Matplotlib

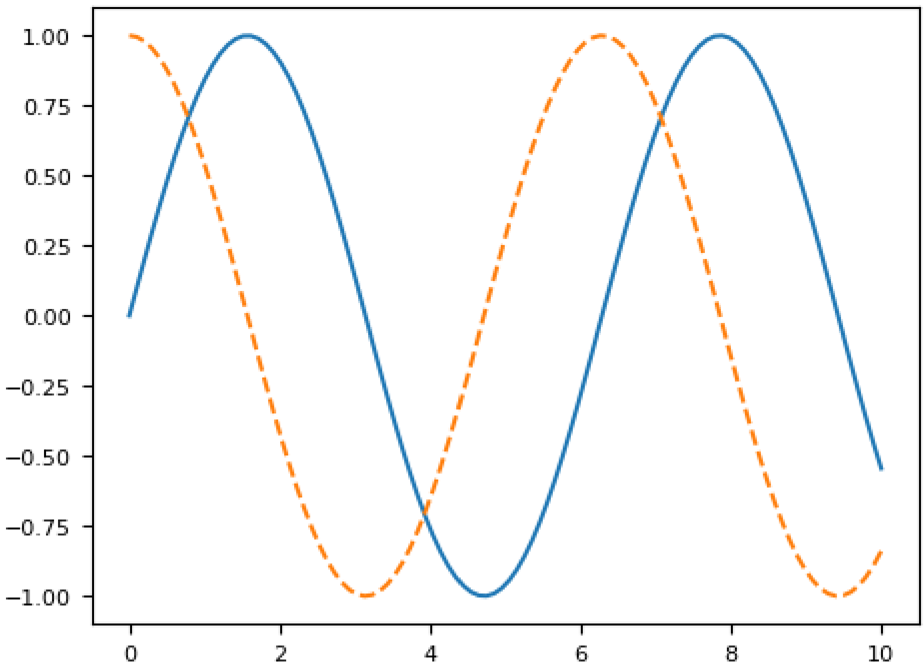
- Jake VanderPlas. 2016. *Python Data Science Handbook: Essential Tools for Working with Data*. O'Reilly Media, Inc.
- Chapter 4 - Visualization with Matplotlib
- https://github.com/jakevdp/PythonDataScienceHandbook
- **NOTE:** many code-examples are deprecated

Matplotlib provides:

- Easy and customizable type of plots (line, scatter, bars, histogram, contour, 3D...)
- Integration with NumPy and Pandas
- Extensible rendering using third-party libraries (Seaborn or Plotly)
- Different output formats
  - Static (`%matplotlib inline`): PNG, JPG, SVG, PDF
  - Interactive (`%matplotlib notebook`): Qt, Tkinter and WebAgg backends

In [1]:
```
import matplotlib as mpl
import matplotlib.pyplot as plt
import seaborn as sns
import numpy as np
import pandas as pd

# Set the default figure size in inches (width, height)
mpl.rcParams['figure.figsize'] = (5.33,4)
# Set the default font sizes for axes ant tick labels in points
mpl.rcParams['axes.labelsize'] = 10  # Example: 14 points
mpl.rcParams['xtick.labelsize'] = 8  # Example: 12 points for x-axis ticks
mpl.rcParams['ytick.labelsize'] = 8  # Example: 12 points for y-axis ticks
```

In [2]:
```
x = np.linspace(0, 10, 100)
fig = plt.figure()
plt.plot(x, np.sin(x), '-')
plt.plot(x, np.cos(x), '--');
```

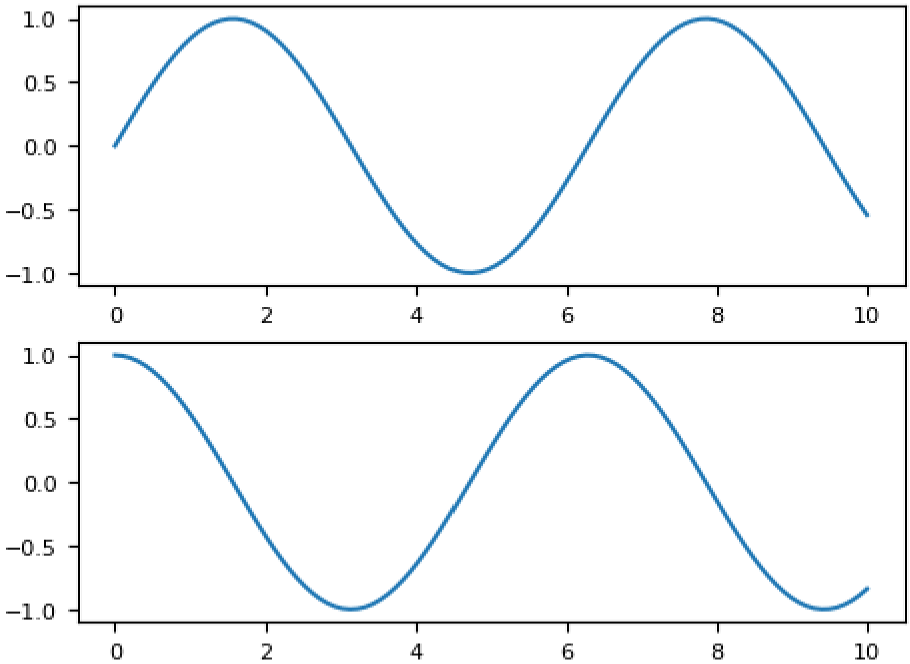


Dual Interface

- MATLAB-style Interface
  - Matplotlib: Python alternative for MATLAB
  - Use `plt` for almost everything
  - Convenient for simple plots
- Object-oriented interface
  - Create objects and call methods on them
  - More flexible

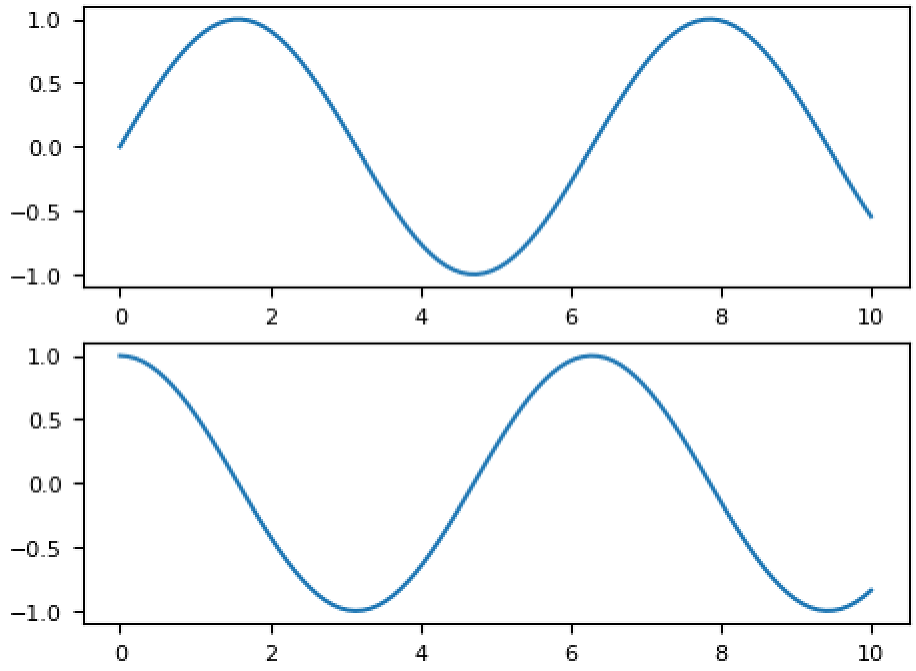
MATLAB-style Interface:

In [3]:
```
plt.figure()  # create a plot figure

# create the first of two panels and set current axis
plt.subplot(2, 1, 1) # (rows, columns, panel number)
plt.plot(x, np.sin(x))

# create the second panel and set current axis
plt.subplot(2, 1, 2)
plt.plot(x, np.cos(x));
```



Object-oriented Interface:

In [4]:
```
# First create a grid of plots
# ax will be an array of two Axes objects
fig, ax = plt.subplots(2,1)

# Call plot() method on the appropriate object
ax[0].plot(x, np.sin(x))
ax[1].plot(x, np.cos(x));
```

