

matplotlib / pyplot & seaborn

Lecture 9

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matplotlib & pyplot

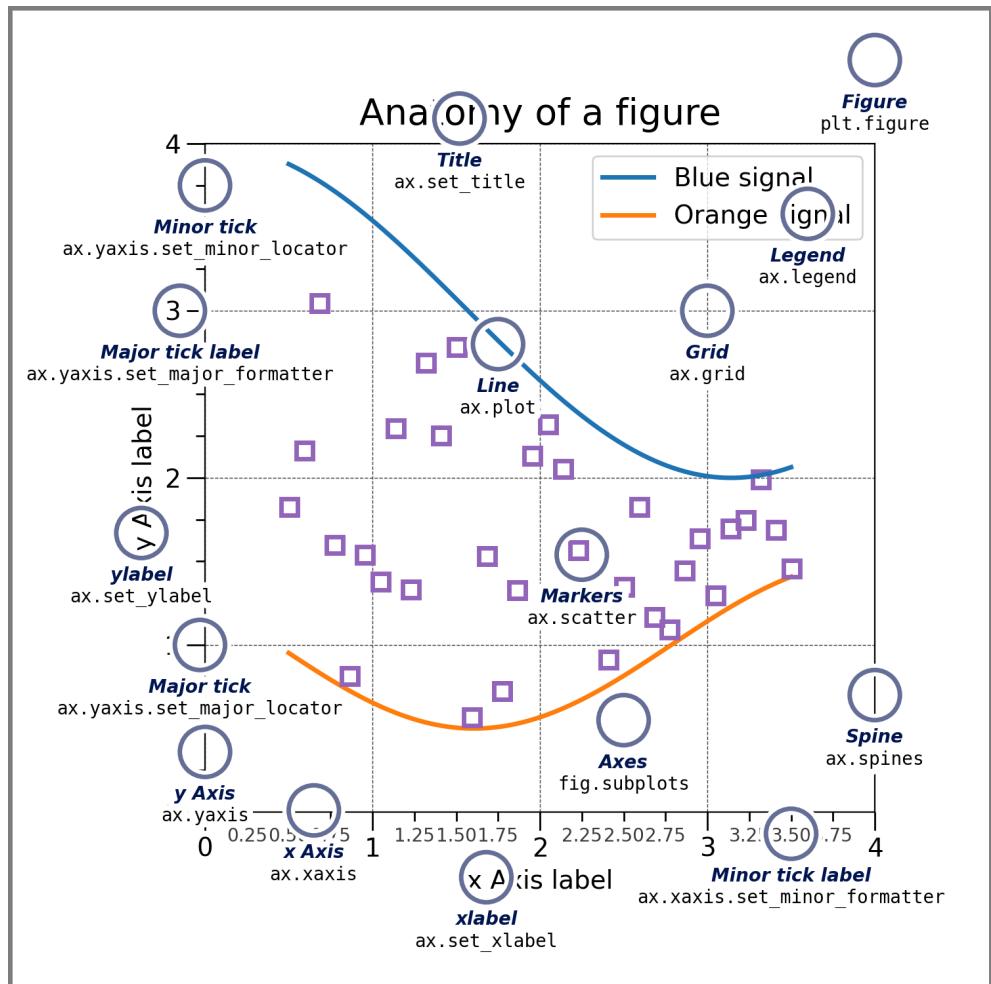
matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python.

```
1 import matplotlib as mpl
```

`matplotlib.pyplot` is a collection of functions that make matplotlib work like MATLAB. Each `pyplot` function makes some change to a figure: e.g., creates a figure, creates a plotting area in a figure, plots some lines in a plotting area, decorates the plot with labels, etc.

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

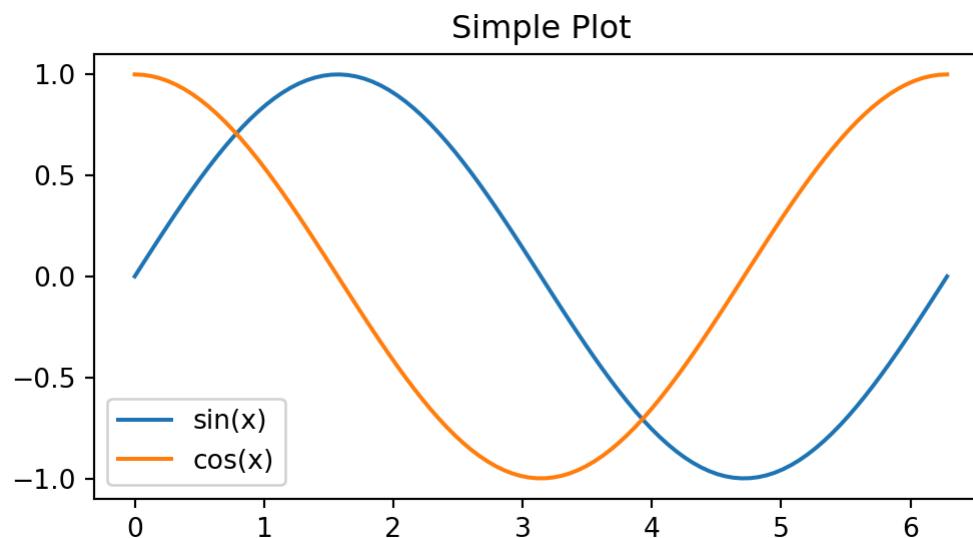
Plot anatomy



- **Figure** - The entire plot (including subplots)
- **Axes** - Subplot attached to a figure, contains the region for plotting data and x & y axis
- **Axis** - Set the scale and limits, generate ticks and ticklabels
- **Artist** - Everything visible on a figure: text, lines, axis, axes, etc.

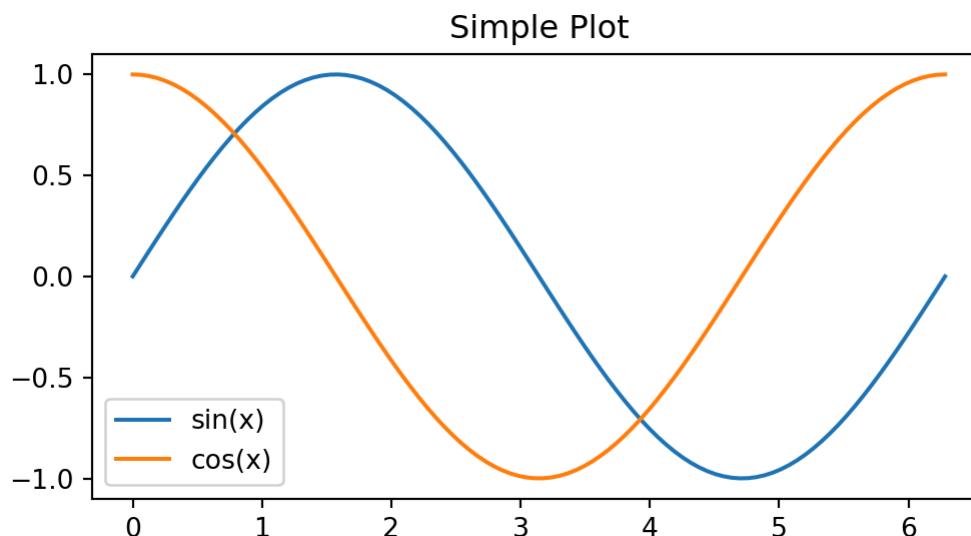
Basic plot - pyplot style

```
1 x = np.linspace(0, 2*np.pi, 100)
2 y1 = np.sin(x)
3 y2 = np.cos(x)
4
5 plt.figure(figsize=(6, 3))
6 plt.plot(x, y1, label="sin(x)")
7 plt.plot(x, y2, label="cos(x)")
8 plt.title("Simple Plot")
9 plt.legend()
```



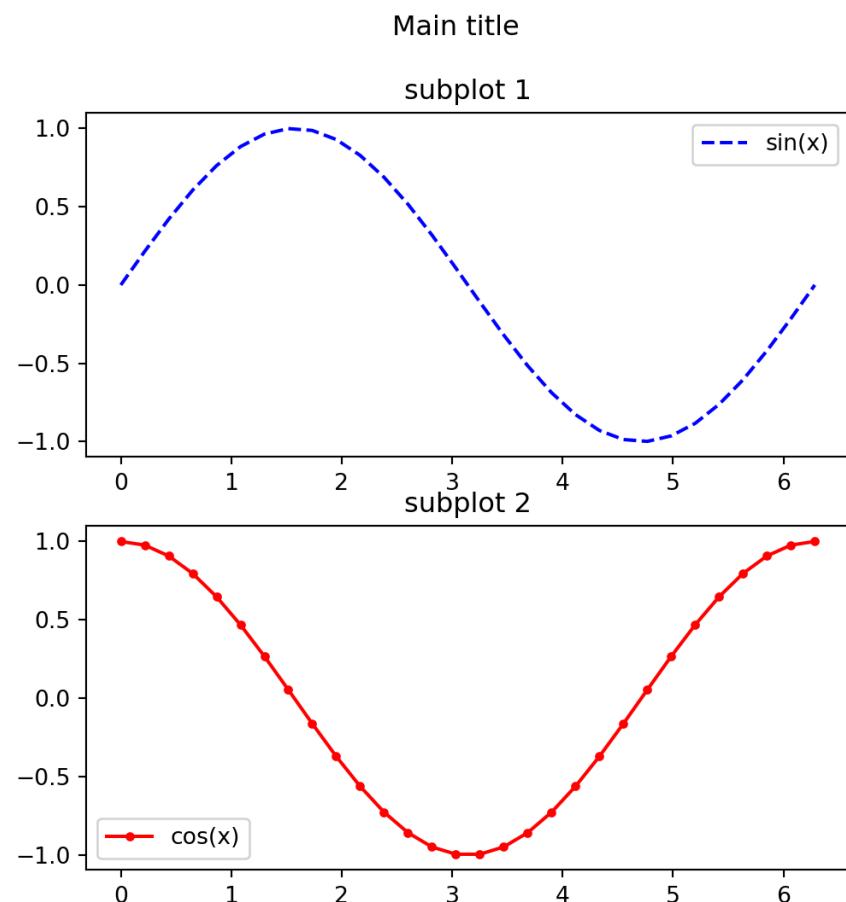
Basic plot - OO style

```
1 x = np.linspace(0, 2*np.pi, 100)
2 y1 = np.sin(x)
3 y2 = np.cos(x)
4
5 fig, ax = plt.subplots(figsize=(6, 3))
6 ax.plot(x, y1, label="sin(x)")
7 ax.plot(x, y2, label="cos(x)")
8 ax.set_title("Simple Plot")
9 ax.legend()
```



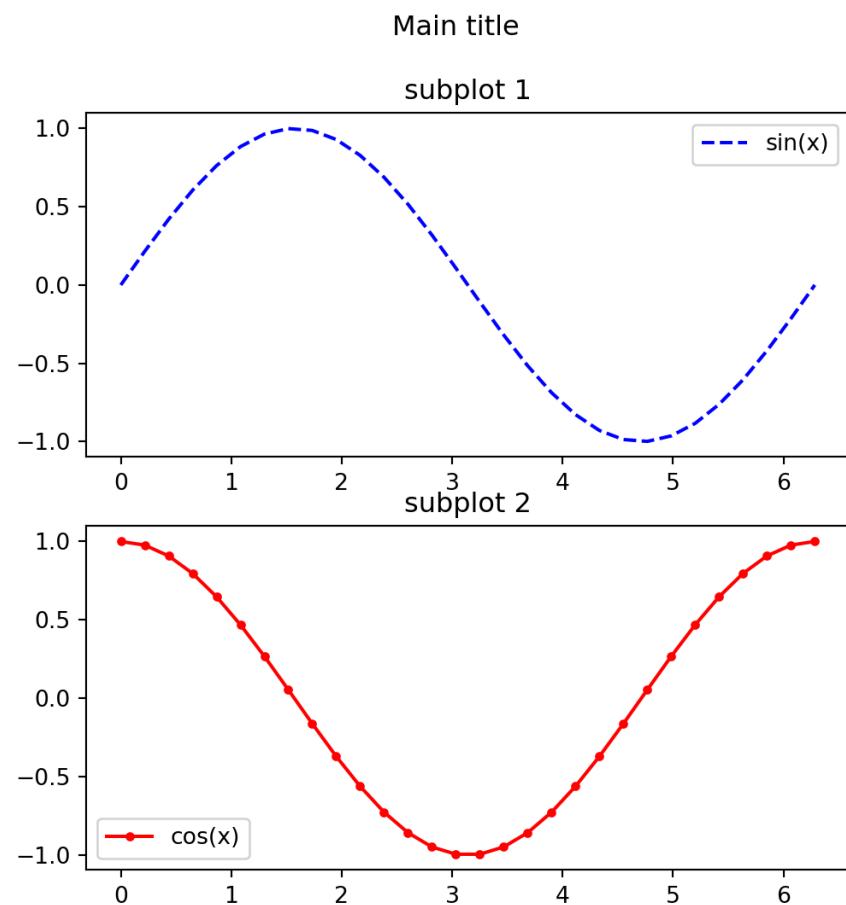
Subplots (00)

```
1 x = np.linspace(0, 2*np.pi, 30)
2 y1 = np.sin(x)
3 y2 = np.cos(x)
4
5 fig, (ax1, ax2) = plt.subplots(
6     2, 1, figsize=(6, 6)
7 )
8
9 fig.suptitle("Main title")
10
11 ax1.plot(x, y1, "--b", label="sin(x)")
12 ax1.set_title("subplot 1")
13 ax1.legend()
14
15 ax2.plot(x, y2, ".-r", label="cos(x)")
16 ax2.set_title("subplot 2")
17 ax2.legend()
```



