matplotlib
Cheat sheet
Version 3.5.0

Quick start `API`

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

X = np.linspace(0, 2*np.pi, 100)
Y = np.cos(X)

fig, ax = plt.subplots()
ax.plot(X, Y, color='green')

fig.savefig("figure.pdf")
fig.show()
```
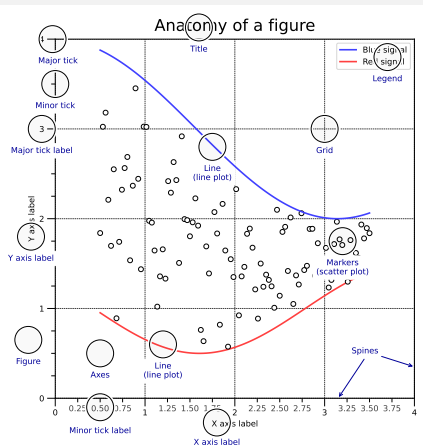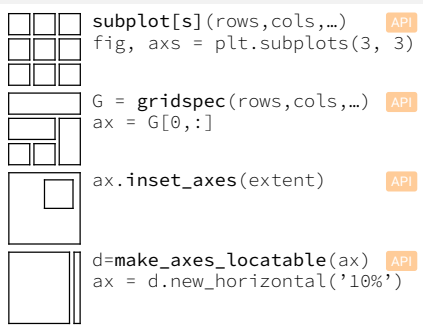
Anatomy of a figure

Anatomy of a figure

Subplots layout `API`

```python
subplot[s](rows,cols,…)      API
fig, axs = plt.subplots(3, 3)

G = gridspec(rows,cols,…)    API
ax = G[0,:]

ax.inset_axes(extent)        API

d=make_axes_locatable(ax)    API
ax = d.new_horizontal('10%')
```

Getting help

- matplotlib.org
- github.com/matplotlib/matplotlib/issues
- discourse.matplotlib.org
- stackoverflow.com/questions/tagged/matplotlib
- gitter.im/matplotlib
- twitter.com/matplotlib
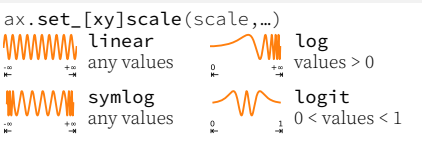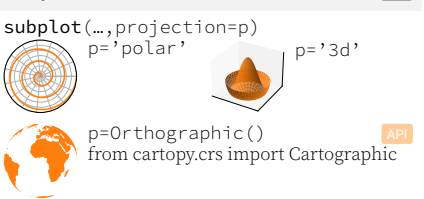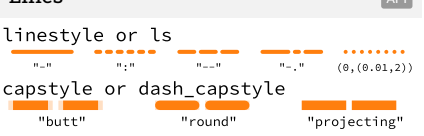- Matplotlib users mailing list

Basic plots

```
plot([X],Y,[fmt],…)          API
```
X, **Y**, fmt, color, marker, linestyle

```
scatter(X,Y,…)               API
```
X, **Y**, [s]izes, [c]olors, marker, cmap

```
bar[h](x,height,…)           API
```
x, **height**, width, bottom, align, color

```
imshow(Z,…)                  API
```
Z, cmap, interpolation, extent, origin

```
contour[f]([X],[Y],Z,…)      API
```
X, Y, **Z**, levels, colors, extent, origin

```
pcolormesh([X],[Y],Z,…)      API
```
X, Y, **Z**, vmin, vmax, cmap

```
quiver([X],[Y],U,V,…)        API
```
X, Y, **U**, **V**, C, units, angles

```
pie(X,…)                     API
```
Z, explode, labels, colors, radius

```
text(x,y,text,…)             API
```
x, y, **text**, va, ha, size, weight, transform

```
fill[_between][x](…)         API
```
X, Y1, Y2, color, where

Advanced plots

```
step(X,Y,[fmt],…)            API
```
X, **Y**, fmt, color, marker, where

```
boxplot(X,…)                 API
```
X, notch, sym, bootstrap, widths

```
errorbar(X,Y,xerr,yerr,…)    API
```
X, **Y**, xerr, yerr, fmt

```
hist(X, bins, …)             API
```
X, bins, range, density, weights

```
violinplot(D,…)              API
```
D, positions, widths, vert

```
barbs([X],[Y], U, V, …)      API
```
X, Y, **U**, **V**, C, length, pivot, sizes

