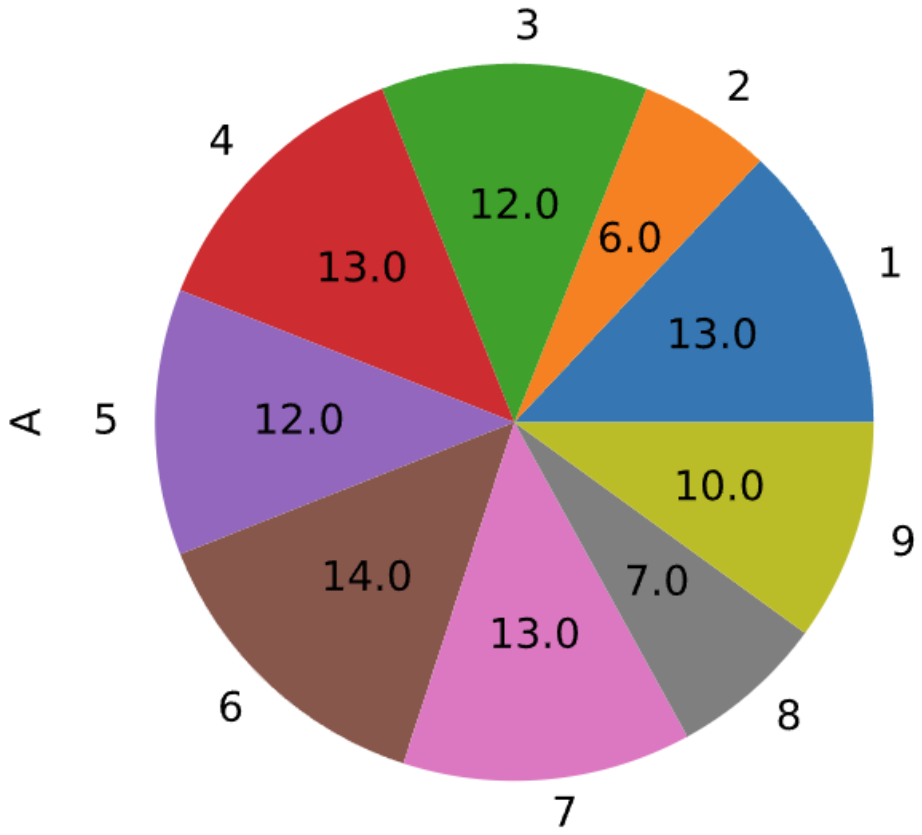



```
df[['B','C']].plot.area(stacked=False)
```



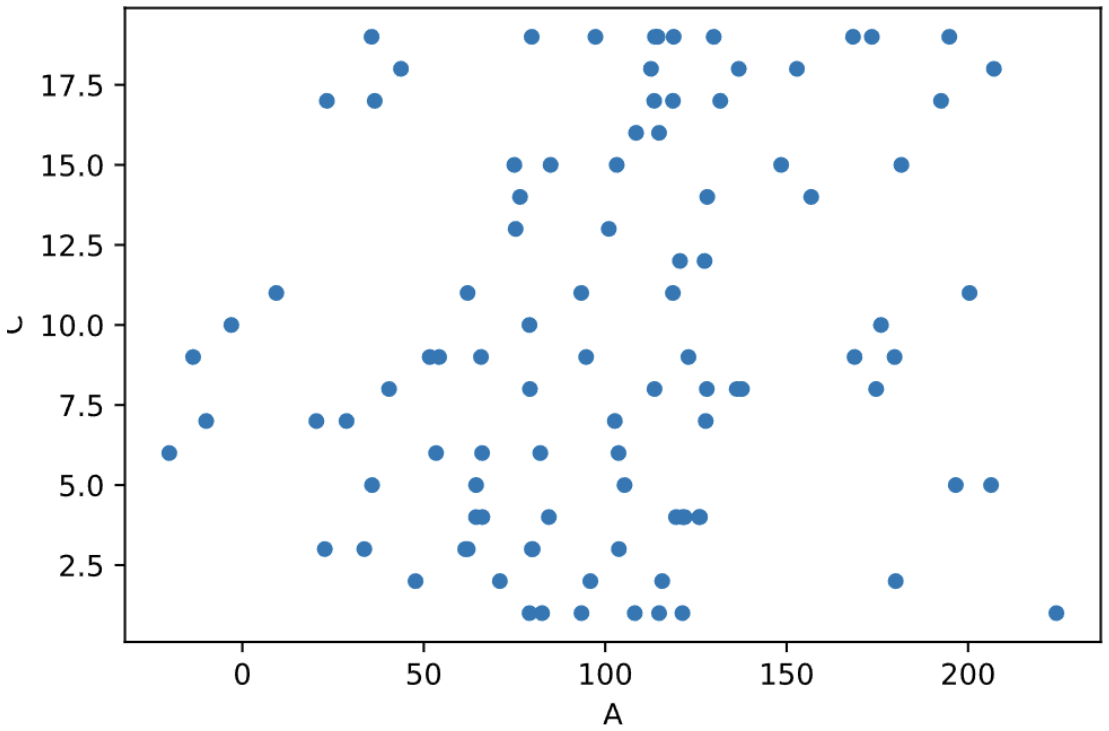
Pie Chart

```
df.groupby('B').count().plot.pie(y='A', legend=False, autopct="%.1f")
```