Subplots (pyplot)

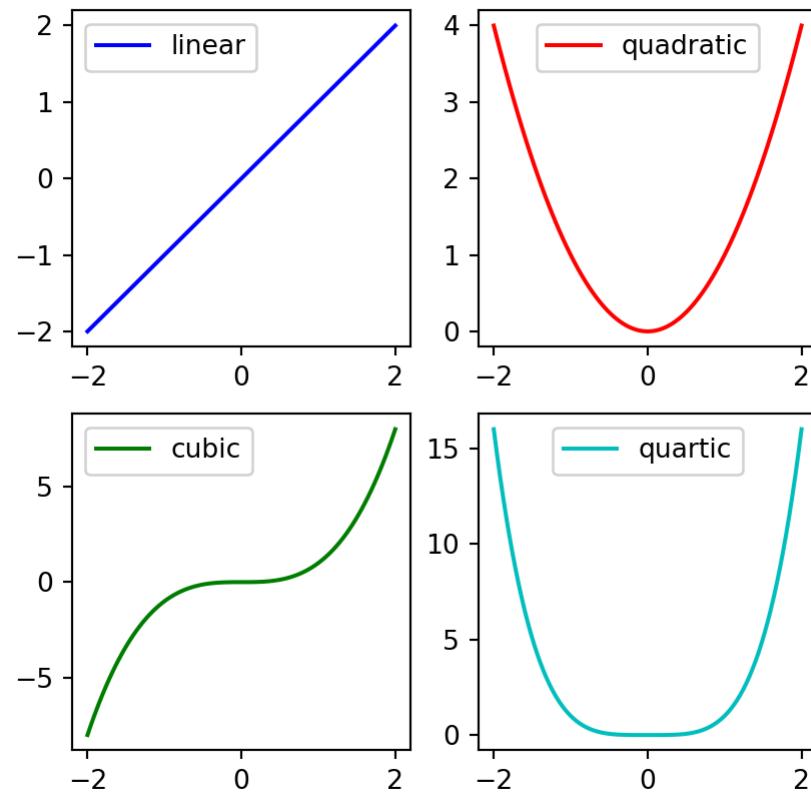
```
1 x = np.linspace(0, 2*np.pi, 30)
2 y1 = np.sin(x)
3 y2 = np.cos(x)
4
5 plt.figure(figsize=(6, 6))
6
7 plt.suptitle("Main title")
8
9 plt.subplot(211)
10 plt.plot(x, y1, "--b", label="sin(x)")
11 plt.title("subplot 1")
12 plt.legend()
13
14 plt.subplot(2,1,2)
15 plt.plot(x, y2, ".-r", label="cos(x)")
16 plt.title("subplot 2")
17 plt.legend()
18
19 plt.show()
```



More subplots

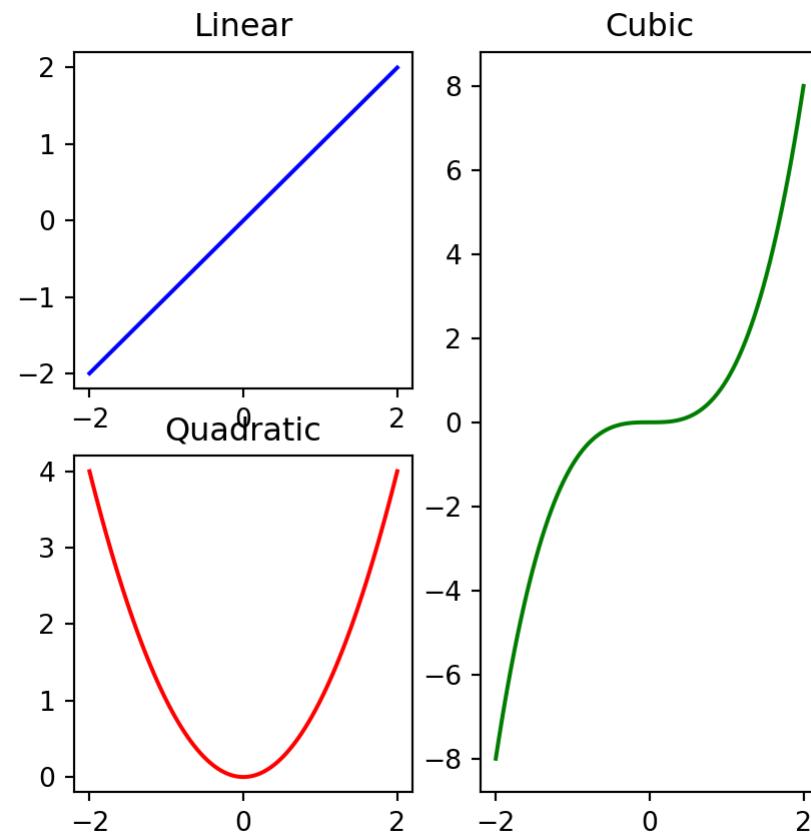
```
1 x = np.linspace(-2, 2, 101)
2
3 fig, axs = plt.subplots(
4     2, 2,
5     figsize=(5, 5)
6 )
7
8 fig.suptitle("More subplots")
9
10 axs[0,0].plot(x, x, "b", label="linear")
11 axs[0,1].plot(x, x**2, "r", label="quadratic")
12 axs[1,0].plot(x, x**3, "g", label="cubic")
13 axs[1,1].plot(x, x**4, "c", label="quartic")
14
15 [ax.legend() for row in axs for ax in row]
```

More subplots



Fancy subplots (mosaic)

```
1 x = np.linspace(-2, 2, 101)
2
3 fig, axd = plt.subplot_mosaic(
4     [['upleft', 'right'],
5      ['lowleft', 'right']],
6     figsize=(5, 5)
7 )
8
9 axd['upleft'].plot(x, x, "b", label="linear")
10 axd['lowleft'].plot(x, x**2, "r", label="quadratic")
11 axd['right'].plot(x, x**3, "g", label="cubic")
12
13 axd['upleft'].set_title("Linear")
14 axd['lowleft'].set_title("Quadratic")
15 axd['right'].set_title("Cubic")
```



Format strings

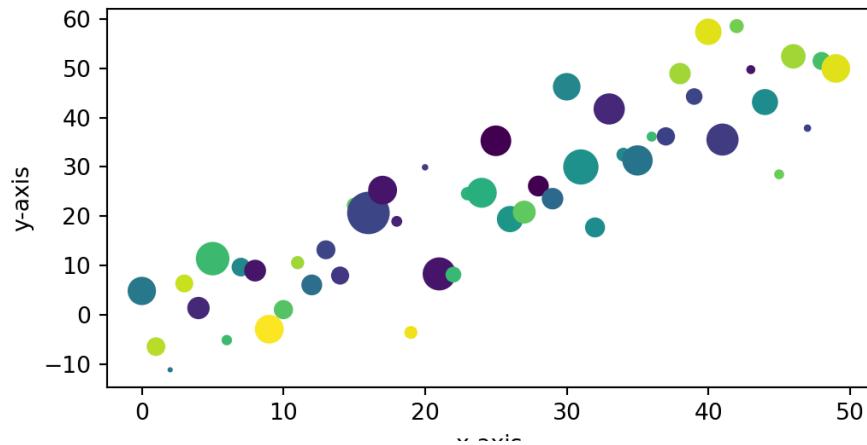
For quick formatting of plots (scatter and line) format strings are a useful shorthand, generally they use the format '`[marker] [line] [color]`',

character	shape	character	line style	character	color
.	point	-	solid	b	blue
,	pixel	--	dashed	g	green
o	circle	-.	dash-dot	r	red
v	triangle down	:	dotted	c	cyan
^	triangle up			m	magenta
<	triangle left			y	yellow
>	triangle right			k	black
...	+ more			w	white

Plotting data

Beyond creating plots for arrays (and lists), addressable objects like dicts and DataFrames can be used via `data`,

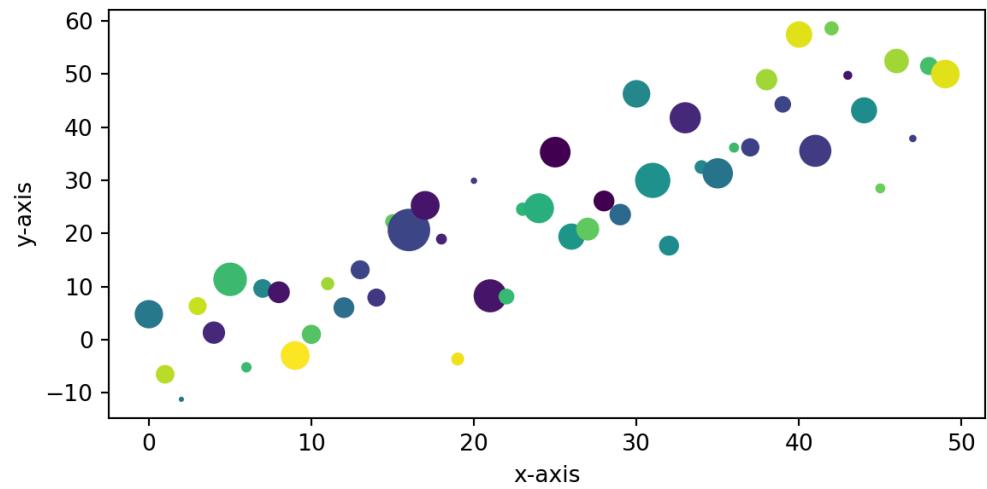
```
1 np.random.seed(19680801)
2 d = {'x': np.arange(50),
3       'color': np.random.randint(0, 50, 50),
4       'size': np.abs(np.random.randn(50)) *
5 d['y'] = d['x'] + 10 * np.random.randn(50)
6
7
8 plt.figure(figsize=(6, 3))
9 plt.scatter(
10   'x', 'y', c='color', s='size',
11   data=d
12 )
13 plt.xlabel("x-axis")
14 plt.ylabel("y-axis")
15
16 plt.show()
```



Constrained layout

To fix the axis label clipping we can use the “constrained” layout to adjust automatically,

```
1 np.random.seed(19680801)
2 d = {'x': np.arange(50),
3       'color': np.random.randint(0, 50, 50),
4       'size': np.abs(np.random.randn(50)) *
5 d['y'] = d['x'] + 10 * np.random.randn(50)
6
7
8 plt.figure(
9     figsize=(6, 3),
10    layout="constrained"
11 )
12 plt.scatter(
13     'x', 'y', c='color', s='size',
14     data=d
15 )
16 plt.xlabel("x-axis")
17 plt.ylabel("y-axis")
18
19 plt.show()
```