```
eventplot(positions,…)       API
```
positions, orientation, lineoffsets

```
hexbin(X,Y,C,…)              API
```
X, **Y**, C, gridsize, bins

Scales `API`

```
ax.set_[xy]scale(scale,…)
```
- linear — any values
- log — values > 0
- symlog — any values
- logit — 0 < values < 1

Projections `API`

```
subplot(…,projection=p)
```
p='polar'   p='3d'

p=Orthographic()   `API`
from cartopy.crs import Cartographic

Lines `API`

linestyle or ls

"-"   ":"   "--"   "-."   (0,(0.01,2))

capstyle or dash_capstyle

"butt"   "round"   "projecting"

Markers `API`

'.' ',' 'o' 's' 'P' 'X' '*' 'p' 'D' '<' '>' '^' 'v'
'1' '2' '3' '4' '+' 'x' '|' '_' '4' '2' '3'
'$♠$''$♣$''$♥$''$♦$''$→$''$←$''$↑$''$↓$''$◐$''$◑$''$◒$''$◓$'

markevery
10   [0, -1]   (25, 5)   [0, 25, -1]

Colors `API`

C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	'Cn'
b	g	r	c	m	y	k	w			'x'
DarkRed	Firebrick	Crimson	IndianRed	Salmon	'name'
(1,0,0)	(1,0,0,0.75)	(1,0,0,0.5)	(1,0,0,0.25)	(R,G,B[,A])
#FF0000	#FF0000B	#FF000088	#FF000044	'#RRGGBB[AA]'
0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	'x.y'

Colormaps `API`

```
plt.get_cmap(name)
```

Uniform
- viridis
- magma
- plasma

Sequential
- Greys
- YlOrBr
- Wistia

Diverging
- Spectral
- coolwarm
- RdGy

Qualitative
- tab10
- tab20

Cyclic
- twilight

Tick locators `API`

```
from matplotlib import ticker
ax.[xy]axis.set_[minor|major]_locator(locator)
```

```
ticker.NullLocator()
ticker.MultipleLocator(0.5)
ticker.FixedLocator([0, 1, 5])
ticker.LinearLocator(numticks=3)
ticker.IndexLocator(base=0.5, offset=0.25)
ticker.AutoLocator()
ticker.MaxNLocator(n=4)
ticker.LogLocator(base=10, numticks=15)
```

Tick formatters `API`

```
from matplotlib import ticker
ax.[xy]axis.set_[minor|major]_formatter(formatter)
```

```
ticker.NullFormatter()
ticker.FixedFormatter(['zero', 'one', 'two', …])
ticker.FuncFormatter(lambda x, pos: "[%.2f]" % x)
ticker.FormatStrFormatter('>%d<')
ticker.ScalarFormatter()
ticker.StrMethodFormatter('{x}')
ticker.PercentFormatter(xmax=5)
```

Ornaments

```
ax.legend(…)                 API
```
handles, labels, loc, title, frameon


```
ax.colorbar(…)               API
```
mappable, ax, cax, orientation

```
ax.annotate(…)               API
```
text, xy, **xytext**, xycoords, textcoords, arrowprops

Event handling `API`

```python
fig, ax = plt.subplots()
def on_click(event):
    print(event)
fig.canvas.mpl_connect(
    'button_press_event', on_click)
```

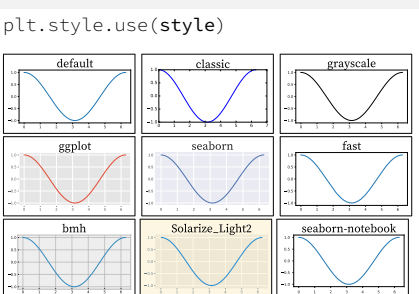## Animation `API`

```python
import matplotlib.animation as mpla

T = np.linspace(0, 2*np.pi, 100)
S = np.sin(T)
line, = plt.plot(T, S)
def animate(i):
    line.set_ydata(np.sin(T+i/50))
anim = mpla.FuncAnimation(
    plt.gcf(), animate, interval=5)
plt.show()
```

Styles `API`

```
plt.style.use(style)
```


default | classic | grayscale
ggplot | seaborn | fast
bmh | Solarize_Light2 | seaborn-notebook

Quick reminder

