# Intro to Notebooks, Modules & Matplotlib

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# Aims

- How to use Jupyter Notebooks for coding
- Introduce Python coding terminology:
  (functions, objects, methods, modules)
- Demonstrate use of example Python modules
- Learn how to make plots with Matplotlib

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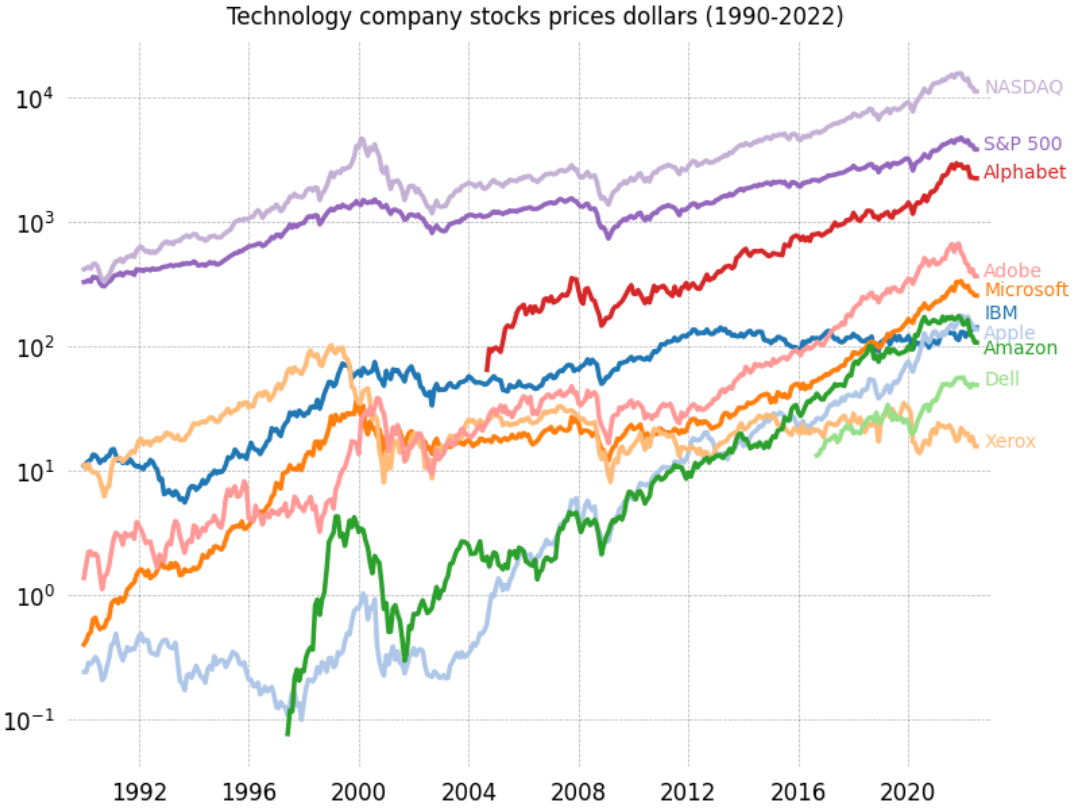
# Target




Adapted from: https://matplotlib.org/stable/gallery/showcase/stock_prices.html

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# Topics

1. JupyterLab and Python Notebooks
2. Python coding: Functions Objects, Methods & Modules
3. Example useful modules
4. Making a Plot with Matplotlib
5. Customising Plots with Matplotlib
6. Plot Types in Matplotlib

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# Python Notebooks and JupyterLab

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# Python Notebooks

- A modern code file format that allows us to store:
  **code & output / formatted text / tables / figures**
- Can include text sections (in markdown format)
- Based on web technology and developed by Jupyter
- `.ipynb` file extension (**i**nteractive **py**thon **n**ote**b**ook)

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# JupyterLab

- A complete code IDE based on browser technology
- Includes notebook editor, .py editor, code terminal, file browser and debugger
- succeeded Jupyter Notebook (which only allowed notebook editing).
- Runs in a web browser window (so has some differences to normal applications).

Install and run via Anaconda Navigator or JupyterLab Desktop
You can also setup within VS Code (Can be tricky)

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# Working in a Notebook

**Please watch the separate demo video!**

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# Key differences .py vs .ipynb

- In notebooks code cells can be run individually (and out-of-sequence!).
- If you encounter odd behaviour use **Run All** to run all code cells in sequence.
- Notebooks are designed for interactive coding. Some outputs e.g. figures, and output from last line in code cells are automatically displayed

In **.py** code files we always need to use:

| | |
|---|---|
| `print()` | for text |
| `plt.show()` | for figures |

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# Python tools:

# Functions, objects, methods & modules

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# Built-in Functions

- Python contains a set of useful tools in its standard installation.
- These include in-built **functions** such as:

```
print()        len()
sorted()       range()
sum()          min() , max()
```

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# Built-in Functions

- a function is a piece of code that does a particular job. (We will see in future sessions how we can write our own functions).
- we run a function by calling it, using the function name followed by round brackets ()
- the brackets hold any input information (arguments) the function needs to run
- commas are used separate values if multiple values are passed.

e.g. `len()` is used to find the length of a list

e.g. exit() can be used to exit an interactive Python session.

e.g. the argument for print( ___ ) is the string or value to display

e.g. range(3,10) can take a lower and upper limit

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# Built-in Functions

Python has conversion functions such as:

```
int()   float()   str()
```

These can convert between data types e.g.

```
myval = 4.1
print( int(myval) )
# 4
```

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# Built-in Functions

We can check the type of a variable using the `type()` function.

```
myval = 4.1

print( type(myval) )

# <class 'float'>
```

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# Built-in Functions

We can round a floating point number using the `round()` function.

```
myval = 5.1234

print( round(myval, 2) )

# 5.12
```

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# Built-in Functions

`abs()` can be used to find the absolute size of a value. It converts a negative into a positive value.

```
x = abs(-6.5)
# x is 6.5
```

`pow()` can be used as an alternative to the ** operator to raise one number to the power of another.

```
y = pow(3,2)
# y is 9
```

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# Objects and Methods

The `sorted`, `reverse`, `min`, `max` and `sum` built-in functions operate on a list, e.g.

```
x = [ 2, 7, 9, 1 ]

sum(x)

# 19
```

However we have also seen special functions that act on lists.

Functions that act on a Python object are called methods.

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# Objects and Methods

An object method is called using the following notation:

*`object.method()`*

For example the `.sort()` method can be called on any list object.

```
x = [ 2, 7, 9, 1 ]
x.sort()
print(x)
# [1, 2, 7, 9]
```

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# Objects and Methods

Like functions some methods take input arguments:

*object.method(arg)*  *object.method(arg1, arg2)*

e.g the `.append()` and `.insert()` methods we used to modify lists.

```
x = ['a', 'b']
x.append('c')
print(x)
# ['a', 'b', 'c']
```

```
y = ['a', 'b']
y.insert(1,'X')
print(y)
# ['a', 'X', 'b']
```

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# Objects and Methods

Like functions some methods take input arguments:

*`object.method(arg)`* *`object.method(arg1, arg2)`*

e.g the `.append()` and `.insert()` methods we used to modify lists.

```
x = ['a', 'b']
x.append('c')
print(x)
# ['a', 'b', 'c']
```

```
y = ['a', 'b']
y.insert(1,'X')
print(y)
# ['a', 'X', 'b']
```

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# Some more useful string methods

| Method | What It Does | Example |
|---|---|---|
| `.replace(old, new)` | Replaces all occurrences of an old substring with a new one. | `'Hi Ann'.replace(Ann', 'Betty')`<br>`→ 'Hi Betty'` |
| `.find(substring)` | Returns the starting index number of the first substring. If not found, it returns -1. | `ada lovelace'.find('love')`<br>`→ 4` |
| `.split(separator)` | Splits the string into a list of smaller strings. If no separator is given, it splits on whitespace. | `'12,1,93'.split(',')`<br>`→ ['12', '1', '93']` |

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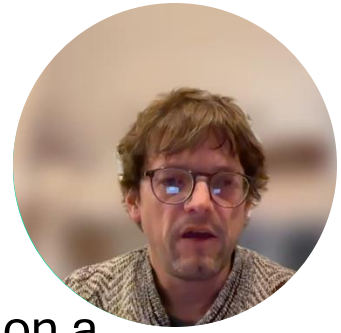
# Modules



In addition to its built-in tools, Python allows us to import modules which contain additional tools for particular jobs.