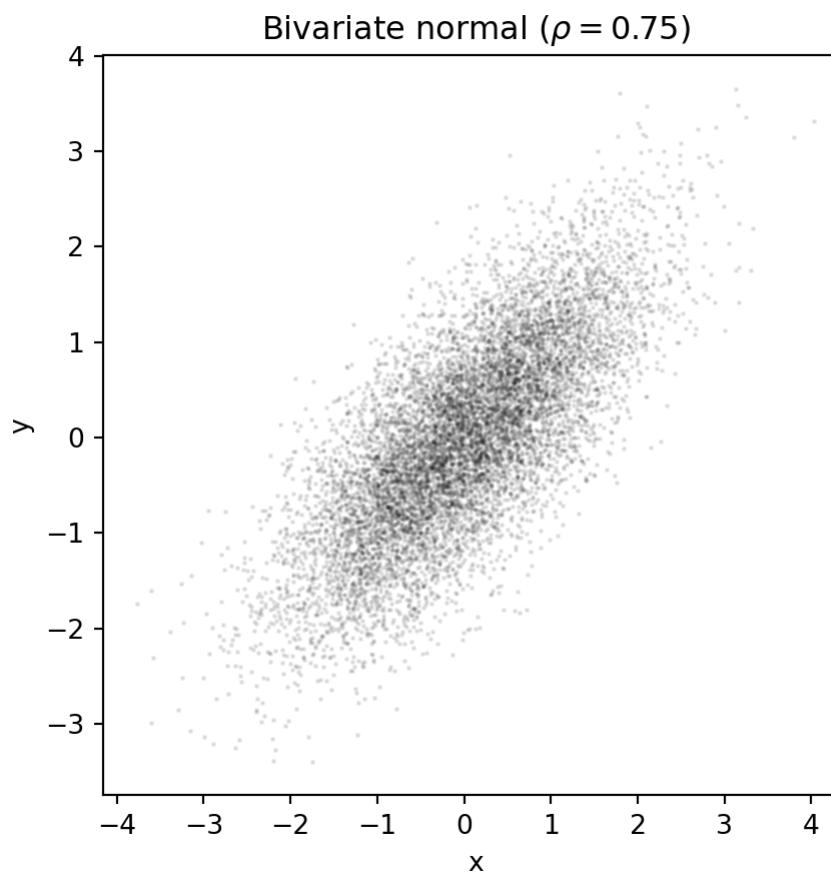


pyplot w/ pandas

Data can also come from DataFrame objects or series,

```
1 rho = 0.75
2 df = pd.DataFrame({
3     "x": np.random.normal(size=10000)
4 }).assign(
5     y = lambda d: np.random.normal(rho*d.x, np.sqrt(1-rho**2), size=10000)
6 )
7
8 fig, ax = plt.subplots(figsize=(5,5))
9
10 ax.scatter('x', 'y', c='k', data=df, alpha=0.1, s=0.5)
11
12 ax.set_xlabel('x')
13 ax.set_ylabel('y')
14 ax.set_title(f"Bivariate normal ($\\rho={rho}$)")
```

pyplot w/ pandas

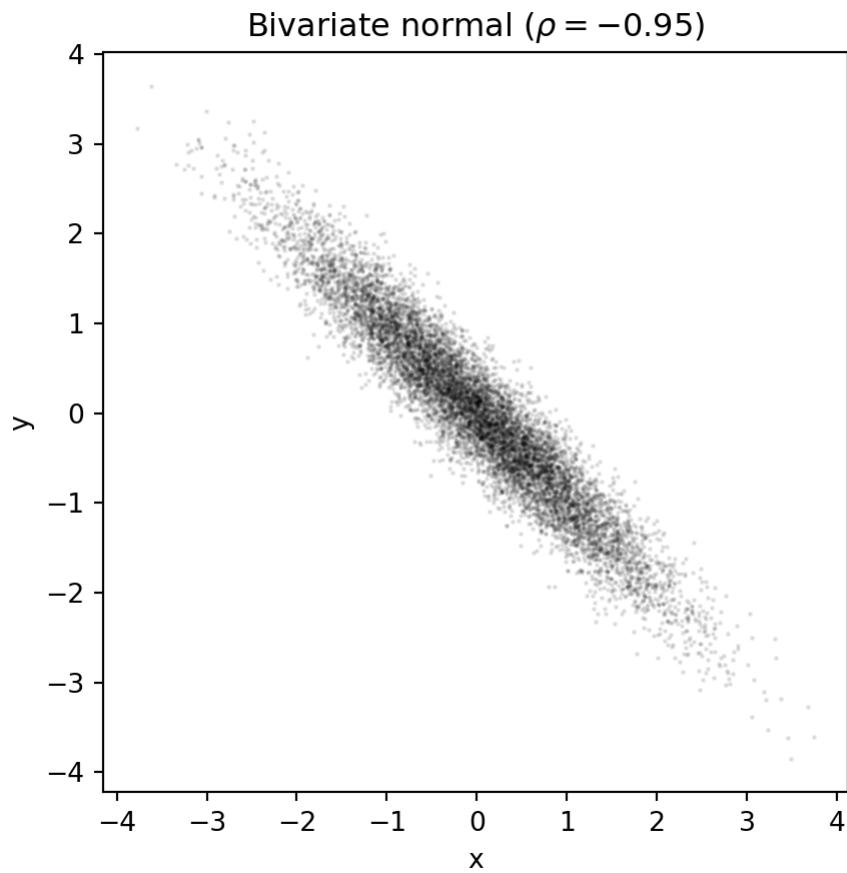


pyplot w/ polars

Data can also come from DataFrame objects or series,

```
1 rho = -0.95
2 df = pl.DataFrame({
3     "x": np.random.normal(size=10000)
4 }).with_columns(
5     y = rho*pl.col("x") + np.random.normal(0, np.sqrt(1-rho**2), size=10000)
6 )
7
8 fig, ax = plt.subplots(figsize=(5,5))
9
10 ax.scatter('x', 'y', c='k', data=df, alpha=0.1, s=0.5)
11
12 ax.set_xlabel('x')
13 ax.set_ylabel('y')
14 ax.set_title(f"Bivariate normal ($\\rho={rho}$)")
```

pyplot w/ polars

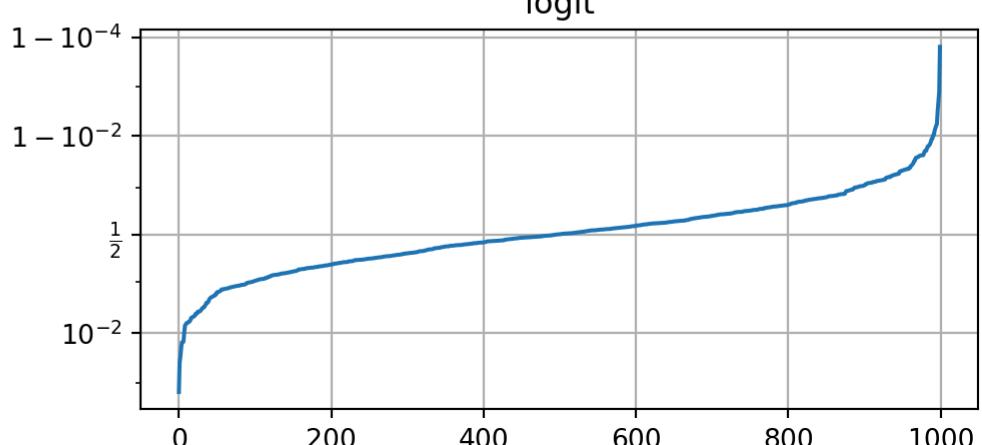
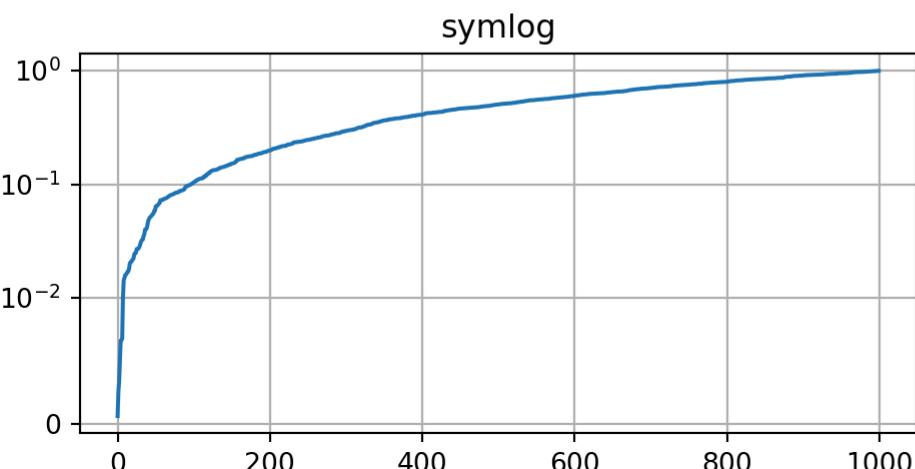
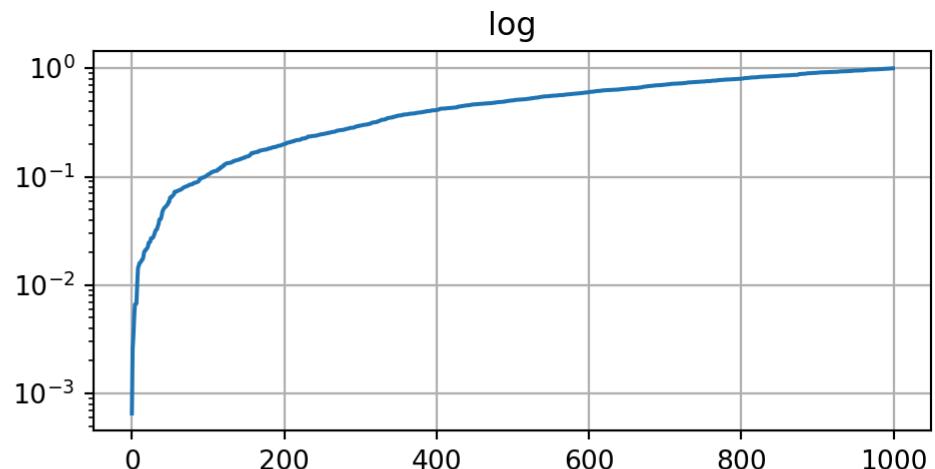
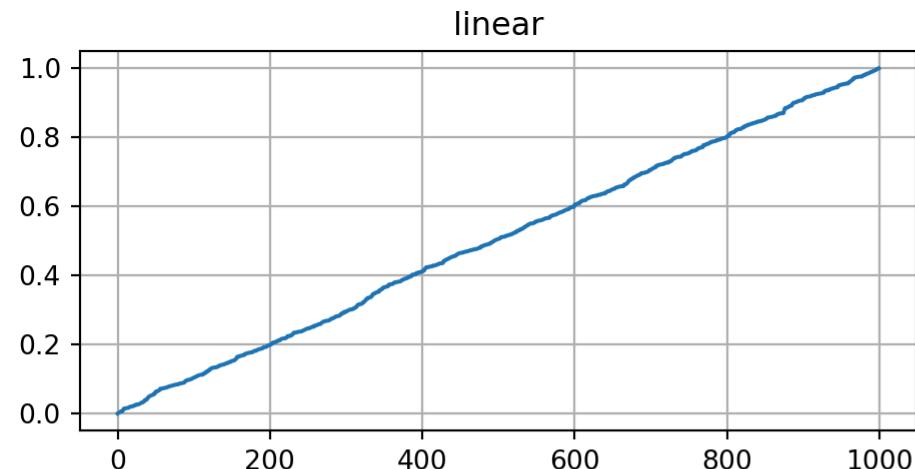


Scales

Axis scales can be changed via `plt.xscale()`, `plt.yscale()`, `ax.set_xscale()`, or `ax.set_yscale()`, supported values are “linear”, “log”, “symlog”, and “logit”.