```
ax.grid()
ax.set_[xy]lim(vmin, vmax)
ax.set_[xy]label(label)
ax.set_[xy]ticks(ticks, [labels])
ax.set_[xy]ticklabels(labels)
ax.set_title(title)
ax.tick_params(width=10, …)
ax.set_axis_[on|off]()

fig.suptitle(title)
fig.tight_layout()
plt.gcf(), plt.gca()
mpl.rc('axes', linewidth=1, …)
[fig|ax].patch.set_alpha(0)
text=r'$\frac{-e^{i\pi}}{2^n}$'
```

Keyboard shortcuts `API`

- ctrl + s Save
- ctrl + w Close plot
- r Reset view
- f Fullscreen 0/1
- f View forward
- b View back
- p Pan view
- o Zoom to rect
- x X pan/zoom
- y Y pan/zoom
- g Minor grid 0/1
- G Major grid 0/1
- l X axis log/linear
- L Y axis log/linear

Ten simple rules `READ`

1. Know Your Audience
2. Identify Your Message
3. Adapt the Figure
4. Captions Are Not Optional
5. Do Not Trust the Defaults
6. Use Color Effectively
7. Do Not Mislead the Reader
8. Avoid "Chartjunk"
9. Message Trumps Beauty
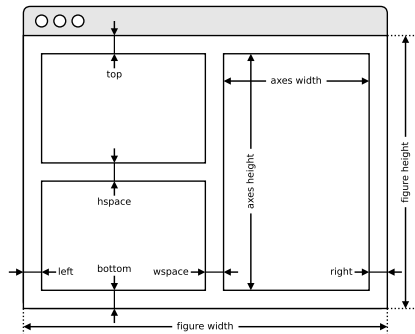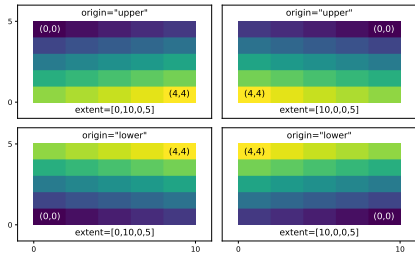10. Get the Right Tool

Axes adjustments [API]

plt.subplots_adjust(...)
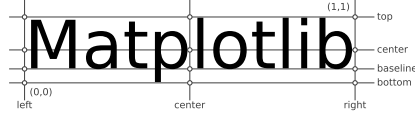

Extent & origin [API]

ax.imshow(extent=..., origin=...)

Text alignments [API]

ax.text(..., ha=..., va=..., ...)

Text parameters [API]

ax.text(..., family=..., size=..., weight=...)
ax.text(..., fontproperties=...)

The quick brown fox	xx-large (1.73)
The quick brown fox	x-large (1.44)
The quick brown fox	large (1.20)
The quick brown fox	medium (1.00)
The quick brown fox	small (0.83)
The quick brown fox	x-small (0.69)
The quick brown fox	xx-small (0.58)
The quick brown fox jumps over the lazy dog	black (900)
The quick brown fox jumps over the lazy dog	bold (700)
The quick brown fox jumps over the lazy dog	semibold (600)
The quick brown fox jumps over the lazy dog	normal (400)
The quick brown fox jumps over the lazy dog	ultralight (100)
The quick brown fox jumps over the lazy dog	monospace
The quick brown fox jumps over the lazy dog	serif
The quick brown fox jumps over the lazy dog	sans
