Code.Hub

Data Visualization (part 1)

> A picture is worth a thousand words.

In many cases we might want to visualize data instead of just printing results or statistical measures on screen. When wanting to make a presentation, graphs and charts are king. They allow for concise viewing of statistical data, especially when that data involves data sets numbering in the hundreds or more.

We'll split this tutorial into two parts: the first will cover **matplotlib**, a somewhat low-level plotting library; the second will cover **seaborn** a higher level plotting library, which is built on top of matplotlib and can generate more advanced plots easily.

Matplotlib

This package is useful for plotting 2D graphics. It is probably the most used and best supported plotting package in python.

The module we will be using the most is `matplotlib.pyplot`. This module provides a procedural interface to the matplotlib object-oriented plotting library. It is modeled closely after Matlab. Therefore, the majority of plotting commands in pyplot have Matlab analogs with similar arguments.

Sample plots

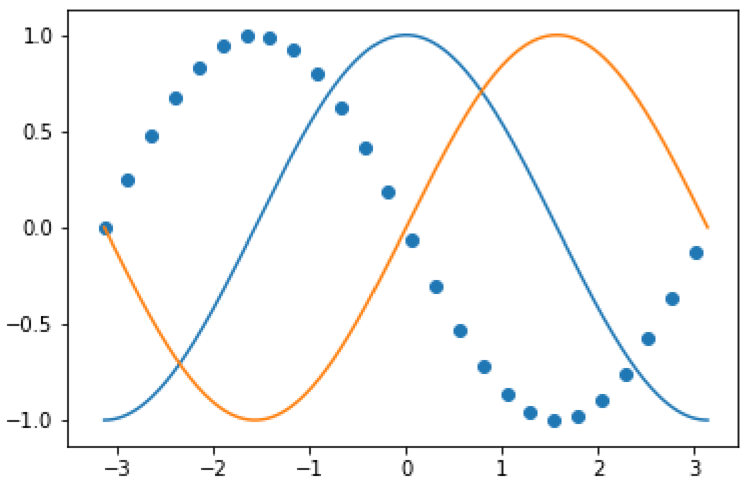
The two most common plots are a **line** plot and a **scatter** plot. Both draw a series of points in a figure; the only difference is that the first type of plot connects the points given to it.

```
plt.plot(x, y)     # lineplot
plt.scatter(x, y)  # scatterplot
```

Both types of plots can be drawn with only two arguments: `x`, which is a sequence of the coordinates of the points on the x-axis, and `y`, which is the same thing for the y-axis.

In [1]:
```
import matplotlib.pyplot as plt  # basic import statement
%matplotlib inline
# this argument is used in the IPython/Jupyter Notebooks.
# It tells is to incorporate the plot in the notebook instead of poping a new wir

# we will need these as well:
import numpy as np
import pandas as pd

x = np.linspace(-np.pi, np.pi, 256, endpoint=True)
# This command returns a numpy.ndarray with 256 values equally distributed in [-p
# If endpoint was False the values would be distributed in [-pi,pi).

c, s = np.cos(x), np.sin(x)
# These two commands return the elementwise cos and sin of the array x.

plt.plot(x, c)  # command that creates a line that connects the points given in t
plt.plot(x, s)  # plots the sine in the same plot
plt.scatter(x[::10], s[::-10])  # command that simply draws the points given as c
# plt.show()
```

Out[1]: <matplotlib.collections.PathCollection at 0x1dbb3a67358>



- If we weren't in the notebook we would also need a `plt.show()` commad at the end.
- If we wanted to save the figure we would use `plt.savefig('plotname.png', dpi=72, bbox_inches='tight')` . Saves the plot in *plotname.png* with 72 dots-per-square-inch. We could also save the figure as a vector image (as a *.pdf*). The `bbox_inches` argument is useful because pyplot leaves a large white box around the image which is often undesirable.

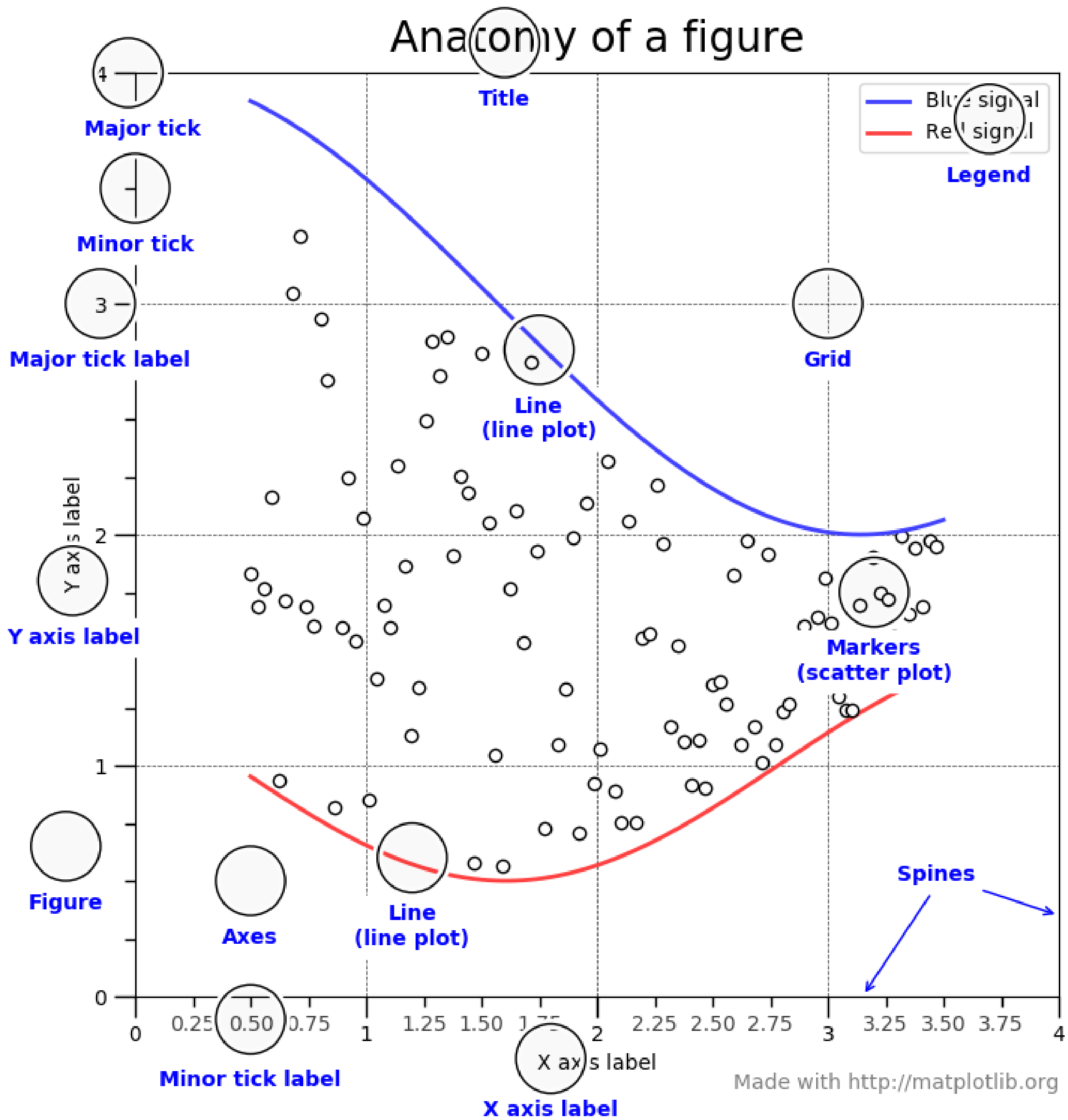
This is the simplest way to create a figure with matplotlib. In order to be able to customize the figure, we need to delve a bit deeper into matplotlib.