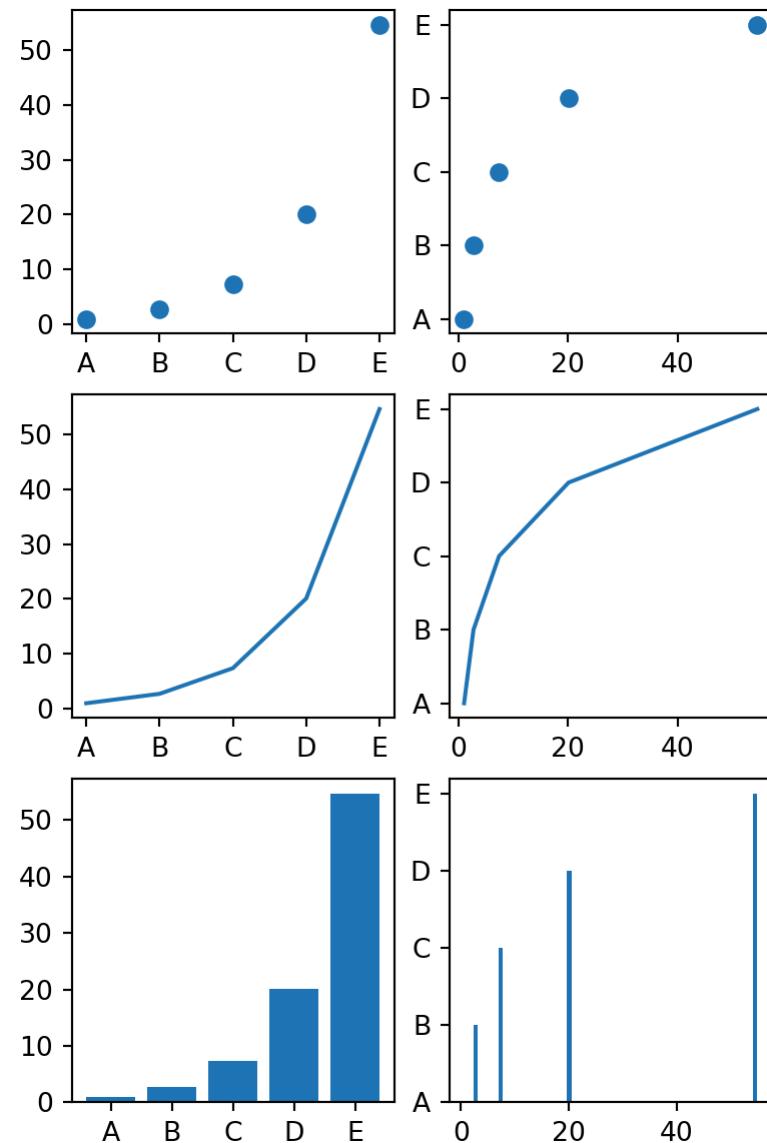
```
1 y = np.sort( np.random.sample(size=1000) )
2 x = np.arange(len(y))
3
4 plt.figure(layout="constrained")
5
6 scales = ['linear', 'log', 'symlog', 'logit']
7 for i, scale in enumerate(scales):
8     plt.subplot(221+i)
9     plt.plot(x, y)
10    plt.grid(True)
11    if scale == 'symlog':
12        plt.yscale(scale, linthresh=0.01)
13    else:
14        plt.yscale(scale)
15    plt.title(scale)
16
17
18 plt.show()
```

Scales



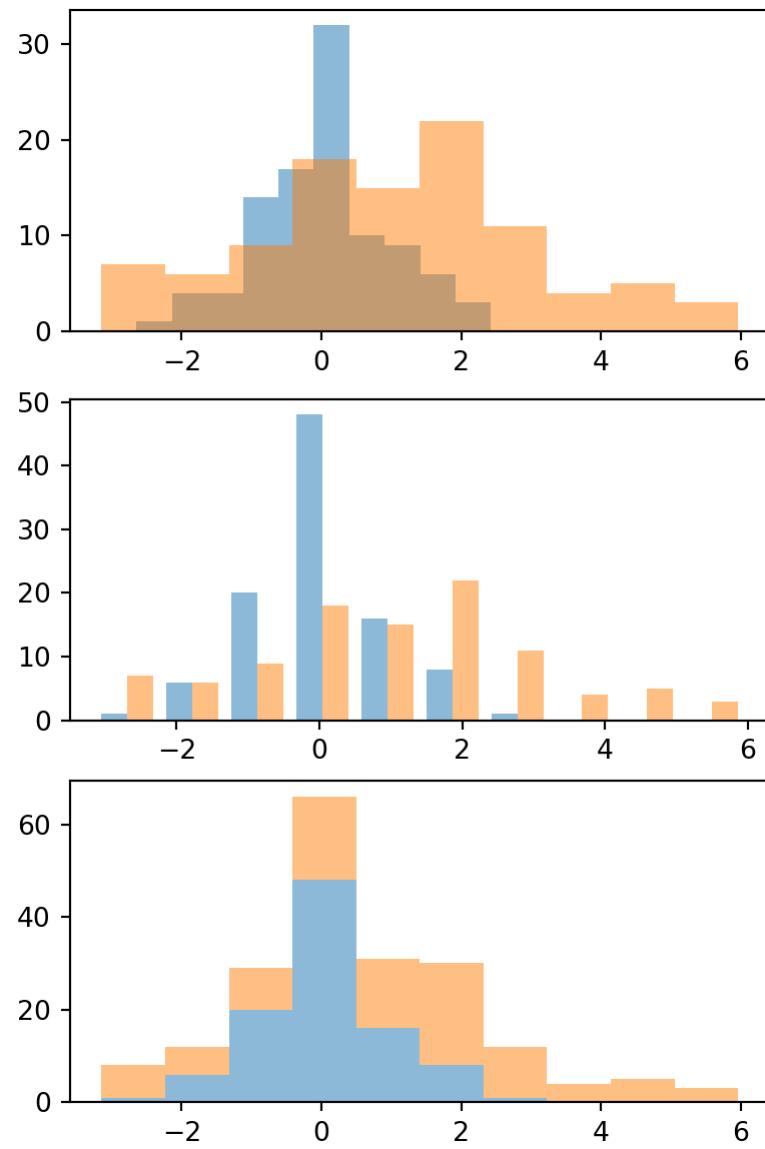
Categorical data

```
1 df = pd.DataFrame({  
2     "cat": ["A", "B", "C", "D", "E"],  
3     "value": np.exp(range(5))  
4 })  
5  
6 plt.figure(figsize=(4, 6), layout="con  
7  
8 plt.subplot(321)  
9 plt.scatter("cat", "value", data=df)  
10 plt.subplot(322)  
11 plt.scatter("value", "cat", data=df)  
12  
13 plt.subplot(323)  
14 plt.plot("cat", "value", data=df)  
15 plt.subplot(324)  
16 plt.plot("value", "cat", data=df)  
17  
18 plt.subplot(325)  
19 b = plt.bar("cat", "value", data=df)  
20 plt.subplot(326)  
21 b = plt.bar("value", "cat", data=df)
```



Histograms

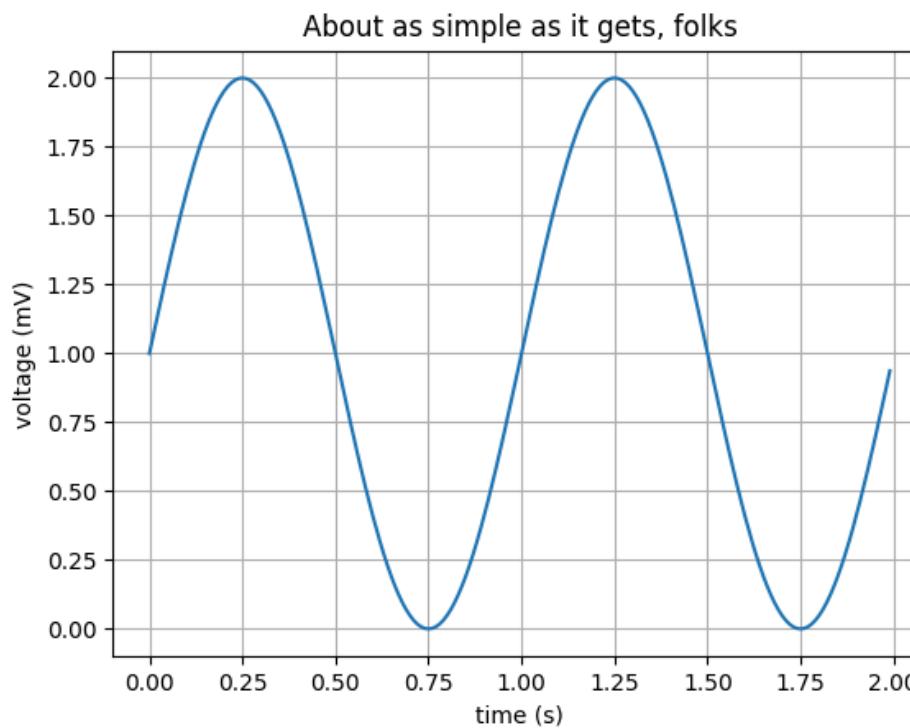
```
1 df = pd.DataFrame({  
2     "x1": np.random.normal(size=100),  
3     "x2": np.random.normal(1,2, size=100)  
4 })  
5  
6 plt.figure(figsize=(4, 6), layout="constrained")  
7  
8 plt.subplot(311)  
9 h = plt.hist("x1", bins=10, data=df, alpha=0.5)  
10 h = plt.hist("x2", bins=10, data=df, alpha=0.5)  
11  
12 plt.subplot(312)  
13 h = plt.hist(df, alpha=0.5)  
14  
15 plt.subplot(313)  
16 h = plt.hist(df, stacked=True, alpha=0.5)  
17  
18 plt.show()
```



Other Plot Types

Exercise 1

To the best of your ability recreate the following plot,



Seaborn

seaborn

Seaborn is a library for making statistical graphics in Python. It builds on top of **matplotlib** and integrates closely with **pandas** data structures.

Seaborn helps you explore and understand your data. Its plotting functions operate on dataframes and arrays containing whole datasets and internally perform the necessary semantic mapping and statistical aggregation to produce informative plots. Its dataset-oriented, declarative API lets you focus on what the different elements of your plots mean, rather than on the details of how to draw them.

```
1 import seaborn as sns
```

Penguins data

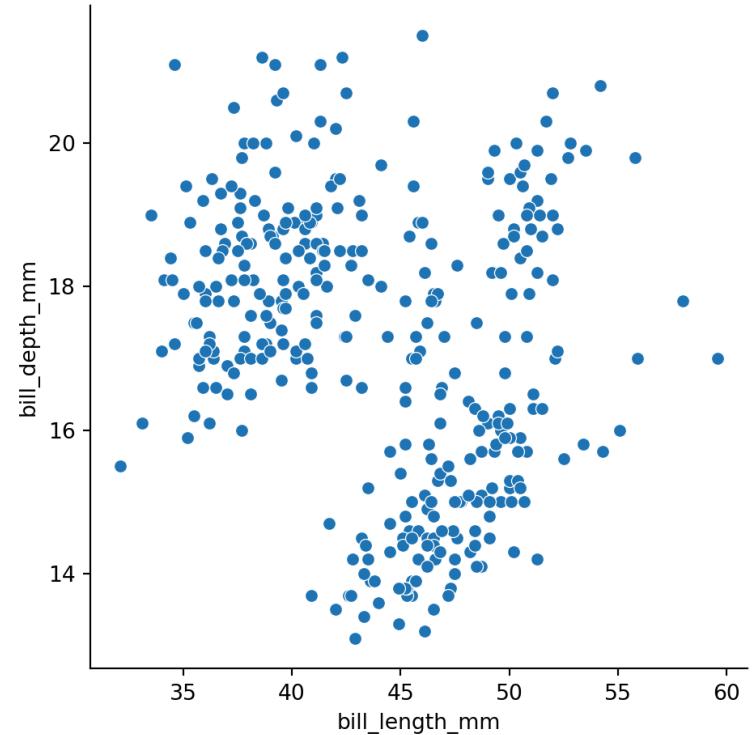
```
1 penguins = sns.load_dataset("penguins")
2 penguins
```

```
species      island bill_length_mm ... flipper_length_mm body_mass_g   sex
0   Adelie    Torgersen        39.1 ...          181.0     3750.0  Male
1   Adelie    Torgersen        39.5 ...          186.0     3800.0 Female
2   Adelie    Torgersen        40.3 ...          195.0     3250.0 Female
3   Adelie    Torgersen       NaN ...           NaN        NaN     NaN
4   Adelie    Torgersen        36.7 ...          193.0     3450.0 Female
...
339  Gentoo   Biscoe         NaN ...           NaN        NaN     NaN
340  Gentoo   Biscoe         46.8 ...          215.0     4850.0 Female
341  Gentoo   Biscoe         50.4 ...          222.0     5750.0  Male
342  Gentoo   Biscoe         45.2 ...          212.0     5200.0 Female
343  Gentoo   Biscoe         49.9 ...          213.0     5400.0  Male
```

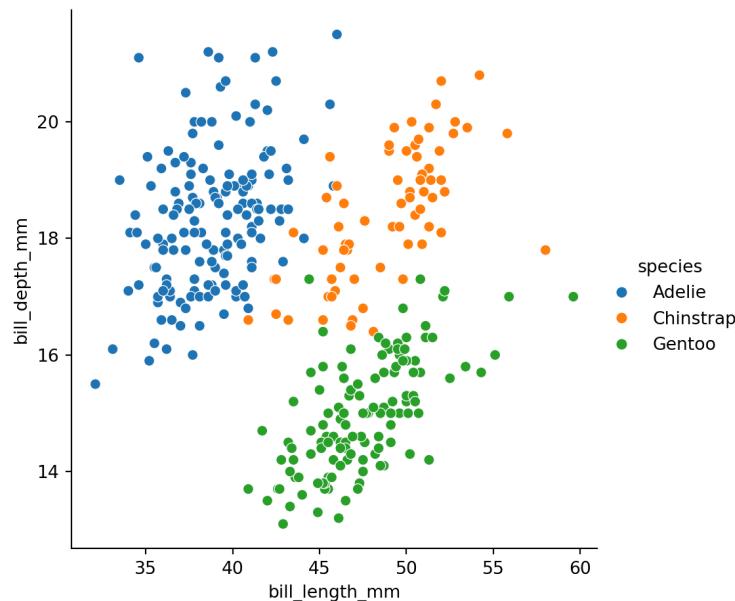
[344 rows x 7 columns]