The math library contains the sorts of functions you can access on a scientific calculator.

To use tools from a module we need to load it using the `import` command.


*method #1*

```
from math import sqrt

x = sqrt(16)

print(x)

# 4
```

*loads the* `sqrt` *function from the* `math` *module*

*import individual items from a module*

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# Modules

We can import a whole module to access all its tools.

*method #2*

```
import math
math.exp(1.5)
# 4.48168907
math.pi
# 3.14159265
math.sin(2)
# 0.90929742
```

*here we access items via module name*

*method #3*

```
from math import *
exp(1.5)
# 4.48168907
pi
# 3.14159265
sin(2)
# 0.90929742
```

*here we can directly use items but it's less clear how things belong to the module*

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# More example modules: `os`, `requests`, `numpy`, `pandas`

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# The `os` module

The commands used to work with files and folders on different operating systems are different.

*windows*

*linux*

*macOS*

```
> dir
```

*windows command to list directory*

```
$ ls
```

*linux / macOS command to list directory*

The `os` module provides a set of standard commands that will work across different computers.

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# The os module

| Function | What It Does | Example |
|---|---|---|
| `os.getcwd()` | Get Current Working Directory (displays the folder you are in) | `os.getcwd()` → `'C:\\Users\\YourName\\Desktop'` |
| `os.listdir()` | Returns a list of all files and folders in the current directory. | `os.listdir()` → `['mycode.py', 'notes.txt']` |
| `os.mkdir( ____ )` | Make a new directory (folder) with the given name. | `os.mkdir('images')` |

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# The `requests` module

A module that allows us to download data from the web

| Function | What It Does | Example |
|---|---|---|
| `requests.get()` | Sends a GET request to a URL to retrieve data from a server. | `import requests`<br><br>`url = 'https://_____'`<br>`response = requests.get(url)` |

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# The `requests` module

A module that allows us to download data from the web

```
import requests

# The Project Gutenberg site store out-of-copyright books.
# Below we download a book using the requests library

# Web address for "Alice's Adventures in Wonderland"
url = 'https://www.gutenberg.org/files/11/11-0.txt'

response = requests.get(url)

# response.text gives us the full content of the file
full_text = response.text

# display the length of the text in characters
print(len(full_text))

# display the first 300 characters
print(full_text[:250])
```

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# The numpy module

A special module for doing maths on numerical arrays

*It is the convention when working with numpy to rename the* **numpy** *to* **np** *for more compact code*

```
import numpy as np

# Create an example list
mylist = [1, 4, 9, 16]

# Convert the list into a NumPy array
numpy_array = np.array(mylist)

# multiplication on the whole array
numpy_array*2
# Output: [ 2  8 18 32]

# apply numpy function across elements
np.sqrt(numpy_array)
# Output: [1. 2. 3. 4.]
```

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# The numpy module

A special module for doing maths on numerical arrays

```
import numpy as np

# Example creating an array filled with zeros
#
myarray = np.zeros(5)
myarray

# array([0. 0. 0. 0. 0.])
```

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# The numpy module

A special module for doing maths on numerical arrays

```
import numpy as np

# Example an array covering a range
#
#                  start end step
myarray = np.arange( 0,   1, 0.2)
myarray

# array([0.0, 0.2, 0.4, 0.6, 0.8])
```

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# The numpy module

A special module for doing maths on numerical arrays

```
import numpy as np

# Example simulate dice rolls

# np.random.randint() generates
# random ints between two limits (upper bound not included)

#                   lower   upper   size
#.                  bound   bound
np.random.randint( 1,      7,      5.  )

# array([3, 5, 2, 3, 1])
```

*If we are generating random values we will get a different set of values each time we run the code!*

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# The numpy module

A special module for doing maths on numerical arrays

```
import numpy as np

# Example generate values from
# normal (Gaussian) distribution

#                    mean  standard  size
#.                        deviation
np.random.normal( 100,    5,        4)

# array([100.89,  97.96, 104.72 ,  98.39])
```

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# The `pandas` module

- `numpy` allows us to work with arrays of data (tables of numbers)
- `pandas` is a library to work with general data tables (tables of columns containing numbers or text)
- It has similar functionality to Excel in MS Office and the specialised coding language **R** used for statistical analysis.

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# The pandas module

In particular **pandas** makes it very easy to work with files that store data tables in **csv** format (comma separated values)

*Data Table*

| Name | Age | City |
|---|---|---|
| Alice | 25 | Exeter |
| Bob | 30 | London |
| Charlie | 23 | Glasgow |

*csv*

```
Name,Age,City
Alice,25,Exeter
Bob,30,London
Charlie,23,Glasgow
```

*e.g. stored as file:* `people.csv`

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# The pandas module

In particular **pandas** makes it very easy to work with files that store data tables in **csv** format (comma separated values)

*Data Table*

| Name | Age | City |
|---|---|---|
| Alice | 25 | Exeter |
| Bob | 30 | London |
| Charlie | 23 | Glasgow |

*csv*

```
Name,Age,City
Alice,25,Exeter
Bob,30,London
Charlie,23,Glasgow
```

*e.g. stored as file:* `people.csv`

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# The pandas module

```
import pandas as pd

df = pd.read_csv('people.csv')
df
```

*It is the convention when working with numpy to rename the* `pandas` *to* `pd` *for more compact code*

*for large datasets we can use the .head() method to show just the first few rows, e.g.* `df.head()`

| | name | age | city |
|---|---|---|---|
| **0** | Alice | 25 | Exeter |
| **1** | Bob | 30 | London |
| **2** | Charlie | 23 | Glasgow |

```
type(df)
```

```
pandas.core.frame.DataFrame
```

*data is loaded as a* ***DataFrame*** *object class*

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# The pandas module

```
df = pd.read_csv('people.csv')
# extract the age column
# and find the number of entries
len( df['age'] )
```

```
3
```

*we use square brackets to select a column using its name as an index*

```
# find the max age
df['age'].max()
```

```
30
```

```
# find the mean age
df['age'].mean()
```

```
26.0
```

*pandas has built in methods for statistics*

```
# find the standard deviation
# of the age values
df['age'].std()
```

```
3.605551275463989
```

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# Installing modules

- Some modules (e.g. `math`, `os` ) are included as standard.
- If you install Python as part of Anaconda (or Jupyterlab Desktop) then additional modules for data analysis will already be installed and ready to use in notebooks (e.g. `numpy`, `pandas` )
- In Jupyterlab you can install modules easily using `pip` (package installer for Python). You can run this in a code cell.

*error if a module is not installed*

```
import doesnotexist
```

```
---------------------------------------
ModuleNotFoundError
Cell In[58], line 1
----> 1 import doesnotexist
```

*how to install a module with pip*

```
pip install numpy
```

```
Requirement already satisfied: numpy
```

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# Summary of example modules

- **`numpy`** and `pandas` allow us to work with data using special **`array`** and **`DataFrame`** objects.
- **`pandas`** makes it easy to read in data from csv formatted files.
- The **`requests`** module is also useful for accessing data from the web.
- The **`os`** module is useful for simple file / folder operations.