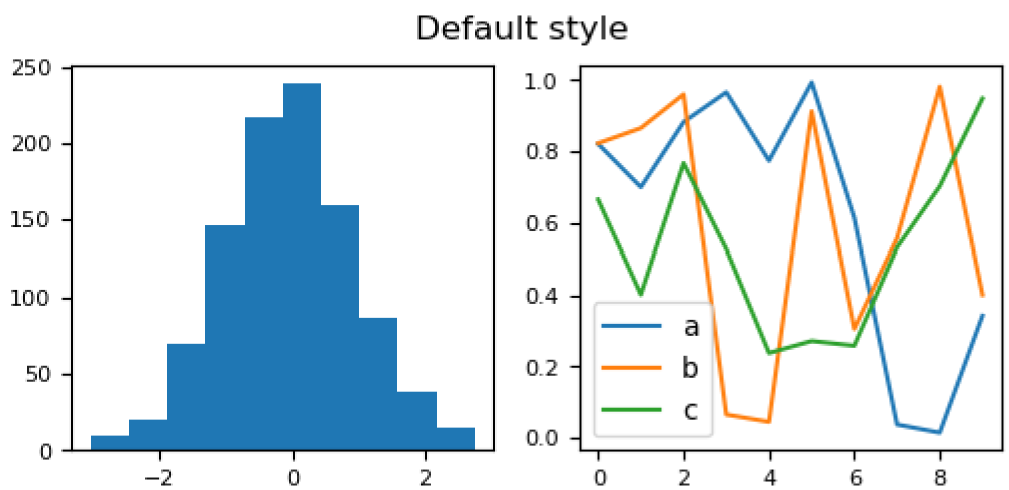


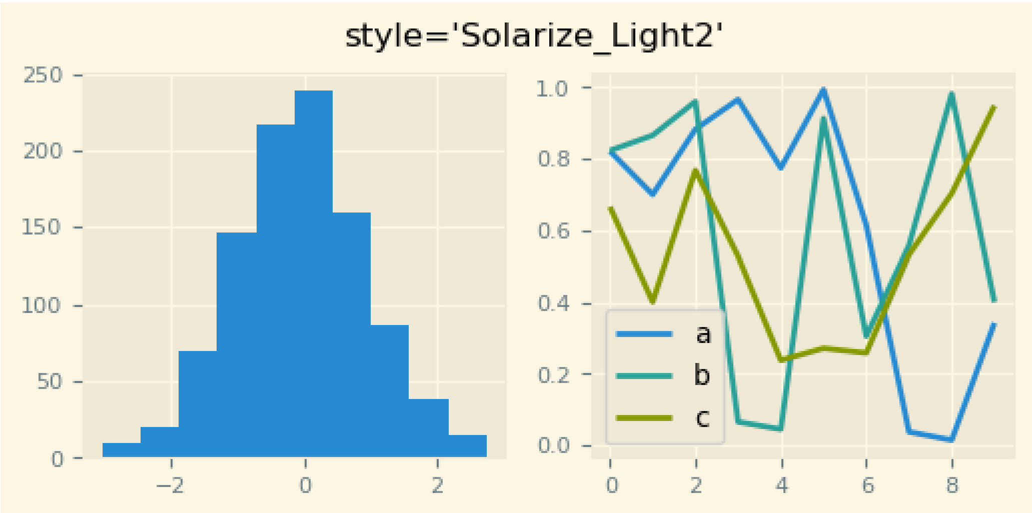
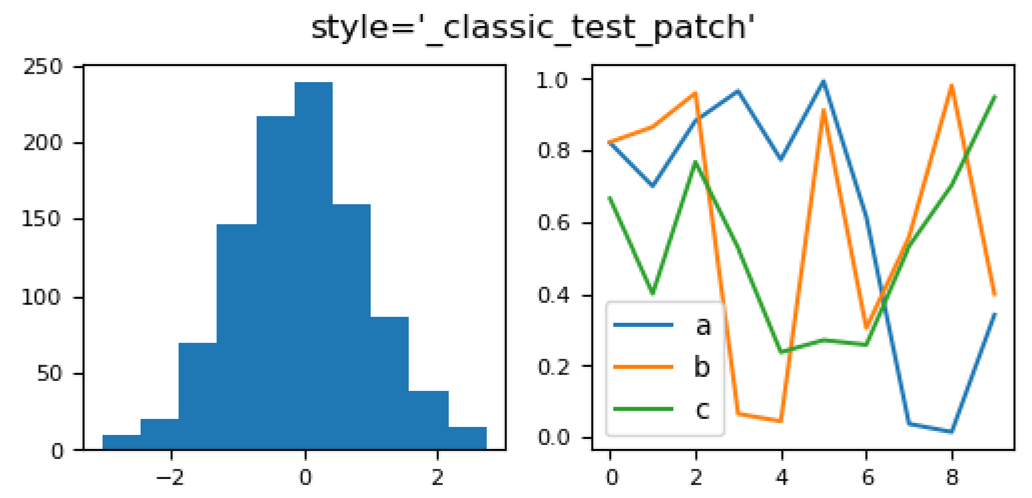
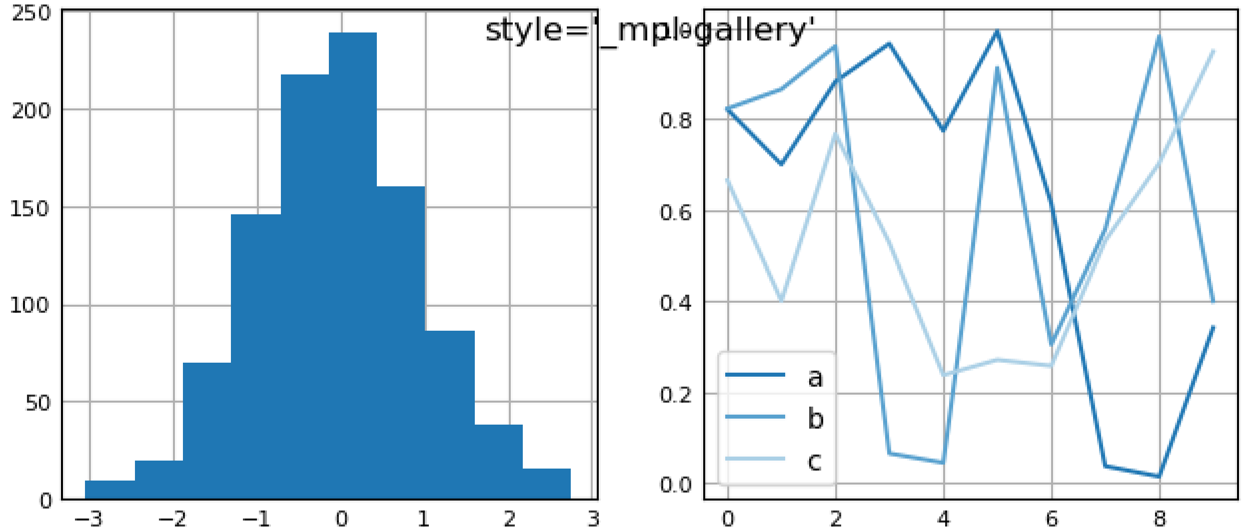
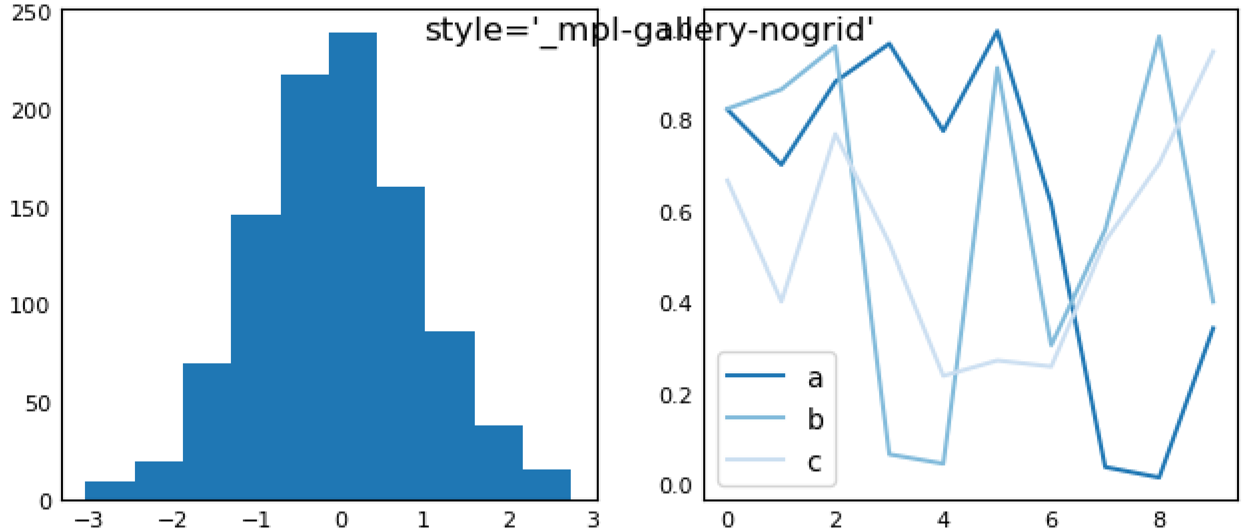
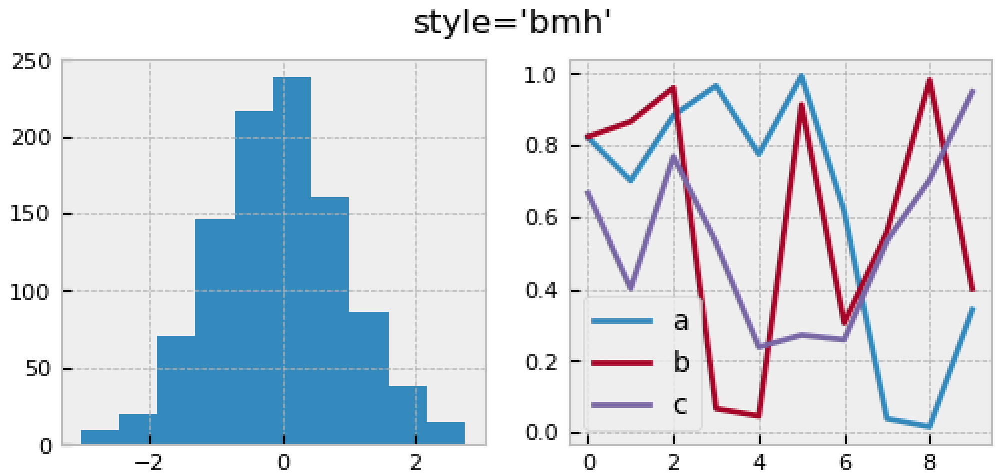
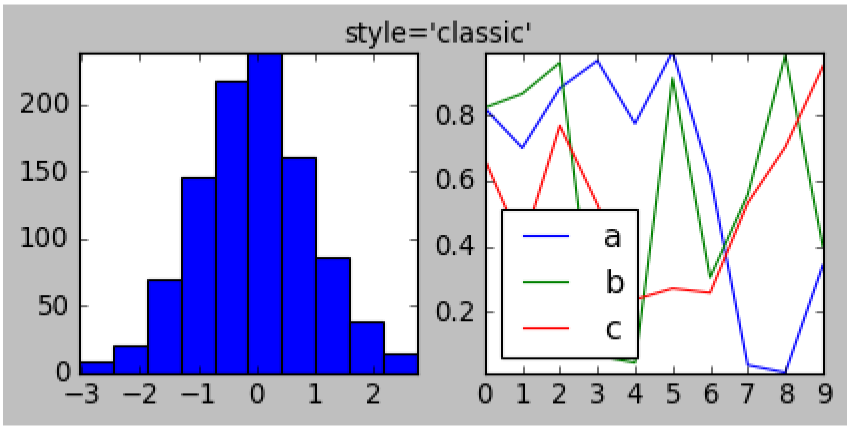
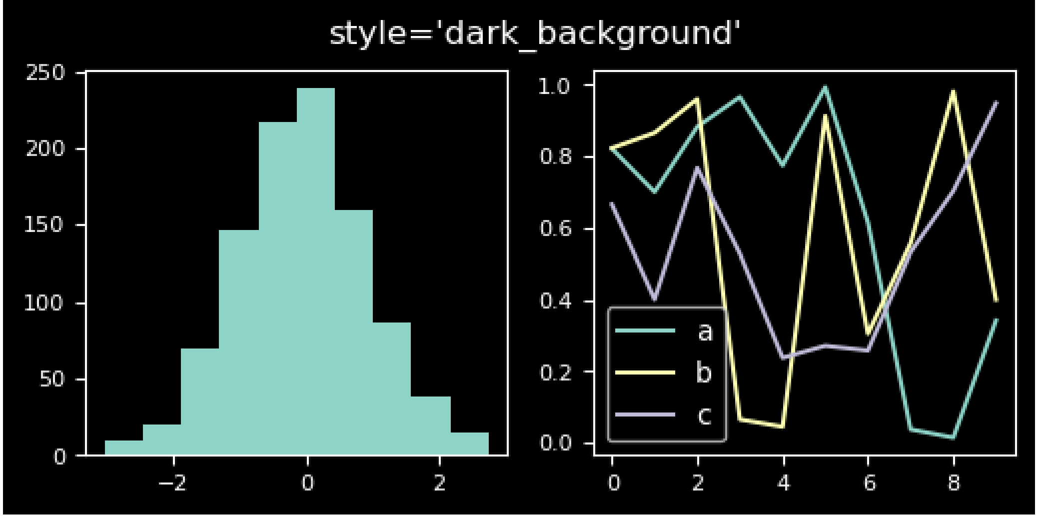
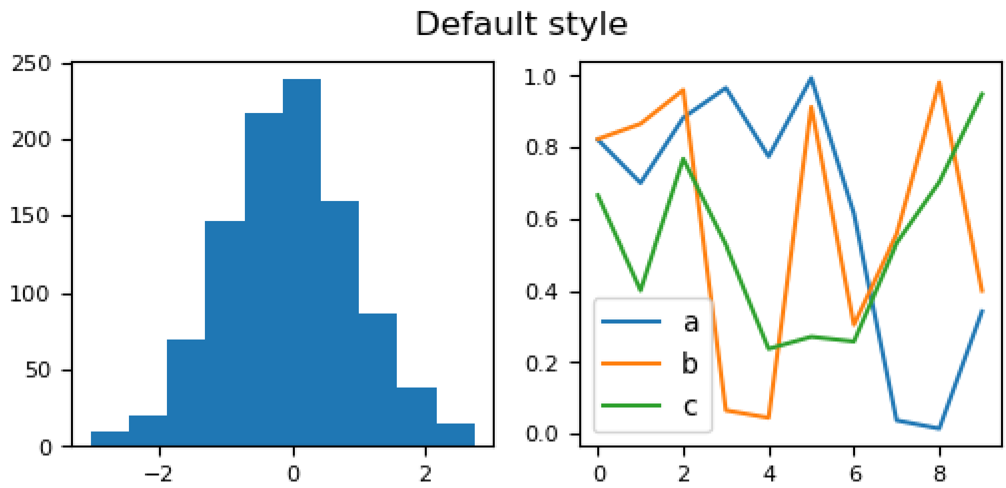
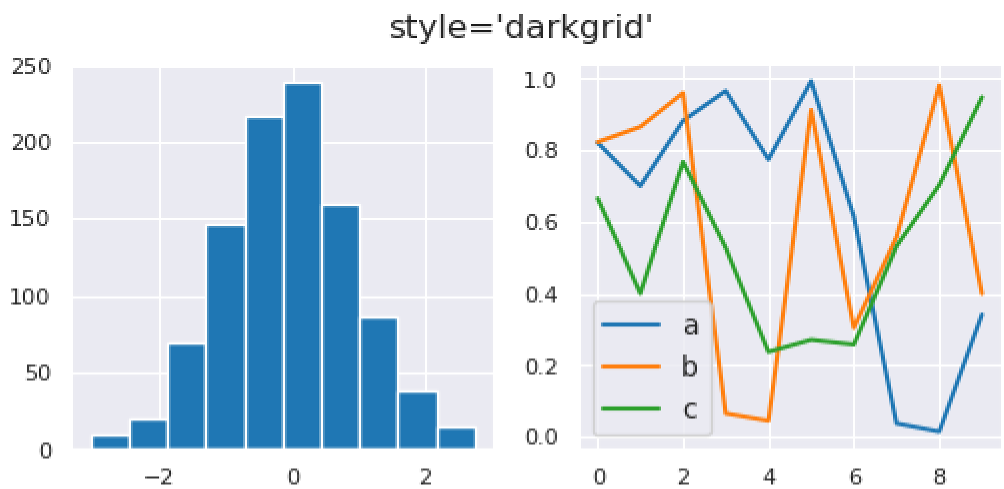
Styles