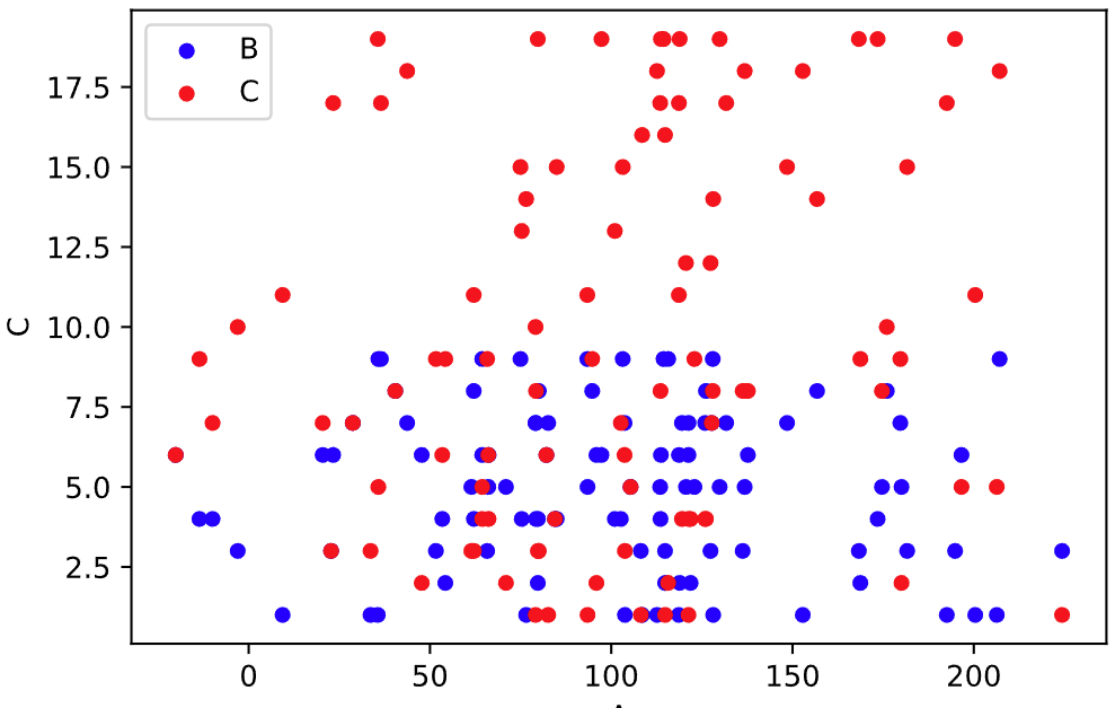


Scatter Plot (1)

```
df.plot(kind='scatter', x='A', y='C')
```

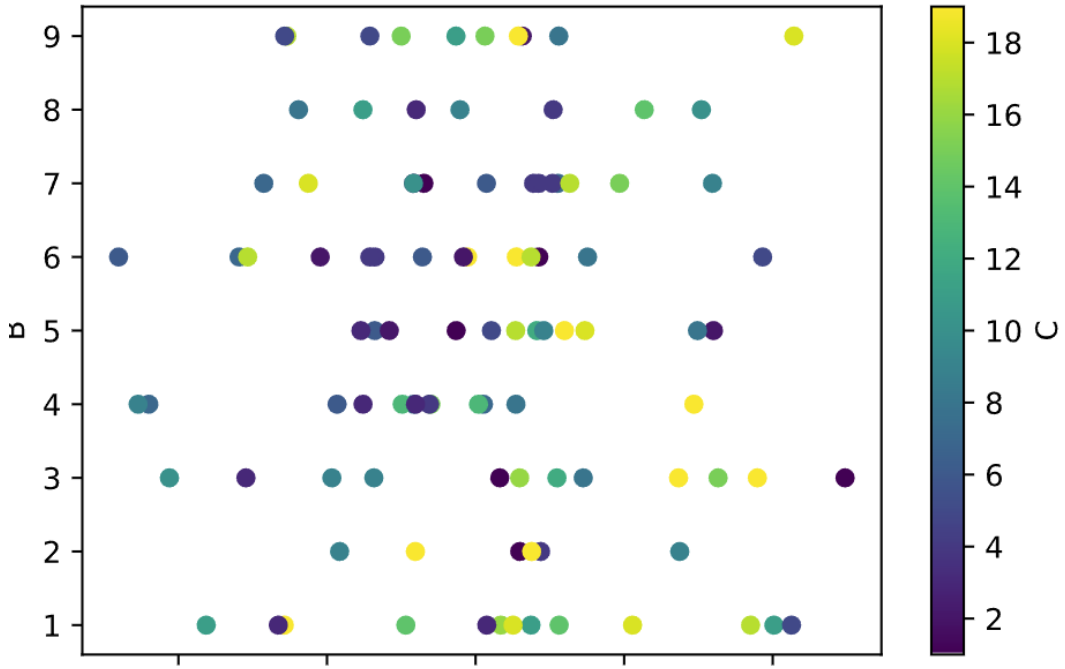



```
ax = df.plot.scatter(x='A', y='B',
                     color='blue', label='B')
df.plot.scatter(x='A', y='C',
                     color='red', label='C', ax=ax)
```



Scatter Plot (2)

```
df.plot.scatter(x='A', y='B', c='C',
                cmap='viridis', s=30)
```




```
df.plot.scatter(x='A', y='B', s=df['C']*10)
```