Figure anatomy

A few things you must be aware of:

- The whole **figure** is represented as an object called a `figure` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.figure.html). This was done **automatically** in the code above, however if we want to customize aspects like the figure's **size**, **resolution**, **borders**, **background**, etc, we'll need to create our own.
- The figure might contain one or more "sub-figures" called **subplots**. Each one is represented as an object called an `axes` (https://matplotlib.org/api/axes_api.html). Every axes consists of several parts, the most important are:
  - The `spines` (https://matplotlib.org/api/spines_api.html), which are the *borders* on the edges of a plot.
  - The `labels` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.xlabel.html) for both x and y axes.
  - The `ticks` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.xticks.html), which are points denoted on the x and y axes. Each tick has a **position** (i.e. where it is placed along its axis) and a **label** (i.e. what the label of the tick is). There are two types of ticks: **major** and **minor**.
  - The `title` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.title.html) of the plot.
  - The `grid` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.grid.html).
  - The `legend` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.legend.html).
  - Any other `artists` (https://matplotlib.org/api/artist_api.html) the plot may contain (e.g. **lines** (https://matplotlib.org/api/_as_gen/matplotlib.lines.Line2D.html), **markers** (https://matplotlib.org/api/markers_api.html), **text** (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.text.html))

All these elements are shown in the image below:

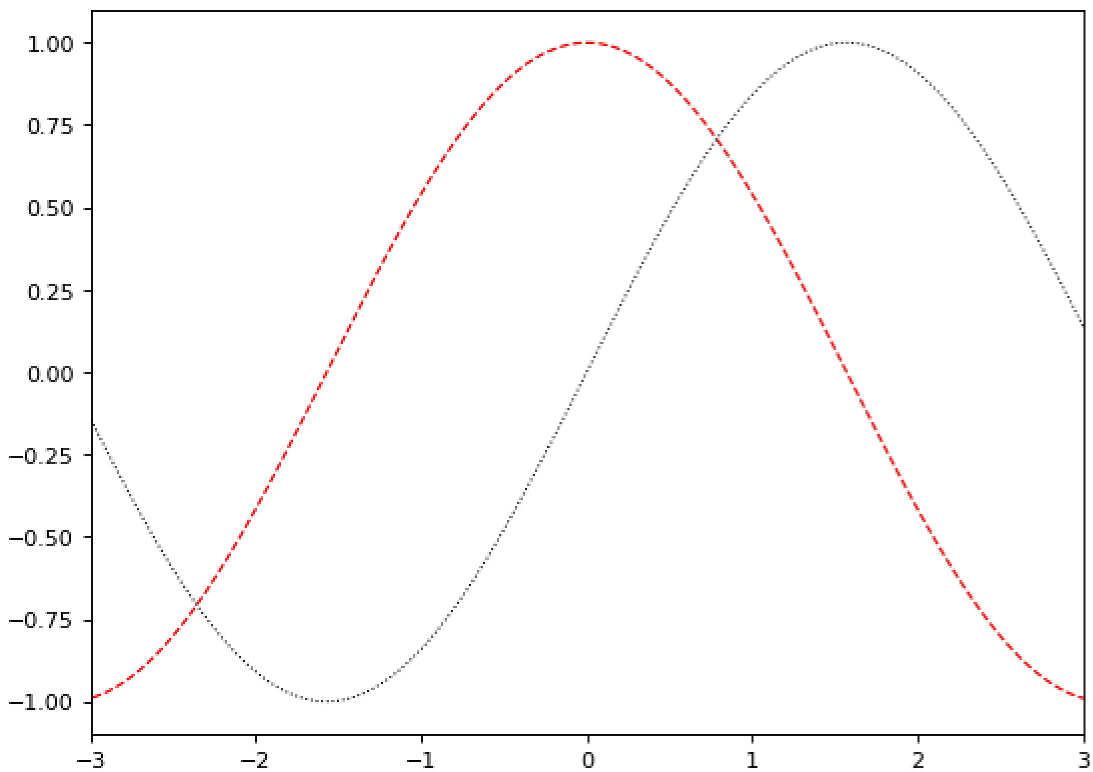


Line plots

We'll gradually build on the two lineplots created above, to customize them as much as possible.