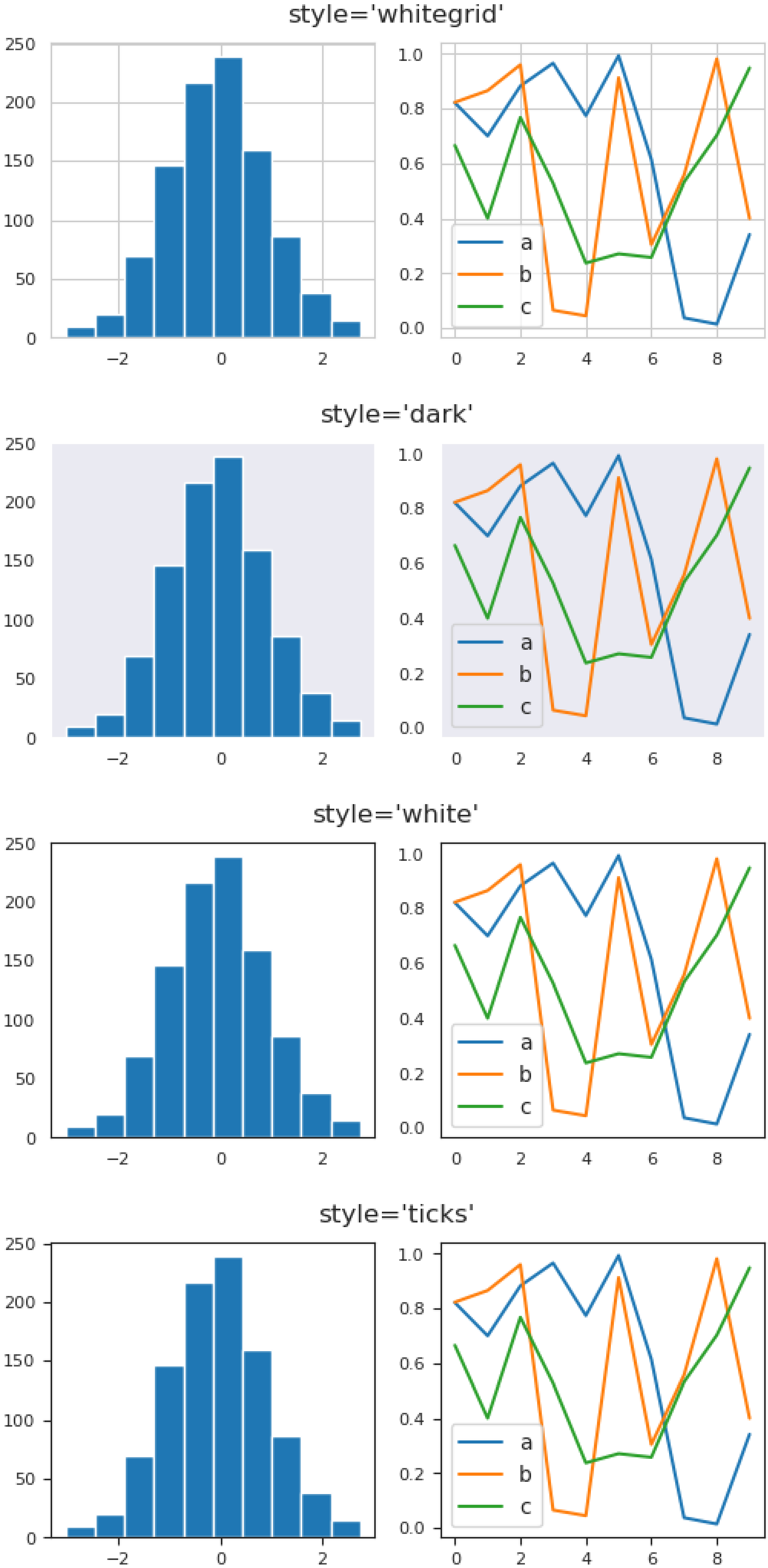
- Predefined collection of visual attributes
- `plt.style.library` → available styles an their parameters
  - `plt.style.available` == `sorted(plt.style.library.keys())`
- `plt.style.use('stylename')` → set global style
  - Use context manager to chancge the style locallY:
  - ```
    with plt.style.context('stylename'):
        make_a_plot()
    ```

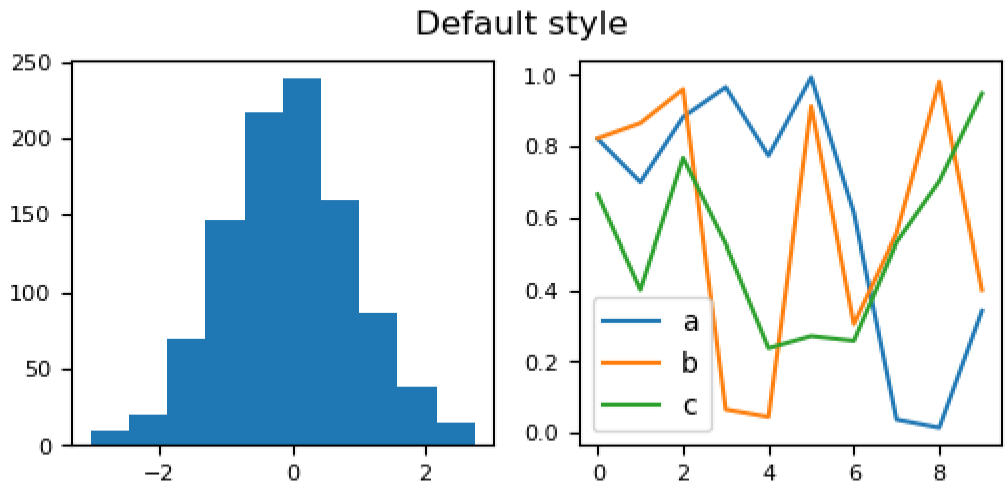
In [5]:
```python
def hist_and_lines(title="Default style"):
    np.random.seed(0)
    fig, ax = plt.subplots(1, 2, figsize=(6, 2.5))
    ax[0].hist(np.random.randn(1000))
    for i in range(3):
        ax[1].plot(np.random.rand(10))
    ax[1].legend(['a', 'b', 'c'], loc='lower left')
    fig.suptitle(title)
```

In [6]:
```python
hist_and_lines()
```



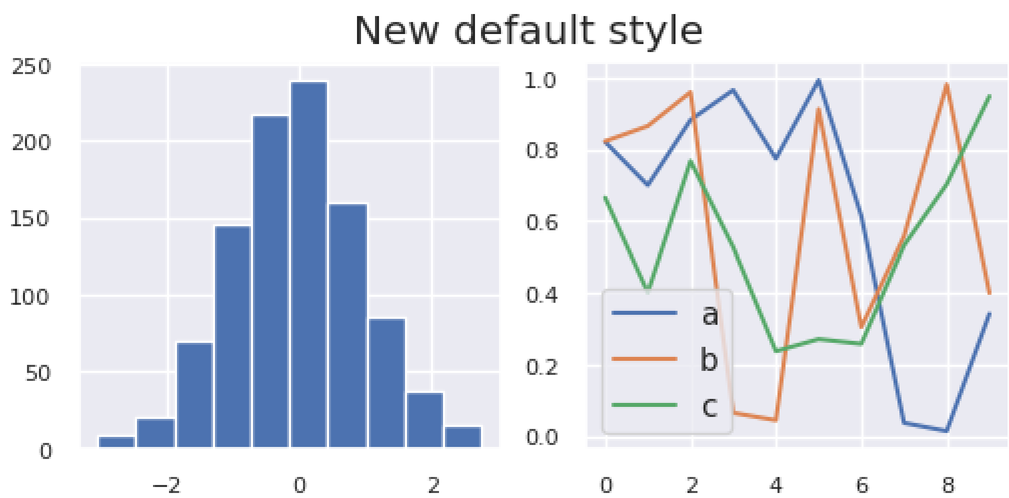
In [7]:
```python
plt.style.available
```
```

```
Out[7]: ['Solarize_Light2',
         '_classic_test_patch',
         '_mpl-gallery',
         '_mpl-gallery-nogrid',
         'bmh',
         'classic',
         'dark_background',
         'fast',
         'fivethirtyeight',
         'ggplot',
         'grayscale',
         'petroff10',
         'seaborn-v0_8',
         'seaborn-v0_8-bright',
         'seaborn-v0_8-colorblind',
         'seaborn-v0_8-dark',
         'seaborn-v0_8-dark-palette',
         'seaborn-v0_8-darkgrid',
         'seaborn-v0_8-deep',
         'seaborn-v0_8-muted',
         'seaborn-v0_8-notebook',
         'seaborn-v0_8-paper',
         'seaborn-v0_8-pastel',
         'seaborn-v0_8-poster',
         'seaborn-v0_8-talk',
         'seaborn-v0_8-ticks',
         'seaborn-v0_8-white',
         'seaborn-v0_8-whitegrid',
         'tableau-colorblind10']
```

```
In [8]: for style in plt.style.available[:7] :
            with plt.style.context(style):
                hist_and_lines(f'{style=}')
        hist_and_lines()
```