The quick brown fox jumps over the lazy dog	cursive
The quick brown fox jumps over the lazy dog	italic
The quick brown fox jumps over the lazy dog	normal
THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG	small-caps
The quick brown fox jumps over the lazy dog	normal
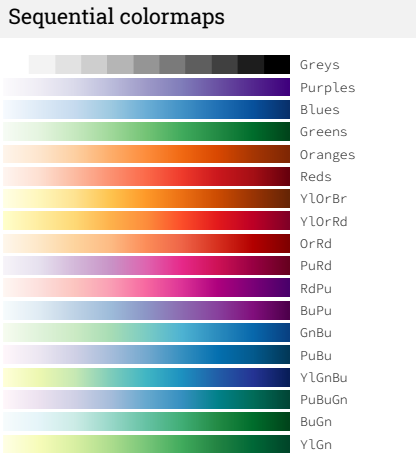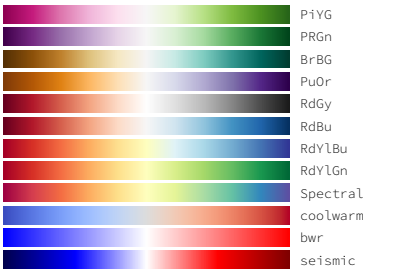
Uniform colormaps

viridis
plasma
inferno
magma
cividis

Sequential colormaps

Greys
Purples
Blues
Greens
Oranges
Reds
YlOrBr
YlOrRd
OrRd
PuRd
RdPu
BuPu
GnBu
PuBu
YlGnBu
PuBuGn
BuGn
YlGn

Diverging colormaps

PiYG
PRGn
BrBG
PuOr
RdGy
RdBu
RdYlBu
RdYlGn
Spectral
coolwarm
bwr
seismic

Qualitative colormaps

Pastel1
Pastel2
Paired
Accent
Dark2
Set1
Set2
Set3
tab10
tab20
tab20b
tab20c
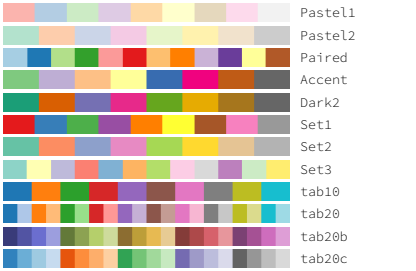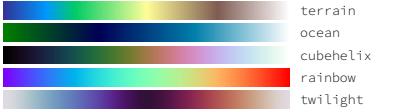
Miscellaneous colormaps

terrain
ocean
cubehelix
rainbow
twilight

Color names [API]
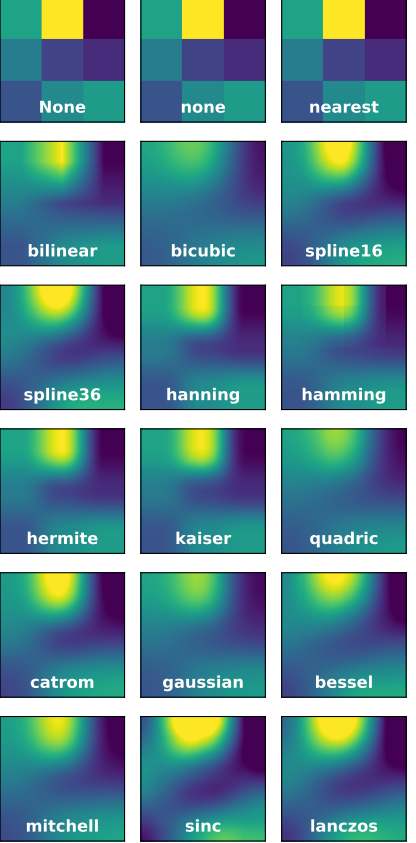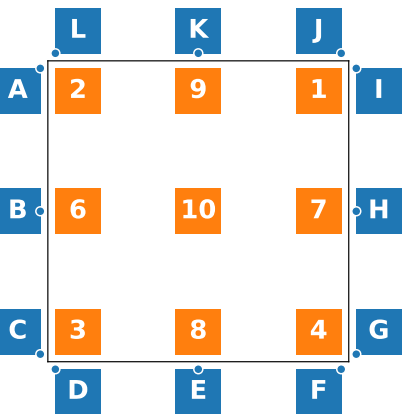
Image interpolation [API]

None   none   nearest
bilinear   bicubic   spline16
spline36   hanning   hamming
hermite   kaiser   quadric
catrom   gaussian   bessel
mitchell   sinc   lanczos

Legend placement
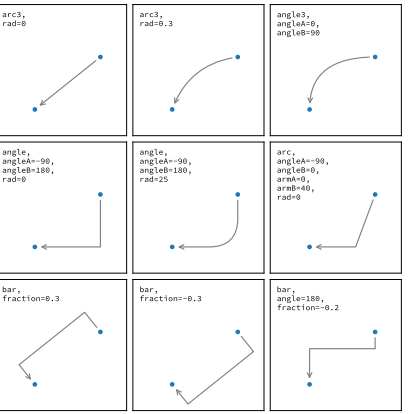
ax.legend(loc="string", bbox_to_anchor=(x,y))

2: upper left   9: upper center   1: upper right
6: center left   10: center   7: center right
3: lower left   8: lower center   4: lower right

A: upper right / (-0.1,0.9)   B: center right / (-0.1,0.5)
C: lower right / (-0.1,0.1)   D: upper left / (0.1,-0.1)
E: upper center / (0.5,-0.1)   F: upper right / (0.9,-0.1)
G: lower left / (1.1,0.1)   H: center left / (1.1,0.5)
I: upper left / (1.1,0.9)   J: lower right / (0.9,1.1)
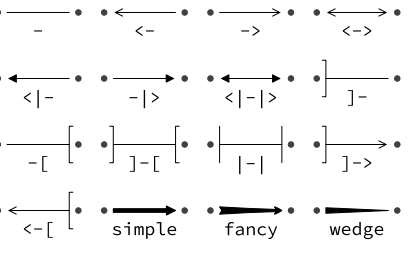K: lower center / (0.5,1.1)   L: lower left / (0.1,1.1)

Annotation connection styles [API]

Annotation arrow styles [API]

How do I ...

... resize a figure?
  → fig.set_size_inches(w, h)
... save a figure?
