INTRODUCTION TO PYTHON

LECTURE 6: Data visualization

Asem Elshimi

asem.elshimi@austin.utexas.edu

Final project roadmap

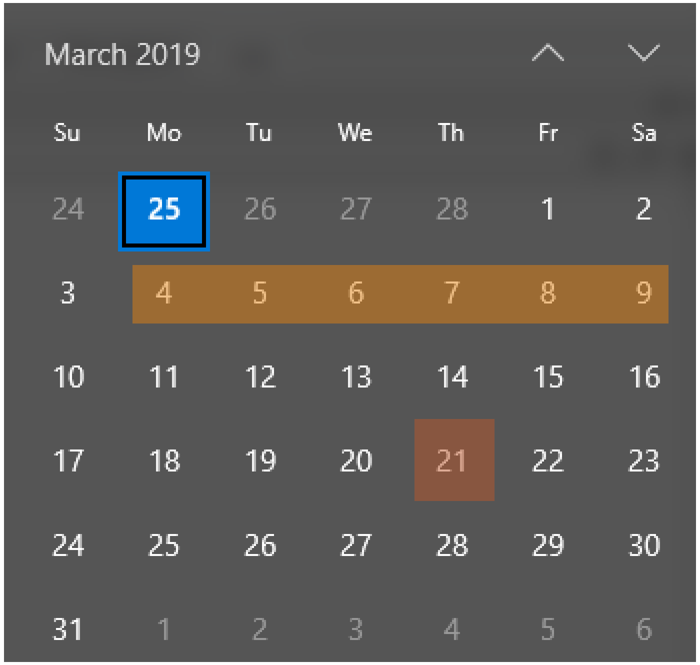
1st evaluation: March 4th

2nd evaluation: March 11th

March 12th: Final report submission open!

Spring break: March 18th to 23rd

Last time to submit: March 21st

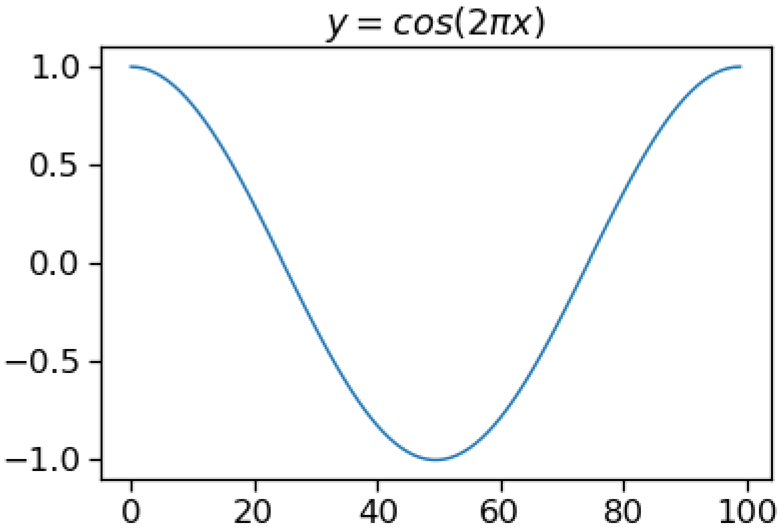


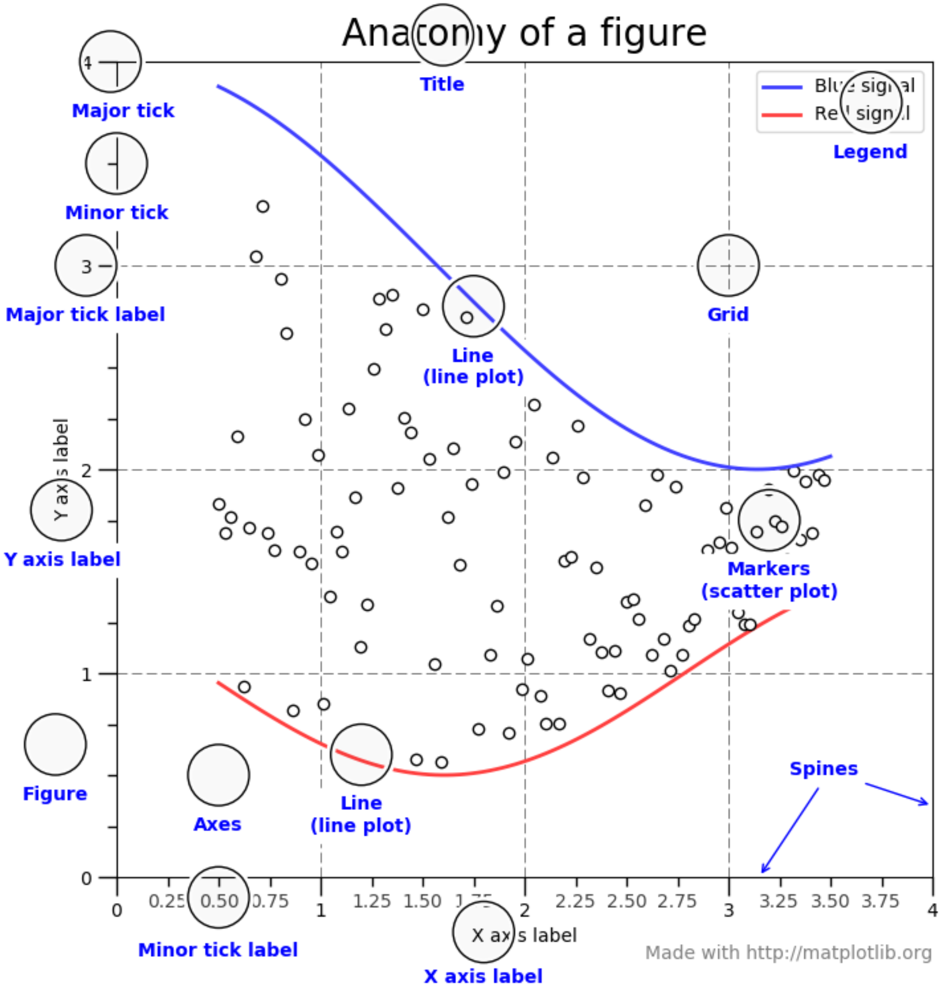
March 2019

Su	Mo	Tu	We	Th	Fr	Sa
24	25	26	27	28	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

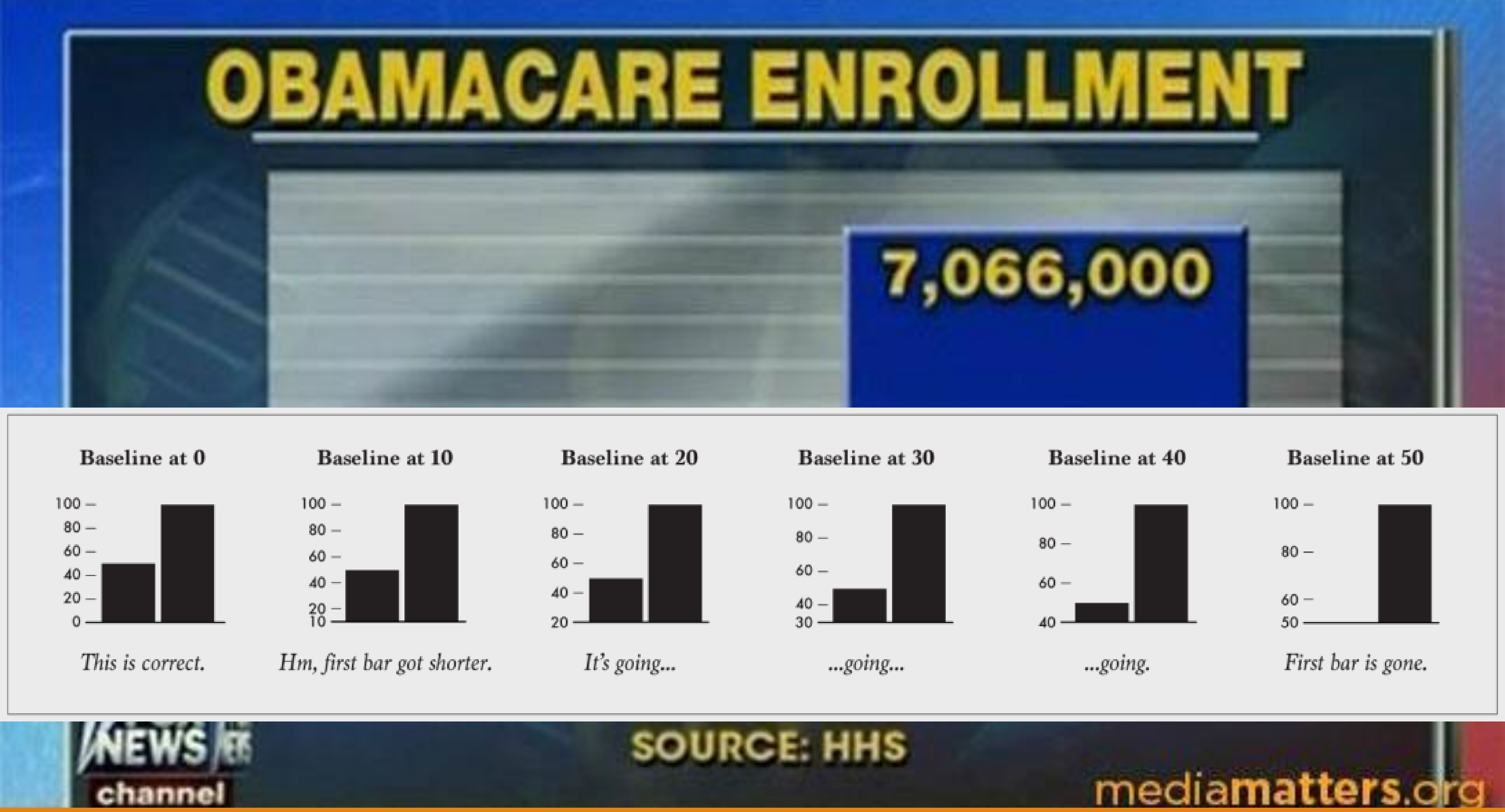
Working with a sequence of numbers

```
xsequence=np.linspace(0,1,100)
y=np.cos(xsequence*2*np.pi)


fig=plt.figure()
ax=fig.add_subplot(1,1,1)
ax.plot(y)
ax.set_title('$y=cos(2 \pi x)$')
plt.show()
```




Anatomy of a figure
Title
Major tick
Minor tick
Major tick label
Grid
Legend
Blue signal
Red signal
Line
(line plot)
Y axis label
Markers
(scatter plot)
Figure
Axes
Line
(line plot)
Spines
Minor tick label
X axis label
Y axis label
X axis label
0
1
2
3
4
0.25
0.50
0.75
1.25
1.50
1.75
2.25
2.50
2.75
3.25
3.50
3.75
Made with http://matplotlib.org

Data visualization



What is wrong with this graph?

COURTESY OF FOX NEWS

Communicating results with scientific graphs.

Do you need a graph?

- Maybe a table is sufficient

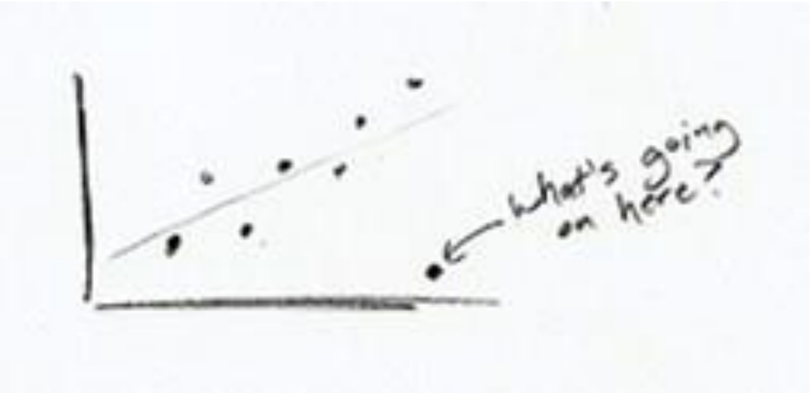
What types of variables do you have?

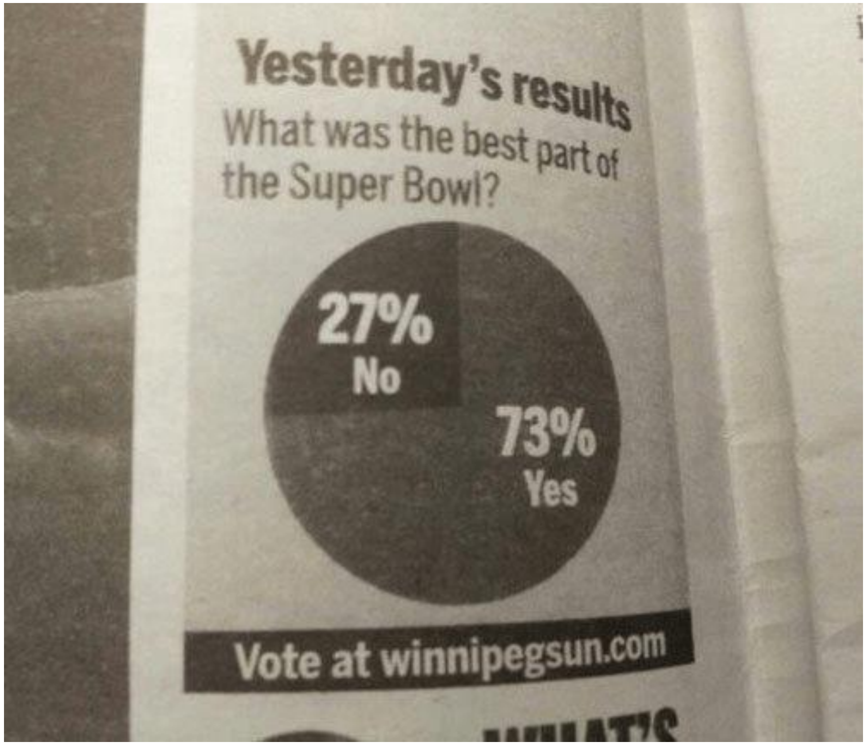
- Continuous, discrete, categorical.
- Independent and dependent variables.

What is your message?

Basic rules:

- Check the data.
- Explain encodings
- Label axes
- Include units
- Include your resources





Yesterday's results

What was the best part of the Super Bowl?