style='_mpl-gallery'
a
b
c


style='_mpl-gallery-nogrid'
a
b
c


style='bmh'
a
b
c


style='classic'
a
b
c





Seaborn Styles

- Five styles: `darkgrid`, `whitegrid`, `dark`, `white`, and `ticks`
- `sns.set_style(stylename)` → set global style
  - Use context manager to chancge the style localIY:
  - ```
    with sns.axes_style(stylename):
        make_a_plot()
    ```

In [9]:
```
for style in ['darkgrid', 'whitegrid', 'dark', 'white', 'ticks'] :
    with sns.axes_style(style):
        hist_and_lines(f'{style=}')
hist_and_lines()
```


```


style='whitegrid'
a
b
c
style='dark'
a
b
c
style='white'
a
b
c
style='ticks'
a
b
c



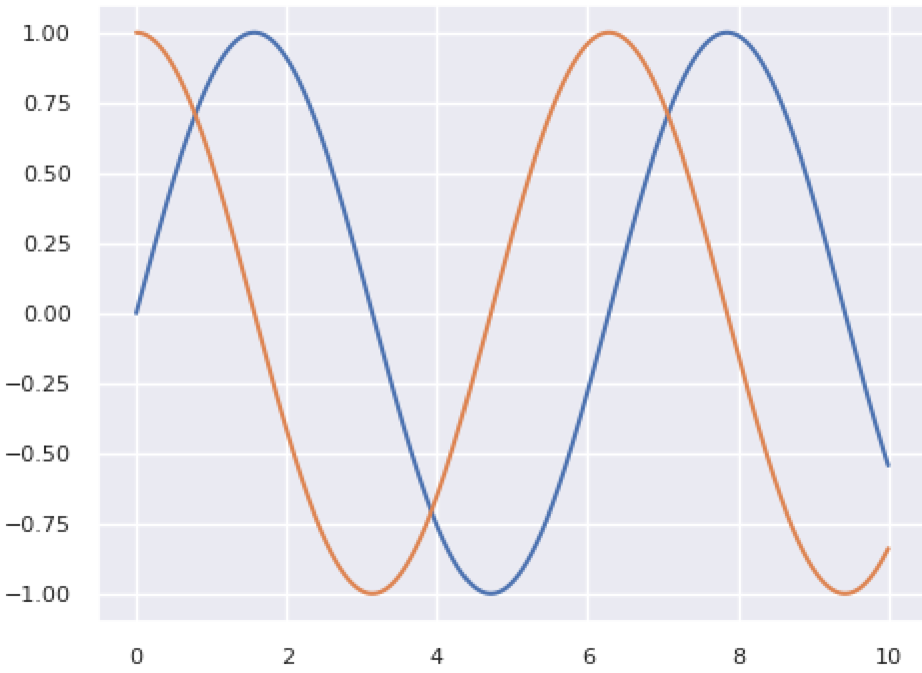
- `sns.set()` == `sns.set_theme()` → sns.set_style('darkgrid') and more

In [10]:
```
sns.set()
mpl.rcParams['figure.figsize'] = (5.33,4)
mpl.rcParams['axes.labelsize'] = 10  # Example: 14 points
mpl.rcParams['xtick.labelsize'] = 8  # Example: 12 points for x-axis ticks
mpl.rcParams['ytick.labelsize'] = 8  # Example: 12 points for y-axis ticks
hist_and_lines("New default style")
```

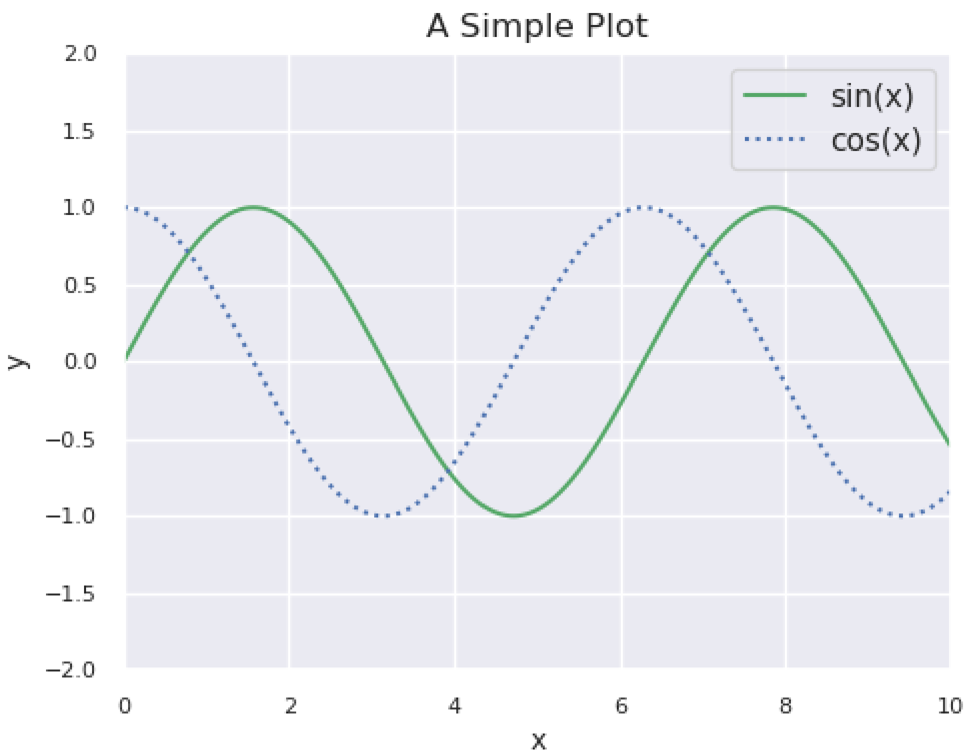


Line, Axes and Label properties

In [11]:
```
x = np.linspace(0, 10, 1000)
ax = plt.axes()
ax.plot(x, np.sin(x))
ax.plot(x, np.cos(x));
```

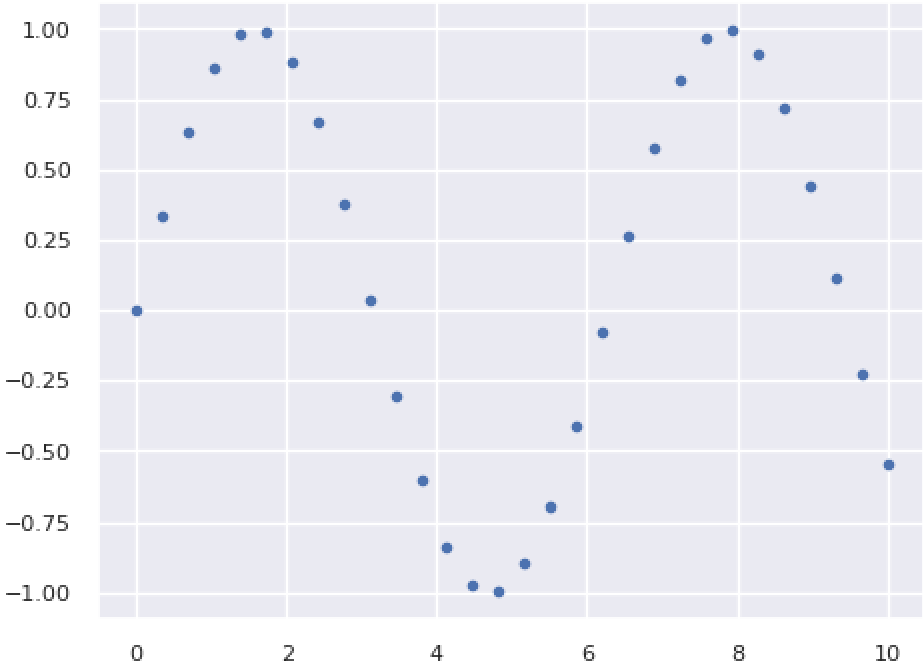


In [12]:
```
x = np.linspace(0, 10, 1000)
ax = plt.axes()
ax.plot(x, np.sin(x), '-g', label='sin(x)')
ax.plot(x, np.cos(x), ':b', label='cos(x)')
ax.set(xlim=(0, 10), ylim=(-2, 2),
       xlabel='x', ylabel='y',
       title='A Simple Plot')
plt.legend();
```