Basic plots

```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm",  
4     y = "bill_depth_mm"  
5 )
```



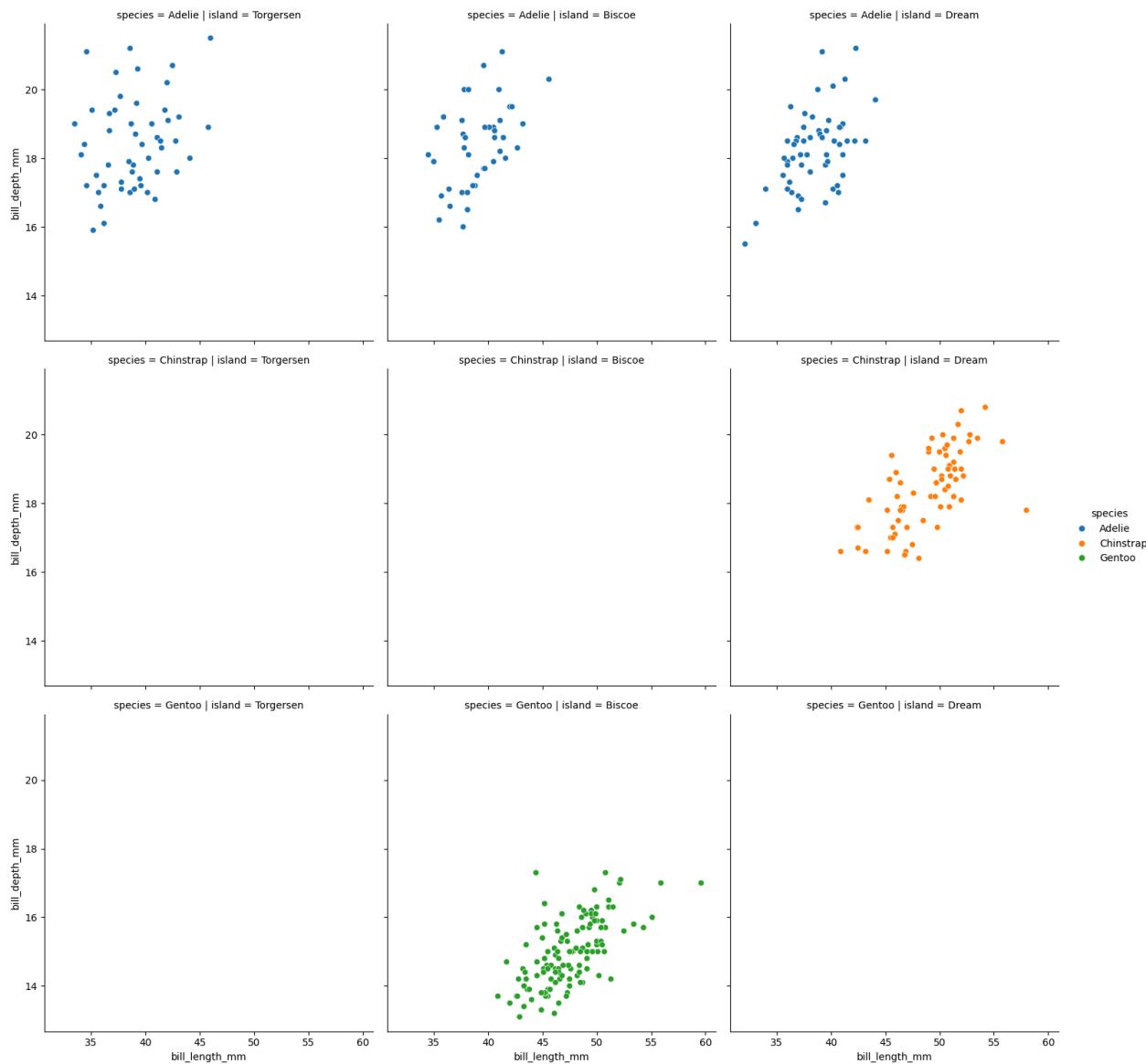
```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm",  
4     y = "bill_depth_mm",  
5     hue = "species"  
6 )
```



A more complex plot

```
1 sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm",  
4     hue = "species",  
5     col = "island", row = "species"  
6 )
```

A more complex plot



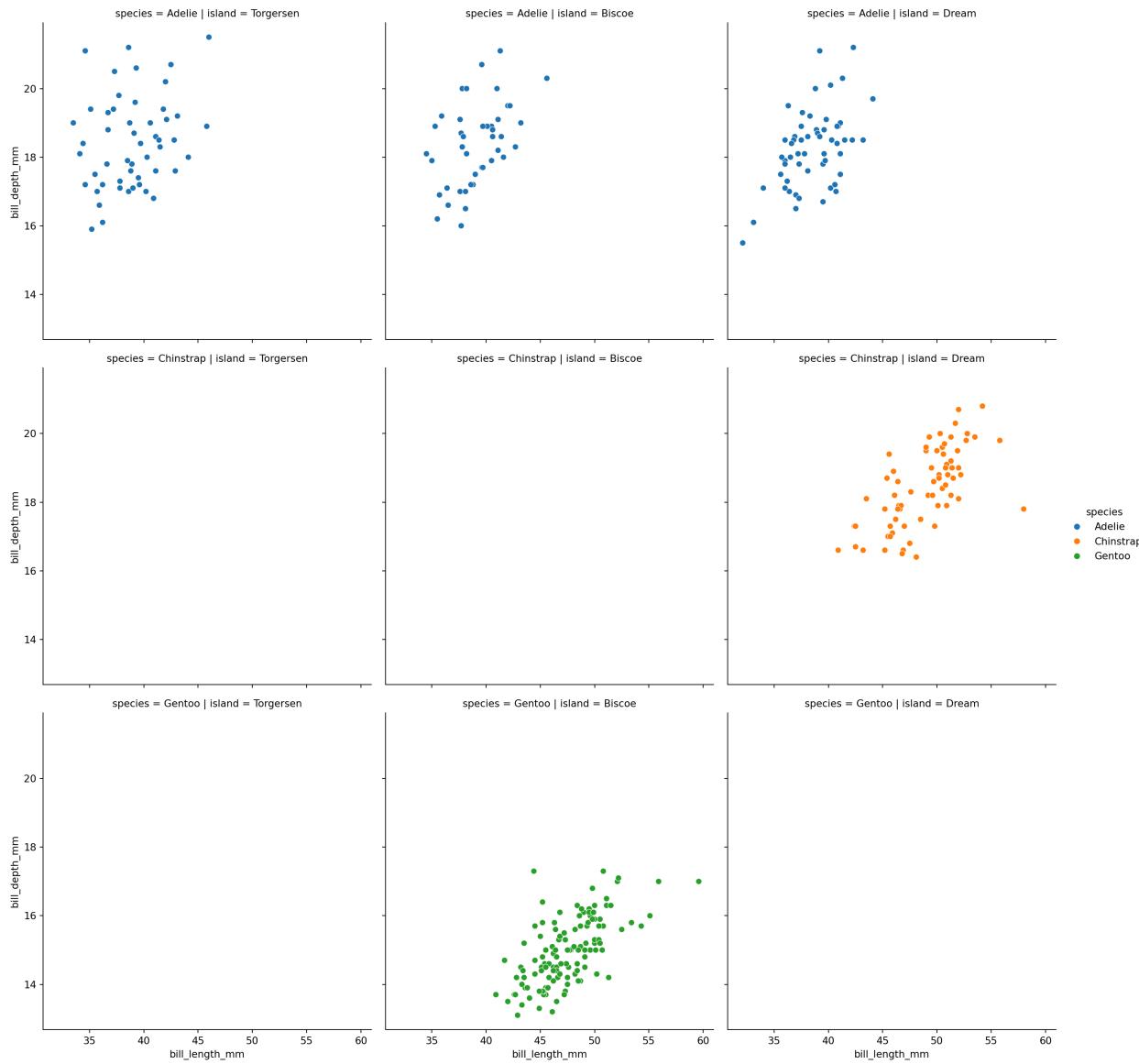
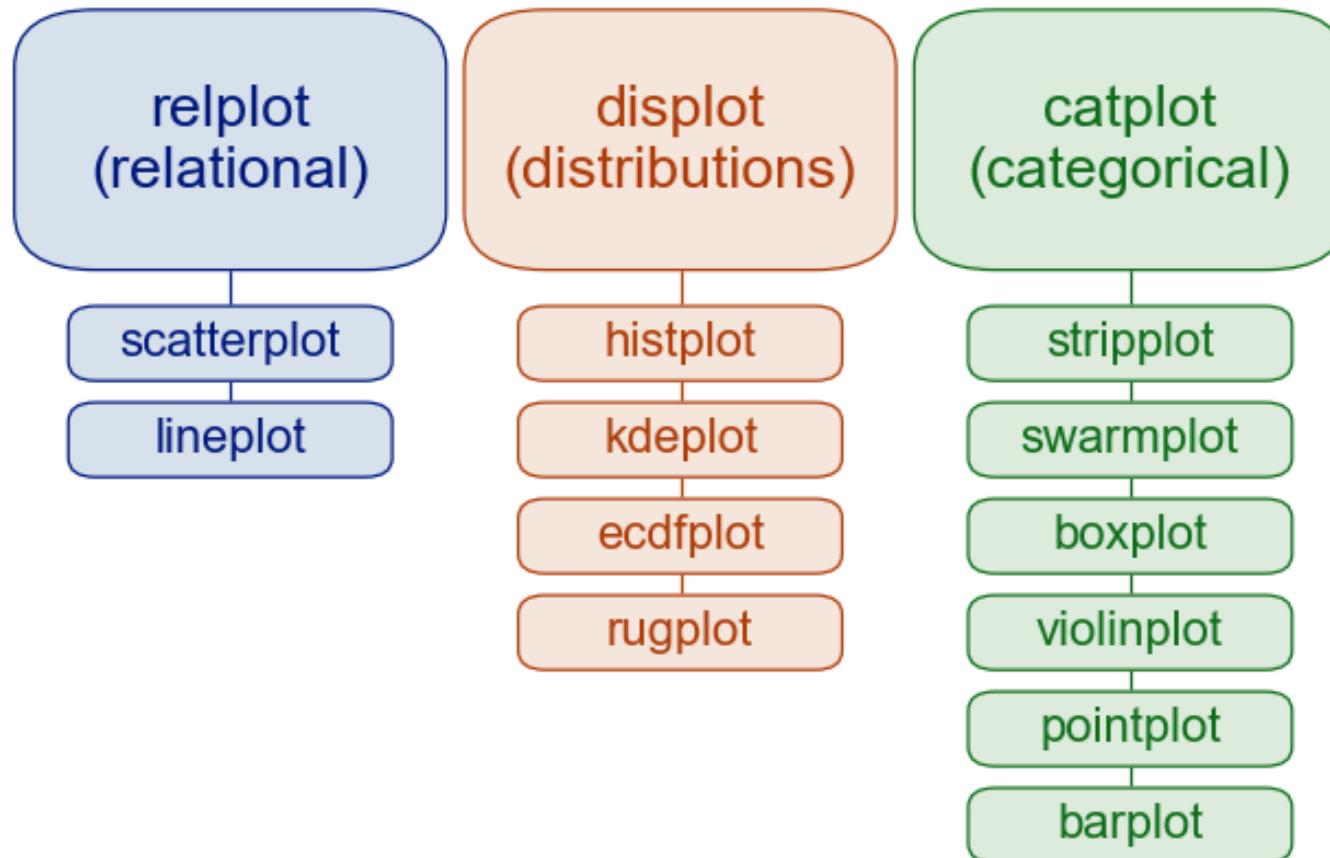
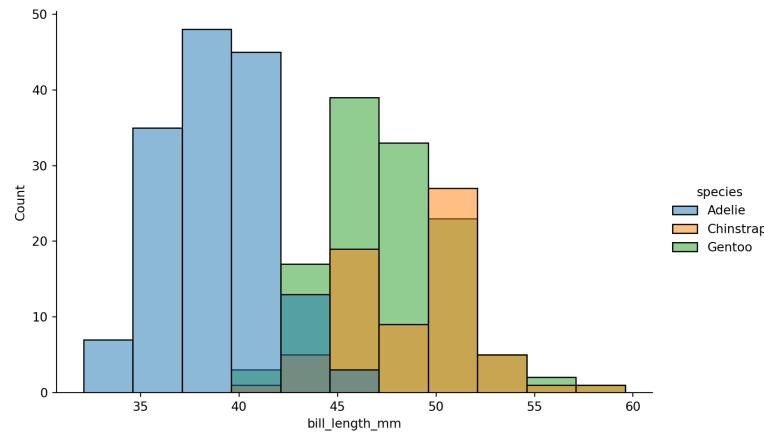