In [2]:
```
# In order to manually select the size and resolution of the plot, we must define
plt.figure(figsize=(8, 6), dpi=80)  # Creates a figure of size 8x6 inches, 80 dot

# We can create our own axes if we like. This is not necessary here
plt.subplot(1, 1, 1)  # Create a single "subplot". More on how subplots are creat

plt.plot(x, c, color="red", linewidth=1.1, linestyle="--")   # Plot cosine with c
plt.plot(x, s, color="black", linewidth=0.9, linestyle=":")  # Plot sine with a b

plt.xlim(-3.0, 3.0)  # Limits the x-axis from -3 to +3
```

Out[2]: (-3.0, 3.0)



Lines have many different parameters; the most common of which are:

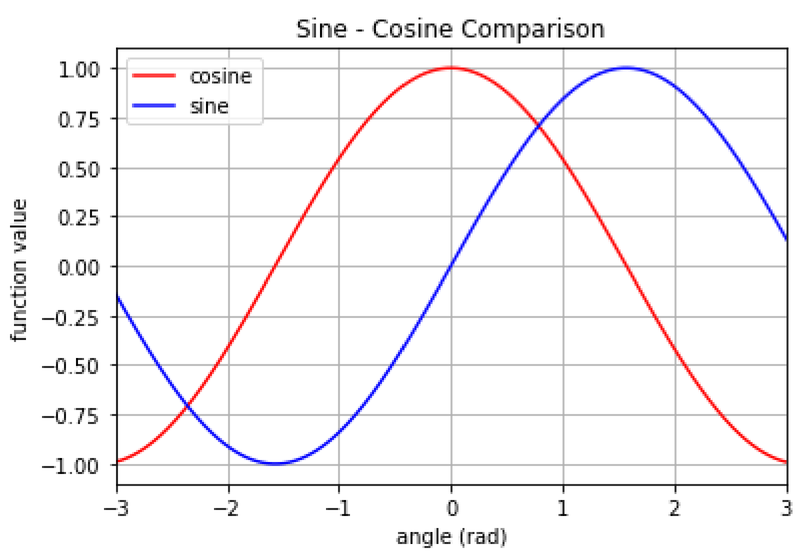
- `color` or `c` , which specifies the **color** each line will have. You can find all available methods of specifying colors [here (https://matplotlib.org/users/colors.html)](https://matplotlib.org/users/colors.html).
- `linewidth` or `lw` , a float value specifying the **width** of the line.
- `linestyle` or `ls` , if we want to change the **style** of the line, from a solid one to something else. Available styles can be found here (https://matplotlib.org/api/_as_gen/matplotlib.lines.Line2D.html#matplotlib.lines.Line2D.set_linest
- `label` is a string that will represent the line if a **legend** is present.
- `alpha` , a float that regulates **transparency**.
- finally `zorder` controls the order with which the lines are drawn. Lines with a higher `zorder` are drawn last and appear on top of the rest.

A full list of parameters we can customize in lines can be found [here (https://matplotlib.org/api/_as_gen/matplotlib.lines.Line2D.html)](https://matplotlib.org/api/_as_gen/matplotlib.lines.Line2D.html).

Furthermore, we can modify the plot by adding a title, axis labels and a legend.

In [3]:
```python
plt.title('Sine - Cosine Comparison')  # adds a title to the plot

plt.xlabel('angle (rad)')  # x axis labels
plt.ylabel('function value')  # y axis labels

plt.grid()  # adds a grid to the plot

plt.xlim(-3.0, 3.0)  # set the limits again

# add a legend
plt.plot(x, c, color="r", label='cosine')
plt.plot(x, s, color="b", label='sine')
plt.legend(['cosine', 'sine'], loc=0)  # loc=0 means 'place it where you think it
# we also modified the lines again to default width/style
```

Out[3]: `<matplotlib.legend.Legend at 0x1dbb3cabef0>`



Scatter plots

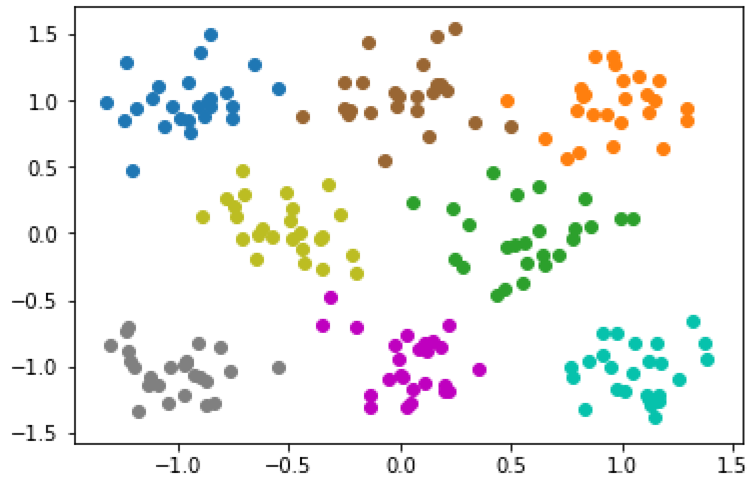
Scatter plots

Let's now discuss most important parameters with which we can customize scatterplots:

- `c` , which specifies the **color** each marker will have. The same colors (https://matplotlib.org/users/colors.html) are available for markers as were for lines. Another option we have is coloring **each point with a different color**. This can be accomplished by providing a sequence (with the same length as the number of points) of valid colors to this parameter. One final option we have is passing a sequence of floats; in this case each marker gets assigned a color from a **colormap**. More on this later.
- `s` is a number denoting the **size** of the markers. Like with colors, we also have the option of selecting a different size for each marker
- `marker` designates the type of the markers to be scattered. A list of valid markers can be found here (https://matplotlib.org/api/markers_api.html#module-matplotlib.markers).
- `alpha` , like before, regulates **transparency**.
- `linewidths` and `edgecolors` control the markers' edges. `edgecolors` can either be set to `'face'` (the same color as the marker), `'none'` (no line at all) or a valid matplotlib color.
- Finally `vmin` , `vmax` and `cmap` can be used if we want to pass a sequence of floats as the colors (`c`) of the markers. We'll examine this in an example later.

In [5]:
```
# First, we'll generate eight groups of random points

# (x,y) values of group 1
x1 = np.random.normal(-1, 0.2, 25)
y1 = np.random.normal(1, 0.2, 25)

# (x,y) values of group 2
x2 = np.random.normal(0, 0.2, 25)
y2 = np.random.normal(1, 0.2, 25)

# (x,y) values of group 3
x3 = np.random.normal(1, 0.2, 25)
y3 = np.random.normal(1, 0.2, 25)

# (x,y) values of group 4
x4 = np.random.normal(-1, 0.2, 25)
y4 = np.random.normal(-1, 0.2, 25)

# (x,y) values of group 5
x5 = np.random.normal(0, 0.2, 25)
y5 = np.random.normal(-1, 0.2, 25)

# (x,y) values of group 6
x6 = np.random.normal(1, 0.2, 25)
y6 = np.random.normal(-1, 0.2, 25)

# (x,y) values of group 7
x7 = np.random.normal(-0.5, 0.2, 25)
y7 = np.random.normal(0, 0.2, 25)

# (x,y) values of group 8
x8 = np.random.normal(0.5, 0.2, 25)
y8 = np.random.normal(0, 0.2, 25)

# Now, we'll plot them on a scatterplot, using a separate color scheme for each:
plt.scatter(x1, y1)                         # (no 'c' parameter) matplotlib default
plt.scatter(x2, y2, c=(0.6, 0.4, 0.2))     # a tuple of RGB float values
plt.scatter(x3, y3, c='#ff7f0e')           # an RGB hex string
plt.scatter(x4, y4, c='0.5')               # a string of a float designating gray l
plt.scatter(x5, y5, c='m')                 # one of the default colors m -> magenta
plt.scatter(x6, y6, c='xkcd:turquoise')    # name from the xkcd color survay
plt.scatter(x7, y7, c='C8')                # 9th color (count starts from 0) from c
plt.scatter(x8, y8, c='tab:green')         # one of Tableau's default colors
```