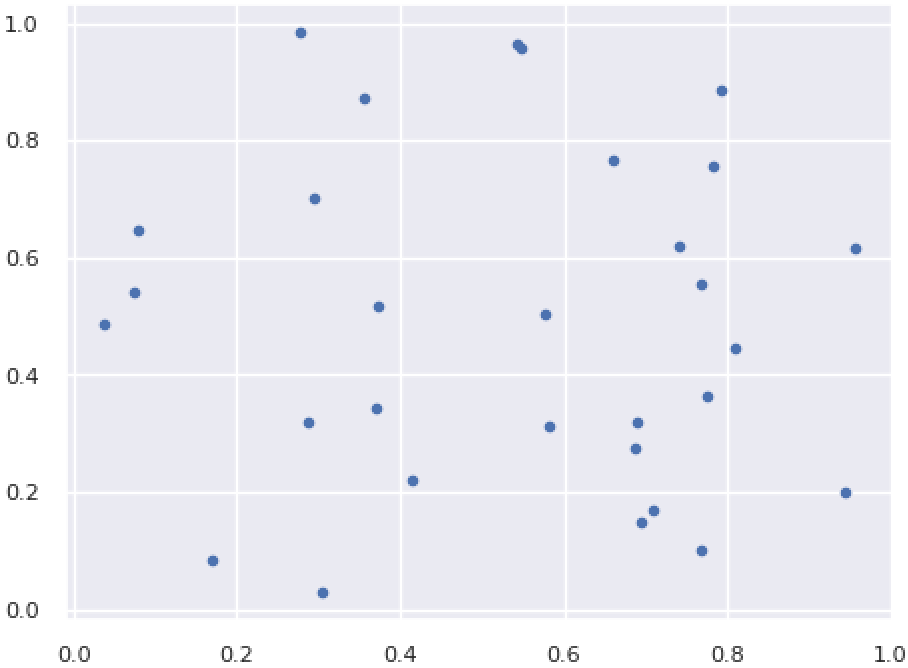


Scatter Plots

In [13]:
```
x = np.linspace(0, 10, 30)
y = np.sin(x)
#plt.plot(x, y);      # default: '-' use lines
plt.plot(x, y, '.'); # use point as marker
```

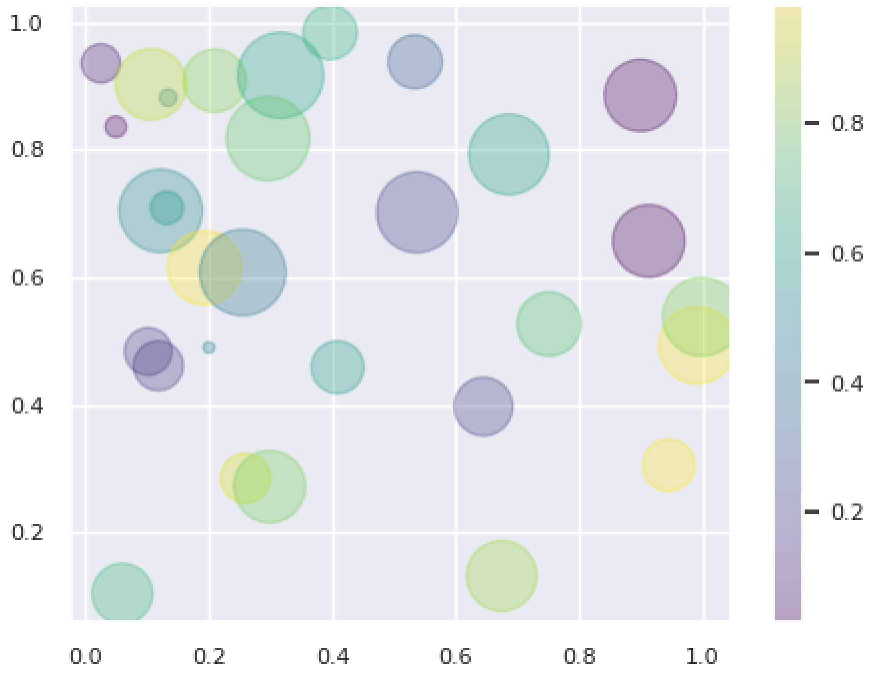


In [14]:
```
x,y  = np.random.rand(2,30)
#plt.plot(x, y);      # default: '-' use lines
plt.plot(x, y, '.'); # use point as marker
```



- `scatter(x, y, s=, c=, cmap=)` → scatter plot with individual size and color

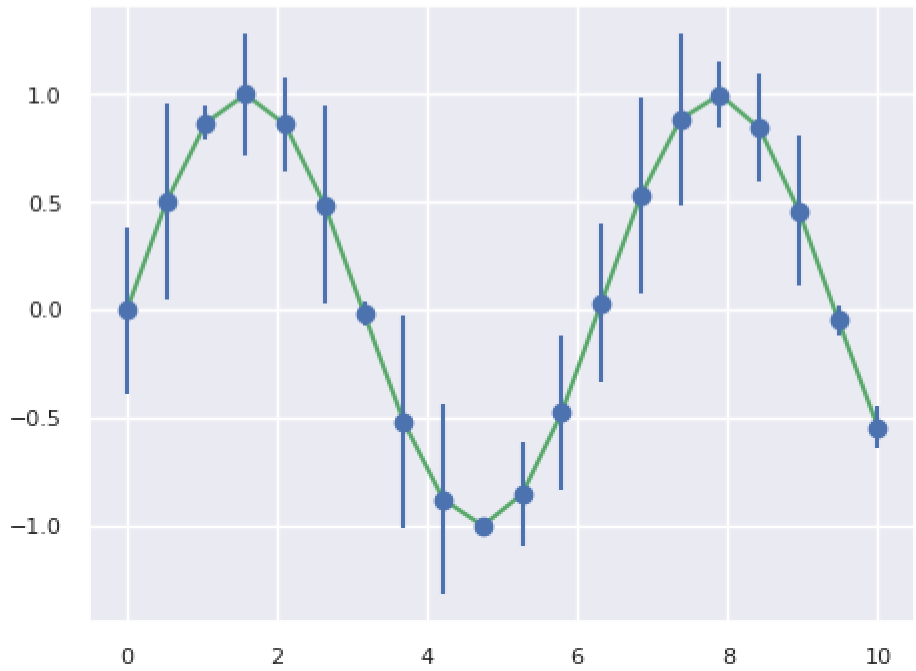
In [15]:
```
x,y,sizes,colors = np.random.rand(4,30)
plt.scatter(x, y, s=sizes*1000, alpha=0.3, c=colors, cmap='viridis')
plt.colorbar(); # show color scale
```



Errorbars

- `plt.errorbar(x, y, yerr=)` → an error bar plot

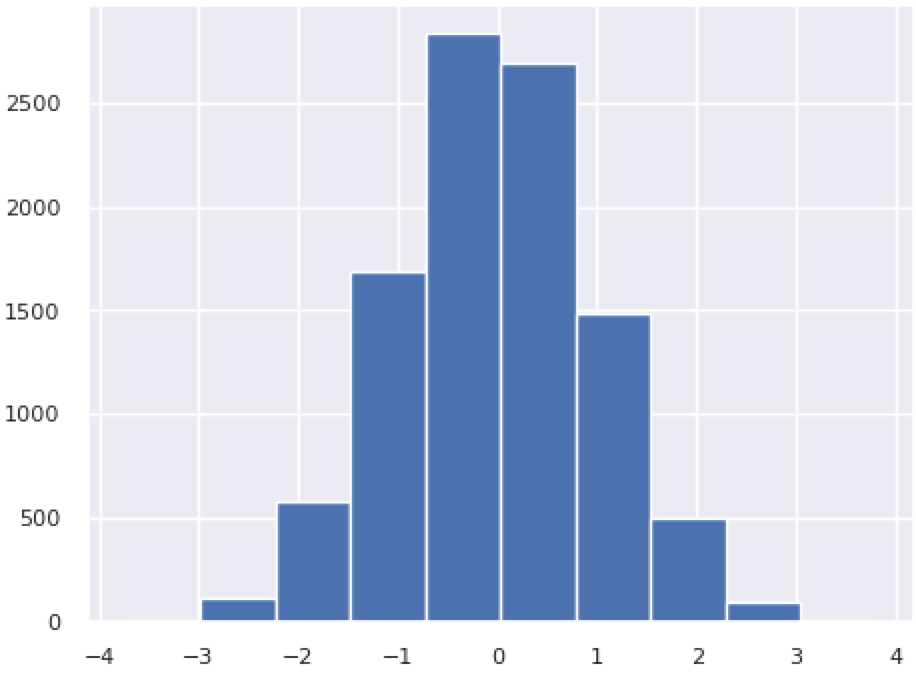
In [16]:
```
x = np.linspace(0, 10, 20)
y = np.sin(x)
dy = 0.5 * np.random.rand(x.size)
plt.plot(x, np.sin(x), 'g')
plt.errorbar(x, np.sin(x), yerr=dy, fmt='o');
```