Figure-level vs. axes-level functions

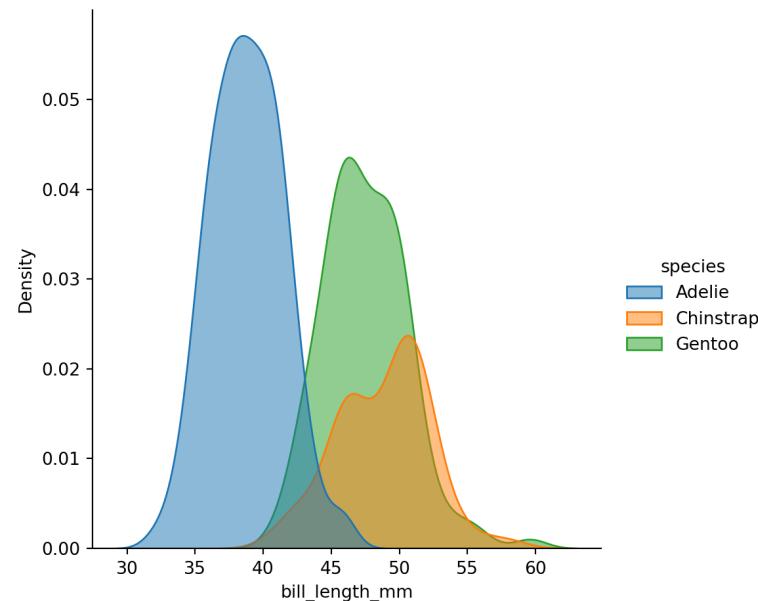


displots

```
1 g = sns.displot(  
2     data = penguins,  
3     x = "bill_length_mm",  
4     hue = "species",  
5     alpha = 0.5, aspect = 1.5  
6 )
```

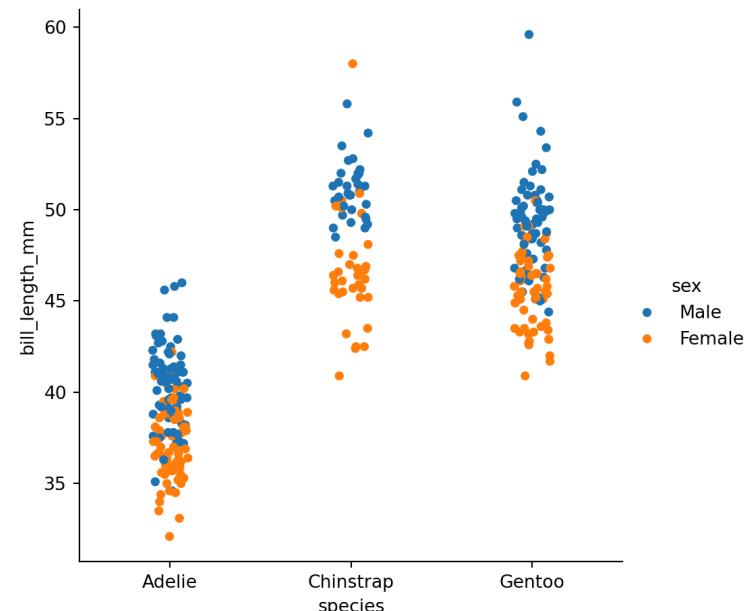


```
1 g = sns.displot(  
2     data = penguins,  
3     x = "bill_length_mm", hue = "species",  
4     kind = "kde", fill=True,  
5     alpha = 0.5, aspect = 1  
6 )
```



catplots

```
1 g = sns.catplot(  
2     data = penguins,  
3     x = "species",  
4     y = "bill_length_mm",  
5     hue = "sex"  
6 )
```



```
1 g = sns.catplot(  
2     data = penguins,  
3     x = "species",  
4     y = "bill_length_mm",  
5     hue = "sex",  
6     kind = "box"  
7 )
```

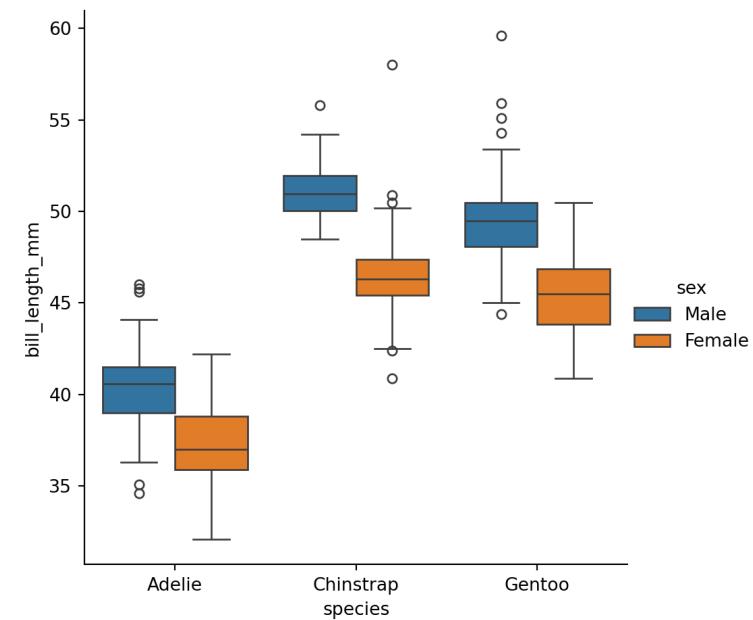
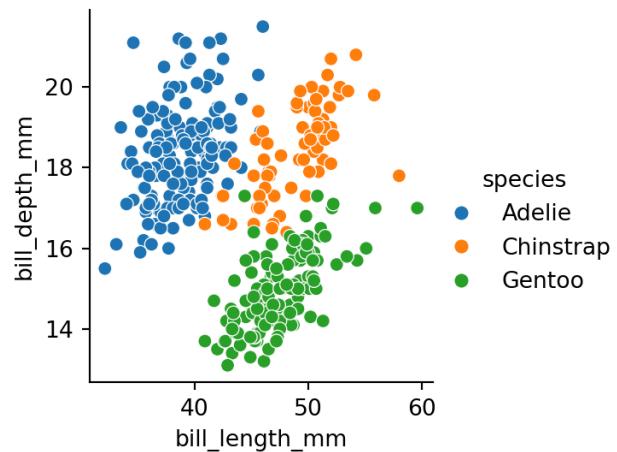


figure-level plot size

To adjust the size of plots generated via a figure-level plotting function adjust the `aspect` and `height` arguments, figure width is `aspect * height`.

```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_dept  
4     hue = "species",  
5     aspect = 1, height = 3  
6 )
```



```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_dept  
4     hue = "species",  
5     aspect = 1, height = 5  
6 )
```

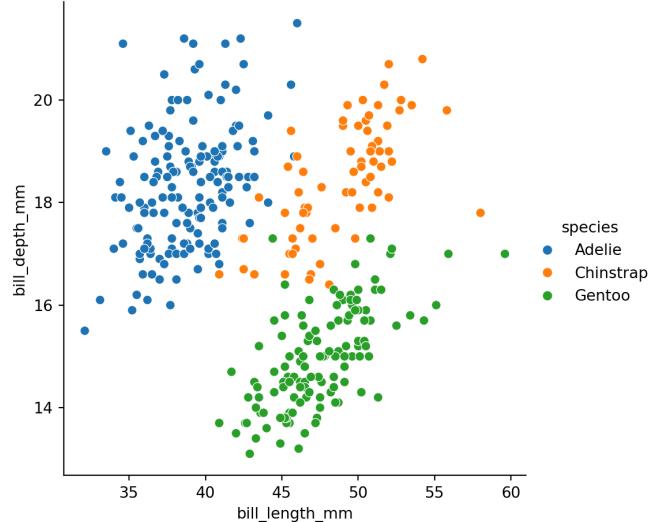
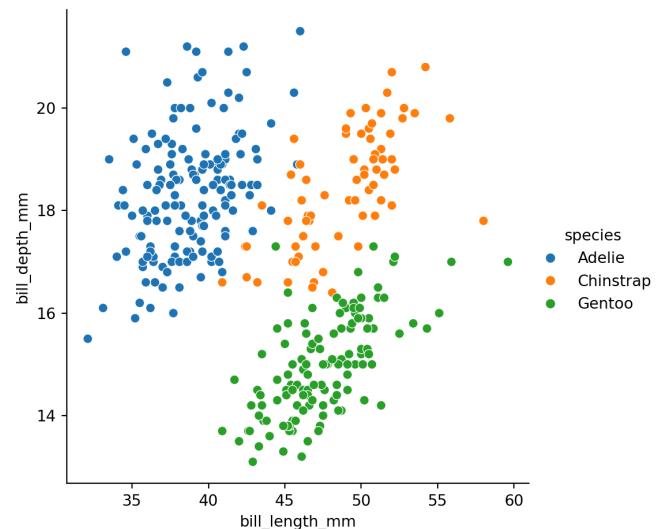


figure-level plots

```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm",  
4     hue = "species",  
5     aspect = 1  
6 )
```



```
1 h = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm",  
4     hue = "species", col = "island",  
5     aspect = 1/2  
6 )
```

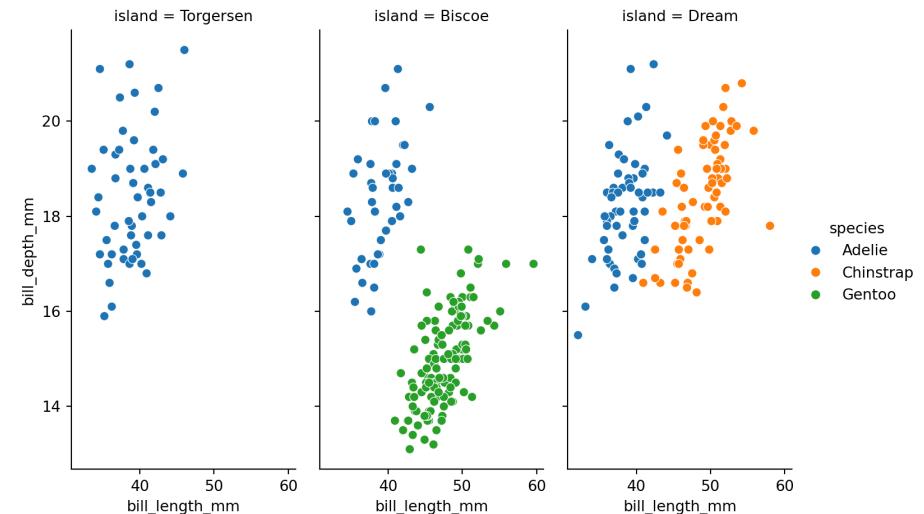


figure-level plot objects

Figure-level plotting methods return a `FacetGrid` object (which is a wrapper around lower level pyplot figure(s) and axes).

```
1 print(g)
```

```
<seaborn.axisgrid.FacetGrid object at 0x30cf0470>
```

```
1 print(h)
```

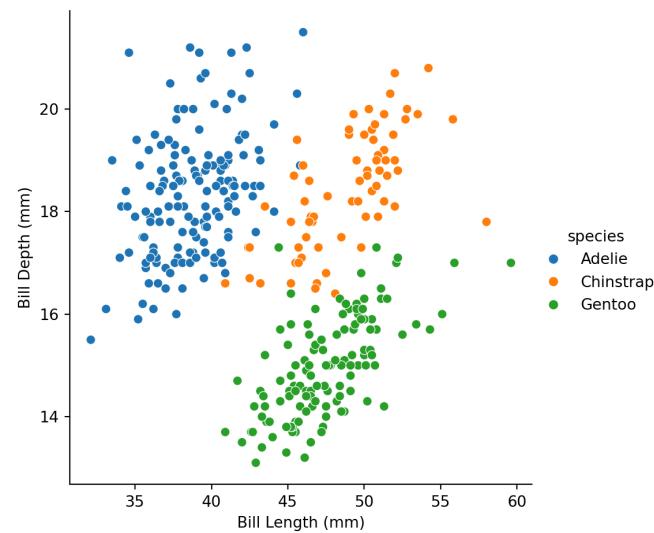
```
<seaborn.axisgrid.FacetGrid object at 0x313588200>
```