# Making Plots with Matplotlib

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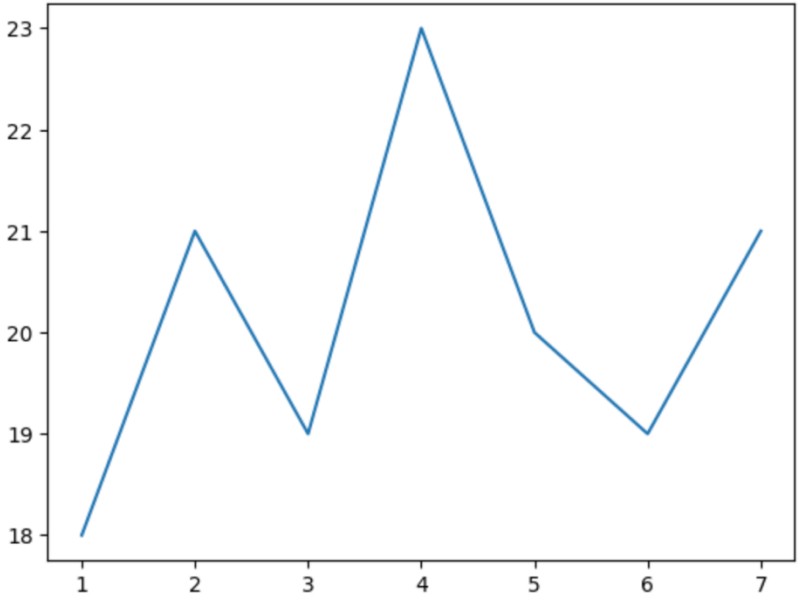
# Plotting data

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

```
x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y_vals = [ 18, 21, 19, 23, 20, 19, 21 ]

plt.plot(x_vals, y_vals)
```

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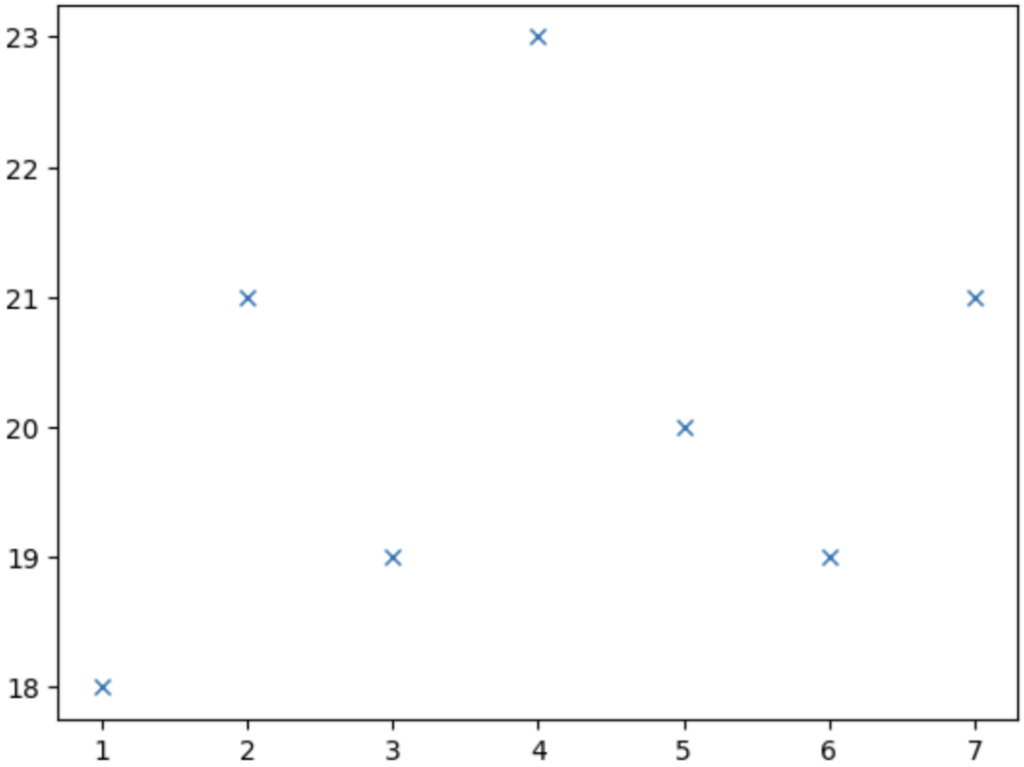
# Plotting with marker only

```
plt.plot(x_vals, y_vals, 'x')
```

```
[<matplotlib.lines.Line2D at 0x1202fb470>]
```




```
plt.plot(x_vals, y_vals, 'x')
plt.plot(x_vals, y_vals, 'o')
plt.plot(x_vals, y_vals, '^')
plt.plot(x_vals, y_vals, '.')
```

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# Quick plot style:

```
plt.plot(x_vals, y_vals, 'bx-')
```

quick style

**color**

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

**marker**

```
. dots      * star
o circles   ^ triangles
x cross     + alt. cross
```

**line**

```
- solid line      : dotted line   -- dashed line
```

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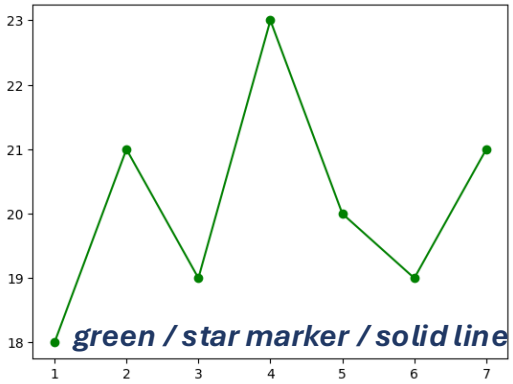
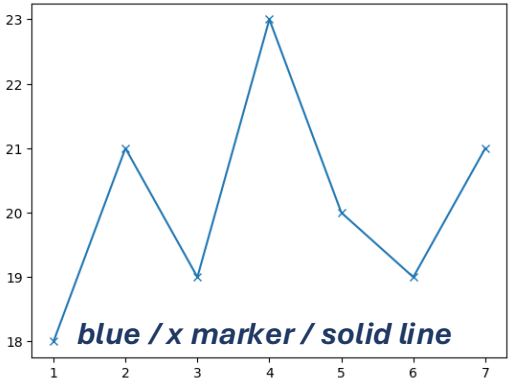
# Quick plot style: color / marker / line

```
plt.plot(x_vals, y_vals, 'r+-')
```

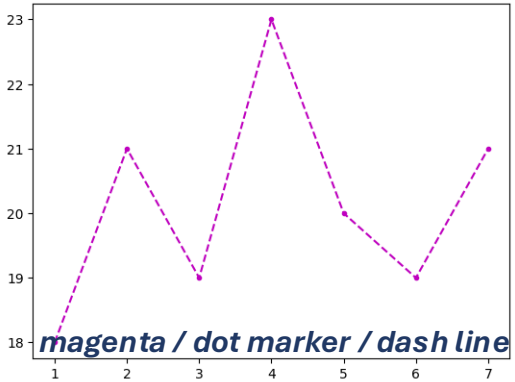

```
plt.plot(x_vals, y_vals, 'go-')
```



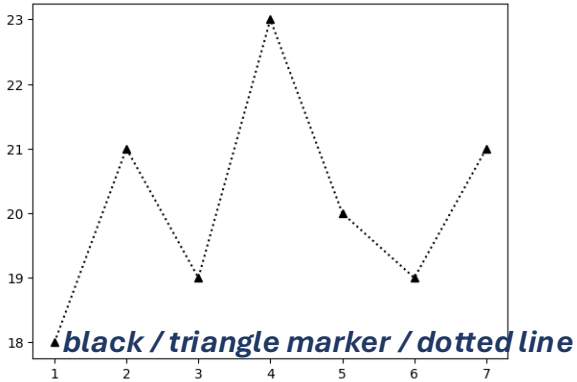

```
plt.plot(x_vals, y_vals, 'bx-')
```




```
plt.plot(x_vals, y_vals, 'm.--')
```




```
plt.plot(x_vals, y_vals, 'k^:')
```