Vote at winnipegsun.com

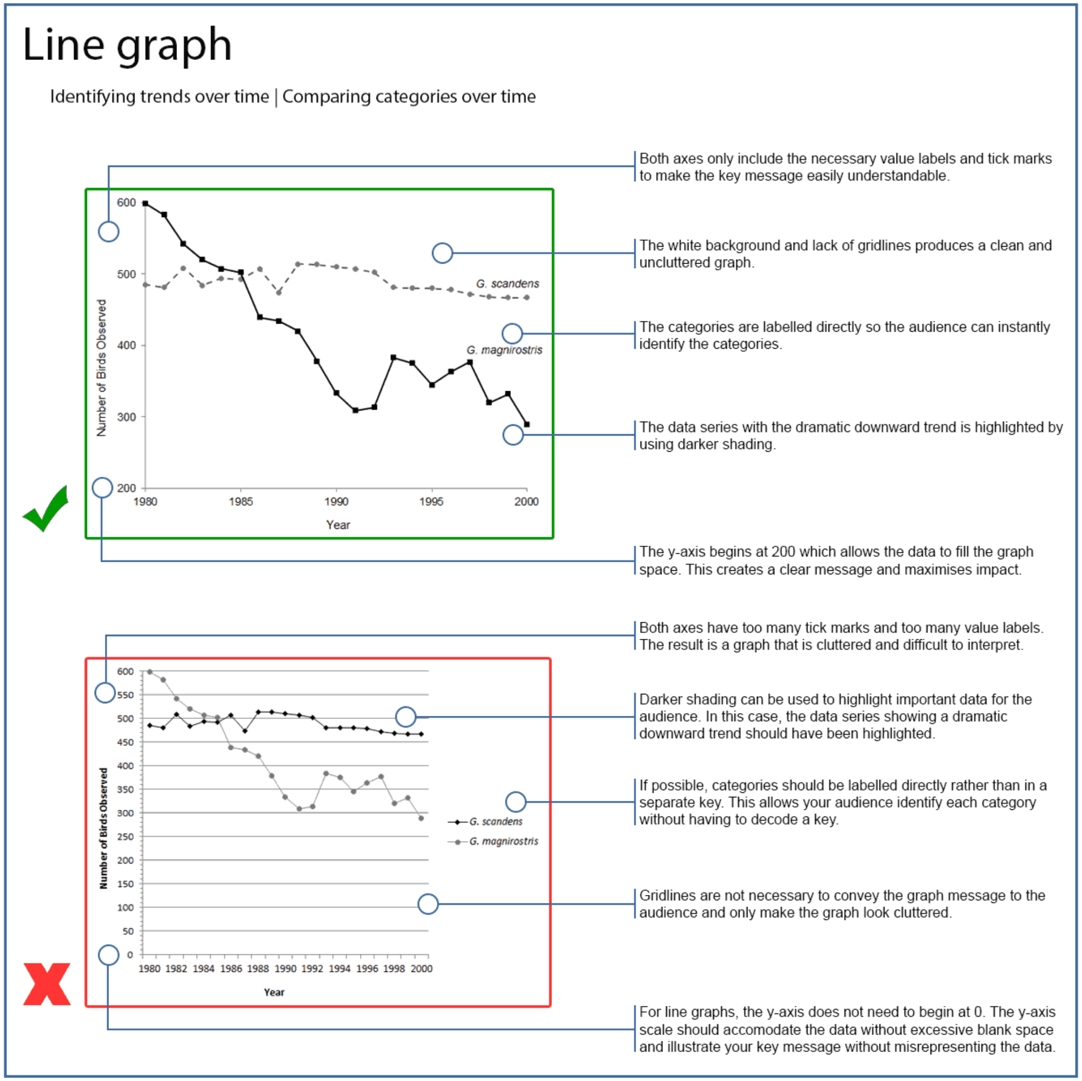
WHAT'S

Basic rules for graphs

Can be interpreted in black and white

Title:

- **Descriptive:** Figure 1. Effects of dam construction on fish biodiversity.
- **Assertive:** Figure 1. Dam construction results in loss of fish biodiversity.



Line graph

Identifying trends over time | Comparing categories over time

Both axes only include the necessary value labels and tick marks to make the key message easily understandable.

The white background and lack of gridlines produces a clean and uncluttered graph.

The categories are labelled directly so the audience can instantly identify the categories.

The data series with the dramatic downward trend is highlighted by using darker shading.

The y-axis begins at 200 which allows the data to fill the graph space. This creates a clear message and maximises impact.

Both axes have too many tick marks and too many value labels. The result is a graph that is cluttered and difficult to interpret.

Darker shading can be used to highlight important data for the audience. In this case, the data series showing a dramatic downward trend should have been highlighted.

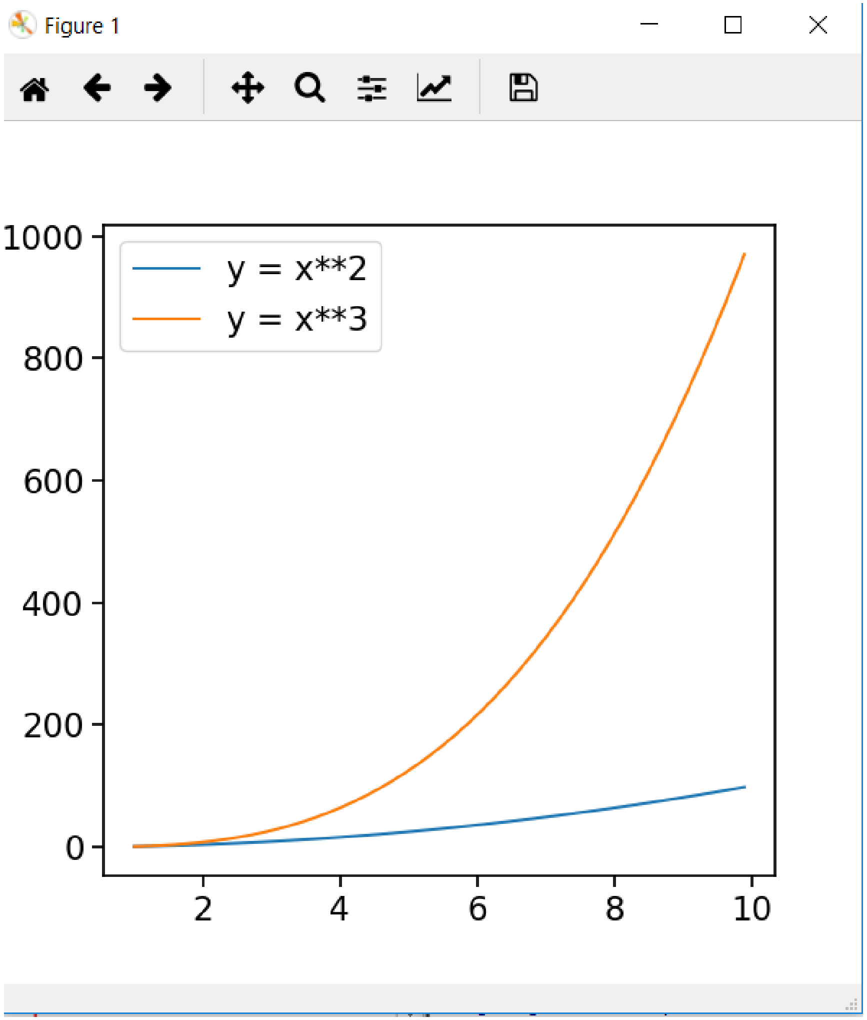
If possible, categories should be labelled directly rather than in a separate key. This allows your audience identify each category without having to decode a key.

Gridlines are not necessary to convey the graph message to the audience and only make the graph look cluttered.

For line graphs, the y-axis does not need to begin at 0. The y-axis scale should accomodate the data without excessive blank space and illustrate your key message without misrepresenting the data.

Line graph syntax in python

```
x=np.arange(1,10,0.1)


##plotting
plt.close("all")
fig = plt.figure(figsize=(6,6), dpi=100)
ax=fig.add_subplot(111)


ax.plot(x, x**2, label="y = x**2")
ax.plot(x, x**3, label="y = x**3")
ax.legend(loc=2); # upper left corner
```



Minimal syntax

Too many spines.

Too many numbers.

Isolated legend.

- Black and white.

Data points missing

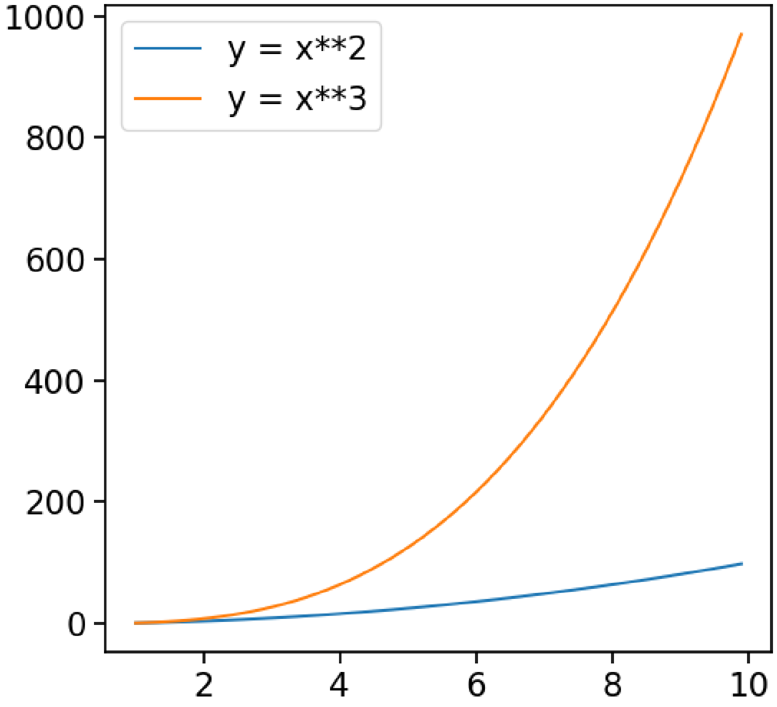
Missing labels

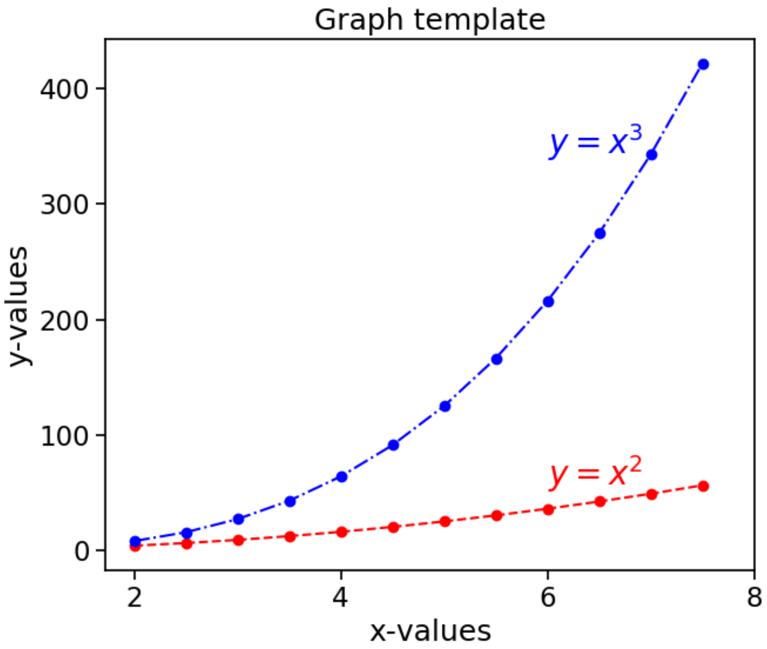
Scientific notation

```
x=np.arange(2,8,0.5)

##plotting
plt.close("all")
fig = plt.figure(figsize=(7,6), dpi=100)
ax=fig.add_subplot(111)

ax.plot(x, x**2,'r--o')
ax.plot(x, x**3, 'b-.o')

#labels
ax.set_xlabel('x-values')
ax.set_ylabel('y-values')
ax.set_title('Graph template')

#limits
#ax.set_ylim(bottom=0)
#ax.set_xlim(left=0)
```

…

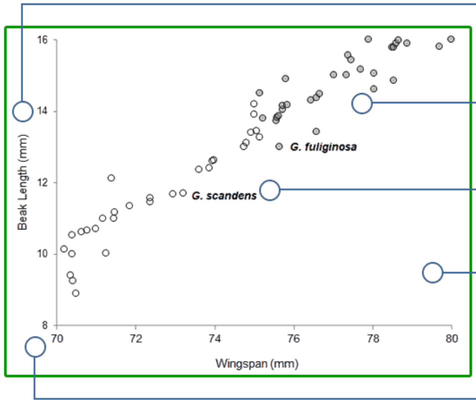
```
#ticks
ax.set_xticks(np.arange(min(x), max(x)+1, 2))

#annotations
ax.text(6,6**2+20, r"$y=x^2$", fontsize=20, color="red")
ax.text(7-1,7**3, r"$y=x^3$", fontsize=20, color="blue")

# Hide the right and top spines
#ax.spines['right'].set_visible(False)
#ax.spines['top'].set_visible(False)

#make sure labels dont overlap
plt.tight_layout()
```


y = x**2
y = x**3
1000
800
600
400
200
0
2
4
6
8
10


Graph template
$y = x^3$
$y = x^2$
400
300
200
100
0
y-values
2
4
6
8
x-values

Scatter plot

Identifying relationships between variables | Displaying trends and correlations



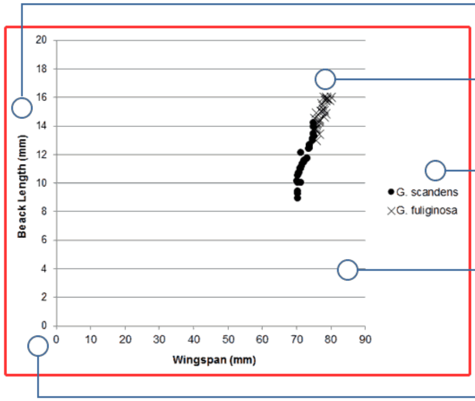
The axes are labelled in a standard font and include only enough value labels and tick marks to interpret the data.