Out[5]:
```
<matplotlib.collections.PathCollection at 0x1dbb3d414a8>
```

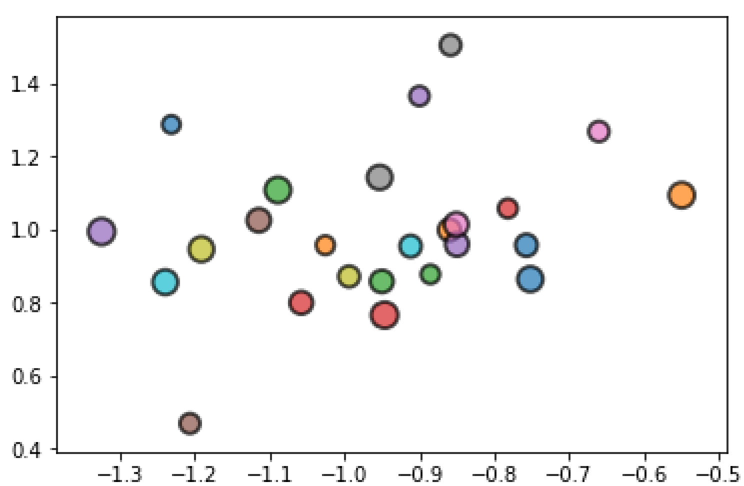


As stated previously, we can select a different color for each point by passing a sequence of colors to the `c` parameter. We'll also try making each of the markers have a different size.

In [6]:
```
# Create a list of 25 different colors
colors = ['C' + str(x) for x in range(10)] * 2
colors += colors[:5]
print('List of colors:\n', colors)

assert len(x1) == len(colors)  # sequence colors NEEDS to have the same length as

# Sequence of sizes
sizes = range(80, 181, 4)

# Draw the points with the desired colors and sizes, while being semi-transparent
plt.scatter(x1, y1, c=colors, s=sizes, edgecolors='black', linewidths=2, alpha=0.
```

```
List of colors:
 ['C0', 'C1', 'C2', 'C3', 'C4', 'C5', 'C6', 'C7', 'C8', 'C9', 'C0', 'C1', 'C2',
'C3', 'C4', 'C5', 'C6', 'C7', 'C8', 'C9', 'C0', 'C1', 'C2', 'C3', 'C4']
```

Out[6]: `<matplotlib.collections.PathCollection at 0x1dbb4d5c898>`

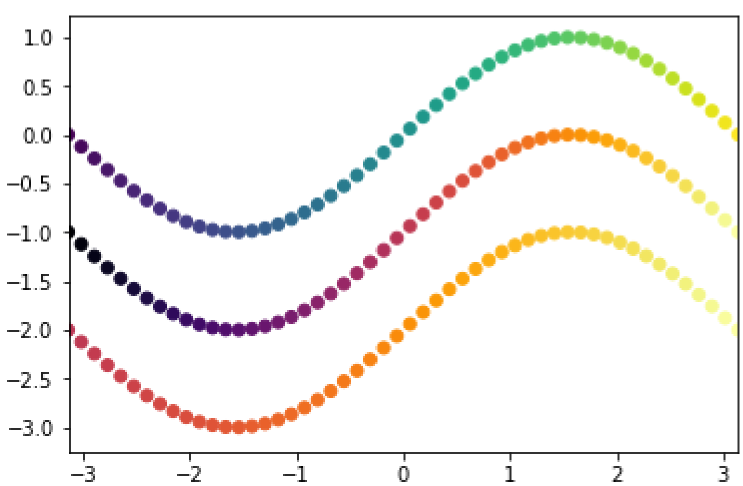


The third way of coloring markers involves a **colormap** (a continuous sprectrum of colors).

To use this we need to pass a **sequence of floats** to the parameter `c`. Each float specifies the color that will be drawn from the colormap. Two parameters (`vmin` and `vmax`) control what numbers will correspond to the edges of the colormap, while the colormap itself can be specified through the `cmap` parameter. A list of available colormaps in matplotlib can be found [here (https://matplotlib.org/examples/color/colormaps_reference.html)](https://matplotlib.org/examples/color/colormaps_reference.html), while a discussion on their properties can be found [here (https://matplotlib.org/users/colormaps.html)](https://matplotlib.org/users/colormaps.html).

In [7]:
```
# Create an array of floats from 0 to 1 to be passed to the parameter 'c'
colors = np.linspace(0, 1, len(x[::5]))

# Limit the x-axis to the range [-pi, +pi]
plt.xlim([-np.pi, np.pi])

# Draw the plots
plt.scatter(x[::5], s[::5], c=colors)  # The first plot is using the default colc
                                       # When not vmin/vmax values are not specif
                                       # values from the sequence to so that the
plt.scatter(x[::5], s[::5]-1, c=colors, cmap='inferno')  # Change colormap to 'ir
plt.scatter(x[::5], s[::5]-2, c=colors, cmap='inferno', vmin=-1, vmax=1)  # Assig
                                                                          # color
```

Out[7]:
```
<matplotlib.collections.PathCollection at 0x1dbb4dbc320>
```



Subplots and axes objects

Subplots are a way of putting more than one figures in the same plot. Imagine it as a grid (or an array) of graphs. In order to create a subplot we need to specify three things:

array) of graphs. In order to create a subplot we need to specify three things:

- The number of **rows**, or how many subplots we want to split the image to on the vertical axis.
- The number of **columns**, or the number of subplots on the vertical axis.
- The **index** of the current subplot.