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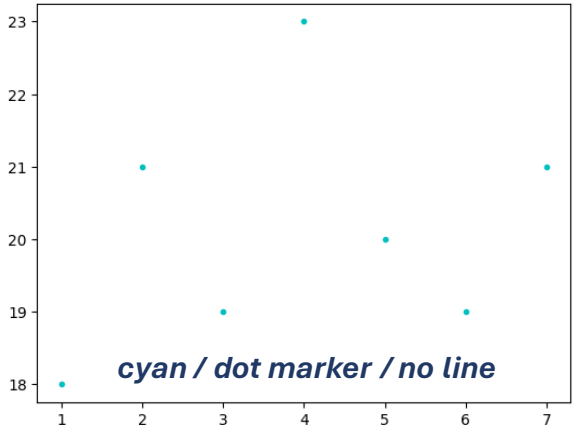
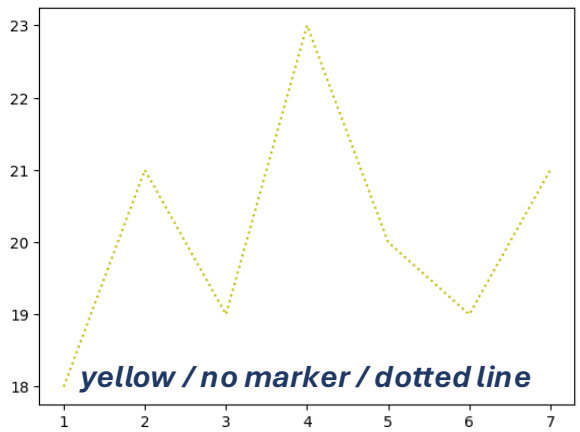
# Quick plot style: color / marker / line

```
plt.plot(x_vals, y_vals, 'c.')
```




```
plt.plot(x_vals, y_vals, 'y:')
```




alternative way to specify styles in full

```
plt.plot(x_vals, y_vals, linestyle='dotted', color='yellow')
```

**see w3 tutorials:**
**https://www.w3schools.com/python/matplotlib_intro.asp**

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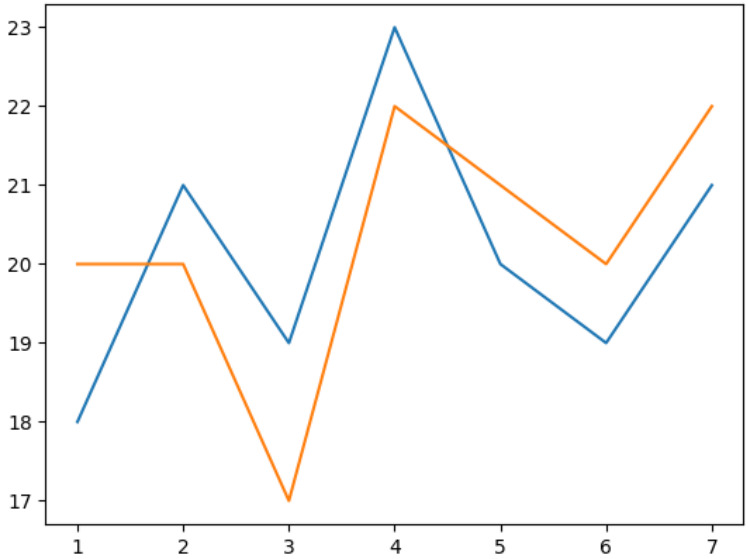
# Multiple trendlines

```
# multiple data series

x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y1_vals = [ 18, 21, 19, 23, 20, 19, 21 ]
y2_vals = [ 20, 20, 17, 22, 21, 20, 22 ]

plt.plot(x_vals, y1_vals)
plt.plot(x_vals, y2_vals)
```

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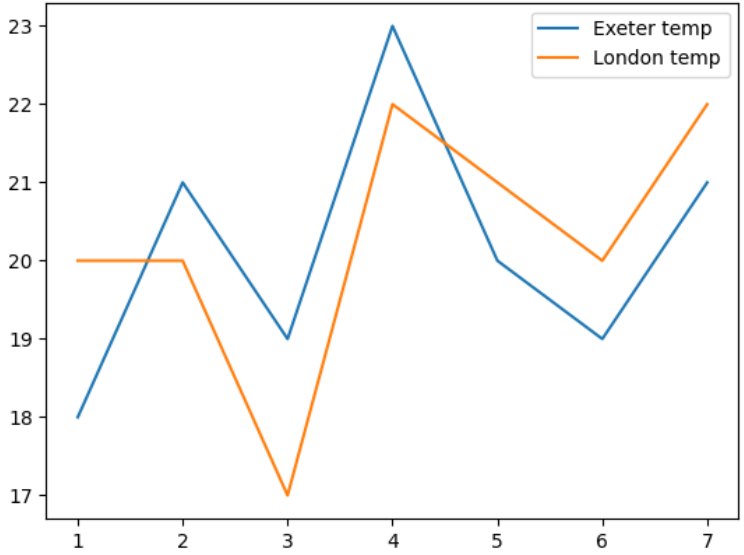
# Multiple trendlines

```
# multiple data series

x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y1_vals = [ 18, 21, 19, 23, 20, 19, 21 ]
y2_vals = [ 20, 20, 17, 22, 21, 20, 22 ]

plt.plot(x_vals, y1_vals, label='Exeter temp')
plt.plot(x_vals, y2_vals, label='London temp')
plt.legend()
```

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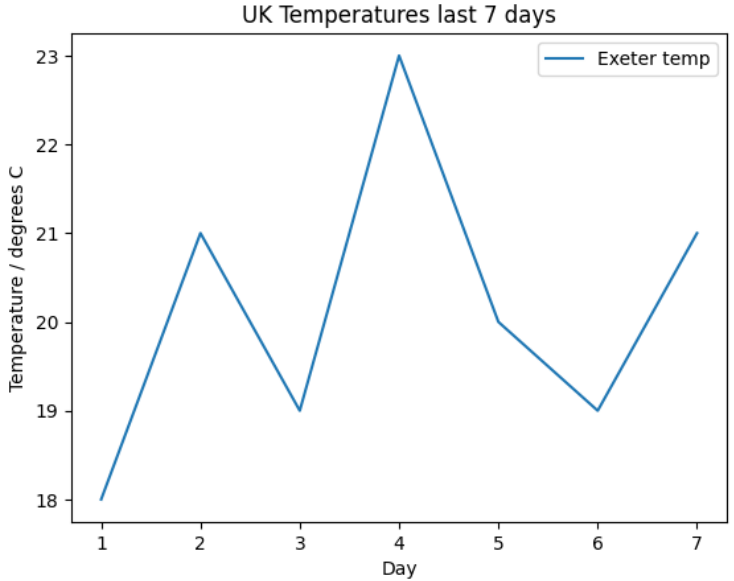
# Title and axes labels

```
# title and axes labels

x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y_vals = [ 18, 21, 19, 23, 20, 19, 21 ]

plt.plot(x_vals, y_vals, label='Exeter temp')
plt.legend()

plt.title('UK Temperatures last 7 days')
plt.xlabel('Day')
plt.ylabel('Temperature / degrees C')
```

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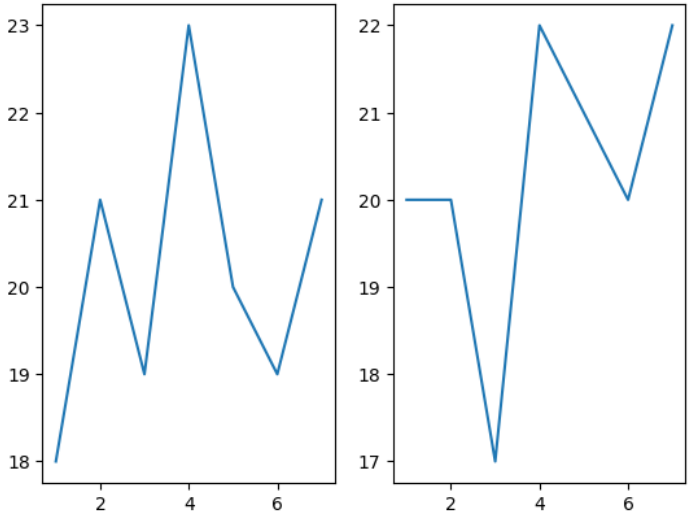
# Multiple plots using `subplot`

```
x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y1_vals = [ 18, 21, 19, 23, 20, 19, 21 ]
y2_vals = [ 20, 20, 17, 22, 21, 20, 22 ]

plt.subplot(1, 2, 1)
#the figure has 1 row, 2 columns, working in subplot 1
plt.plot(x_vals, y1_vals)

plt.subplot(1, 2, 2)
#the figure has 1 row, 2 columns, working in subplot 2
plt.plot(x_vals, y2_vals)
```