The data maximises the available space. The distribution of data points will vary but you should aim to have your data spread across the graph space.

The categories are labelled directly so the audience can instantly identify the categories. Each category is distinguished by differences in shading.

The white background and lack of gridlines produces a clean and uncluttered graph.

The scale of both axes are appropriate for displaying the data in a meaningful way without an excess of blank space.



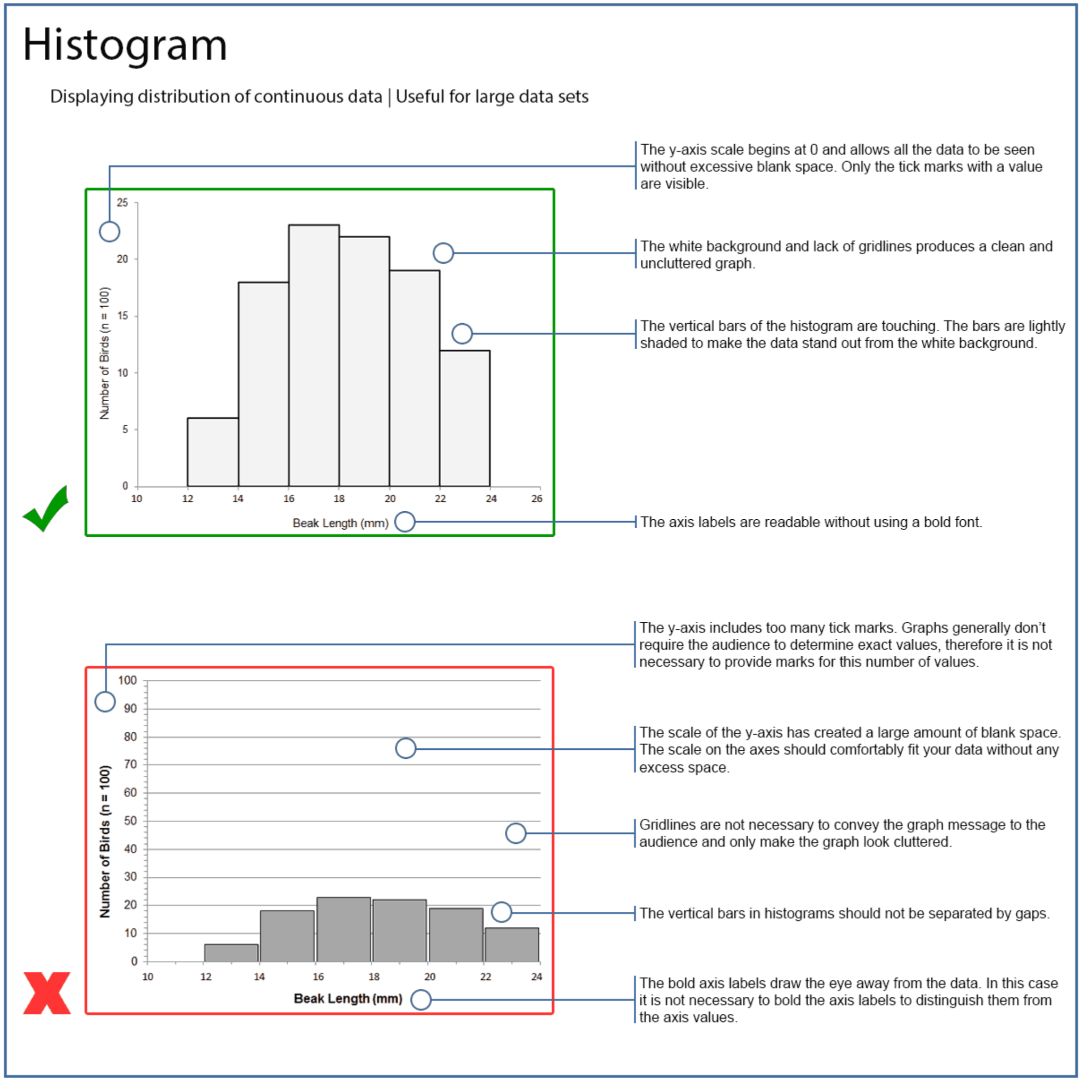
Axis labels don't need a bold font unless they could be confused with value labels. In this case a bold font is not necessary.

Data should not be bunched into a small region of the graph. If the data looks similar to this, the axis scales should be adjusted so the data is filling the graph space.

Categories in scatter plots can be labelled directly rather than using a key.This allows your audience to identify each category without having to decode a key.

Gridlines are not necessary to convey the graph message to the audience and only make the graph look cluttered.

For scatter plots, the x and y axes do not need to begin at 0. The scales should accomodate the data without excessive blank space and illustrate your key message without misrepresenting the data.



Histogram

Displaying distribution of continuous data | Useful for large data sets

The y-axis scale begins at 0 and allows all the data to be seen without excessive blank space. Only the tick marks with a value are visible.

The white background and lack of gridlines produces a clean and uncluttered graph.

The vertical bars of the histogram are touching. The bars are lightly shaded to make the data stand out from the white background.

The axis labels are readable without using a bold font.

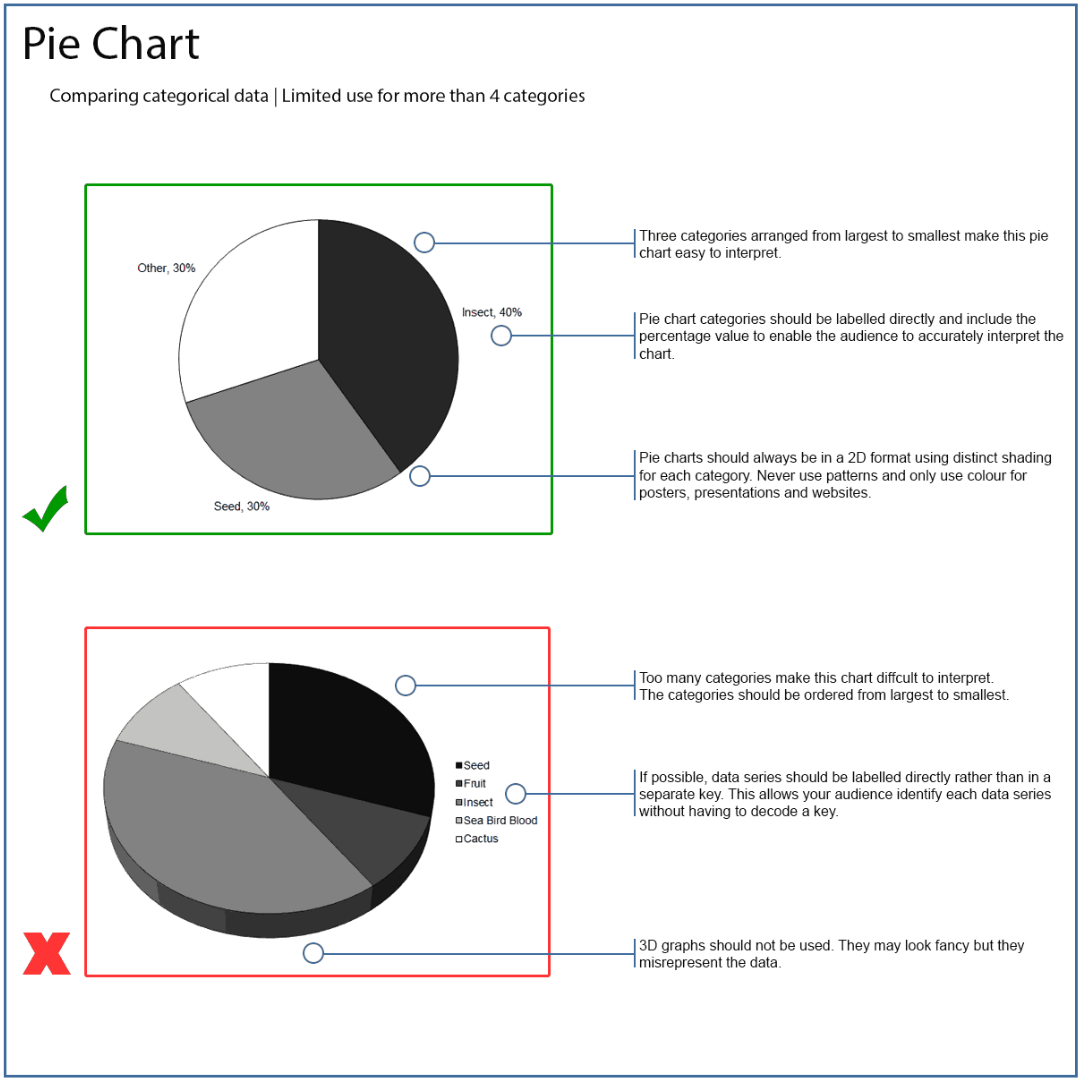
The y-axis includes too many tick marks. Graphs generally don't require the audience to determine exact values, therefore it is not necessary to provide marks for this number of values.

The scale of the y-axis has created a large amount of blank space. The scale on the axes should comfortably fit your data without any excess space.

Gridlines are not necessary to convey the graph message to the audience and only make the graph look cluttered.

The vertical bars in histograms should not be separated by gaps.

The bold axis labels draw the eye away from the data. In this case it is not necessary to bold the axis labels to distinguish them from the axis values.



Pie Chart

Comparing categorical data | Limited use for more than 4 categories

Other, 30%
Insect, 40%
Seed, 30%
✓

Three categories arranged from largest to smallest make this pie chart easy to interpret.

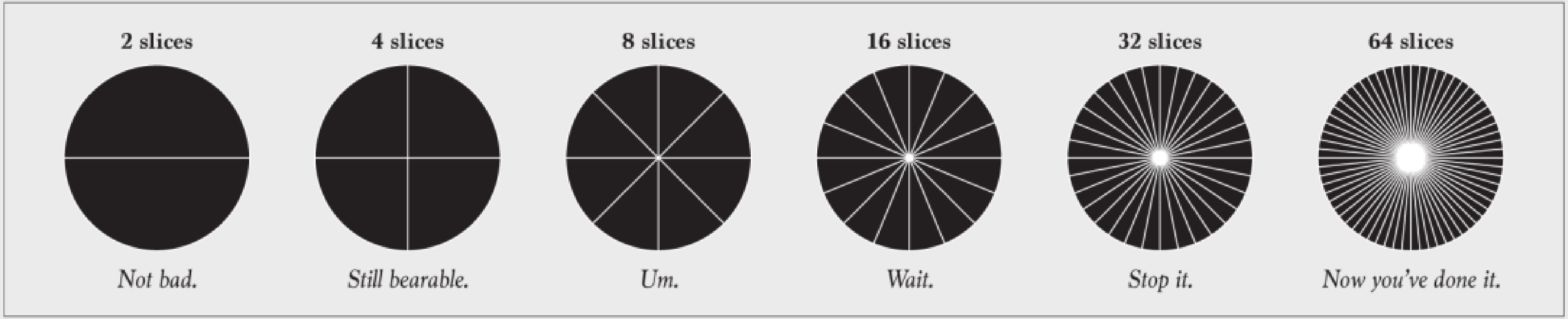
Pie chart categories should be labelled directly and include the percentage value to enable the audience to accurately interpret the chart.

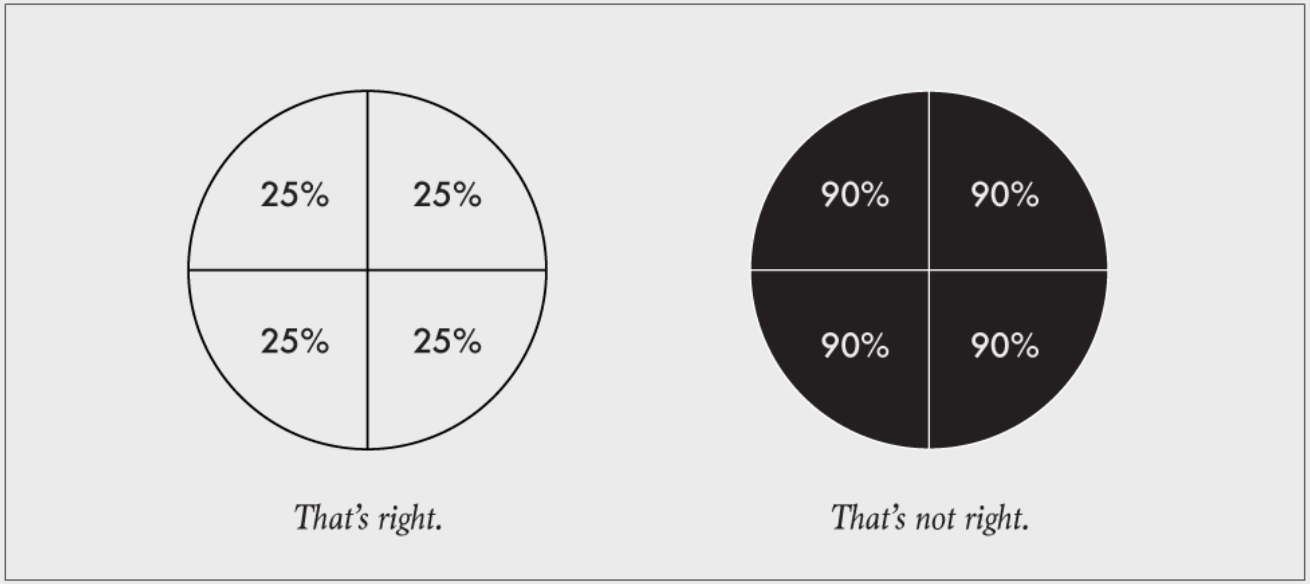
Pie charts should always be in a 2D format using distinct shading for each category. Never use patterns and only use colour for posters, presentations and websites.