These can be either given as a 3-digit number or 3 single digit arguments.

```
ax = plt.subplot(234)      # these two are
ax = plt.subplot(2, 3, 4)  # the same thing
```

The above would create a grid of 2-by-3 and place the subplot in the 4th spot:

$$\begin{pmatrix} 1 & 2 & 3 \\ \mathbf{4} & 5 & 6 \end{pmatrix}$$

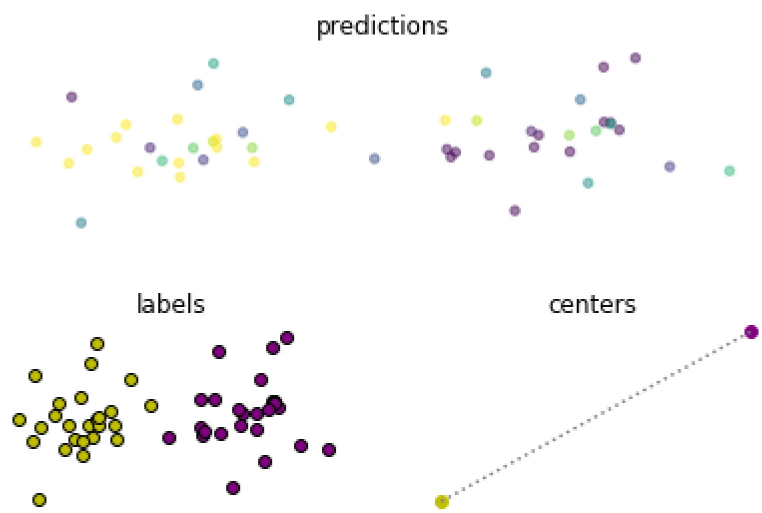
Some examples:

```
subplot(111)  # means the subplot covers the whole figure

# we split the figure in two (horizontally):
subplot(121)  # left subplot
subplot(122)  # right subplot

# again, we split it in two (vertically):
subplot(211)  # top subplot
subplot(212)  # bottom subplot

# now, we split it in four:
subplot(221)  # top left subplot
subplot(222)  # top right subplot
subplot(223)  # bottom left subplot
subplot(224)  # bottom right subplot
```

The `subplot` function is a conveinent way to create an **axes** object. Even when we have just 1 subplot in our figure we might want to use `subplot(111)` just to gain access to the axes.

A list of the full functionality of the axes object can be found here (https://matplotlib.org/api/axes_api.html); it is a lot (most of pyplot's functionality falls under this object)!

In [9]:
```
# Create 3 subplots
ax1 = plt.subplot(211)  # we have one subplot in the first row
ax2 = plt.subplot(223)  # and two in the second row
ax3 = plt.subplot(224)

# First subplot: Scatter two groups with colors from a colormap. Each group will
ax1.scatter(x1, y1, c=np.linspace(-1, 1, len(x1)), vmin=-1, vmax=0, s=20, alpha=0
ax1.scatter(x2, y2, c=np.linspace(-1, 1, len(x2)), vmin=0, vmax=1, s=20, alpha=0.
ax1.axis('off')  # this is a neat way of completely removing the axis (spines, ti
ax1.set_title('predictions')

# Second subplot: Scatter same groups but with constant colors
ax2.scatter(x1,  y1, c='y', edgecolor='black')
ax2.scatter(x2, y2, c='purple', edgecolor='black')
ax2.axis('off')
ax2.set_title('labels')

# Third subplot: Scatter the centers of each group and draw a line between them
x1m = sum(x1)/len(x1)
y1m = sum(x1)/len(x1)
x2m = sum(x2)/len(x2)
y2m = sum(y2)/len(y2)

ax3.scatter([x1m,], [y1m,], c='y')
ax3.scatter([x2m,], [y2m,], c='purple')
ax3.plot([x1m, x2m], [y1m, y2m], ls=':', c='0.5')  # draw dashed line from the fi
ax3.axis('off')
ax3.set_title('centers')

plt.tight_layout()
```



A couple things to comment on the figure above:

1. The `axes.axis('off')` command is an easy way of **removing the axis** from a subplot. This however might have the undesired effect of removing all elements belonging to it. Namely, the spines, the ticks, the tick labels and the axis labels. If you want to have some of these elements to be visible, the `axes.axis('off')` command isn't very useful.
2. The final command `plt.tight_layout()` is an **very convenient** way of ensuring that elements of one subplot don't fall onto another (e.g. the x-axis lavel of a subplot falling on the title of the subplot below it). `plt.tight_layout()` makes sure each element has the appropriate space. A guide on how to use the tight layout can be found [here (https://matplotlib.org/users/tight_layout_guide.html)](https://matplotlib.org/users/tight_layout_guide.html).

There is a secondary syntax to create subplots in matplotlib (i.e. [plt.subplots(rows, cols) (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplots.html)](https://matplotlib.org/api/_as_gen/matplotlib.pyplot.subplots.html)):

```
fig, ax = plt.subplots(2, 3)  # creates 6 subplots in a 2-by-3 grid
                              # fig is the handle of the plot's figure
                              # ax is an array containing the 6 axes
```

This created an array of 6 subplots aranged like below:

$$\begin{pmatrix} 1 & 2 & 3 \\ \mathbf{4} & 5 & 6 \end{pmatrix}$$

With this syntax we have an actual array (like the one above) with the `axes` objects of the corresponding subplot. To draw on the 4th (bottom left) subplot:

```
ax[1, 0].plot(x, y)  # draw on the first subplot of the second row
```

Bar plots

Barplots are a way of visualizing the relationship of a **categorical** variable with a **continuous** one. Barplots can be drawn through [`plt.bar` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.bar.html)](https://matplotlib.org/api/_as_gen/matplotlib.pyplot.bar.html). There are two main parameters to create a bar plot:

- A sequence of the categories we want to plot or their desired positions (`x`).
- The height of each bar (`height`).

```
plt.bar(x, height)
```

Other parameters include:

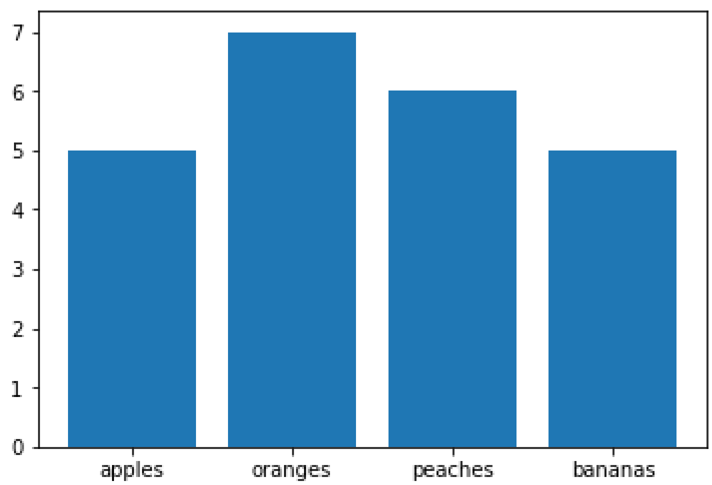
- `bottom` chooses the height from which the bars start. Used for stacked barplots.