1 row
2 columns

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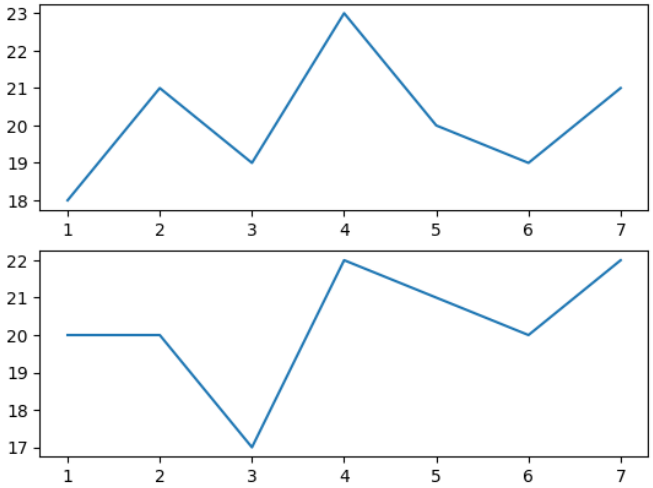
# Multiple plots using `subplot`

```
x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y1_vals = [ 18, 21, 19, 23, 20, 19, 21 ]
y2_vals = [ 20, 20, 17, 22, 21, 20, 22 ]

plt.subplot(2, 1, 1)
#the figure has 2 rows, 1 column, working in subplot 1
plt.plot(x_vals, y1_vals)

plt.subplot(2, 1, 2)
#the figure has 2 rows, 1 column, working in subplot 2
plt.plot(x_vals, y2_vals)
```

2 rows
1 column

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# Labelling multiple plots

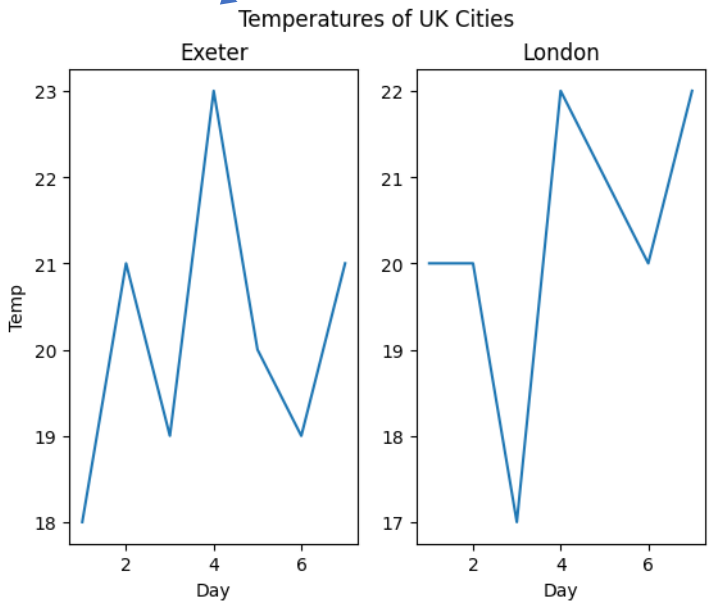
*super title*

```
x_vals = [  1,  2,  3,  4, 5,   6,  7 ]
y1_vals = [ 18, 21, 19, 23, 20, 19, 21 ]
y2_vals = [ 20, 20, 17, 22, 21, 20, 22 ]

plt.subplot(1, 2, 1)
#the figure has 2 rows, 1 column, working in subplot 1
plt.plot(x_vals, y1_vals)
plt.title('Exeter')
plt.ylabel('Temp')
plt.xlabel('Day')


plt.subplot(1, 2, 2)
#the figure has 2 rows, 1 column, working in subplot 2
plt.plot(x_vals, y2_vals)
plt.title('London')
plt.xlabel('Day')

plt.suptitle('Temperatures of UK Cities')
```

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# Customising Plots with Matplotlib

Dr Philip Lewis

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# Customising

You can configure all plot aspects!

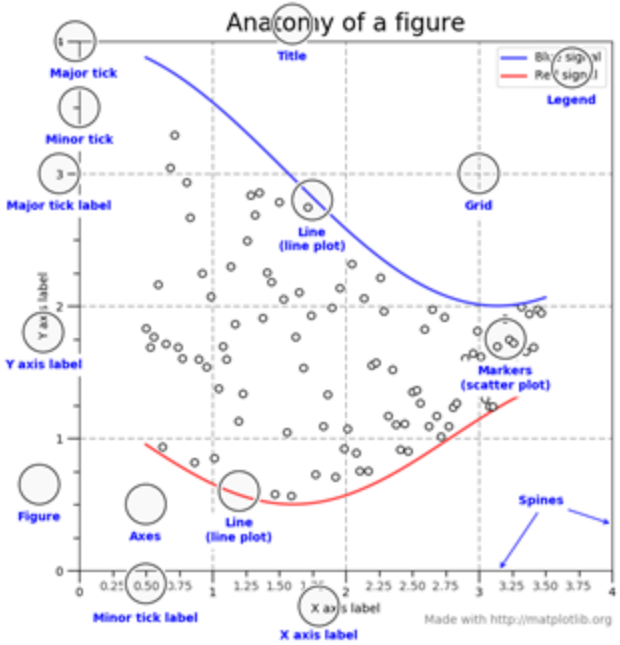
*link to tutorials: https://www.w3schools.com/python/matplotlib_intro.asp*

schools Tutorials Refer

HTML CSS JAVASCRIPT

Python Matplotlib

- Matplotlib Intro
- Matplotlib Get Started
- Matplotlib Pyplot
- Matplotlib Plotting
- Matplotlib Markers
- Matplotlib Line
- Matplotlib Labels
- Matplotlib Grid
- Matplotlib Subplot




Rather than try to learn everything, get the basics and ask Google / GenAI what you want to do in a particular case.

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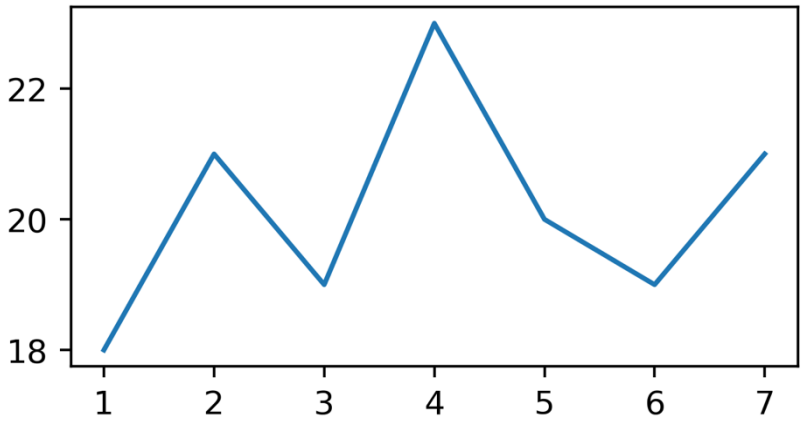
# Customising plots

You can configure all plot aspects!

*link to tutorials: https://www.w3schools.com/python/matplotlib_intro.asp*

```
plt.figure(figsize=(4, 2), dpi=400)
plt.plot(x_vals, y_vals)
```




*To set a custom figure width, height we create the figure before we plot.*

*You can also improve the sharpness of the image by setting the dpi (dots per inch)*

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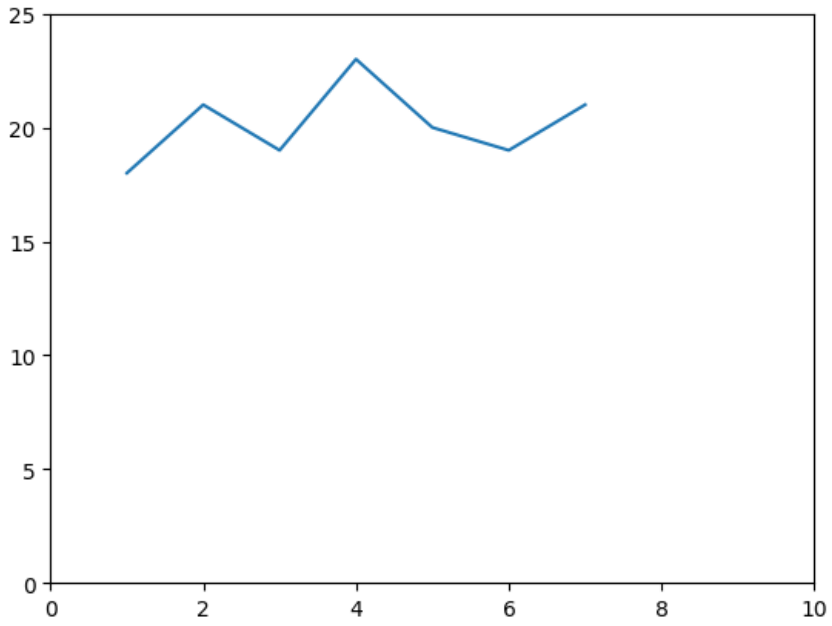
# Customising axes limits

You can configure all plot aspects!