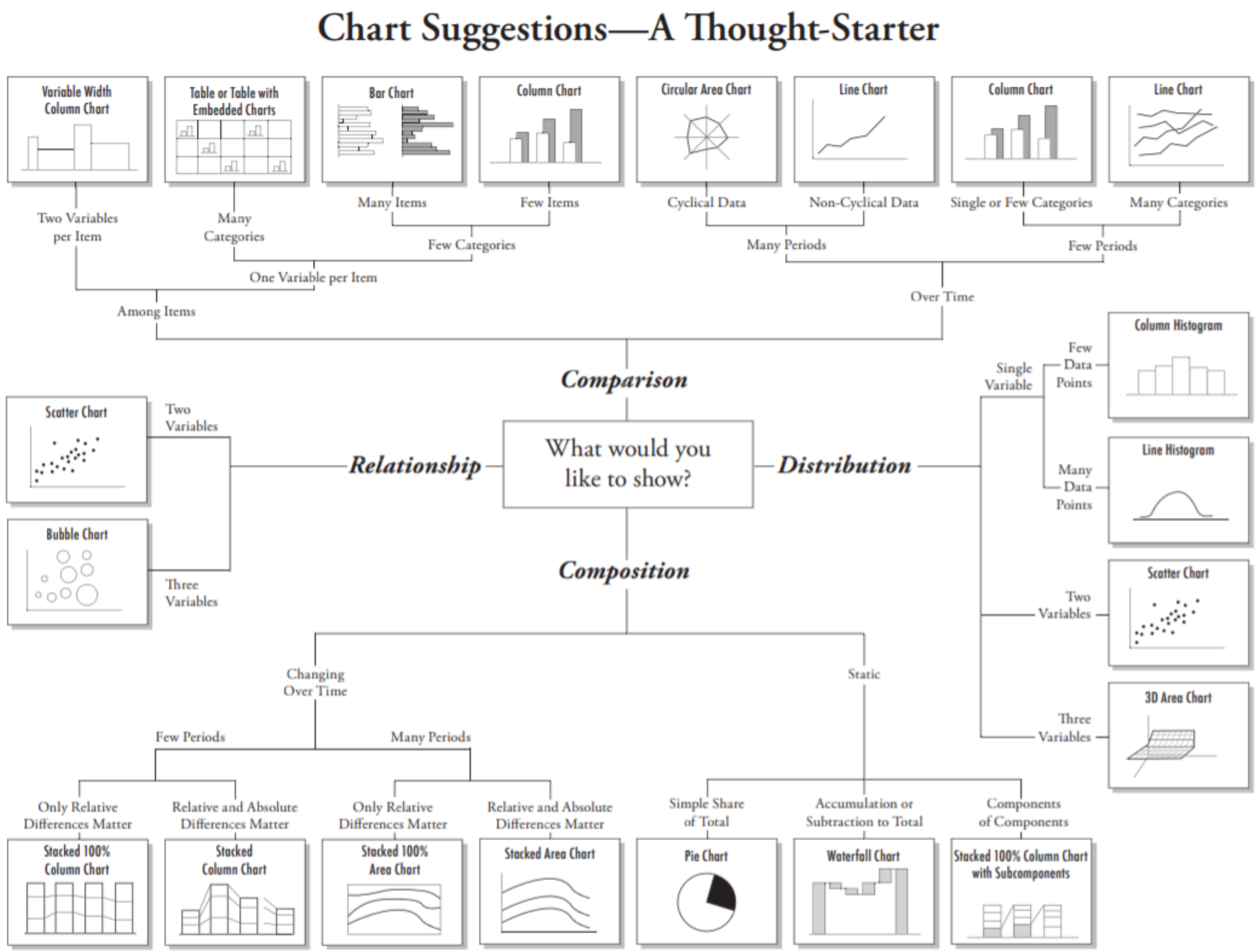
Too many categories make this chart diffcult to interpret. The categories should be ordered from largest to smallest.

If possible, data series should be labelled directly rather than in a separate key. This allows your audience identify each data series without having to decode a key.

3D graphs should not be used. They may look fancy but they misrepresent the data.


2 slices
4 slices
8 slices
16 slices
32 slices
64 slices
Not bad.
Still bearable.
Um.
Wait.
Stop it.
Now you've done it.


25%
25%
25%
25%
90%
90%
90%
90%
That's right.
That's not right.



HTTP://WWW.CLIPS.EDU.AU/WP-CONTENT/UPLOADS/CHOOSING-A-GOOD-GRAPH.PDF

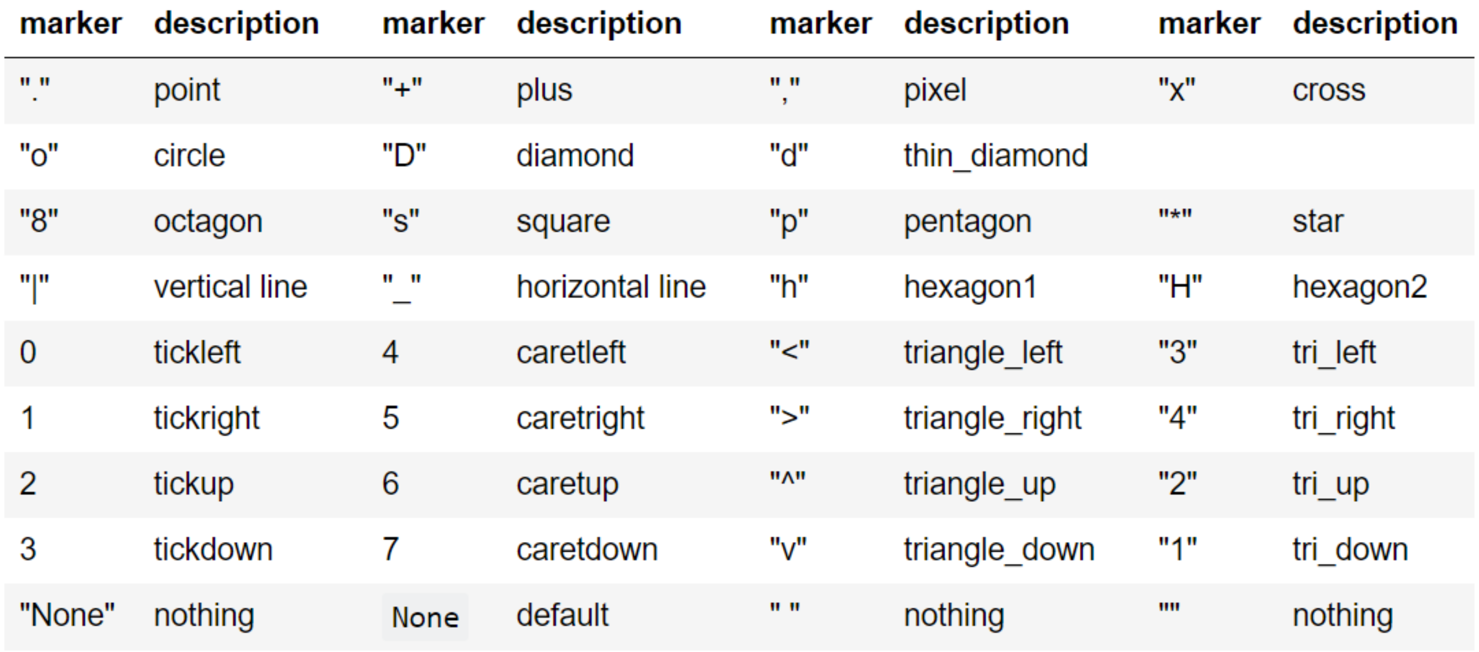
How to speak MPL

Colornames:

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

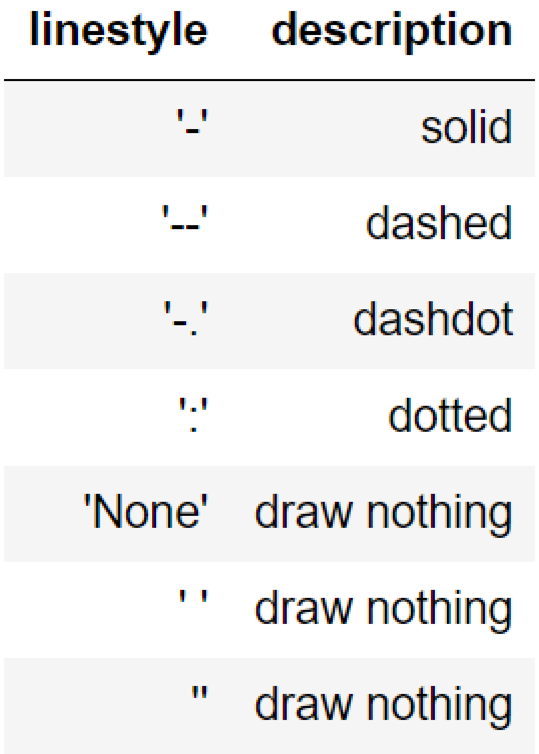
Full list: https://www.w3schools.com/Colors/colors_names.asp

Markers



marker	description	marker	description	marker	description	marker	description
"."	point	"+"	plus	","	pixel	"x"	cross
"o"	circle	"D"	diamond	"d"	thin_diamond		
"8"	octagon	"s"	square	"p"	pentagon	"*"	star
"|"	vertical line	"_"	horizontal line	"h"	hexagon1	"H"	hexagon2
0	tickleft	4	caretleft	"<"	triangle_left	"3"	tri_left
1	tickright	5	caretright	">"	triangle_right	"4"	tri_right
2	tickup	6	caretup	"^"	triangle_up	"2"	tri_up
3	tickdown	7	caretdown	"v"	triangle_down	"1"	tri_down
"None"	nothing	`None`	default	" "	nothing	""	nothing

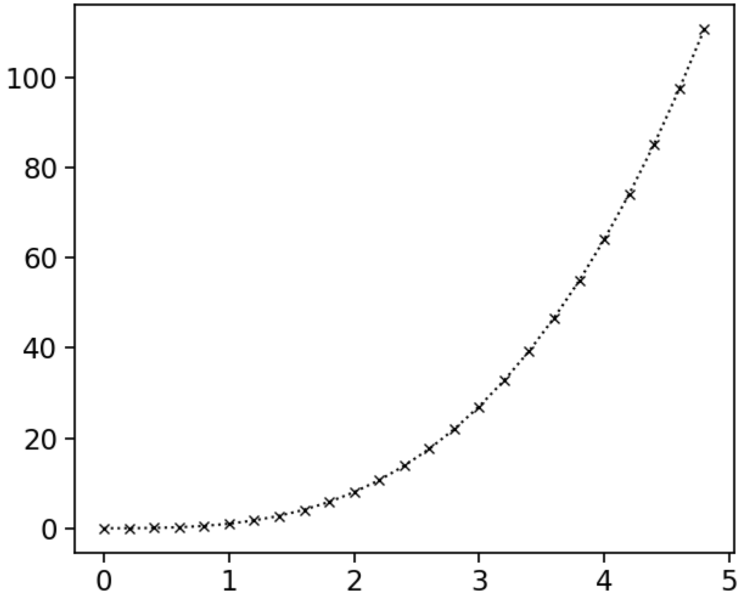
Linestyle



linestyle	description
'-'	solid
'--'	dashed
'-.'	dashdot
':'	dotted
'None'	draw nothing
' '	draw nothing
''	draw nothing

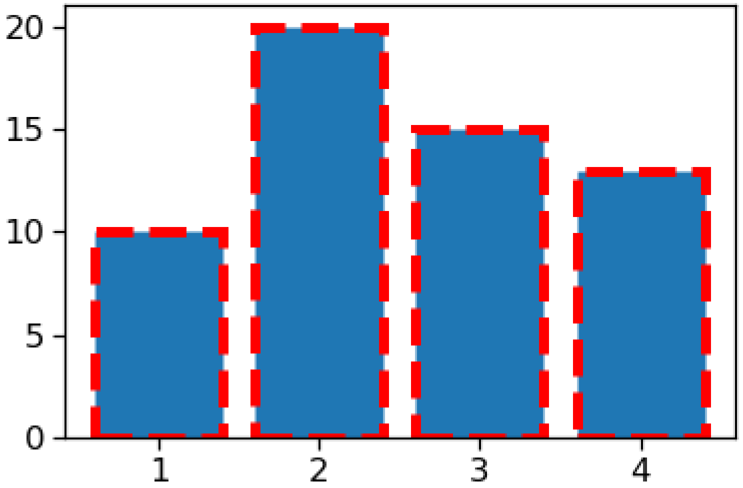
Example

```
ax=fig.add_subplot(111)
t = np.arange(0.0, 5.0, 0.2)
plt.plot( t, t**3,
         color='black',
         marker='x',
         linestyle=':')
plt.show()
```



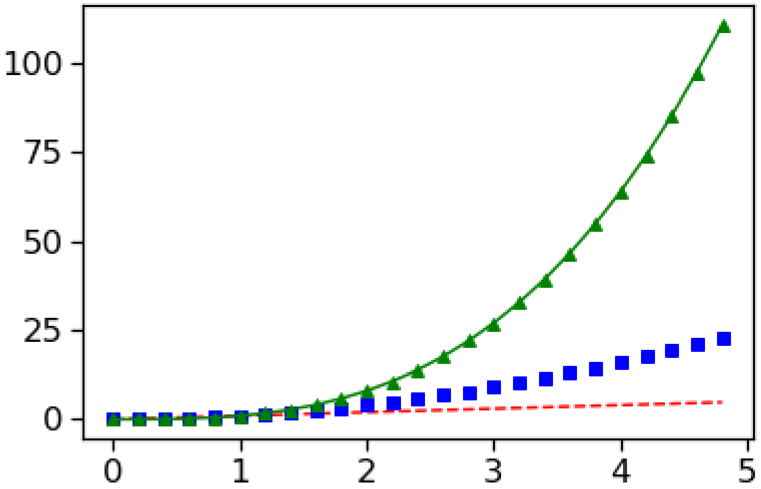
Style for other plots

```
fig, ax = plt.subplots(1, 1)
ax.bar([1, 2, 3, 4], [10, 20, 15, 13],
       linestyle='--', #linestyle
       ec='r', #color
       lw=5) #linewidth
plt.show()
```



Simple syntax, but too implicit!

```
fig, ax = plt.subplots(1, 1)
t = np.arange(0., 5., 0.2)
# red dashes, blue squares and green triangles
plt.plot(t, t, 'r--', t, t**2, 'bs', t, t**3, 'g^-')
plt.show()
```

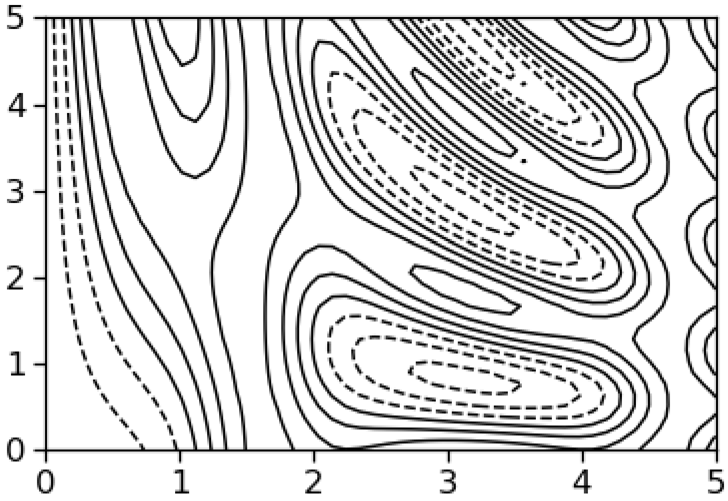


Property	Value Type
alpha	float
color or c	any matplotlib color
dash_capstyle	['butt', 'round' 'projecting']
dash_joinstyle	['miter' 'round' 'bevel']
dashes	sequence of on/off ink in points
drawstyle	[‘default’ ‘steps’ ‘steps-pre’
	‘steps-mid’ ‘steps-post’]
linestyle or ls	['-' '--' '-.' ':' 'None' ' ' '']
	and any drawstyle in combination with a
	linestyle, e.g. 'steps--'.
linewidth or lw	float value in points
marker	[0 1 2 3 4 5 6 7 'o' 'd' 'D' 'h' 'H'
	'' 'None' ' ' None '8' 'p' ','
	'+' 'x' '.' 's' '*' '_' '|'
	'1' '2' '3' '4' 'v' '<' '>' '^']
markeredgecolor or mec	any matplotlib color
markeredgewidth or mew	float value in points
markerfacecolor or mfc	any matplotlib color
markersize or ms	float
solid_capstyle	['butt' 'round' 'projecting']
solid_joinstyle	['miter' 'round' 'bevel']
visible	[True False]
zorder	any number

The 3rd dimension.