FacetGrid methods

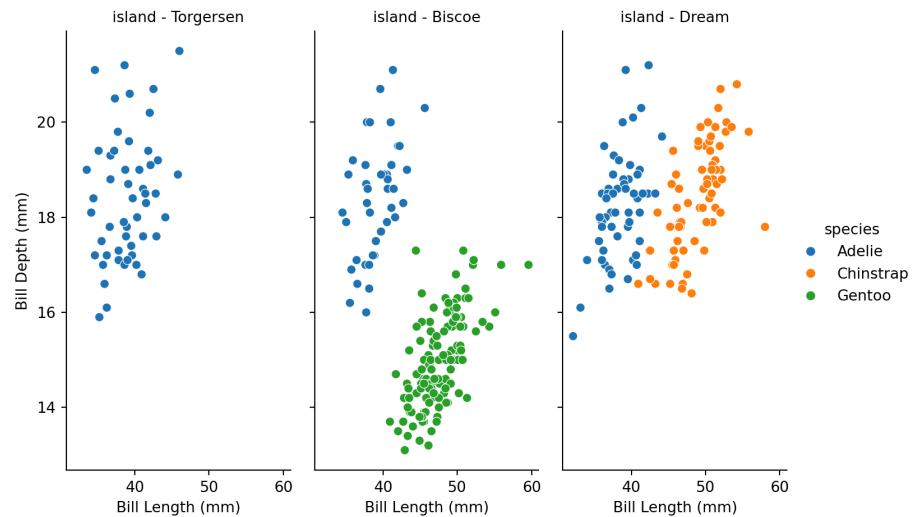
Method	Description
<code>add_legend()</code>	Draw a legend, maybe placing it outside axes and resizing the figure
<code>despine()</code>	Remove axis spines from the facets.
<code>facet_axis()</code>	Make the axis identified by these indices active and return it.
<code>facet_data()</code>	Generator for name indices and data subsets for each facet.
<code>map()</code>	Apply a plotting function to each facet's subset of the data.
<code>map_dataframe()</code>	Like <code>.map()</code> but passes args as strings and inserts data in kwargs.
<code>refline()</code>	Add a reference line(s) to each facet.
<code>savefig()</code>	Save an image of the plot.
<code>set()</code>	Set attributes on each subplot Axes.
<code>set_axis_labels()</code>	Set axis labels on the left column and bottom row of the grid.
<code>set_titles()</code>	Draw titles either above each facet or on the grid margins.
<code>set_xlabels()</code>	Label the x axis on the bottom row of the grid.
<code>set_xticklabels()</code>	Set x axis tick labels of the grid.
<code>set_ylabels()</code>	Label the y axis on the left column of the grid.
<code>set_yticklabels()</code>	Set y axis tick labels on the left column of the grid.
<code>tight_layout()</code>	Call <code>fig.tight_layout</code> within rect that exclude the legend.

Adjusting labels

```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm"  
4     hue = "species",  
5     aspect = 1  
6 ).set_axis_labels(  
7     "Bill Length (mm)",  
8     "Bill Depth (mm)"  
9 )
```



```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm"  
4     hue = "species", col = "island",  
5     aspect = 1/2  
6 ).set_axis_labels(  
7     "Bill Length (mm)",  
8     "Bill Depth (mm)"  
9 ).set_titles(  
10    "{col_var} - {col_name}"  
11 )
```

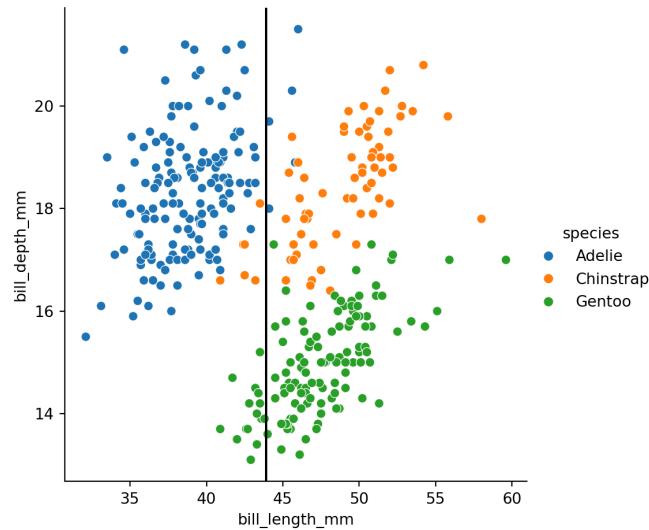


FacetGrid attributes

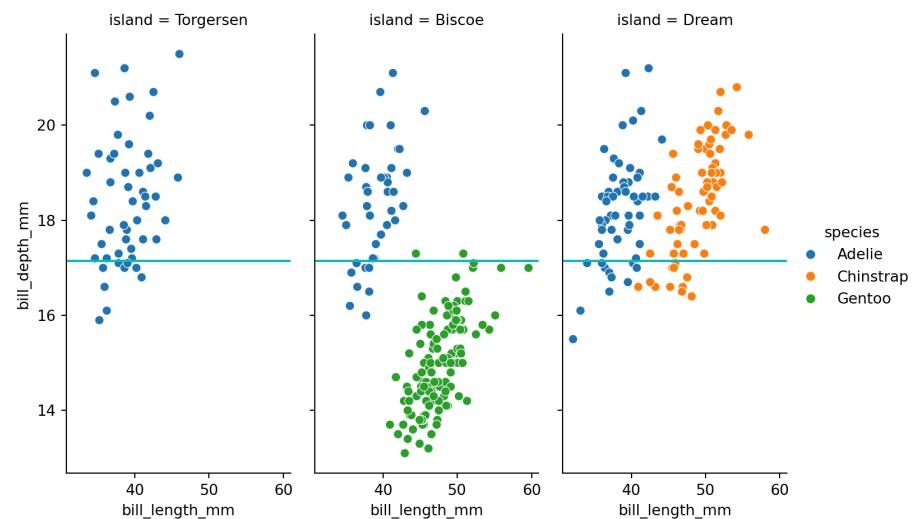
Attribute	Description
ax	The <code>matplotlib.axes.Axes</code> when no faceting variables are assigned.
axes	An array of the <code>matplotlib.axes.Axes</code> objects in the grid.
axes_dict	A mapping of facet names to corresponding <code>matplotlib.axes.Axes</code> .
figure	Access the <code>matplotlib.figure.Figure</code> object underlying the grid.
legend	The <code>matplotlib.legend.Legend</code> object, if present.

Using axes to modify plots

```
1 g = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm"  
4     hue = "species",  
5     aspect = 1  
6 )  
7 g.ax.axvline(  
8     x = penguins.bill_length_mm.mean(), c = "c")  
9 )
```



```
1 h = sns.relplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm",  
4     hue = "species", col = "island",  
5     aspect = 1/2  
6 )  
7 mean_bill_dep = penguins.bill_depth_mm.mean()  
8  
9 [ ax.axhline(y=mean_bill_dep, c = "c")  
10   for row in h.axes for ax in row ]
```



Why figure-level functions?

Advantages:

- Easy faceting by data variables
- Legend outside of plot by default
- Easy figure-level customization
- Different figure size parameterization

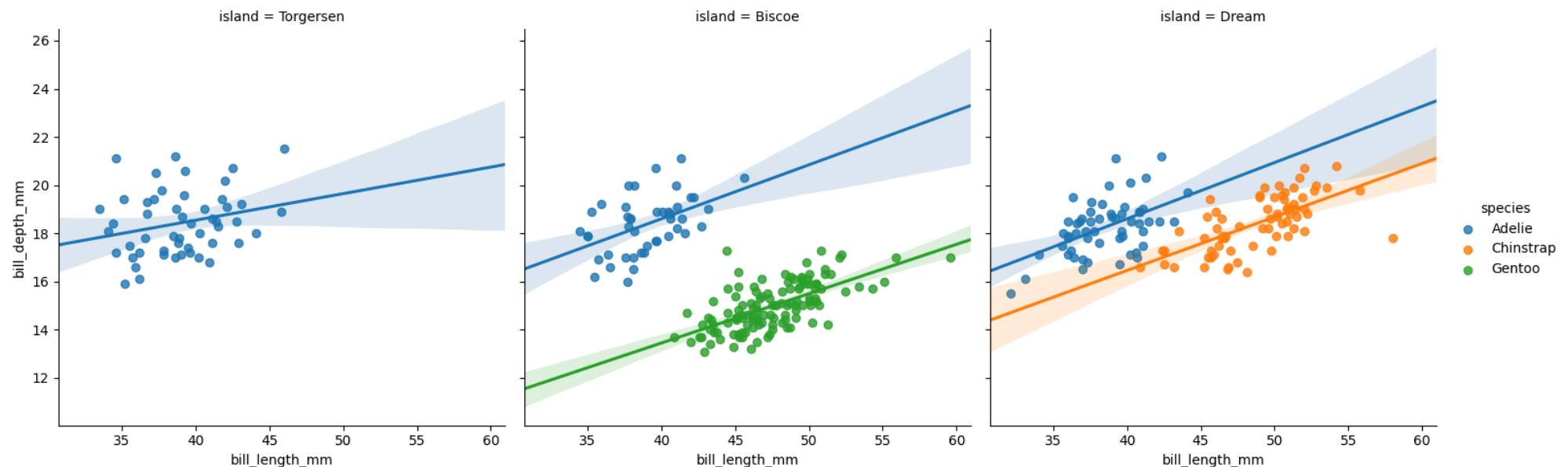
Disadvantages:

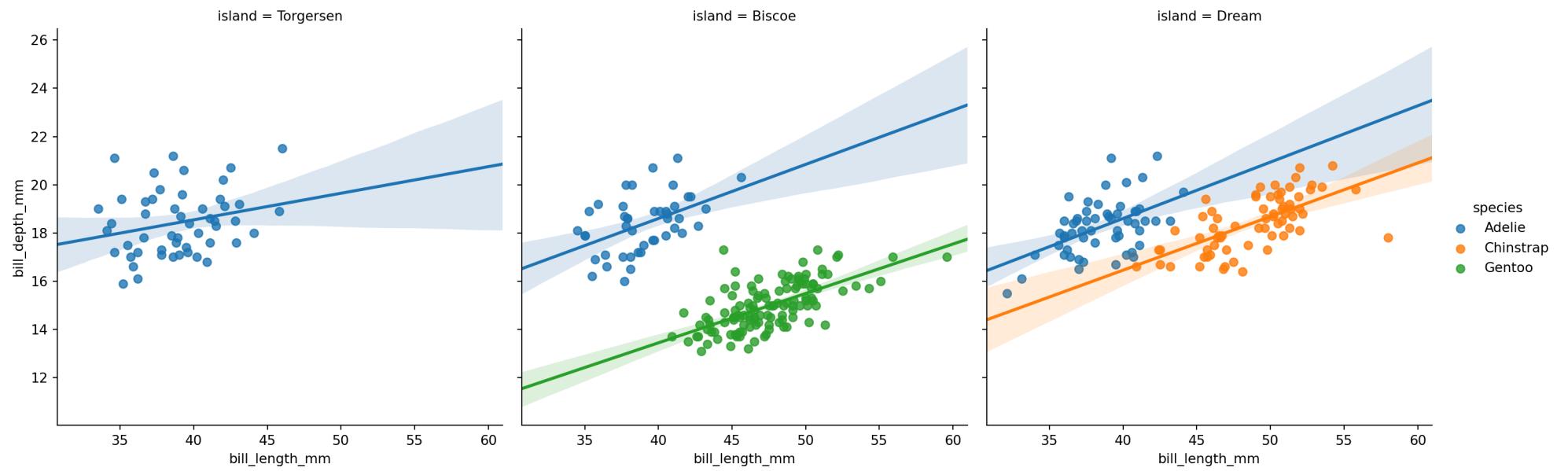
- Many parameters not in function signature
- Cannot be part of a larger matplotlib figure
- Different API from matplotlib
- Different figure size parameterization

lmplots

There is one additional figure-level plot type - `lmplot()` which is a convenient interface to fitting and plotting regression models across subsets of data,

```
1 sns.lmplot(  
2     data = penguins,  
3     x = "bill_length_mm", y = "bill_depth_mm",  
4     hue = "species", col = "island",  
5     aspect = 1, truncate = False  
6 )
```