- `width` regulates the *width* of the bars.
- `align` allows us to select the *alignment* of the bars. Default is `'center'`; align left with `'edge'`; align right with the same, but by passing a negative `width`.
- `color`, `edgecolor`, `linewidth` all have a similar behavior to what we saw previously.

If we want a horizontal barplot use [`plt.barh` (https://matplotlib.org/api/_as_gen/matplotlib.pyplot.barh.html#matplotlib.pyplot.barh)](https://matplotlib.org/api/_as_gen/matplotlib.pyplot.barh.html#matplotlib.pyplot.barh) instead.

In [11]:
```
categories = ['apples', 'oranges', 'peaches', 'bananas']
heights = [5, 7, 6, 5]

plt.bar(categories, heights)
```

Out[11]: `<BarContainer object of 4 artists>`

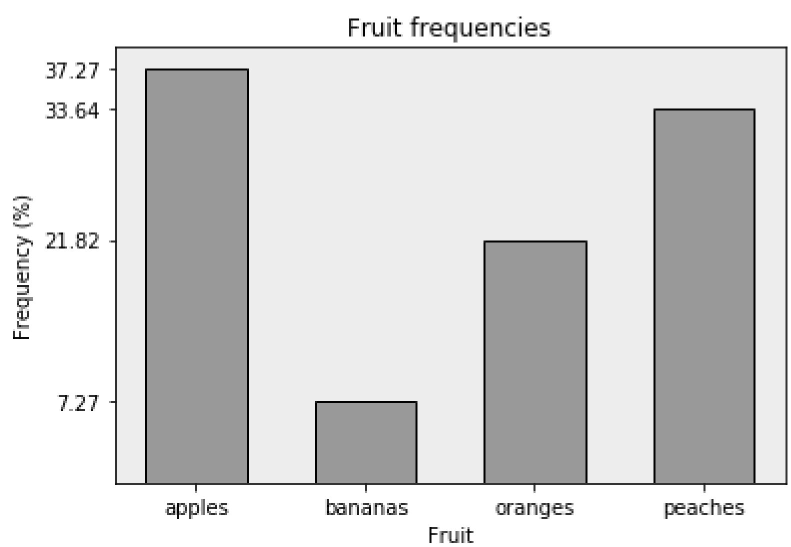


Barplots can also be drawn on an `axes` object.

An example would be having a list containing lots of the fruits above and wanting to plot their frequencies in a barplot.

In [12]:
```
np.random.seed(13)

# Data to draw from
data = ['apples']  * np.random.randint(100) + ['oranges'] * np.random.randint(10
       ['peaches'] * np.random.randint(100) + ['bananas'] * np.random.randint(10

# Find unique categories and their total number of counts
categories, heights = np.unique(data, return_counts=True)

# Create an axes object
ax = plt.subplot(111)

# Draw the bar plot
ax.bar(categories, heights * 100 / heights.sum(), color='0.6', width=0.6, edgecol

# Tint the background gray
ax.set_facecolor('0.93')

# Set custom ticks on the y-axis
ax.set_yticks(sorted(heights * 100 / heights.sum()))

# Set a title and axis labels
ax.set_title('Fruit frequencies')
ax.set_xlabel('Fruit')
ax.set_ylabel('Frequency (%)')
```

Out[12]: Text(0,0.5,'Frequency (%)')



Pie charts

> **Warning!** Before using a pie chart make sure it is really necessary. Even though pie charts are one of the most popular plots, most times the information that they convay is better described in a barplot. The limitations of pie charts are discussed [here (https://www.businessinsider.com.au/pie-charts-are-the-worst-2013-6#buSPkKhseDbRJ90s.99)](https://www.businessinsider.com.au/pie-charts-are-the-worst-2013-6#buSPkKhseDbRJ90s.99).
>
> Pie charts aren't meant to be used to compare categories amongst each other, but to visualize what percentage each category occupies of the whole population. For instance, in the previous example, if you want to see how many apples there are compared to peaches you should use a barplot; if you want to illustrate the percentage of apples compared to the whole set of fruits, use a pie chart. Other examples include visualizing market shares, election/poll results, etc.

Matplotlib supports pie charts through [plt.pie (https://matplotlib.org/1.2.1/api/pyplot_api.html?highlight=pie#matplotlib.pyplot.pie)](https://matplotlib.org/1.2.1/api/pyplot_api.html?highlight=pie#matplotlib.pyplot.pie). They can be drawn with only one argument, a list containing the **size** of each slice.

```
plt.pie(sizes)
```

Other parameters include:

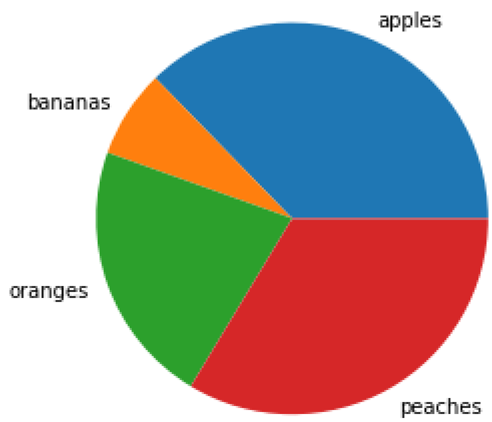
- `labels` accepts a sequence of classes and adds them as *labels* next to each slice.
- `explode` parameter can *detatch* one or more slices from the pie.
- `shadow` draws a shadow if set to `True` .
- `startangle` offsets the starting point of the pie chart by the specified angle.
- `autopct` is used to label the slices by the percentage of each. It is drawn on the inside of each slice. If the argument is a format string, the label will be `'fmt%pct'` .

In matplotlib the piechart slices are objects called [**wedges** (https://matplotlib.org/api/_as_gen/matplotlib.patches.Wedge.html)](https://matplotlib.org/api/_as_gen/matplotlib.patches.Wedge.html).