Contour plot

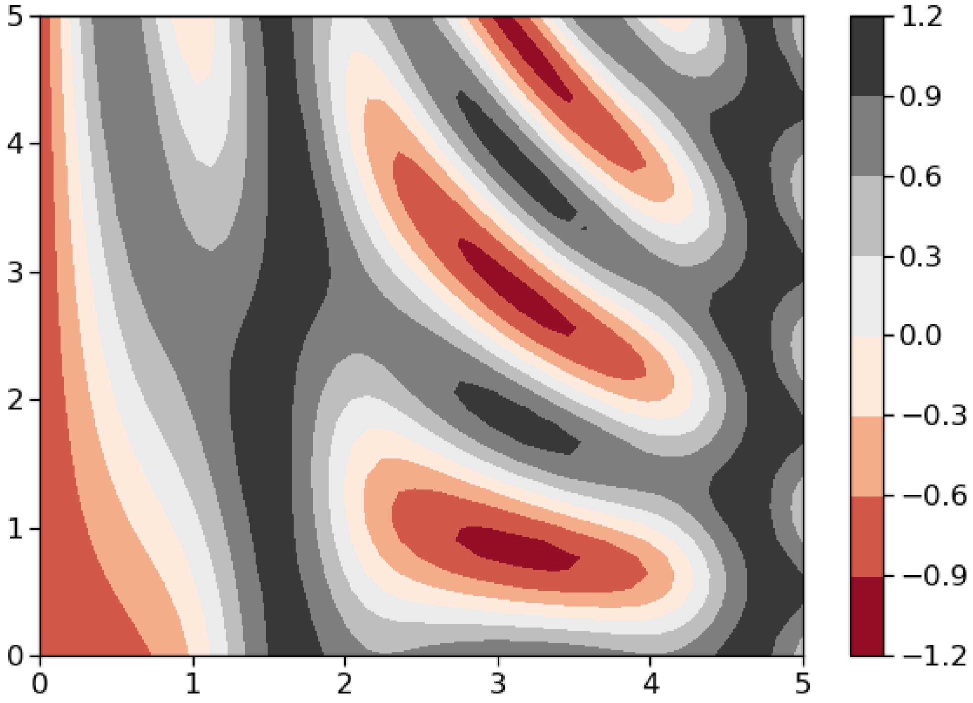
```
def f(x, y):
    return np.sin(x) ** 10 + np.cos(10 + y * x) * np.cos(x)


x = np.linspace(0, 5, 50)
y = np.linspace(0, 5, 40)


X, Y = np.meshgrid(x, y)
Z = f(X, Y)


plt.contour(X, Y, Z, colors='bla
```



Colorful contour

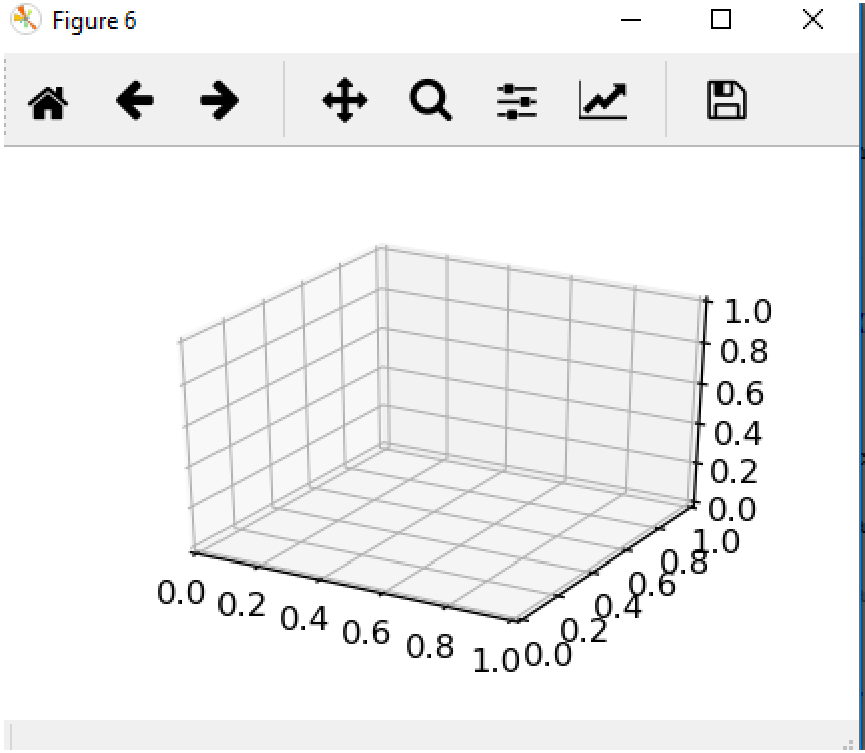
```
def f(x, y):
    return np.sin(x) ** 10 + np.cos(10 + y * x) * np.cos(x)
```

```
x = np.linspace(0, 5, 50)
y = np.linspace(0, 5, 40)

X, Y = np.meshgrid(x, y)
Z = f(X, Y)
plt.contourf(X, Y, Z, cmap
plt.colorbar()
plt.tight_layout()
```

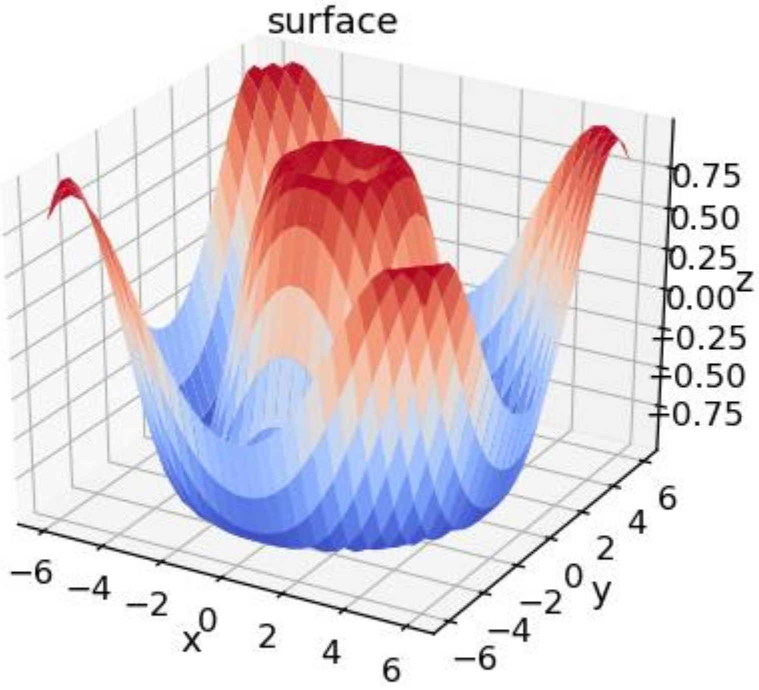


3D plotting

```
fig = plt.figure()

ax = fig.gca(projection="3d")

plt.show()
```



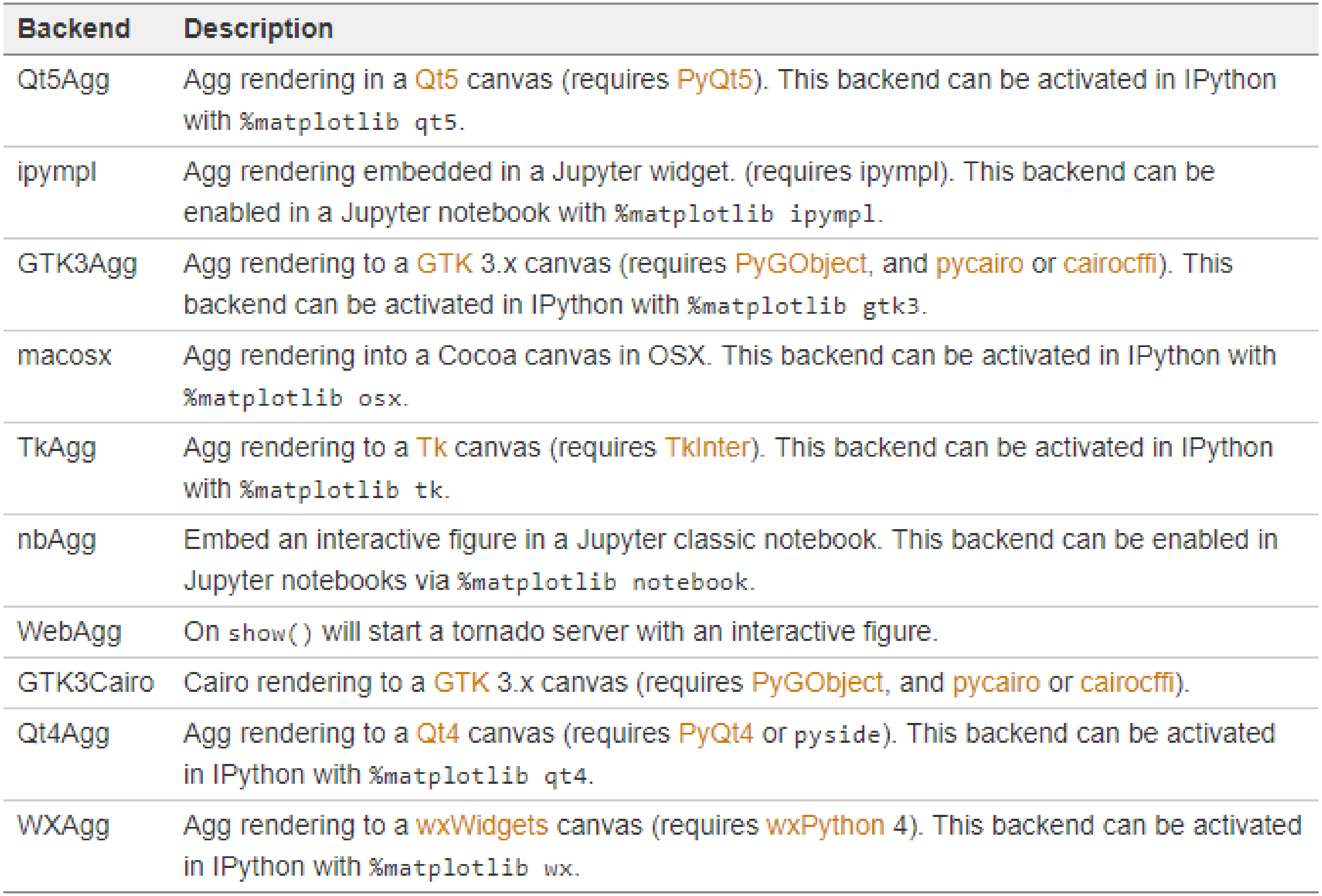
```
plt.close("all")
def f(x, y):
    return np.sin(np.sqrt(x ** 2 + y ** 2))

x = np.linspace(-6, 6, 30)
y = np.linspace(-6, 6, 30)

X, Y = np.meshgrid(x, y)
Z = f(X, Y)

fig = plt.figure()
ax = fig.gca(projection="3d")
ax.plot_surface(X, Y, Z,
               cmap=‘coolwarm')

ax.set_title('surface');
ax.set_xlabel('x')
ax.set_ylabel('y')
ax.set_zlabel('z');
plt.tight_layout()
plt.show()
```