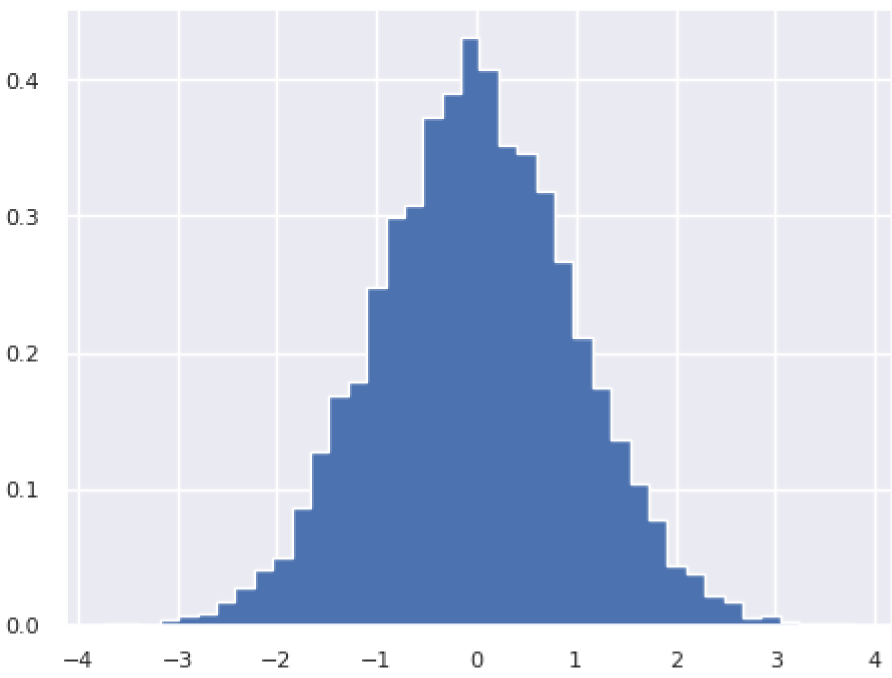
Histograms

- `plt.hist(x, bins=, density=, histtype=)` → a histogram plot

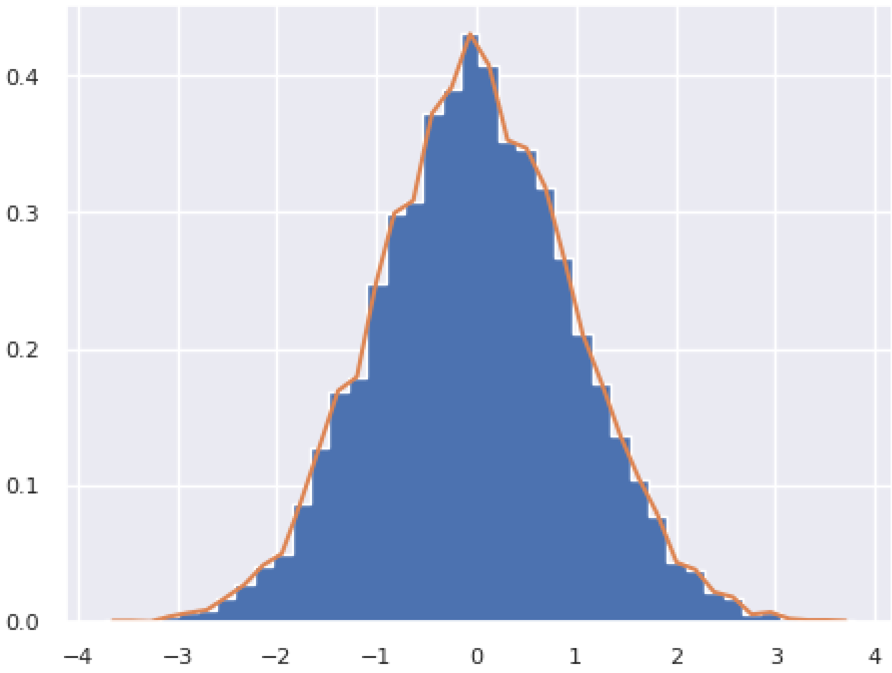
In [17]:
```
x = np.random.randn(10000)
plt.hist(x);
```



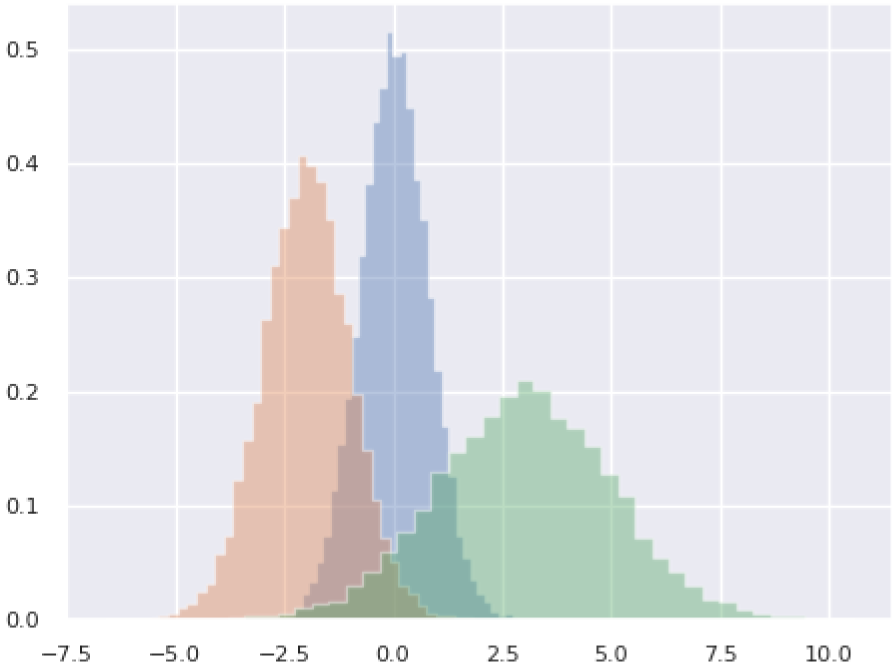
In [18]:
```
plt.hist(x, bins=40, density=True, histtype='stepfilled');
```



In [19]:
```
density, bins, patches = plt.hist(x, bins=40, density=True, histtype='stepfilled')
# Calculate the center of the bins
bin_centers = (bins[:-1] + bins[1:]) / 2
# Plot the probability density as a line
plt.plot(bin_centers, density);
```



In [20]:
```
x1 = np.random.normal(0, 0.8, 10000)
x2 = np.random.normal(-2, 1, 10000)
x3 = np.random.normal(3, 2, 10000)
kwargs = dict(bins=40, density=True, histtype='stepfilled', alpha=0.4)
plt.hist(x1, **kwargs)
plt.hist(x2, **kwargs)
plt.hist(x3, **kwargs);
```



Seaborn

- Matplotlib predated Pandas by more than a decade
  - It is not designed for use with Pandas (is being updated)
- Seaborn provides an API on top of Matplotlib and integrates with Pandas
  - Statistical tools: regressions, errors and distributions
  - Simple multivariate visualization

In [21]:
```
a = np.random.multivariate_normal(mean=[0, 1], cov=[[5, 2], [2, 2]], size=2000)
df = pd.DataFrame(a, columns=['x', 'y'])
df.head()
```

Out[21]:

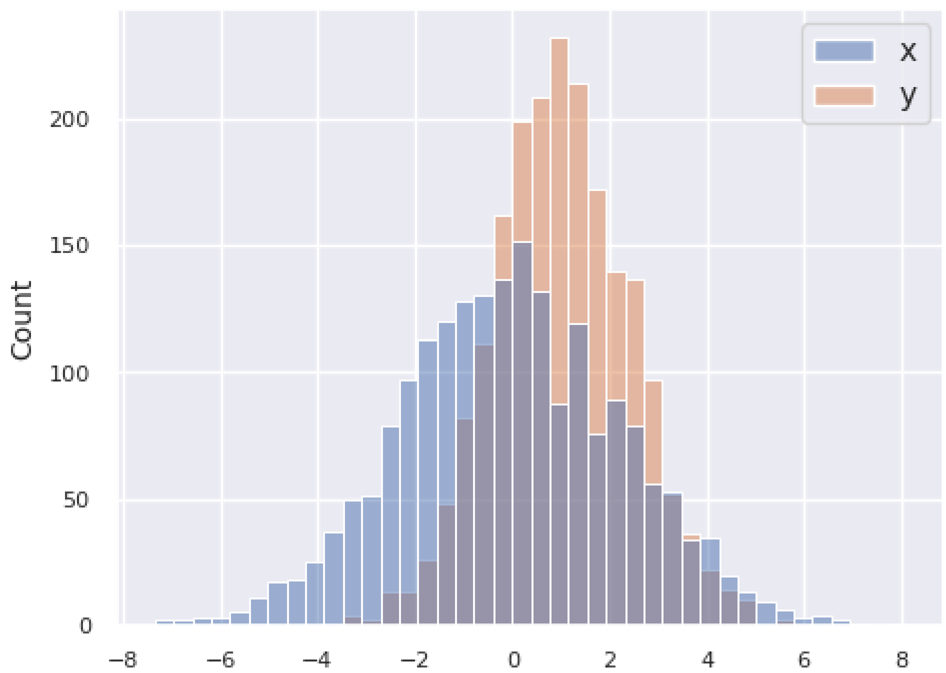
	x	y
0	0.422732	0.152363
1	-0.733416	0.678723
2	-1.825696	0.841521
3	2.113652	1.340771
4	1.254496	1.035458

Plotting two histograms (widths of the bins differ)

In [22]:
```
plt.hist(df['x'], bins=40, alpha=0.5, label='x')
plt.hist(df['y'], bins=40, alpha=0.5, label='y')
plt.legend();
```

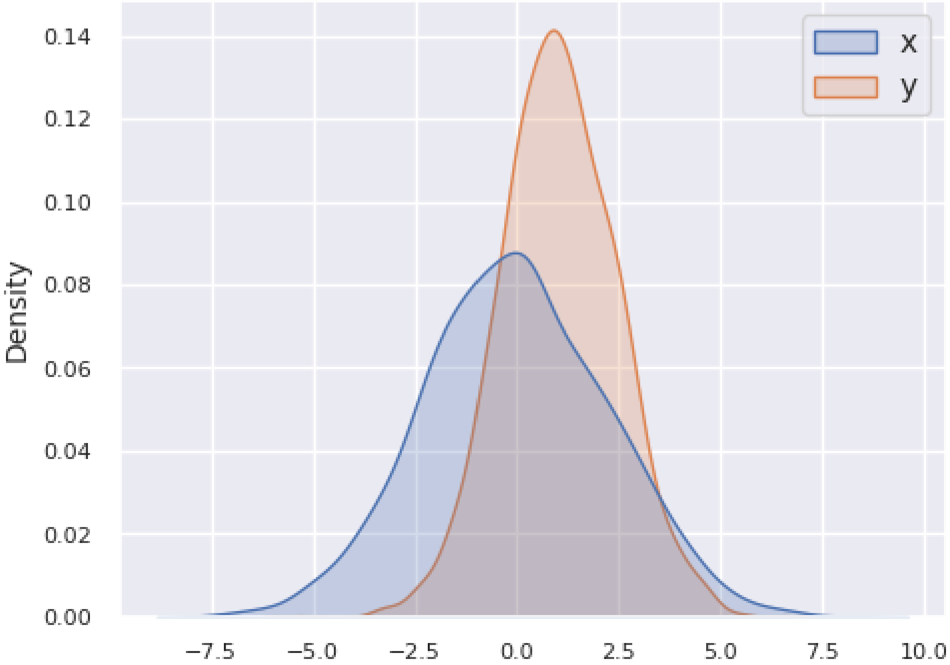
Seaborn can plot the histograms of the DataFrame variables (equal bin widths):