One thing we might want to do when drawing pie charts in matplotlib is to make the unit length of both axes equal. This will cause the pie chart to be a **perfect circle**. This can be done through [`axes.axis('equal')` (https://matplotlib.org/gallery/subplots_axes_and_figures/axis_equal_demo.html)](https://matplotlib.org/gallery/subplots_axes_and_figures/axis_equal_demo.html).

In [13]:
```
ax = plt.subplot(111)
ax.pie(heights, labels=categories)  # pie charts can also be drawn from axes obje
ax.axis('equal')  # make the axes have an equal aspect ratio
```

Out[13]:
```
(-1.120336493112345,
 1.1009684131211968,
 -1.1035036063812522,
 1.1201713704546403)
```



Other useful functions

Here we'll see a few more matplotlib functions that can be of use:

Text

We can add a text box to arbitrary locations in a plot through `plt.text` (https://matplotlib.org/api/text_api.html).

```
plt.text(x, y, text)
```

Two parameters are actually necessary here:

- the coordinates where the string should be placed, `x` and `y` and
- the actual string, `text` .

Optional parameters include:

- the color of the text, `color`
- the background color of the text box, `backgroundcolor`
- `alpha` , which regulates transparency
- `rotation` is used to rotate the tect

Arrow

Arrows are types of patches that can be placed in figures. They can be created through

```
plt.arrow(x, y, dx, dy)
```

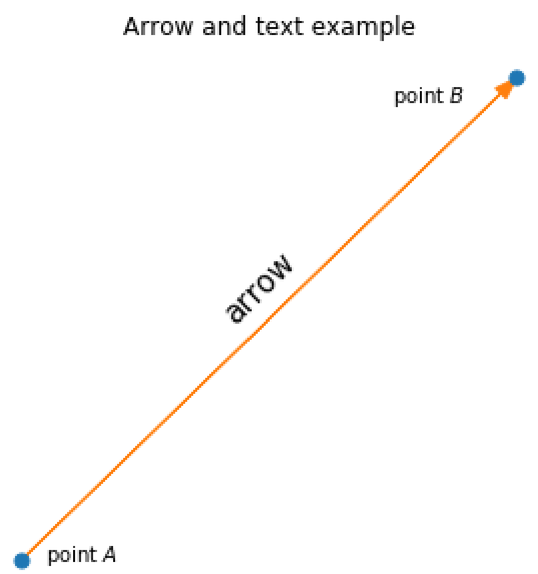
where

- `x` , `y` are the starting coordinates (x, y).
- `dx` , `dy` is the arrow's displacement on the x and y axes correspondingly.

The rest are optional properties of the arrow (e.g. `width` , `head_width` , `head_length`). They can be found here (matplotlib.axes.Axes.arrow).

In [15]:
```
# Create an axes a figure object
f, ax = plt.subplots(1, figsize=(5, 5))

# Scatter the points (0, 0) and (1, 1)
ax.scatter([0, 1], [0, 1], s=50)

# Create an arrow that connects the two
ax.arrow(0, 0, 1, 1, length_includes_head=True, head_width=0.03, color='#ff7f0e',

# Add three text patches to the plot
ax.text(0.4, 0.6, 'arrow', rotation=45, size=15)
ax.text(0.05, 0, 'point $A$')
ax.text(0.75, 0.95, 'point $B$')

# Add a title to the plot
ax.set_title('Arrow and text example')

# Remove the two axes
ax.axis('off')
```

Out[15]:
```
(-0.06393938099113264,
 1.0639393809911326,
 -0.06430863611672558,
 1.0643086361167255)
```



Styles

There is a number of pre-defined figure styles probided by matplotlib. To select a valid style, you can use:

```
plt.style.use('style_name')
```

To see a list of available styles type:

```
print(plt.style.available)
```

Final remarks

A nice guide on the advanced features of matplotlib can be found here (https://python4mpia.github.io/plotting/advanced.html). While we convered most of the stuff in it, there are a few things we left out (like how to change some of matplotlib's default parameters, named rc parameters (https://python4mpia.github.io/plotting/advanced.html#rc-parameters)).

Finally, you can get lots of ideas for plots in the matplotlib gallery (https://matplotlib.org/gallery.html). Each figure is accompanied by the code that produced it. Be sure to check it out!

This tutorial covered the most popular data visualization tools in python. However, making attractive figures has much more to do than just knowing a couple of libraries. While *figure attractiveness* is quite subjective, there are a few steps you could take to make them better looking.

Tips

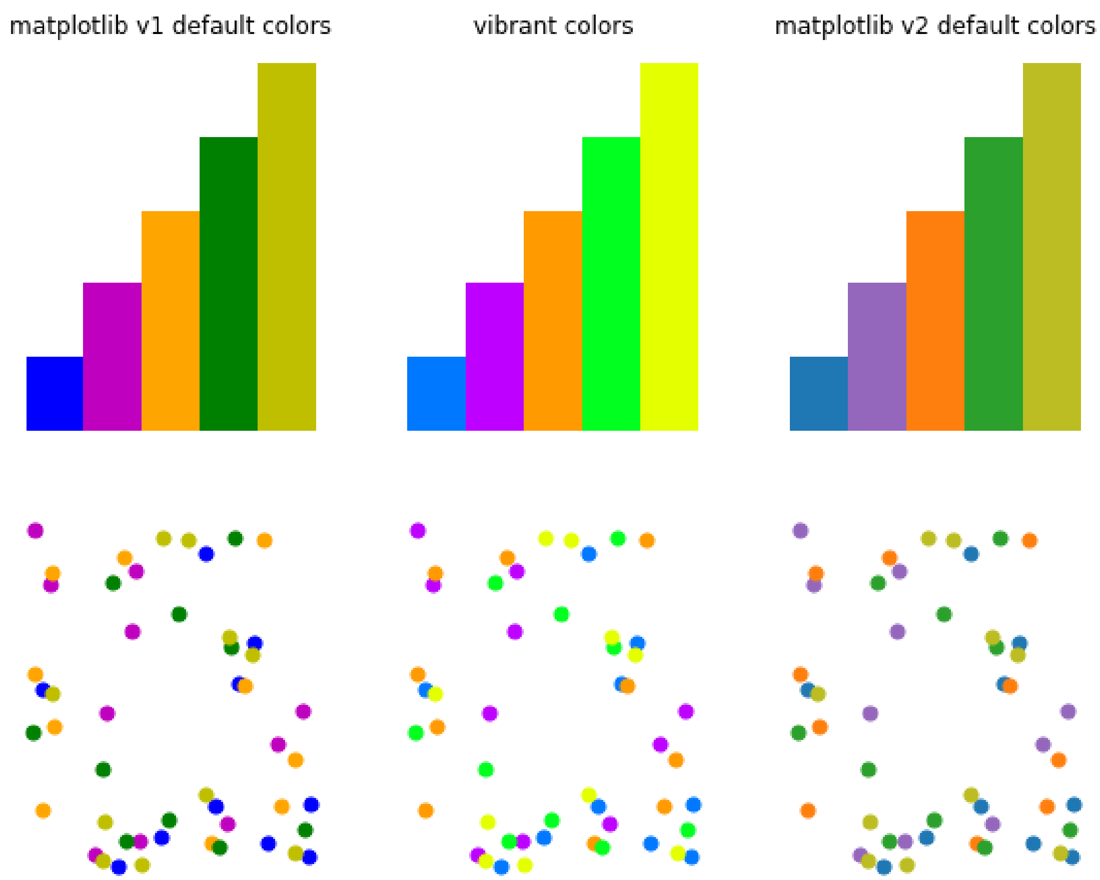
The most important tips are to rid your figures of chartjuck (https://en.wikipedia.org/wiki/Chartjunk) (yes, that's actually a term!), remove any **redundant information** (excess lines, borders, labels, etc.) and try to make the colors easier on the eye.