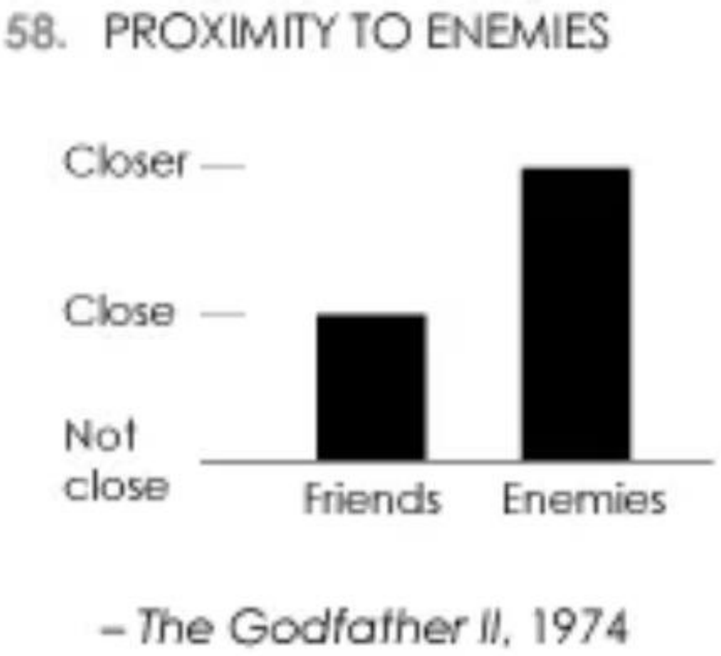
Matplotlib backends

```
import matplotlib

matplotlib.get_backend()

matplotlib.use('Qt5Agg’)
```

https://matplotlib.org/tutorials/introductory/usage.html



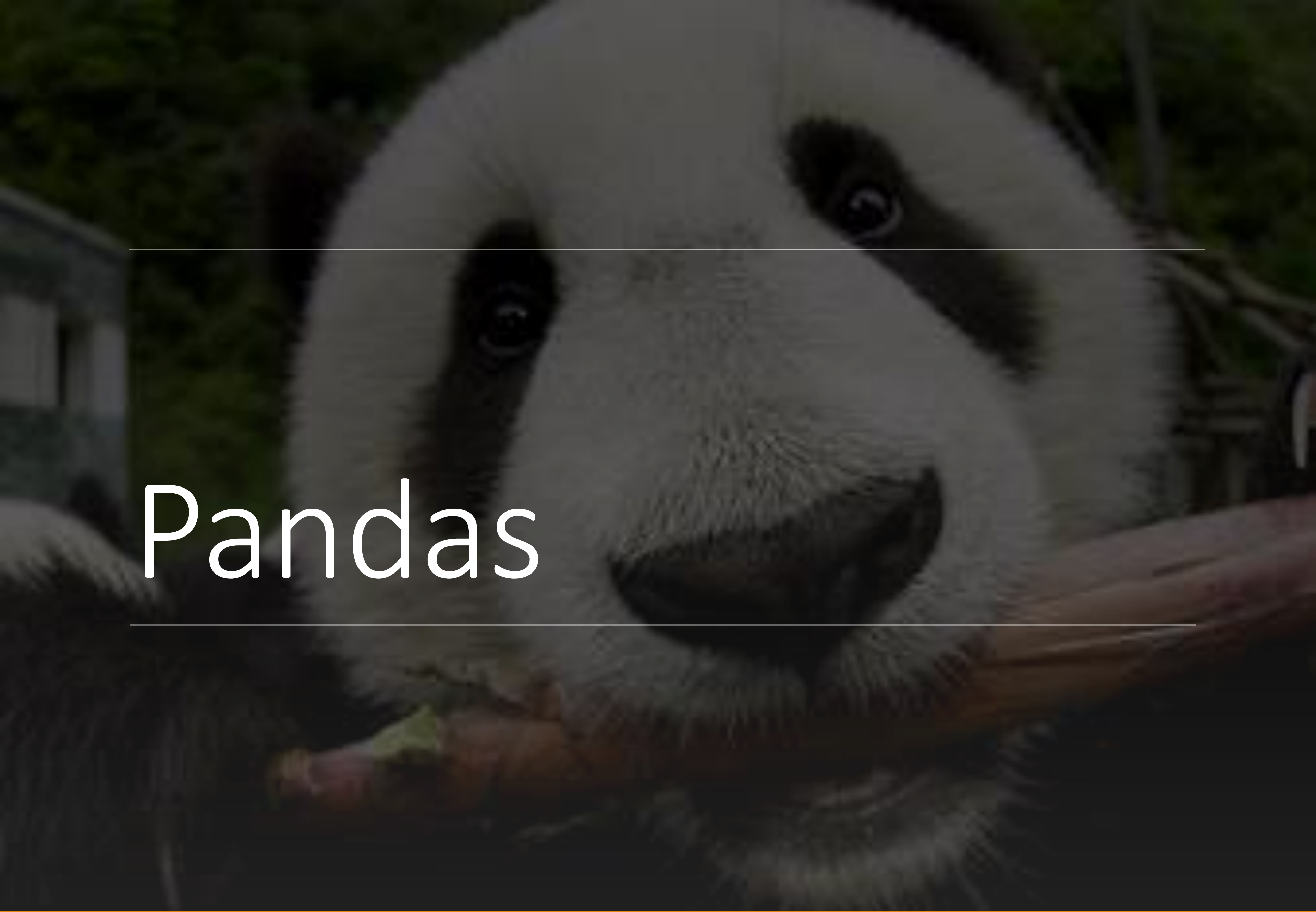
Backend	Description
Qt5Agg	Agg rendering in a Qt5 canvas (requires PyQt5). This backend can be activated in IPython with `%matplotlib qt5`.
ipympl	Agg rendering embedded in a Jupyter widget. (requires ipympl). This backend can be enabled in a Jupyter notebook with `%matplotlib ipympl`.
GTK3Agg	Agg rendering to a GTK 3.x canvas (requires PyGObject, and pycairo or cairocffi). This backend can be activated in IPython with `%matplotlib gtk3`.
macosx	Agg rendering into a Cocoa canvas in OSX. This backend can be activated in IPython with `%matplotlib osx`.
TkAgg	Agg rendering to a Tk canvas (requires TkInter). This backend can be activated in IPython with `%matplotlib tk`.
nbAgg	Embed an interactive figure in a Jupyter classic notebook. This backend can be enabled in Jupyter notebooks via `%matplotlib notebook`.
WebAgg	On `show()` will start a tornado server with an interactive figure.
GTK3Cairo	Cairo rendering to a GTK 3.x canvas (requires PyGObject, and pycairo or cairocffi).
Qt4Agg	Agg rendering to a Qt4 canvas (requires PyQt4 or `pyside`). This backend can be activated in IPython with `%matplotlib qt4`.
WXAgg	Agg rendering to a wxWidgets canvas (requires wxPython 4). This backend can be activated in IPython with `%matplotlib wx`.



Galleries

https://matplotlib.org/gallery.html

https://flowingdata.com/famous-movie-quotes-as-charts/



Pandas

Pandas

(**P**ython **an**d **D**ata **A**nalysi**s**)

https://pandas.pydata.org/pandas-docs/stable/getting_started/10min.html#min

A fast and efficient **DataFrame** object.

reading and writing data

Flexible **reshaping, slicing**, **fancy indexing**

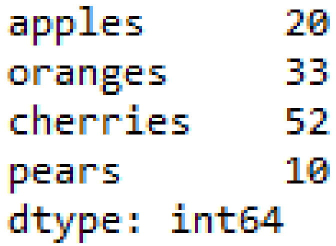
Python with *pandas* is in use in a wide variety of **academic and commercial** domains, including Finance, Neuroscience, Economics, Statistics, Advertising, Web Analytics, and more.

```
import pandas as pd
```

Series

One dimensional fancy indexed arrays:

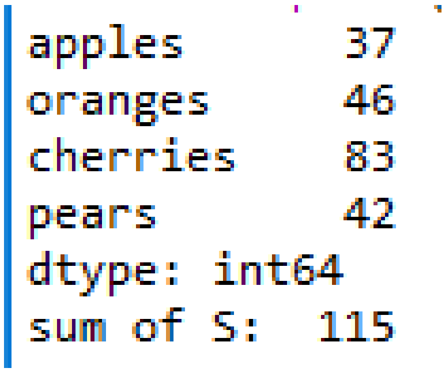
```
fruits = ['apples', 'oranges', 'cherries', 'pears']

quantities = [20, 33, 52, 10]

S = pd.Series(quantities, index=fruits)

S
```



```
apples      20
oranges     33
cherries    52
pears       10
dtype: int64
```

Add two series objects

```
fruits = ['apples', 'oranges', 'cherries',
'pears']

S = pd.Series([20, 33, 52, 10], index=fruits)

S2 = pd.Series([17, 13, 31, 32], index=fruits)

print(S + S2)

print("sum of S: ", sum(S))
```



```
apples       37
oranges      46
cherries     83
pears        42
dtype: int64
sum of S:  115
```

Accessing elements

```
print(S['apples'])
```

```
20
```

```
print(S[['apples', 'oranges', 'cherries']])
```

```
apples      20
oranges      33
cherries    52
dtype: int64
```

Operations

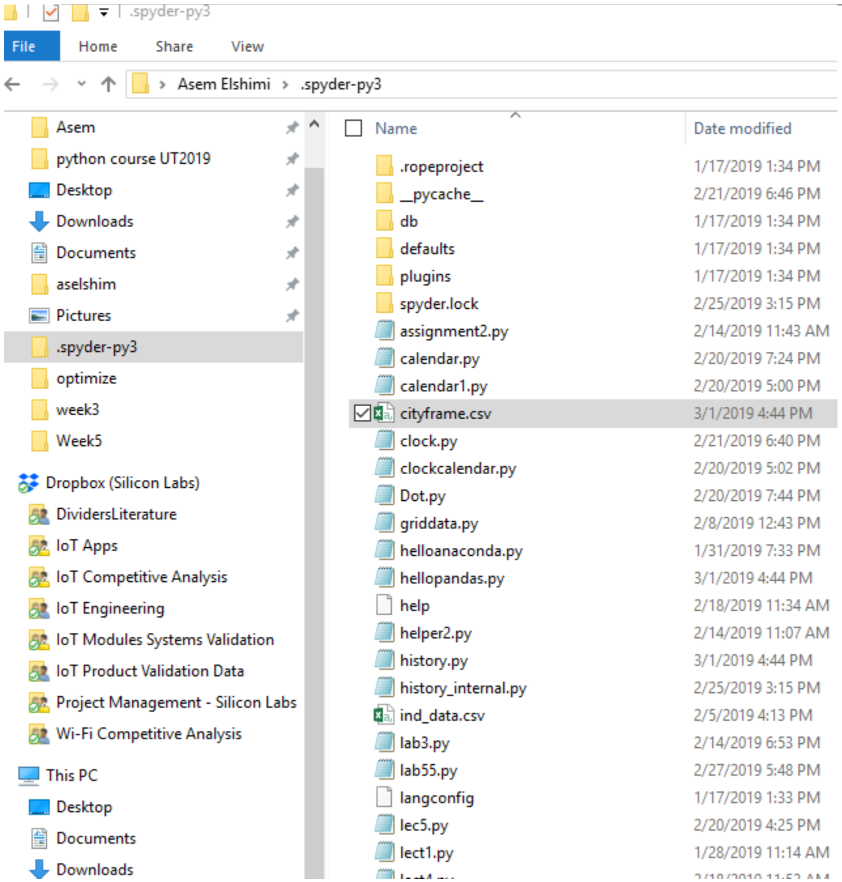
```
import numpy as np

S.apply(np.sin)
```

```
apples      30
oranges     43
cherries    52
pears       20
dtype: int64
```

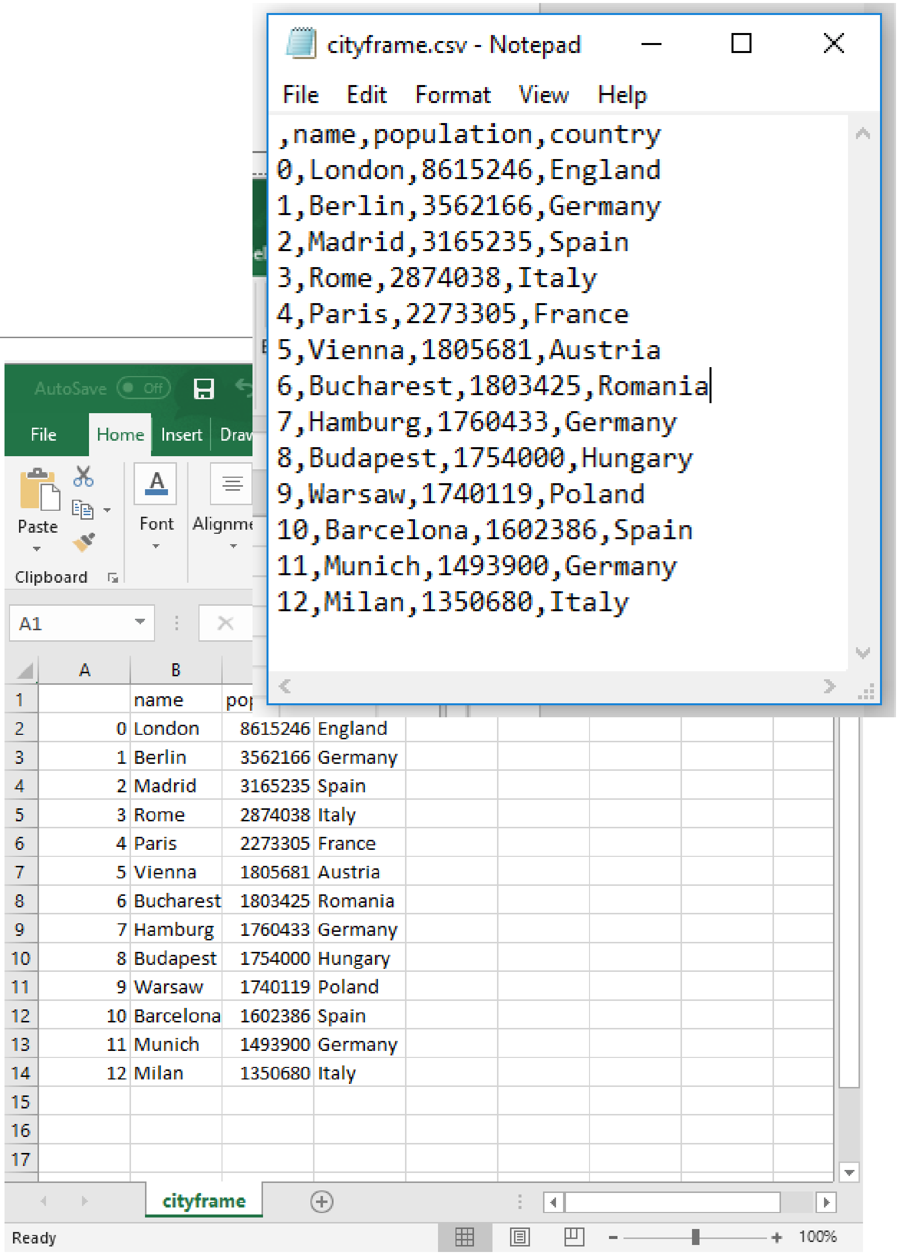
```
S.apply(lambda x: x if x > 50 else x+10 )

S[S>30] #boolean indexing
```

```
oranges     33
cherries    52
dtype: int64
```