  → fig.savefig("figure.pdf")
... save a transparent figure?
  → fig.savefig("figure.pdf", transparent=True)
... clear a figure/an axes?
  → fig.clear() or ax.clear()
... close all figures?
  → plt.close("all")
... remove ticks?
  → ax.set_[xy]ticks([])
... remove tick labels ?
  → ax.set_[xy]ticklabels([])
... rotate tick labels ?
  → ax.tick_params(axis="x", rotation=90)
... hide top spine?
  → ax.spines['top'].set_visible(False)
... hide legend border?
  → ax.legend(frameon=False)
... show error as shaded region?
  → ax.fill_between(X, Y+error, Y-error)
... draw a rectangle?
  → ax.add_patch(plt.Rectangle((0, 0), 1, 1)
... draw a vertical line?
  → ax.axvline(x=0.5)
... draw outside frame?
  → ax.plot(..., clip_on=False)
... use transparency?
  → ax.plot(..., alpha=0.25)
... convert an RGB image into a gray image?
  → gray = 0.2989*R + 0.5870*G + 0.1140*B
... set figure background color?
  → fig.patch.set_facecolor("grey")
... get a reversed colormap?
  → plt.get_cmap("viridis_r")
... get a discrete colormap?
  → plt.get_cmap("viridis", 10)
... show a figure for one second?
  → fig.show(block=False), time.sleep(1)

Performance tips

scatter(X, Y)	slow
plot(X, Y, marker="o", ls="")	fast
for i in range(n): plot(X[i])	slow
plot(sum([x+[None] for x in X],[]))	fast
cla(), imshow(…), canvas.draw()	slow
im.set_data(…), canvas.draw()	fast

Beyond Matplotlib

Seaborn: Statistical Data Visualization
Cartopy: Geospatial Data Processing
yt: Volumetric data Visualization
mpld3: Bringing Matplotlib to the browser
Datashader: Large data processing pipeline
plotnine: A Grammar of Graphics for Python

NUMFOCUS
OPEN CODE = BETTER SCIENCE

Matplotlib for beginners

Matplotlib is a library for making 2D plots in Python. It is designed with the philosophy that you should be able to create simple plots with just a few commands:

1 Initialize

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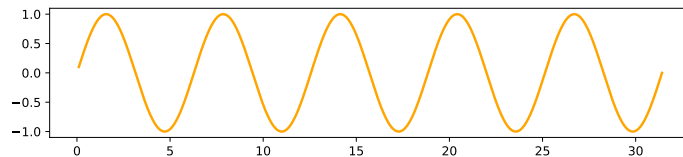
2 Prepare