*link to tutorials: https://www.w3schools.com/python/matplotlib_intro.asp*

```
plt.plot(x_vals, y_vals)
plt.ylim(0,25)
plt.xlim(0,10)
```




*matplotlib sets the axes range to fit the plotted data, but often we might need to adjust this*

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# Customising axes limits

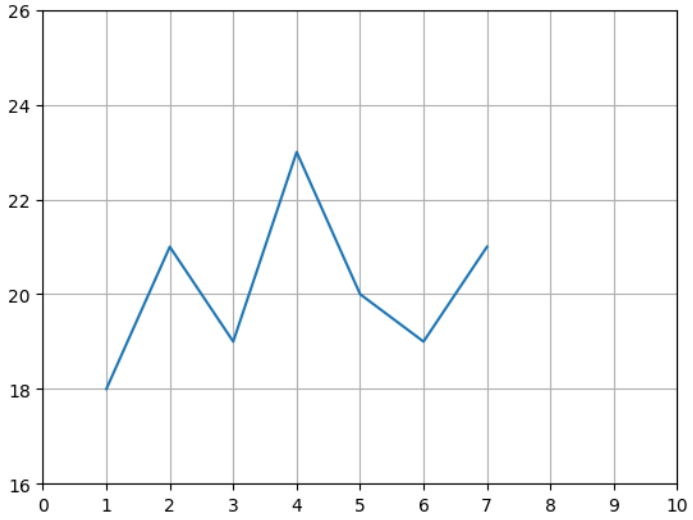
You can configure all plot aspects!

*link to tutorials: https://www.w3schools.com/python/matplotlib_intro.asp*

```
import numpy as np

plt.plot(x_vals, y_vals)
plt.xticks(np.arange(0,10.1,1))
plt.yticks(np.arange(16,27,2))

plt.grid()
```




*we can specify tick intervals (e.g. using numpy's arange function)*
*and draw on a grid for clarity*

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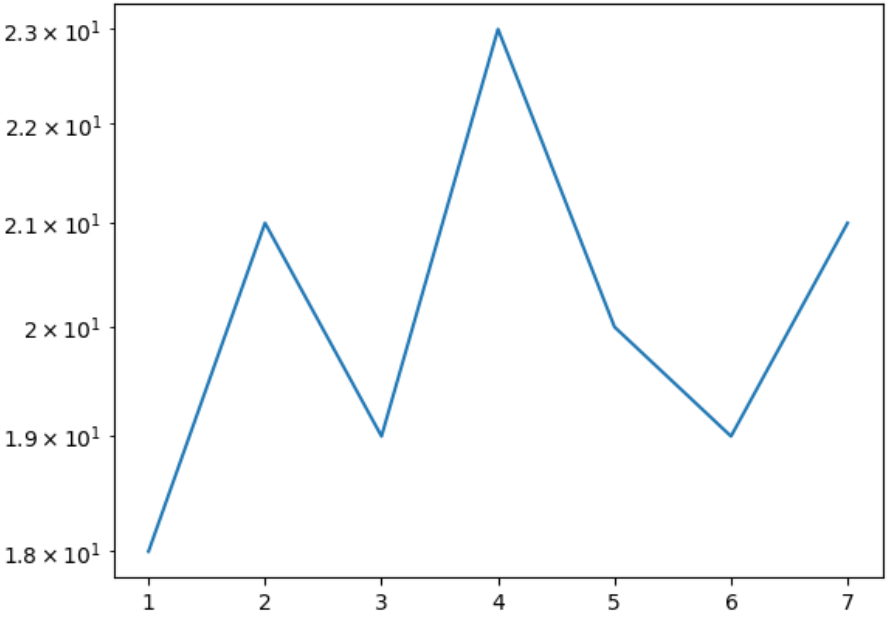
# Customising axes limits

You can configure all plot aspects!

*link to tutorials: https://www.w3schools.com/python/matplotlib_intro.asp*

```
plt.plot(x_vals, y_vals)
plt.yscale('log')
```




*where data spans a wide range, using log axes can help us visualise the data from the smallest and largest scale*

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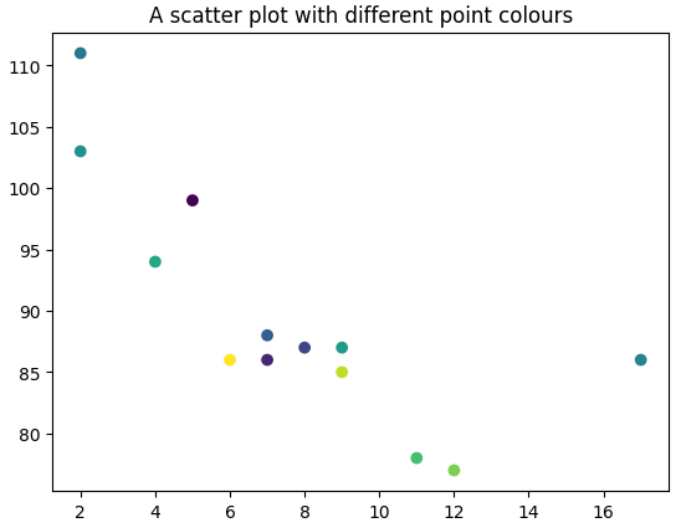
# Scatter plots: point colours

```
import matplotlib.pyplot as plt
import numpy as np

x_vals = np.array([5,7,8,7,2,17,2,9,4,11,12,9,6])
y_vals = np.array([99,86,87,88,111,86,103,87,94,78,77,85,86])
n_vals = np.array([0, 10, 20, 30, 40, 45, 50, 55, 60, 70, 80, 90, 100])

plt.scatter(x, y, c=n_vals, cmap='viridis')
plt.colorbar
plt.title('A scatter plot with different point colours')
```




*using plt.scatter() to make a scatter plot lets us customise points further.*

*e.g. where we have additional data on each point we can plot an extra variable using a colour mapping to translate values to different colours.*

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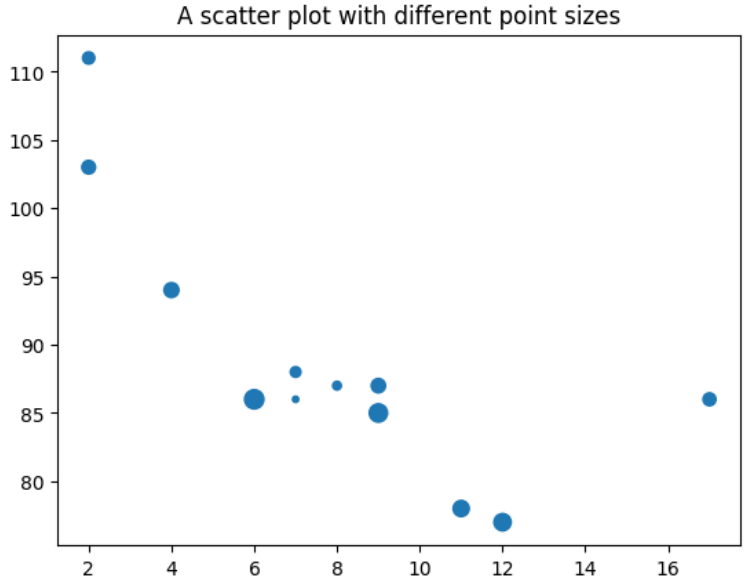
# Scatter plots: point sizes

```
import matplotlib.pyplot as plt
import numpy as np

x_vals = np.array([5,7,8,7,2,17,2,9,4,11,12,9,6])
y_vals = np.array([99,86,87,88,111,86,103,87,94,78,77,85,86])
n_vals = np.array([0, 10, 20, 30, 40, 45, 50, 55, 60, 70, 80, 90, 100])

plt.scatter(x, y, s=n_vals)
plt.title('A scatter plot with different point sizes')
```