In [23]:
```
sns.histplot(df, bins=40);
```



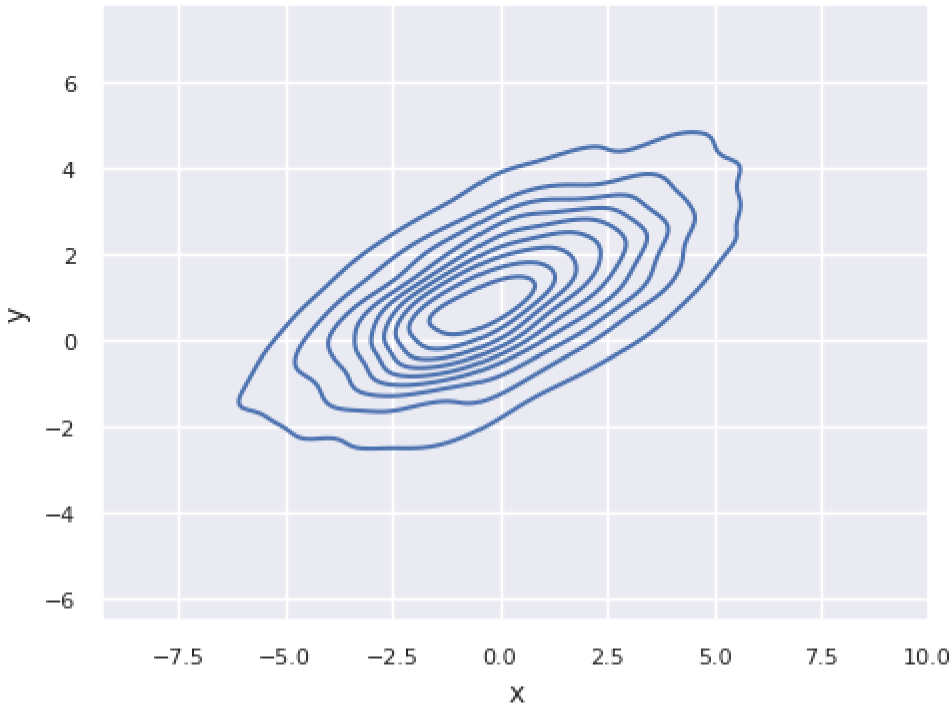
Kernel density estimation of the DataFrame variables:

```
In [24]: sns.kdeplot(df, fill=True);
```



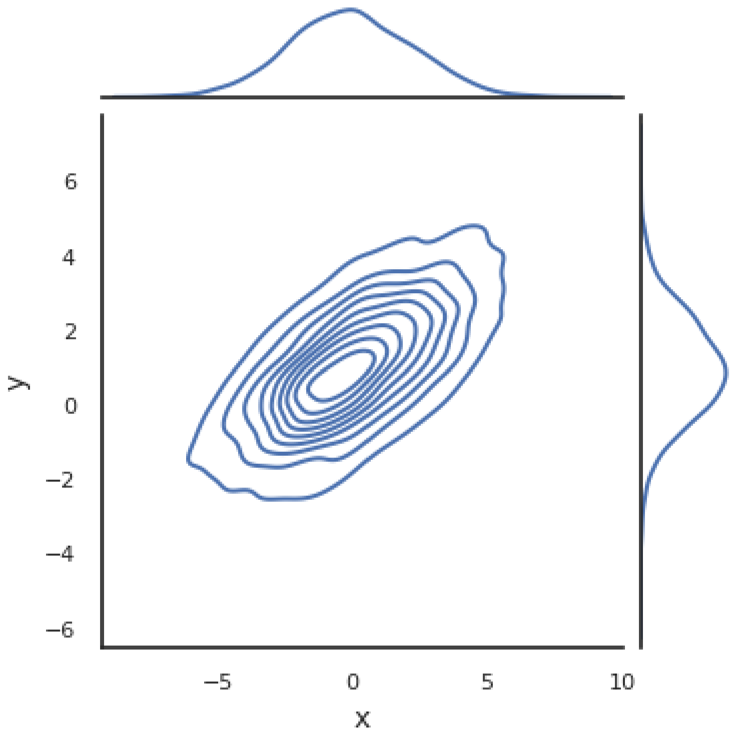
Two-dimensional visualization of the kernel density estimation:

```
In [25]: sns.kdeplot(df, x='x', y='y');
```



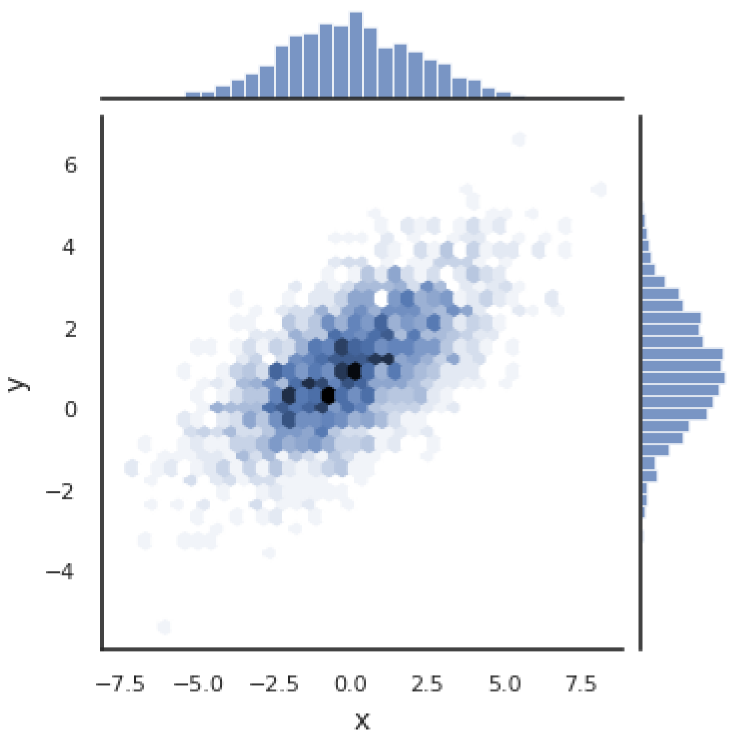
Joint and marginal distributions together:

```
In [26]: with sns.axes_style('white'):
             sns.jointplot(df, x='x', y='y', kind='kde', height=4);
```



Same but using an hexagonally based histogram instead:

In [27]:
```
with sns.axes_style('white'):
    sns.jointplot(df, x='x', y='y', kind='hex', height=4);
```



Multivariate visualization

Iris dataset: measurements of petals and sepals of three iris species:

In [28]:
```
iris = sns.load_dataset("iris")
print(iris.shape)
iris.head()
```

```
(150, 5)
```

Out[28]:

	sepal_length	sepal_width	petal_length	petal_width	species
0	5.1	3.5	1.4	0.2	setosa
1	4.9	3.0	1.4	0.2	setosa
2	4.7	3.2	1.3	0.2	setosa
3	4.6	3.1	1.5	0.2	setosa
4	5.0	3.6	1.4	0.2	setosa

The correlation matrix of the data:

In [29]:
```
iris.drop(['species'], axis=1).corr()
```

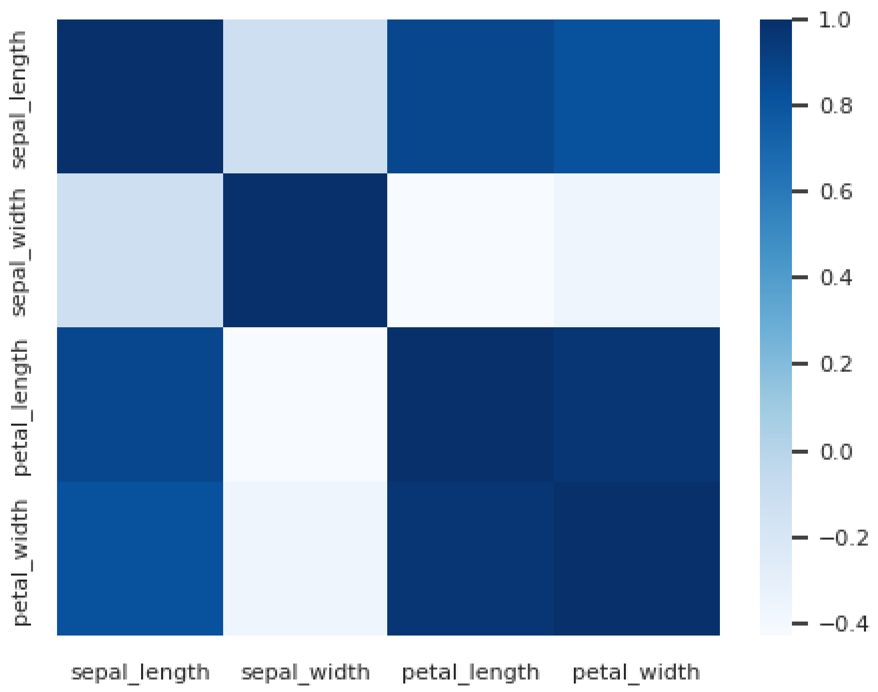
Out[29]:

	sepal_length	sepal_width	petal_length	petal_width
sepal_length	1.000000	-0.117570	0.871754	0.817941
sepal_width	-0.117570	1.000000	-0.428440	-0.366126
petal_length	0.871754	-0.428440	1.000000	0.962865
petal_width	0.817941	-0.366126	0.962865	1.000000

A heat map of the correlation matrix:

In [30]:
```
c = iris.drop(['species'], axis=1).corr()
sns.heatmap(c, cmap="Blues")
```

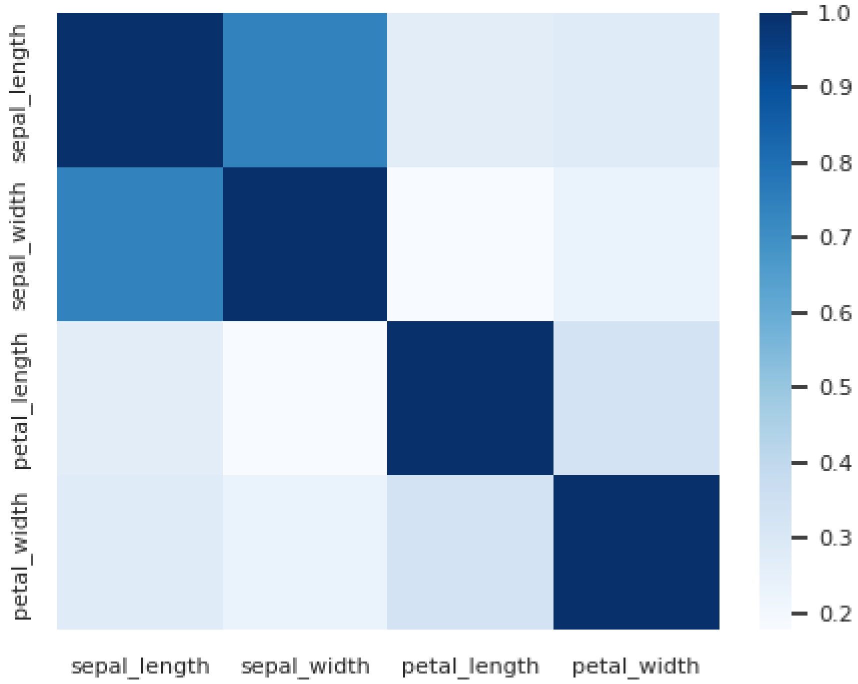
Out[30]: <Axes: >



A heat map of the correlation matrix just for `setosa` specie:

In [31]:
```
c = iris[iris['species']=='setosa'].drop('species', axis=1).corr()
sns.heatmap(c, cmap="Blues")
```

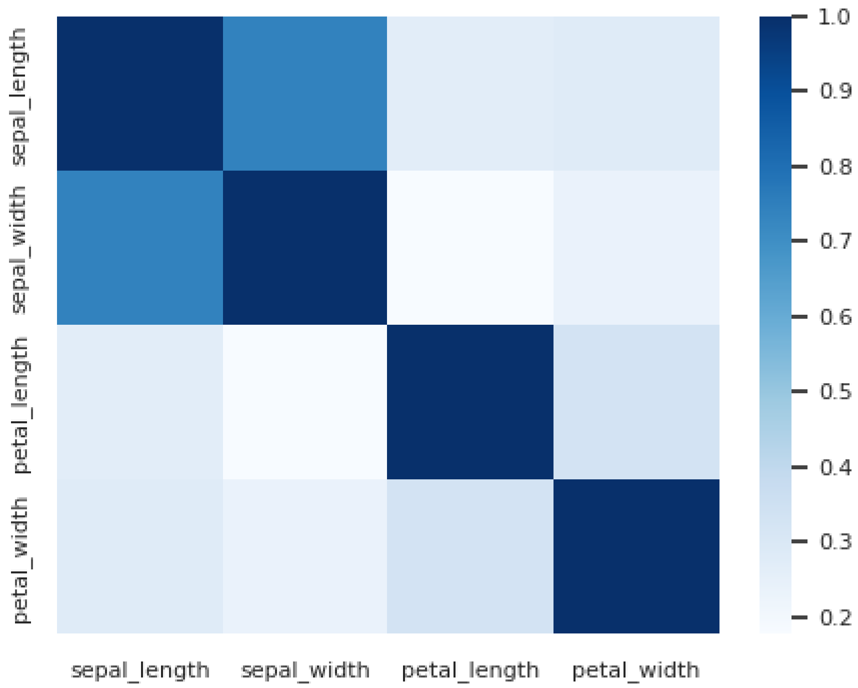
Out[31]: <Axes: >



Same but using the `species` variable as index:

In [32]:
```
c = iris.set_index('species').loc['setosa'].corr()
sns.heatmap(c, cmap="Blues")
```

Out[32]: <Axes: >



Correlation matrix for each specie:

In [33]:
```
iris.groupby('species').corr()
```

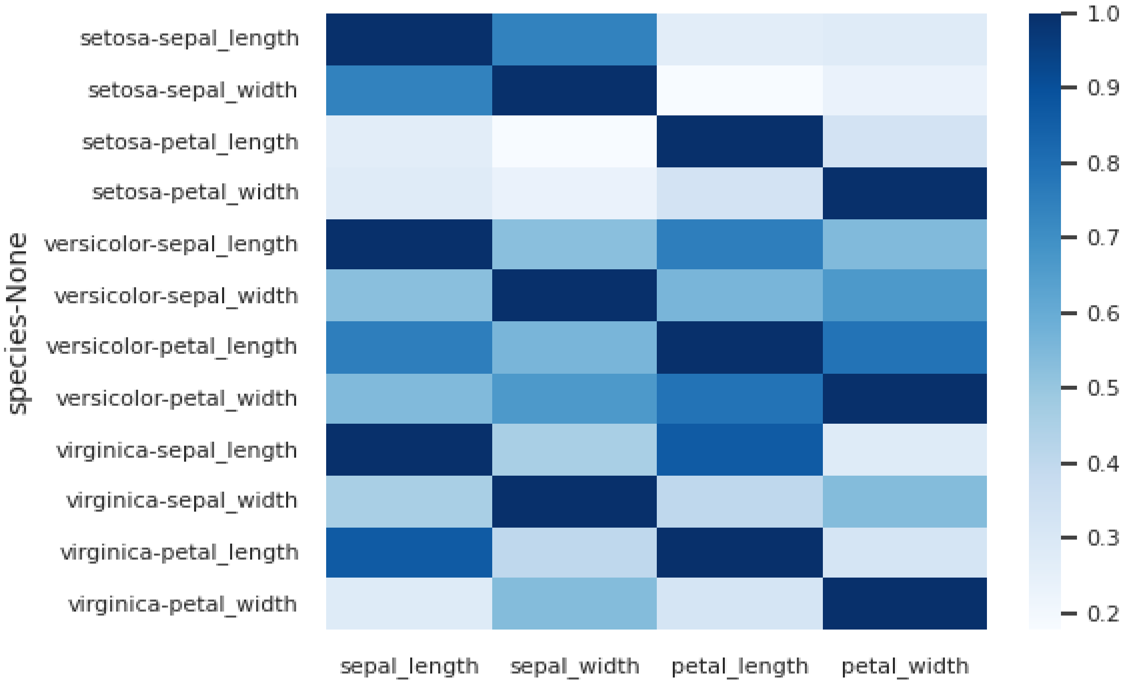
Out[33]:

species		sepal_length	sepal_width	petal_length	petal_width
setosa	**sepal_length**	1.000000	0.742547	0.267176	0.278098
	sepal_width	0.742547	1.000000	0.177700	0.232752
	petal_length	0.267176	0.177700	1.000000	0.331630
	petal_width	0.278098	0.232752	0.331630	1.000000
versicolor	**sepal_length**	1.000000	0.525911	0.754049	0.546461
	sepal_width	0.525911	1.000000	0.560522	0.663999
	petal_length	0.754049	0.560522	1.000000	0.786668
	petal_width	0.546461	0.663999	0.786668	1.000000
virginica	**sepal_length**	1.000000	0.457228	0.864225	0.281108
	sepal_width	0.457228	1.000000	0.401045	0.537728
	petal_length	0.864225	0.401045	1.000000	0.322108
	petal_width	0.281108	0.537728	0.322108	1.000000

Correlation matrix heat map for each specie:

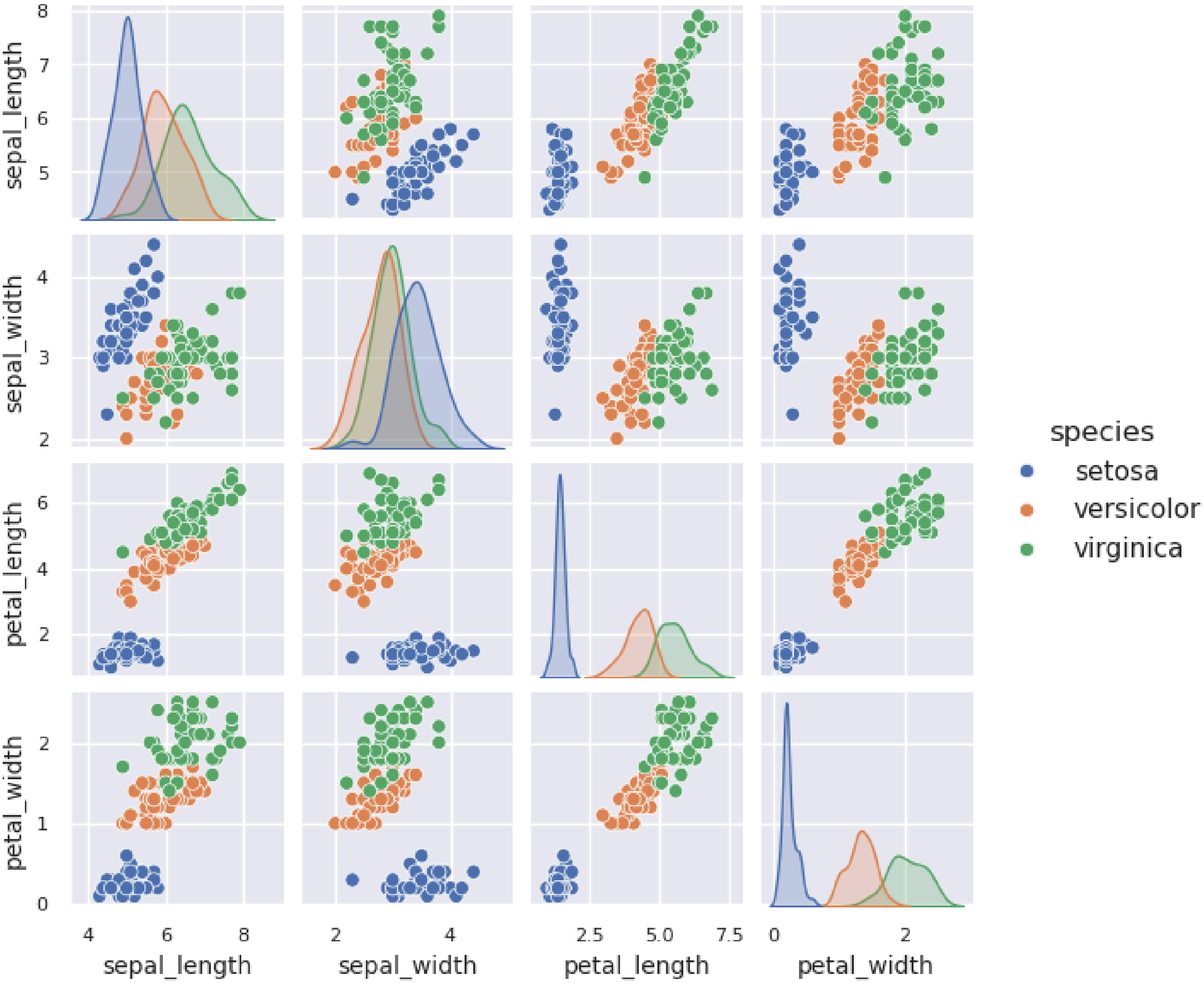
In [34]:
```
sns.heatmap(iris.groupby('species').corr(),cmap="Blues")
```

Out[34]: <Axes: ylabel='species-None'>



Plot with pair-wise scatter plots and kde:

In [35]:
```
sns.pairplot(iris, hue='species', height=1.5);
```


sepal_length
sepal_width
petal_length
petal_width
species
setosa
versicolor
virginica
4
6
8
2
4
2.5
5.0
7.5
0
2
5
6
7
8
2
3
4
2
4
6
0
1
2