.CSV



Name	Date modified
.ropeproject	1/17/2019 1:34 PM
__pycache__	2/21/2019 6:46 PM
db	1/17/2019 1:34 PM
defaults	1/17/2019 1:34 PM
plugins	1/17/2019 1:34 PM
spyder.lock	2/25/2019 3:15 PM
assignment2.py	2/14/2019 11:43 AM
calendar.py	2/20/2019 7:24 PM
calendar1.py	2/20/2019 5:00 PM
☑ cityframe.csv	3/1/2019 4:44 PM
clock.py	2/21/2019 6:40 PM
clockcalendar.py	2/20/2019 5:02 PM
Dot.py	2/20/2019 7:44 PM
griddata.py	2/8/2019 12:43 PM
helloanaconda.py	1/31/2019 7:33 PM
hellopandas.py	3/1/2019 4:44 PM
help	2/18/2019 11:34 AM
helper2.py	2/14/2019 11:07 AM
history.py	3/1/2019 4:44 PM
history_internal.py	2/25/2019 3:15 PM
ind_data.csv	2/5/2019 4:13 PM
lab3.py	2/14/2019 6:53 PM
lab55.py	2/27/2019 5:48 PM
langconfig	1/17/2019 1:33 PM
lec5.py	2/20/2019 4:25 PM
lect1.py	1/28/2019 11:14 AM



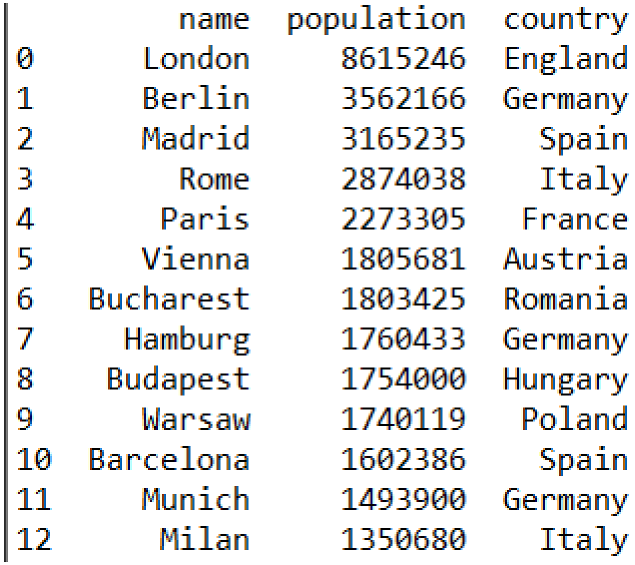
```
,name,population,country
0,London,8615246,England
1,Berlin,3562166,Germany
2,Madrid,3165235,Spain
3,Rome,2874038,Italy
4,Paris,2273305,France
5,Vienna,1805681,Austria
6,Bucharest,1803425,Romania
7,Hamburg,1760433,Germany
8,Budapest,1754000,Hungary
9,Warsaw,1740119,Poland
10,Barcelona,1602386,Spain
11,Munich,1493900,Germany
12,Milan,1350680,Italy
```

	A	B		
1		name	pop	
2	0	London	8615246	England
3	1	Berlin	3562166	Germany
4	2	Madrid	3165235	Spain
5	3	Rome	2874038	Italy
6	4	Paris	2273305	France
7	5	Vienna	1805681	Austria
8	6	Bucharest	1803425	Romania
9	7	Hamburg	1760433	Germany
10	8	Budapest	1754000	Hungary
11	9	Warsaw	1740119	Poland
12	10	Barcelona	1602386	Spain
13	11	Munich	1493900	Germany
14	12	Milan	1350680	Italy
15				
16				
17				

DataFrame

```
city_frame=pd.read_csv("cityframe.csv")
```

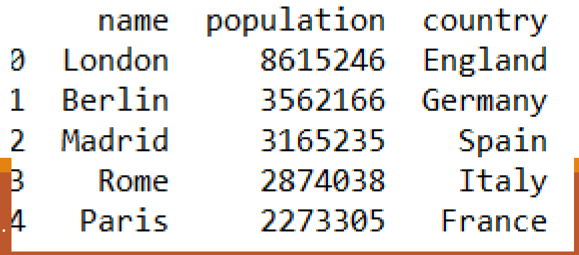
```
print(city_frame)

print(type(city_frame))
```



```
         name  population  country
0      London     8615246  England
1      Berlin     3562166  Germany
2      Madrid     3165235    Spain
3        Rome     2874038    Italy
4       Paris     2273305   France
5      Vienna     1805681  Austria
6   Bucharest     1803425  Romania
7     Hamburg     1760433  Germany
8    Budapest     1754000  Hungary
9      Warsaw     1740119   Poland
10  Barcelona     1602386    Spain
11     Munich     1493900  Germany
12      Milan     1350680    Italy
```

<class 'pandas.core.frame.DataFrame'>

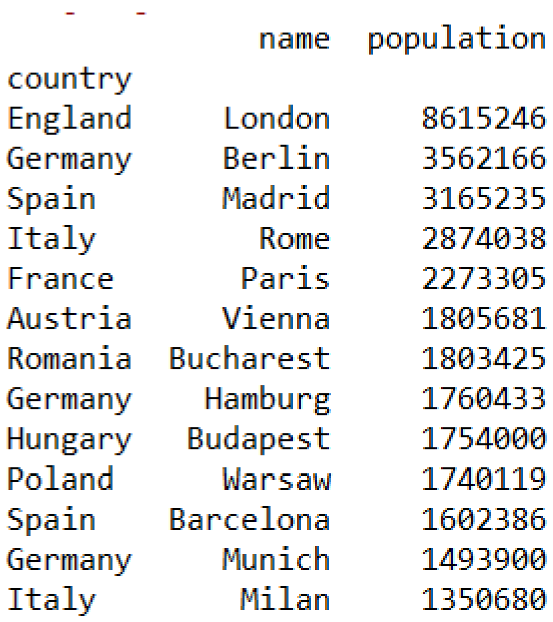
```
city_frame.head()
```



```
     name  population  country
0  London     8615246  England
1  Berlin     3562166  Germany
2  Madrid     3165235    Spain
3    Rome     2874038    Italy
4   Paris     2273305   France
```

Fancy index

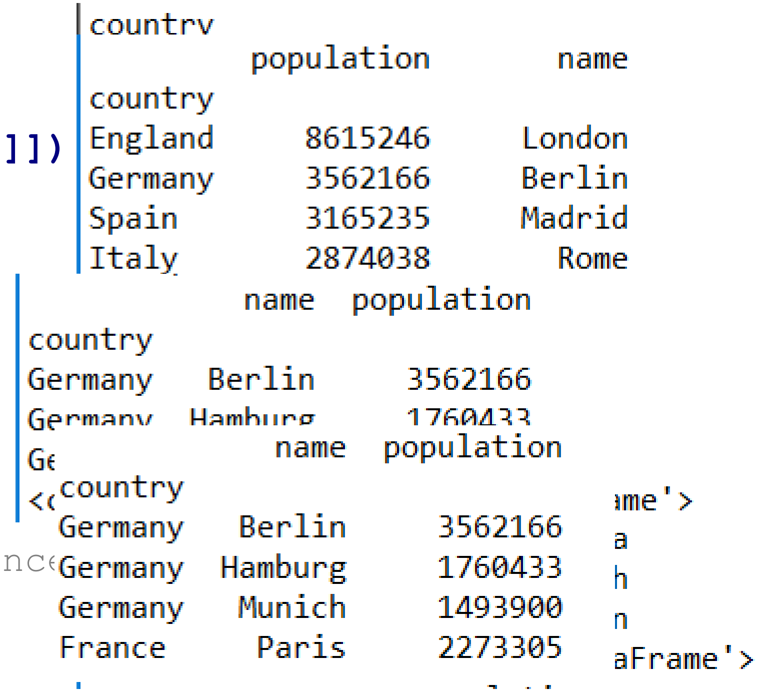
```
#Fancy index

city_frame.set_index("country", inplace=True)
```



```
              name  population
country                       
England     London     8615246
Germany     Berlin     3562166
Spain       Madrid     3165235
Italy         Rome     2874038
France       Paris     2273305
Austria     Vienna     1805681
Romania  Bucharest     1803425
Germany    Hamburg     1760433
Hungary   Budapest     1754000
Poland      Warsaw     1740119
Spain    Barcelona     1602386
Germany     Munich     1493900
Italy        Milan     1350680
```

Accessing rows and colns

```
#access coln
city_frame['population']
type(city_frame['population']) #series is 1D dataframe
#for multiple indicies, pass a list:
city_frame[['population','name']]
type(city_frame[['population','name']])

#access row
city_frame.loc["Germany"]
type(city_frame.loc["Germany"])
#for multiple indicies, pass a list:
print(city_frame.loc[["Germany",'Franc
```



```
country
          population     name
country
England      8615246   London
Germany      3562166   Berlin
Spain        3165235   Madrid
Italy        2874038     Rome
```

```
            name   population
country
Germany    Berlin     3562166
Germany   Hamburg     1760433
Ge
<c
```

```
            name   population
country
Germany    Berlin     3562166
Germany   Hamburg     1760433
Germany    Munich     1493900
France      Paris     2273305
```

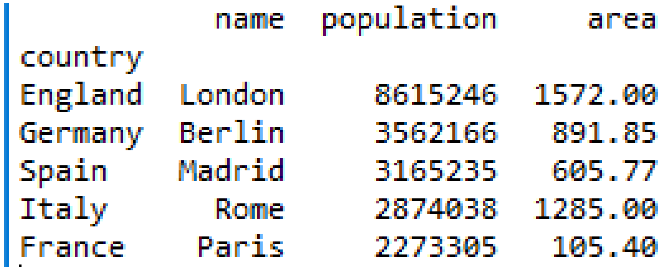
```
ame'>
a
h
n
aFrame'>
```

Q: How to access a single element of a dataframe?

Adding new coln

```
area = [1572, 891.85, 605.77, 1285,
        105.4, 414.6, 228, 755,
        525.2, 517, 101.9, 310.4,
        181.8]
# area could have been designed as a list,
#a Series, an array or a scalar
city_frame["area"] = area
```

city_frame.head()



```
            name  population     area
country
England   London     8615246  1572.00
Germany   Berlin     3562166   891.85
Spain     Madrid     3165235   605.77
Italy       Rome     2874038  1285.00
France     Paris     2273305   105.40
```

World population

LIVE EXAMPLE

Hierarchical indicies

```
shop1 = {"foo":{2010:23, 2011:25}, "bar":{2010:13,
2011:29}}

shop2 = {"foo":{2010:223, 2011:225}, "bar":{2010:213,
2011:229}}

shop1 = pd.DataFrame(shop1)

shop2 = pd.DataFrame(shop2)

both_shops = shop1 + shop2
```

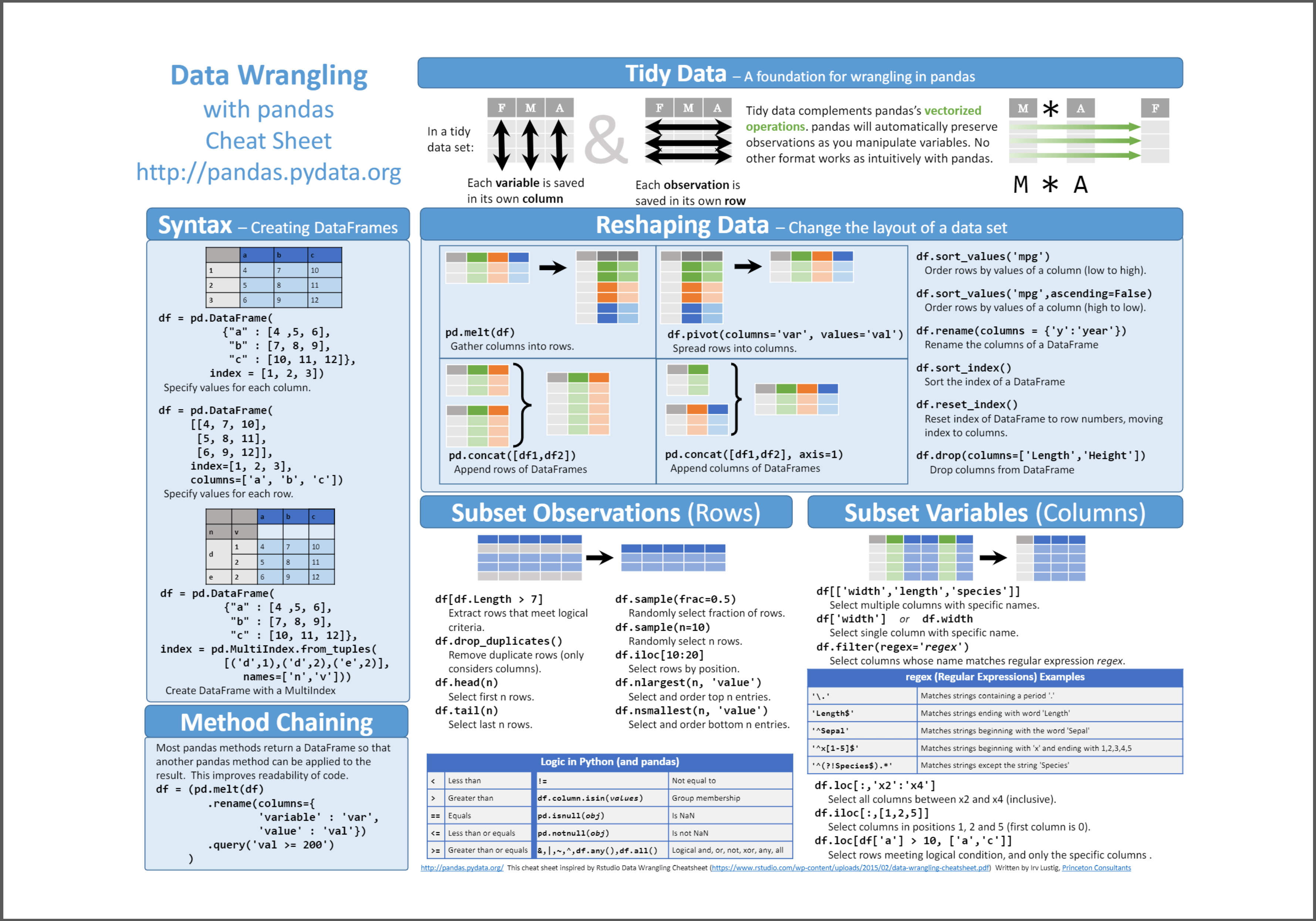
```
shops = pd.concat([shop1, shop2], keys=["one", "two"])

shops.swaplevel()

shops.swaplevel().sort_index()
```

World population

BACK TO EXAMPLE

Useful methods

```
df.T

df.describe()

df.to_numpy()

df.tail(3)

df.sort_values(by='B’)


df[df > 0]

df.apply(np.cumsum)
```



Data Wrangling
with pandas
Cheat Sheet
http://pandas.pydata.org

Tidy Data – A foundation for wrangling in pandas

In a tidy data set:

Each **variable** is saved in its own **column**

Each **observation** is saved in its own **row**

Tidy data complements pandas's **vectorized operations**. pandas will automatically preserve observations as you manipulate variables. No other format works as intuitively with pandas.