*using plt.scatter() to make a scatter plot lets us customise points further.*

*e.g. we can use the additional data to set the size of each point*

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# Plot types in Matplotlib

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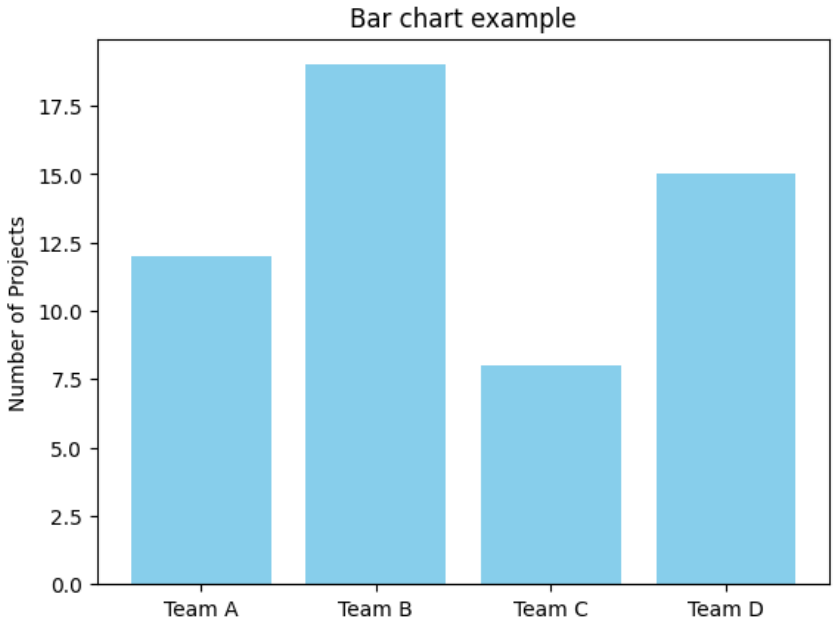
# Bar chart

```
import matplotlib.pyplot as plt

teams = ['Team A', 'Team B', 'Team C', 'Team D']
projects_completed = [12, 19, 8, 15]

plt.bar(teams, projects_completed, color='skyblue')

plt.title('Bar chart example')
plt.ylabel('Number of Projects')
```

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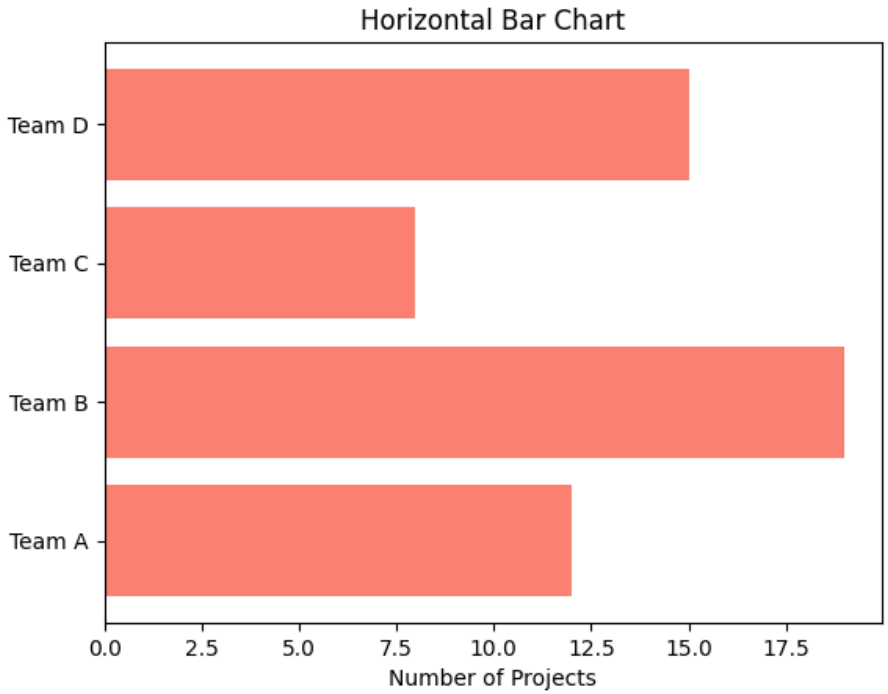
# Horiztonal bar chart

```
plt.barh(teams, projects_completed, color='salmon')

plt.title('Horizontal Bar Chart')
plt.xlabel('Number of Projects')
```

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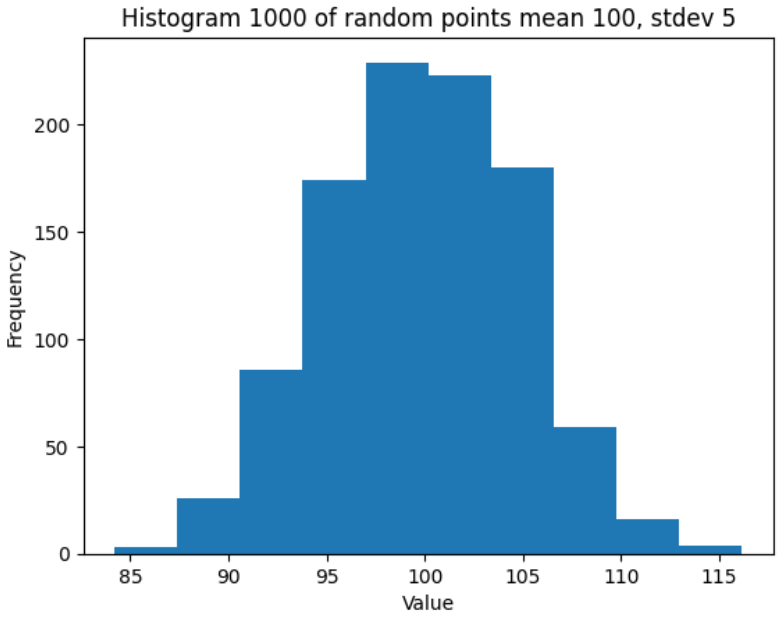
# Histogram

```
import numpy as np
data_points = np.random.normal(100, 5, 1000)
```

```
plt.hist(data_points)

plt.title('Histogram 1000 of random points mean 100, stdev 5')
plt.xlabel('Value')
plt.ylabel('Frequency')
```

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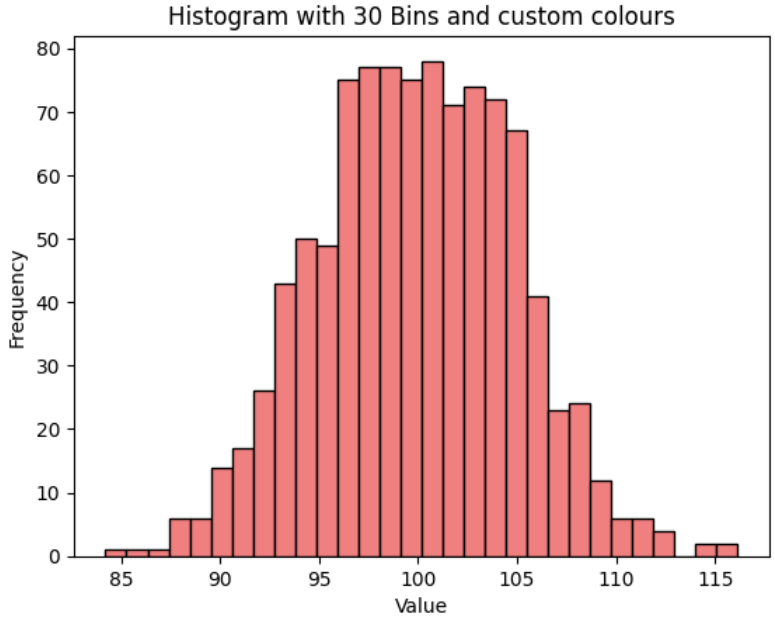
# Histogram: custom number of bins

```
plt.hist(data_points, bins=30, color='lightcoral', edgecolor='black')

plt.title('Histogram with 30 Bins and custom colours')
plt.xlabel('Value')
plt.ylabel('Frequency')
```