```
X = np.linspace(0, 4*np.pi, 1000)
Y = np.sin(X)
```

3 Render

```
fig, ax = plt.subplots()
ax.plot(X, Y)
fig.show()
```
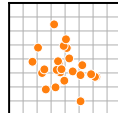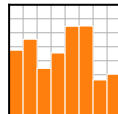
4 Observe

Choose

Matplotlib offers several kind of plots (see Gallery):

```
X = np.random.uniform(0, 1, 100)
Y = np.random.uniform(0, 1, 100)
ax.scatter(X, Y)
```

```
X = np.arange(10)
Y = np.random.uniform(1, 10, 10)
ax.bar(X, Y)
```

```
Z = np.random.uniform(0, 1, (8,8))

ax.imshow(Z)
```
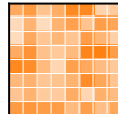
```
Z = np.random.uniform(0, 1, (8,8))

ax.contourf(Z)
```

```
Z = np.random.uniform(0, 1, 4)

ax.pie(Z)
```
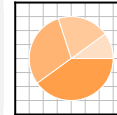
```
Z = np.random.normal(0, 1, 100)

ax.hist(Z)
```
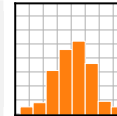
```
X = np.arange(5)
Y = np.random.uniform(0, 1, 5)
ax.errorbar(X, Y, Y/4)
```
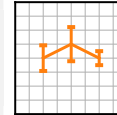
```
Z = np.random.normal(0, 1, (100,3))

ax.boxplot(Z)
```
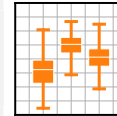
Tweak

You can modify pretty much anything in a plot, including limits, colors, markers, line width and styles, ticks and ticks labels, titles, etc.

```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, color="black")
```
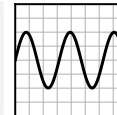
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linestyle="--")
```
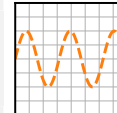
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, linewidth=5)
```
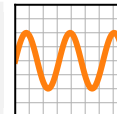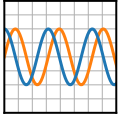
```
X = np.linspace(0, 10, 100)
Y = np.sin(X)
ax.plot(X, Y, marker="o")
```
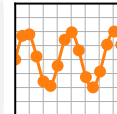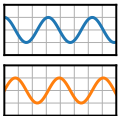
Organize

You can plot several data on the the same figure, but you can also split a figure in several subplots (named *Axes*):
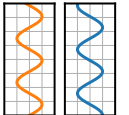
```
X = np.linspace(0, 10, 100)
Y1, Y2 = np.sin(X), np.cos(X)
ax.plot(X, Y1, X, Y2)
```

```
fig, (ax1, ax2) = plt.subplots((2,1))
ax1.plot(X, Y1, color="C1")
ax2.plot(X, Y2, color="C0")
```
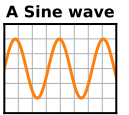
```
fig, (ax1, ax2) = plt.subplots((1,2))
ax1.plot(Y1, X, color="C1")
ax2.plot(Y2, X, color="C0")
```
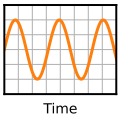
Label (everything)

```
ax.plot(X, Y)
fig.suptitle(None)
ax.set_title("A Sine wave")
```

```
ax.plot(X, Y)
ax.set_ylabel(None)
ax.set_xlabel("Time")
```

Explore

Figures are shown with a graphical user interface that allows to zoom and pan the figure, to navigate between the different views and to show the value under the mouse.

Save (bitmap or vector format)

```
fig.savefig("my-first-figure.png", dpi=300)
fig.savefig("my-first-figure.pdf")
```

Matplotlib for intermediate users

A matplotlib figure is composed of a hierarchy of elements that forms the actual figure. Each element can be modified.
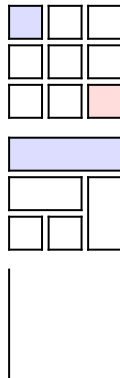

Anatomy of a figure
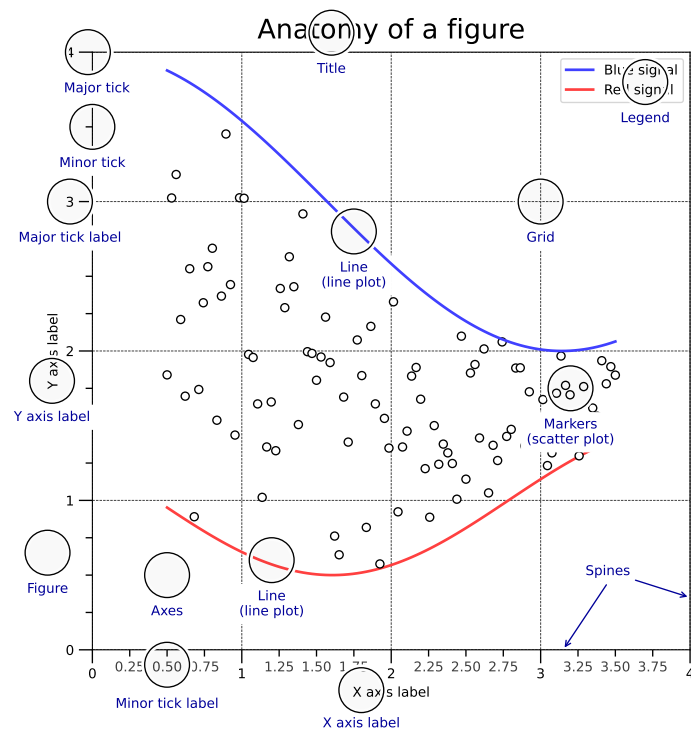
Figure, axes & spines