Syntax – Creating DataFrames

	a	b	c
1	4	7	10
2	5	8	11
3	6	9	12

```
df = pd.DataFrame(
          {"a" : [4 ,5, 6],
           "b" : [7, 8, 9],
           "c" : [10, 11, 12]},
        index = [1, 2, 3])
```

Specify values for each column.

```
df = pd.DataFrame(
     [[4, 7, 10],
      [5, 8, 11],
      [6, 9, 12]],
     index=[1, 2, 3],
     columns=['a', 'b', 'c'])
```

Specify values for each row.

		a	b	c
n	v			
d	1	4	7	10
	2	5	8	11
e	2	6	9	12

```
df = pd.DataFrame(
          {"a" : [4 ,5, 6],
           "b" : [7, 8, 9],
           "c" : [10, 11, 12]},
index = pd.MultiIndex.from_tuples(
          [('d',1),('d',2),('e',2)],
             names=['n','v']))
```

Create DataFrame with a MultiIndex

Method Chaining

Most pandas methods return a DataFrame so that another pandas method can be applied to the result. This improves readability of code.

```
df = (pd.melt(df)
        .rename(columns={
                'variable' : 'var',
                'value' : 'val'})
        .query('val >= 200')
     )
```

Reshaping Data – Change the layout of a data set

`pd.melt(df)`
Gather columns into rows.

`df.pivot(columns='var', values='val')`
Spread rows into columns.

`pd.concat([df1,df2])`
Append rows of DataFrames

`pd.concat([df1,df2], axis=1)`
Append columns of DataFrames

`df.sort_values('mpg')`
Order rows by values of a column (low to high).

`df.sort_values('mpg',ascending=False)`
Order rows by values of a column (high to low).

`df.rename(columns = {'y':'year'})`
Rename the columns of a DataFrame

`df.sort_index()`
Sort the index of a DataFrame

`df.reset_index()`
Reset index of DataFrame to row numbers, moving index to columns.

`df.drop(columns=['Length','Height'])`
Drop columns from DataFrame

Subset Observations (Rows)

`df[df.Length > 7]`
Extract rows that meet logical criteria.

`df.drop_duplicates()`
Remove duplicate rows (only considers columns).

`df.head(n)`
Select first n rows.

`df.tail(n)`
Select last n rows.

`df.sample(frac=0.5)`
Randomly select fraction of rows.

`df.sample(n=10)`
Randomly select n rows.

`df.iloc[10:20]`
Select rows by position.

`df.nlargest(n, 'value')`
Select and order top n entries.

`df.nsmallest(n, 'value')`
Select and order bottom n entries.

Logic in Python (and pandas)			
<	Less than	!=	Not equal to
>	Greater than	df.column.isin(*values*)	Group membership
==	Equals	pd.isnull(*obj*)	Is NaN
<=	Less than or equals	pd.notnull(*obj*)	Is not NaN
>=	Greater than or equals	&,|,~,^,df.any(),df.all()	Logical and, or, not, xor, any, all

Subset Variables (Columns)

`df[['width','length','species']]`
Select multiple columns with specific names.

`df['width']` *or* `df.width`
Select single column with specific name.

`df.filter(regex='`*`regex`*`')`
Select columns whose name matches regular expression *regex*.

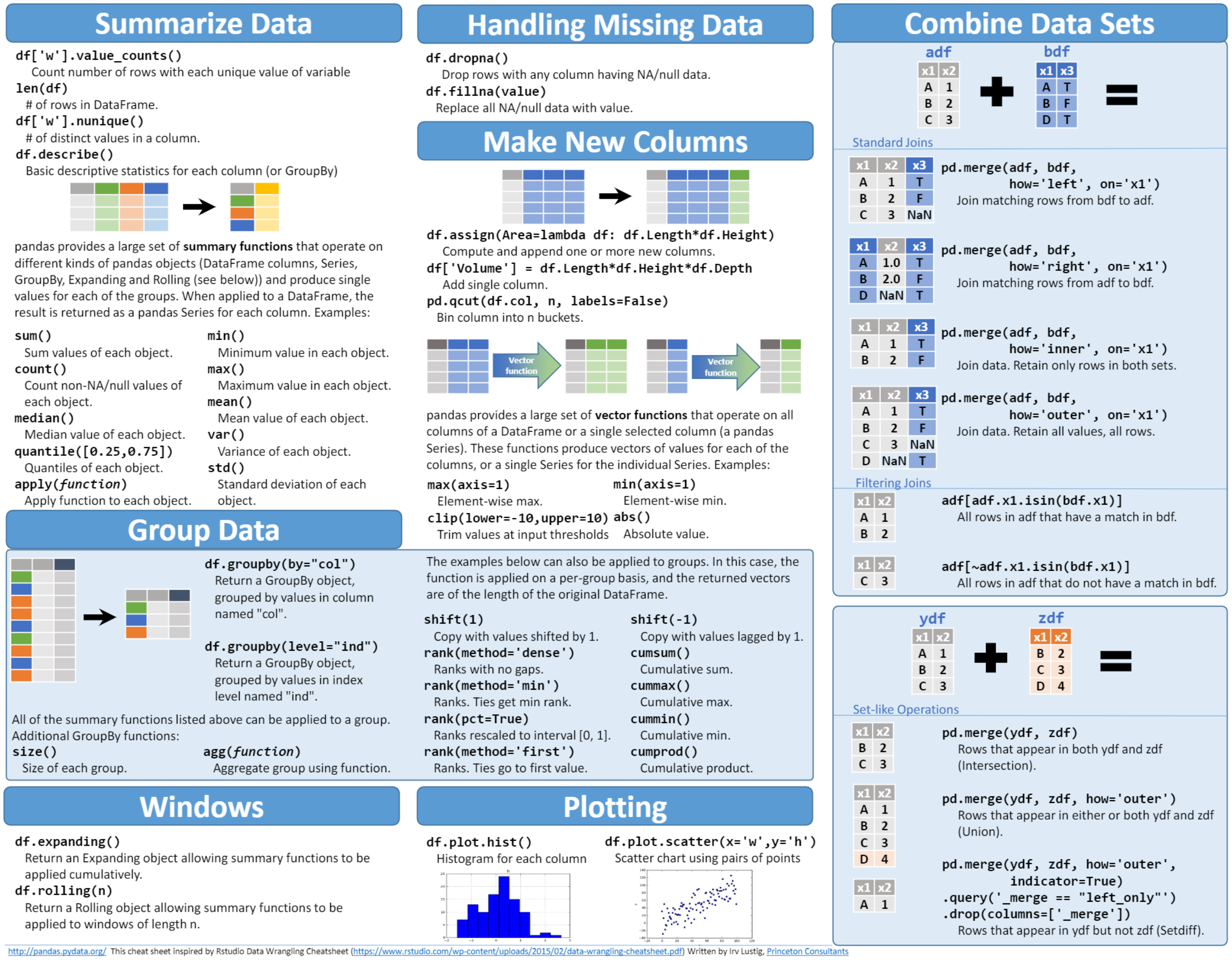
regex (Regular Expressions) Examples	
'\.'	Matches strings containing a period '.'
'Length$'	Matches strings ending with word 'Length'
'^Sepal'	Matches strings beginning with the word 'Sepal'
'^x[1-5]$'	Matches strings beginning with 'x' and ending with 1,2,3,4,5
'^(?!Species$).*'	Matches strings except the string 'Species'

`df.loc[:,'x2':'x4']`
Select all columns between x2 and x4 (inclusive).

`df.iloc[:,[1,2,5]]`
Select columns in positions 1, 2 and 5 (first column is 0).

`df.loc[df['a'] > 10, ['a','c']]`
Select rows meeting logical condition, and only the specific columns .

http://pandas.pydata.org/ This cheat sheet inspired by Rstudio Data Wrangling Cheatsheet (https://www.rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf) Written by Irv Lustig, Princeton Consultants



Summarize Data

`df['w'].value_counts()`
Count number of rows with each unique value of variable

`len(df)`
# of rows in DataFrame.

`df['w'].nunique()`
# of distinct values in a column.

`df.describe()`
Basic descriptive statistics for each column (or GroupBy)

pandas provides a large set of **summary functions** that operate on different kinds of pandas objects (DataFrame columns, Series, GroupBy, Expanding and Rolling (see below)) and produce single values for each of the groups. When applied to a DataFrame, the result is returned as a pandas Series for each column. Examples:

`sum()`
Sum values of each object.

`count()`
Count non-NA/null values of each object.

`median()`
Median value of each object.

`quantile([0.25,0.75])`
Quantiles of each object.

`apply(function)`
Apply function to each object.

`min()`
Minimum value in each object.

`max()`
Maximum value in each object.

`mean()`
Mean value of each object.

`var()`
Variance of each object.

`std()`
Standard deviation of each object.

Group Data

`df.groupby(by="col")`
Return a GroupBy object, grouped by values in column named "col".

`df.groupby(level="ind")`
Return a GroupBy object, grouped by values in index level named "ind".

All of the summary functions listed above can be applied to a group. Additional GroupBy functions:

`size()`
Size of each group.

`agg(function)`
Aggregate group using function.

Windows

`df.expanding()`
Return an Expanding object allowing summary functions to be applied cumulatively.

`df.rolling(n)`
Return a Rolling object allowing summary functions to be applied to windows of length n.

Handling Missing Data

`df.dropna()`
Drop rows with any column having NA/null data.

`df.fillna(value)`
Replace all NA/null data with value.

Make New Columns

`df.assign(Area=lambda df: df.Length*df.Height)`
Compute and append one or more new columns.

`df['Volume'] = df.Length*df.Height*df.Depth`
Add single column.

`pd.qcut(df.col, n, labels=False)`
Bin column into n buckets.

pandas provides a large set of **vector functions** that operate on all columns of a DataFrame or a single selected column (a pandas Series). These functions produce vectors of values for each of the columns, or a single Series for the individual Series. Examples:

`max(axis=1)`
Element-wise max.

`clip(lower=-10,upper=10)`
Trim values at input thresholds

`min(axis=1)`
Element-wise min.

`abs()`
Absolute value.

The examples below can also be applied to groups. In this case, the function is applied on a per-group basis, and the returned vectors are of the length of the original DataFrame.

`shift(1)`
Copy with values shifted by 1.

`rank(method='dense')`
Ranks with no gaps.

`rank(method='min')`
Ranks. Ties get min rank.

`rank(pct=True)`
Ranks rescaled to interval [0, 1].

`rank(method='first')`
Ranks. Ties go to first value.

`shift(-1)`
Copy with values lagged by 1.

`cumsum()`
Cumulative sum.

`cummax()`
Cumulative max.

`cummin()`
Cumulative min.

`cumprod()`
Cumulative product.

Plotting

`df.plot.hist()`
Histogram for each column

`df.plot.scatter(x='w',y='h')`
Scatter chart using pairs of points

Combine Data Sets

adf

x1	x2
A	1
B	2
C	3

✚

bdf

x1	x3
A	T
B	F
D	T

=

Standard Joins

x1	x2	x3
A	1	T
B	2	F
C	3	NaN

```
pd.merge(adf, bdf,
         how='left', on='x1')
```
Join matching rows from bdf to adf.

x1	x2	x3
A	1.0	T
B	2.0	F
D	NaN	T

```
pd.merge(adf, bdf,
         how='right', on='x1')
```
Join matching rows from adf to bdf.

x1	x2	x3
A	1	T
B	2	F

```
pd.merge(adf, bdf,
         how='inner', on='x1')
```
Join data. Retain only rows in both sets.

x1	x2	x3
A	1	T
B	2	F
C	3	NaN
D	NaN	T

```
pd.merge(adf, bdf,
         how='outer', on='x1')
```
Join data. Retain all values, all rows.

Filtering Joins

x1	x2
A	1
B	2

`adf[adf.x1.isin(bdf.x1)]`
All rows in adf that have a match in bdf.

x1	x2
C	3

`adf[~adf.x1.isin(bdf.x1)]`
All rows in adf that do not have a match in bdf.

ydf

x1	x2
A	1
B	2
C	3

✚

zdf

x1	x2
B	2
C	3
D	4

=

Set-like Operations

x1	x2
B	2
C	3

`pd.merge(ydf, zdf)`
Rows that appear in both ydf and zdf (Intersection).

x1	x2
A	1
B	2
C	3
D	4

`pd.merge(ydf, zdf, how='outer')`
Rows that appear in either or both ydf and zdf (Union).

x1	x2
A	1

```
pd.merge(ydf, zdf, how='outer',
         indicator=True)
.query('_merge == "left_only"')
.drop(columns=['_merge'])
```
Rows that appear in ydf but not zdf (Setdiff).

http://pandas.pydata.org/ This cheat sheet inspired by Rstudio Data Wrangling Cheatsheet (https://www.rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf) Written by Irv Lustig, Princeton Consultants

Pandas vs excel!

Analyze large datasets:

- Excel is sluggish at 10000 rows

More high level functions.

More file formats: CSV, HTML, SQL.

Automated procedures.

Co-existence!

Lab sessions this week

More pandas data analysis.

Project presentations:

- 5~10 mins:
  - Progress.
    - Code samples, tests, etc
  - Future plans.
- Make sure to attend
  (Missing groups receive -15%)