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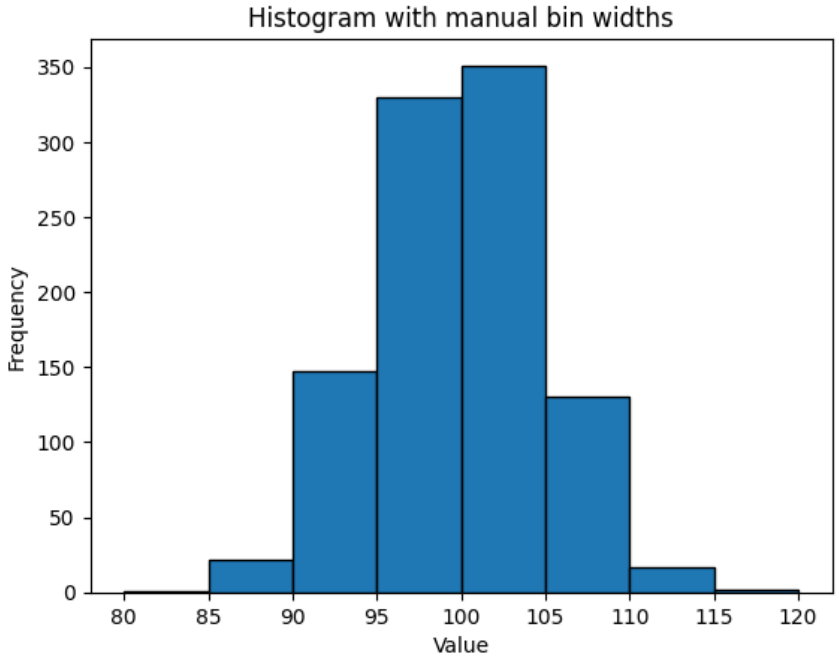
# Histogram: custom bin values

```
plt.hist(data_points, bins=np.arange(80, 121, 5), edgecolor='black')

plt.title('Histogram with manual bin widths')
plt.xlabel('Value')
plt.ylabel('Frequency')
```

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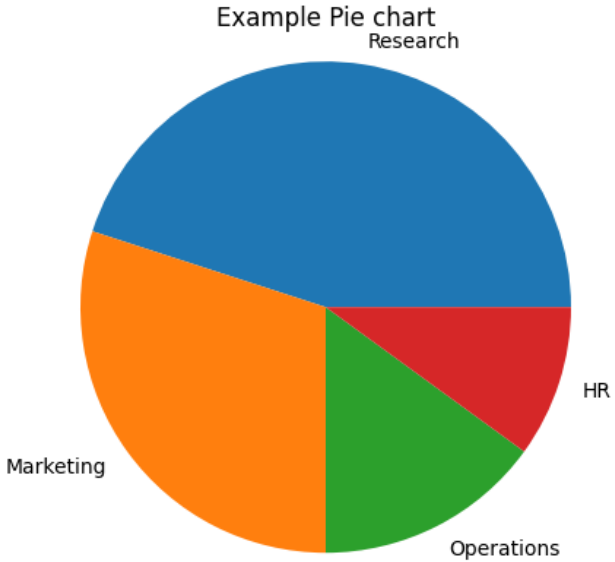
# Pie chart

```
labels = ['Research', 'Marketing', 'Operations', 'HR']
sizes = [45, 30, 15, 10]  # Percentages

plt.pie(sizes, labels=labels )

plt.title('Example Pie chart')
plt.axis('equal')  # Ensures the pie chart is a circle.
```

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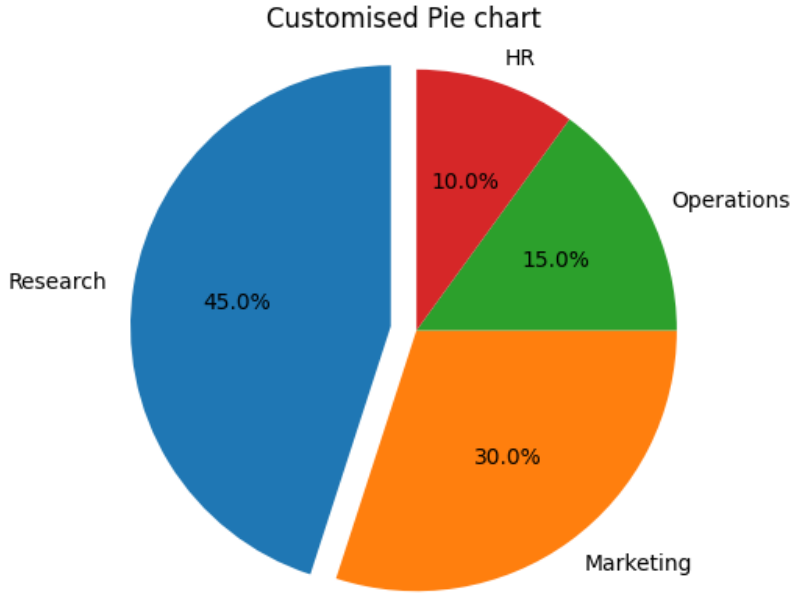
# Customised Pie chart

```
labels = ['Research', 'Marketing', 'Operations', 'HR']
sizes = [45, 30, 15, 10]  # Percentages
explode = (0.1, 0, 0, 0)  # "Explode" the 1st slice (Research)

plt.pie(sizes, explode=explode, labels=labels, autopct='%1.1f%%', startangle=90)

plt.title('Customised Pie chart')
plt.axis('equal')  # Ensures the pie chart is a circle.
```

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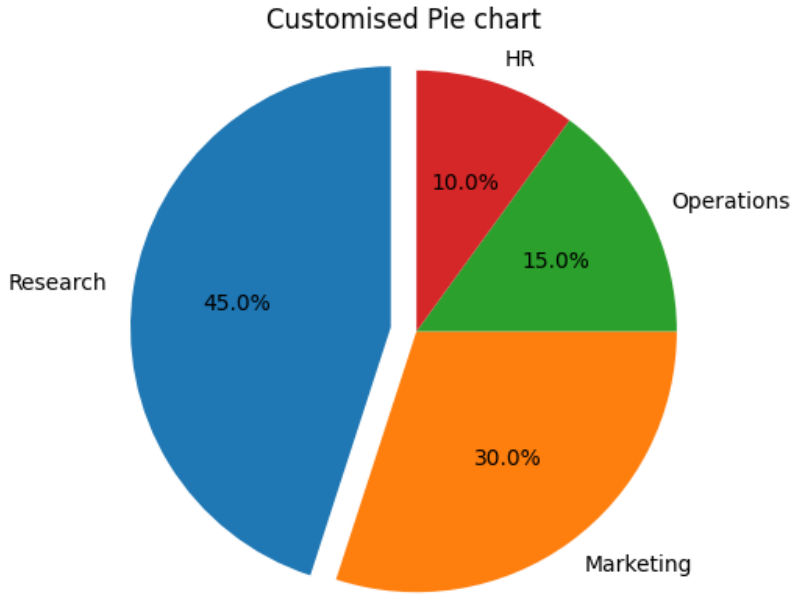
# Customised Pie chart

```
labels = ['Research', 'Marketing', 'Operations', 'HR']
sizes = [45, 30, 15, 10]  # Percentages
explode = (0.1, 0, 0, 0)  # "Explode" the 1st slice (Research)

plt.pie(sizes, explode=explode, labels=labels, autopct='%1.1f%%', startangle=90)

plt.title('Customised Pie chart')
plt.axis('equal')  # Ensures the pie chart is a circle.
```

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