```
fig, axs = plt.subplots(3,3)
axs[0,0].set_facecolor("#ddddff")
axs[2,2].set_facecolor("#ffffdd")
```
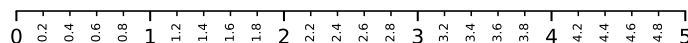
```
gs = fig.add_gridspec(3, 3)
ax = fig.add_subplot(gs[0, :])
ax.set_facecolor("#ddddff")
```

```
fig, ax = plt.subplots()
ax.spines["top"].set_color("None")
ax.spines["right"].set_color("None")
```
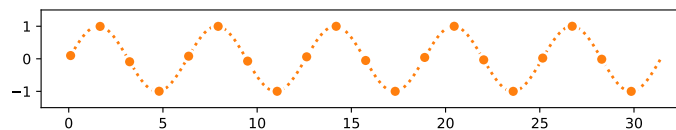
Ticks & labels

```
from mpl.ticker import MultipleLocator as ML
from mpl.ticker import ScalarFormatter as SF
ax.xaxis.set_minor_locator(ML(0.2))
ax.xaxis.set_minor_formatter(SF())
ax.tick_params(axis='x',which='minor',rotation=90)
```
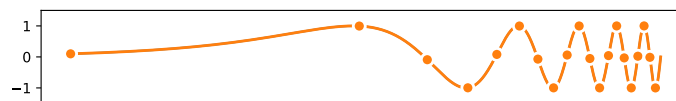

Lines & markers

```
X = np.linspace(0.1, 10*np.pi, 1000)
Y = np.sin(X)
ax.plot(X, Y, "C1o:", markevery=25, mec="1.0")
```
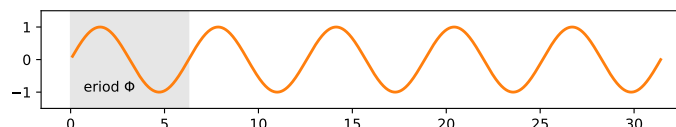

Scales & projections

```
fig, ax = plt.subplots()
ax.set_xscale("log")
ax.plot(X, Y, "C1o-", markevery=25, mec="1.0")
```
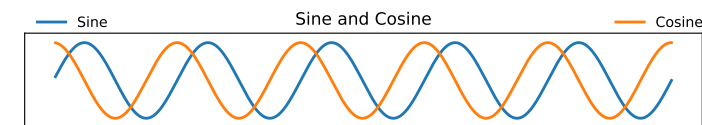

Text & ornaments

```
ax.fill_betweenx([-1,1],[0],[2*np.pi])
ax.text(0, -1, r" Period $\Phi$")
```
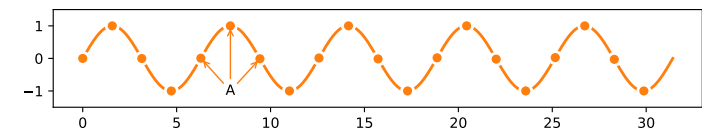

Legend

```
ax.plot(X, np.sin(X), "C0", label="Sine")
ax.plot(X, np.cos(X), "C1", label="Cosine")
ax.legend(bbox_to_anchor=(0,1,1,.1),ncol=2,
          mode="expand",  loc="lower left")
```
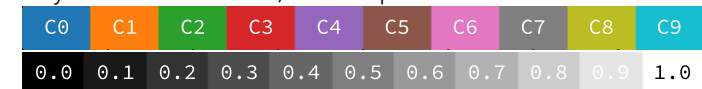

Annotation

```
ax.annotate("A", (X[250],Y[250]),(X[250],-1),
    ha="center", va="center",arrowprops =
    {"arrowstyle" : "->", "color": "C1"})
```


Colors

Any color can be used, but Matplotlib offers sets of colors:

Size & DPI

Consider a square figure to be included in a two-columns A4 paper with 2cm margins on each side and a column separation of 1cm. The width of a figure is (21 - 2*2 - 1)/2 = 8cm. One inch being 2.54cm, figure size should be 3.15×3.15 in.