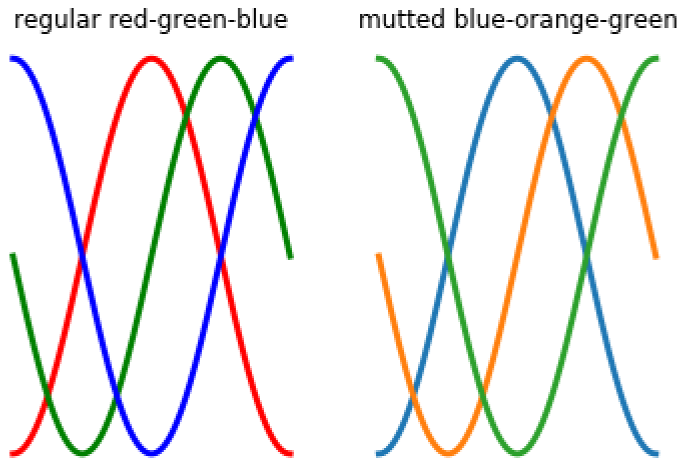
For the last, you should avoid *pure* RGB colors (e.g. $(0, 0, 255)$ for blue), vibrant colors and very opposite RGB colors (https://upload.wikimedia.org/wikipedia/commons/a/af/RGB_scheme_contrast_of_complementary_co
Instead try selecting **muted colors**. Matplotlib's default colors (https://matplotlib.org/users/dflt_style_changes.html#colors-color-cycles-and-color-maps) are an excellent example.

Below is a comparison of three different color schemes: matplotlib's original colors, a more vibrant set of colors and matplotlib's current color scheme. We'll also compare how a red-green colored plot looks compared to a blue-orange one (which is also good for colorblind).

In [16]:
```
# Regular colors (matplotlib v1 defaults):
rgb_colors = ['b', 'm', 'orange', 'g', 'y']

# Vibrant color scheme:
vibrant_colors = ['#0078ff', '#bd00ff', '#ff9a00', '#01ff1f', '#e3ff00']
# equivalent RGB colors: [(0, 120, 255), (189, 0, 255), (255, 154, 0), (1, 255, 3

# Mutted color scheme (matplotlib v2 defaults):
mutted_colors = ['#1f77b4', '#9467bd', '#ff7f0e', '#2ca02c', '#bcbd22']

# Define bins and their heights for the barplots
labels = range(5)
heights = range(1, 6)

# Create a figure which will be used for comparing the different color schemes
plt.figure(figsize=(10, 8))

# First barplot: regular colors
ax = plt.subplot(231)
ax.bar(labels, heights, width=1, color=rgb_colors)
ax.axis('off')
ax.set_title('matplotlib v1 default colors')

# Second barplot: vibrant colors
ax = plt.subplot(232)
ax.bar(labels, heights, width=1, color=vibrant_colors)
ax.axis('off')
ax.set_title('vibrant colors')

# Third barplot: mutted colors
ax = plt.subplot(233)
ax.bar(labels, heights, width=1, color=mutted_colors)
ax.axis('off')
ax.set_title("matplotlib v2 default colors")

# Now, we'll do the same thing with scatterplots

# Create 5 groups of 10 points each in the same range
x1, x2, x3, x4, x5 = [np.random.random(10) for _ in range(5)]
y1, y2, y3, y4, y5 = [np.random.random(10) for _ in range(5)]
xs = [x1, x2, x3, x4, x5]
ys = [y1, y2, y3, y4, y5]

# First scatterplot: regular colors
ax = plt.subplot(234)
for i in range(5):
    ax.scatter(xs[i], ys[i], c=rgb_colors[i], s=50)
ax.axis('off')

# Second scatterplot: vibrant colors
ax = plt.subplot(235)
for i in range(5):
    ax.scatter(xs[i], ys[i], c=vibrant_colors[i], s=50)
ax.axis('off')

# Third scatterplot: mutted colors
```

```
ax = plt.subplot(236)
for i in range(5):
    ax.scatter(xs[i], ys[i], c=mutted_colors[i], s=50)
ax.axis('off')

# Draw the figure so that we can create a new one
plt.show()

# Create a new figure
plt.figsize=(10, 4)

# First plot: regular colors (matplotlib v1 defaults)
ax = plt.subplot(121)
ax.plot(x, c, color='r', lw=3)
ax.plot(x, s, color='g', lw=3)
ax.plot(x, -c, color='b', lw=3)
ax.set_title('regular red-green-blue')
ax.axis('off')

# First plot: regular colors (matplotlib v2 defaults)
ax = plt.subplot(122)
ax.plot(x, c,  color=mutted_colors[0], lw=3)
ax.plot(x, s,  color=mutted_colors[2], lw=3)
ax.plot(x, -c, color=mutted_colors[3], lw=3)
ax.set_title('mutted blue-orange-green')
ax.axis('off')

print()
```




regular red-green-blue
mutted blue-orange-green