```
fig = plt.figure(figsize=(3.15,3.15), dpi=50)
plt.savefig("figure.pdf", dpi=600)
```
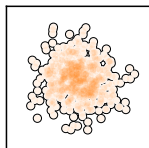
Matplotlib tips & tricks

Transparency

Scatter plots can be enhanced by using transparency (alpha) in order to show area with higher density. Multiple scatter plots can be used to delineate a frontier.

```
X = np.random.normal(-1, 1, 500)
Y = np.random.normal(-1, 1, 500)
ax.scatter(X, Y, 50, "0.0", lw=2) # optional
ax.scatter(X, Y, 50, "1.0", lw=0) # optional
ax.scatter(X, Y, 40, "C1",  lw=0, alpha=0.1)
```

Rasterization

If your figure has many graphical elements, such as a huge scatter, you can rasterize them to save memory and keep other elements in vector format.

```
X = np.random.normal(-1, 1, 10_000)
Y = np.random.normal(-1, 1, 10_000)
ax.scatter(X, Y, rasterized=True)
fig.savefig("rasterized-figure.pdf", dpi=600)
```

Offline rendering

Use the Agg backend to render a figure directly in an array.
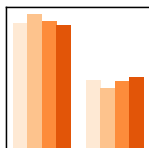
```
from matplotlib.backends.backend_agg import FigureCanvas
canvas = FigureCanvas(Figure())
... # draw some stuff
canvas.draw()
Z = np.array(canvas.renderer.buffer_rgba())
```

Range of continuous colors

You can use colormap to pick from a range of continuous colors.

```
X = np.random.randn(1000, 4)
cmap = plt.get_cmap("Oranges")
colors = cmap([0.2, 0.4, 0.6, 0.8])

ax.hist(X, 2, histtype='bar', color=colors)
```

Text outline

Use text outline to make text more visible.

```
import matplotlib.patheffects as fx
text = ax.text(0.5, 0.1, "Label")
text.set_path_effects([
  fx.Stroke(linewidth=3, foreground='1.0'),
  fx.Normal()])
```

Multiline plot

You can plot several lines at once using None as separator.

```
X,Y = [], []
for x in np.linspace(0, 10*np.pi, 100):
  X.extend([x, x, None]), Y.extend([0, sin(x), None])
ax.plot(X, Y, "black")
```

Dotted lines

To have rounded dotted lines, use a custom `linestyle` and modify `dash_capstyle`.
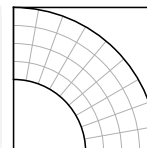
```
ax.plot([0,1], [0,0], "C1",
        linestyle = (0, (0.01, 1)), dash_capstyle="round")
ax.plot([0,1], [1,1], "C1",
        linestyle = (0, (0.01, 2)), dash_capstyle="round")
```

Combining axes

You can use overlaid axes with different projections.
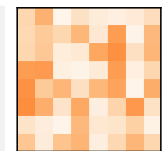
```
ax1 = fig.add_axes([0,0,1,1],
                    label="cartesian")
ax2 = fig.add_axes([0,0,1,1],
                    label="polar",
                    projection="polar")
```

Colorbar adjustment

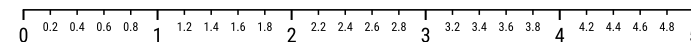You can adjust a colorbar's size when adding it.

```
im = ax.imshow(Z)

cb = plt.colorbar(im,
        fraction=0.046, pad=0.04)
cb.set_ticks([])
```

Taking advantage of typography

You can use a condensed font such as Roboto Condensed to save space on tick labels.

```
for tick in ax.get_xticklabels(which='both'):
    tick.set_fontname("Roboto Condensed")
```

Getting rid of margins

Once your figure is finished, you can call `tight_layout()` to remove white margins. If there are remaining margins, you can use the `pdfcrop` utility (comes with TeX live).

Hatching

You can achieve a nice visual effect with thick hatch patterns.

```
cmap = plt.get_cmap("Oranges")
plt.rcParams['hatch.color'] = cmap(0.2)
plt.rcParams['hatch.linewidth'] = 8
ax.bar(X, Y, color=cmap(0.6), hatch="/" )
```
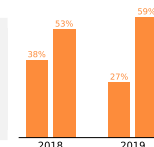
Read the documentation

Matplotlib comes with an extensive documentation explaining the details of each command and is generally accompanied by examples. Together with the huge online gallery, this documentation is a gold-mine.