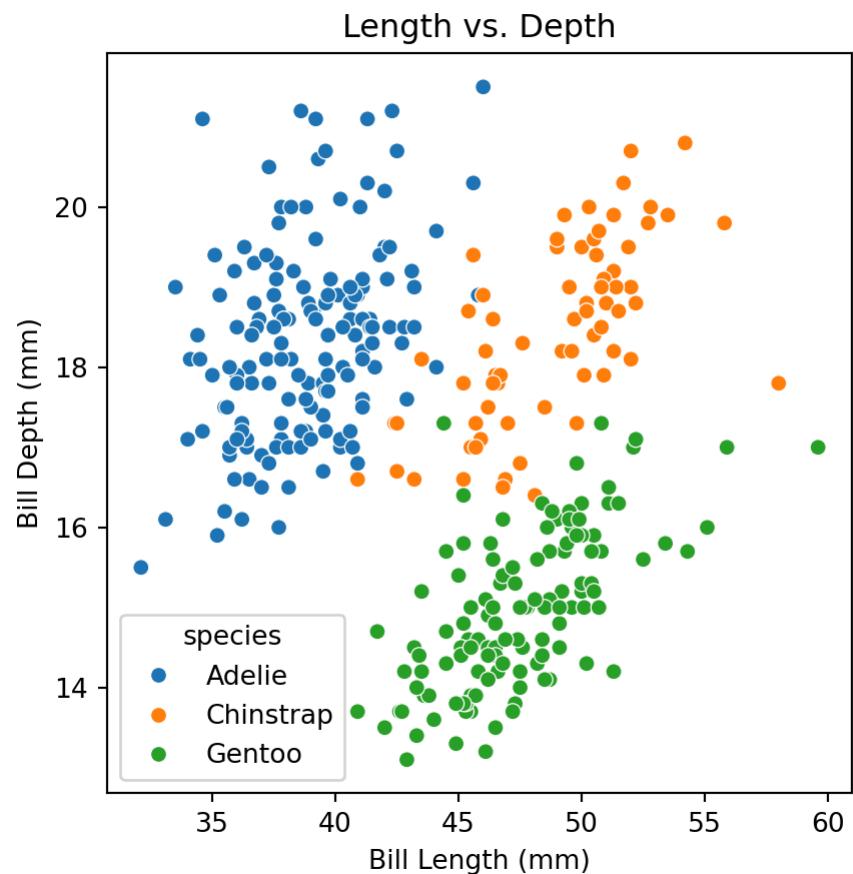


axes-level plots

axes-level functions

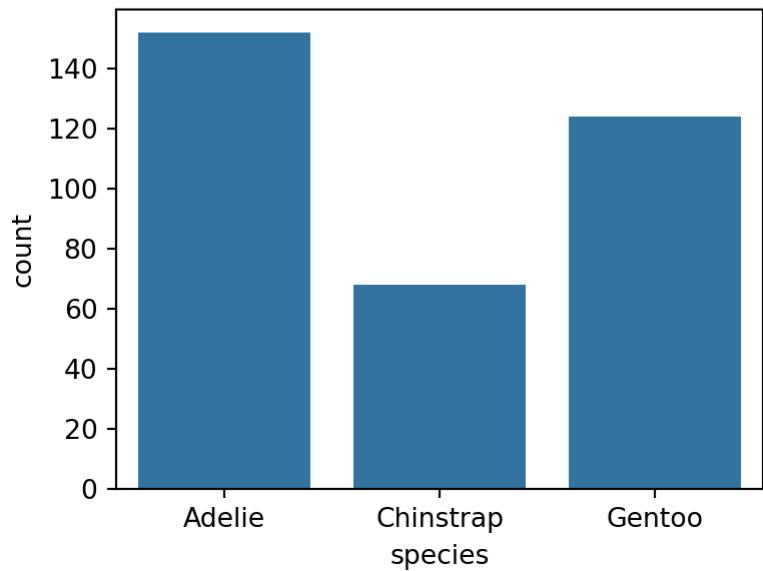
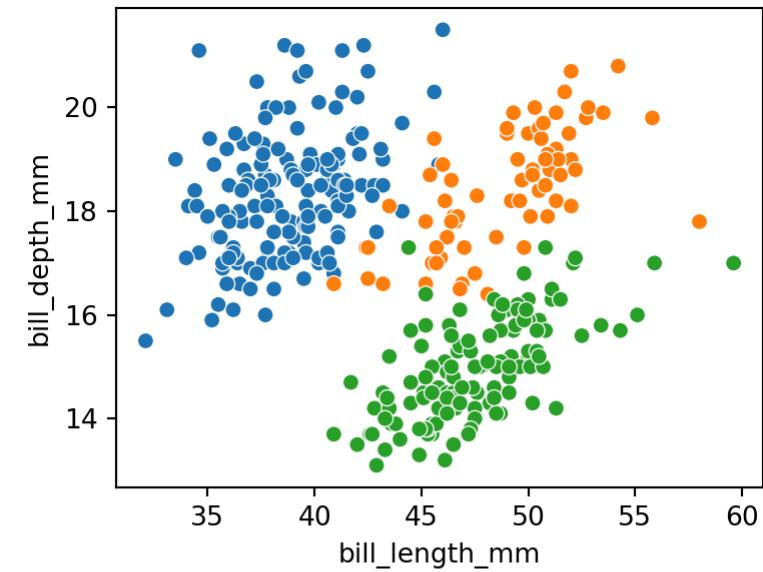
These functions return a `matplotlib.pyplot.Axes` object instead of a `FacetGrid`, giving more direct control over the plot using basic matplotlib tools.

```
1 plt.figure(figsize=(5,5))
2
3 sns.scatterplot(
4     data = penguins,
5     x = "bill_length_mm",
6     y = "bill_depth_mm",
7     hue = "species"
8 )
9
10 plt.xlabel("Bill Length (mm)")
11 plt.ylabel("Bill Depth (mm)")
12 plt.title("Length vs. Depth")
13
14 plt.show()
```



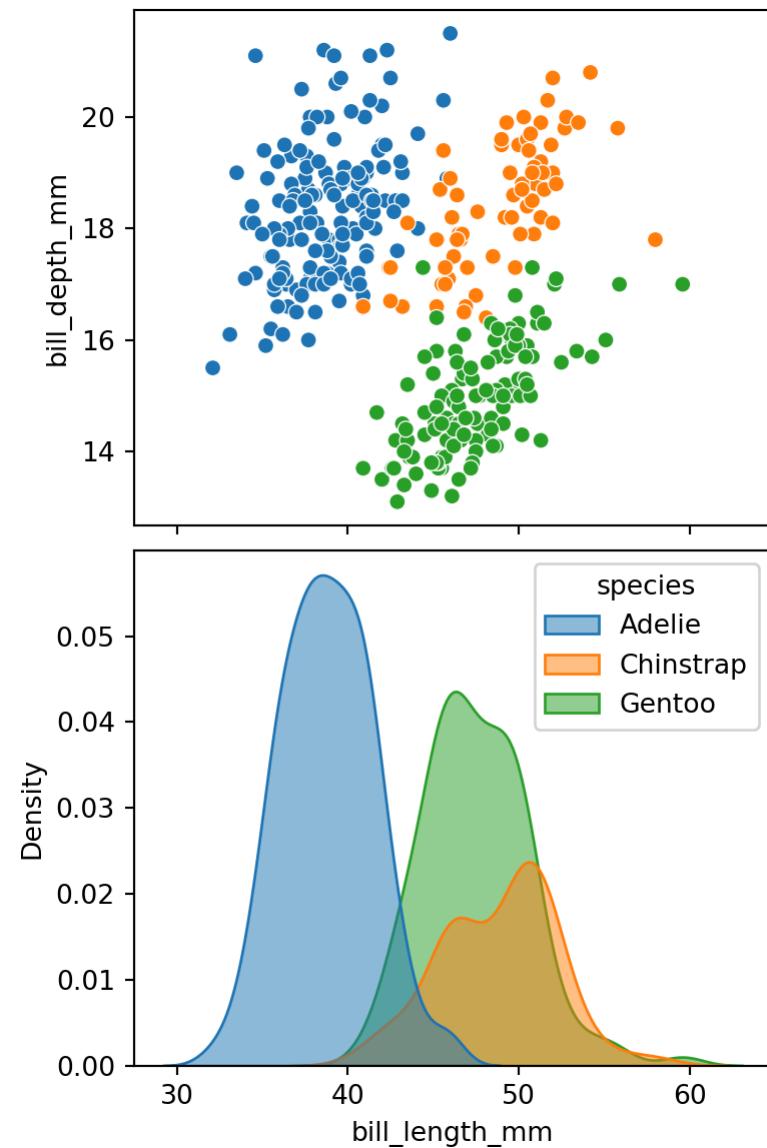
subplots - pyplot style

```
1 plt.figure(  
2     figsize=(4,6),  
3     layout = "constrained"  
4 )  
5  
6 plt.subplot(211)  
7 sns.scatterplot(  
8     data = penguins,  
9     x = "bill_length_mm",  
10    y = "bill_depth_mm",  
11    hue = "species"  
12 )  
13 plt.legend().remove()  
14  
15 plt.subplot(212)  
16 sns.countplot(  
17     data = penguins,  
18     x = "species"  
19 )  
20  
21 plt.show()
```



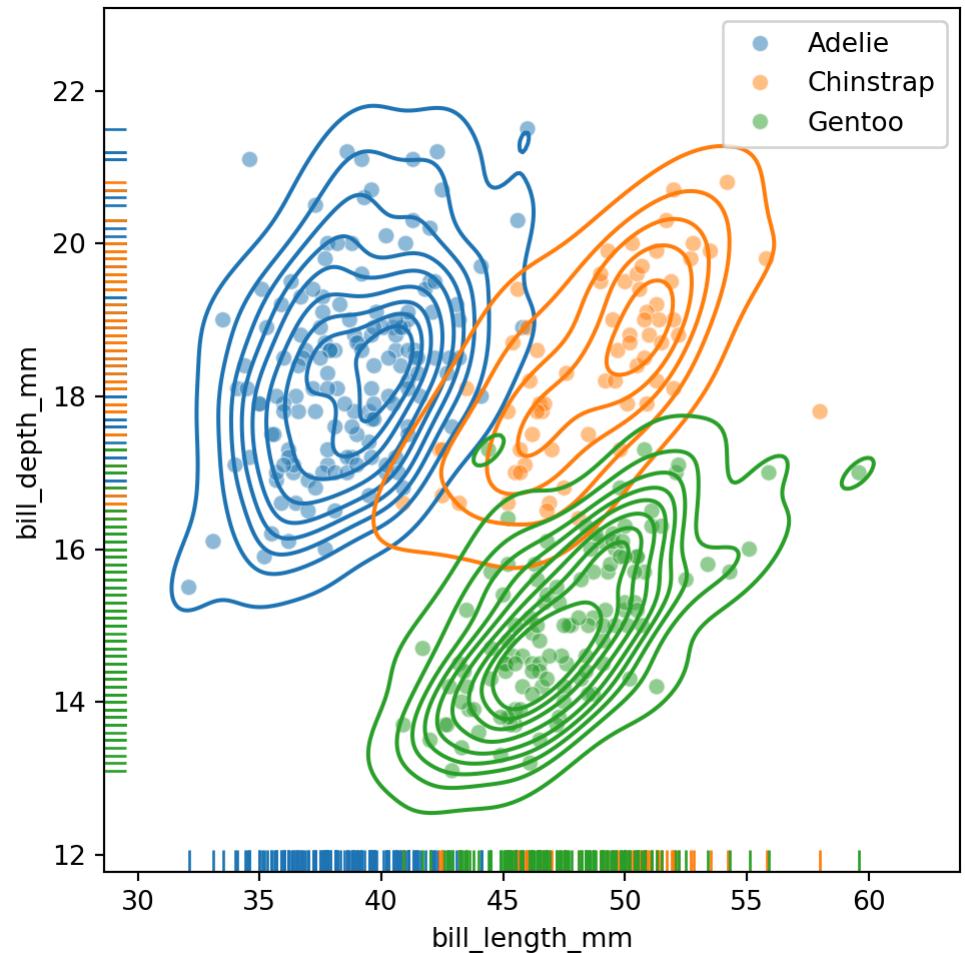
subplots - OO style

```
1 fig, axs = plt.subplots(  
2     2, 1, figsize=(4,6),  
3     layout = "constrained",  
4     sharex=True  
5 )  
6  
7 sns.scatterplot(  
8     data = penguins,  
9     x = "bill_length_mm", y = "bill_dept  
10    hue = "species",  
11    ax = axs[0]  
12 )  
13 axs[0].get_legend().remove()  
14  
15 sns.kdeplot(  
16     data = penguins,  
17     x = "bill_length_mm", hue = "species"  
18     fill=True, alpha=0.5,  
19     ax = axs[1]  
20 )  
21 ...
```



layering plots

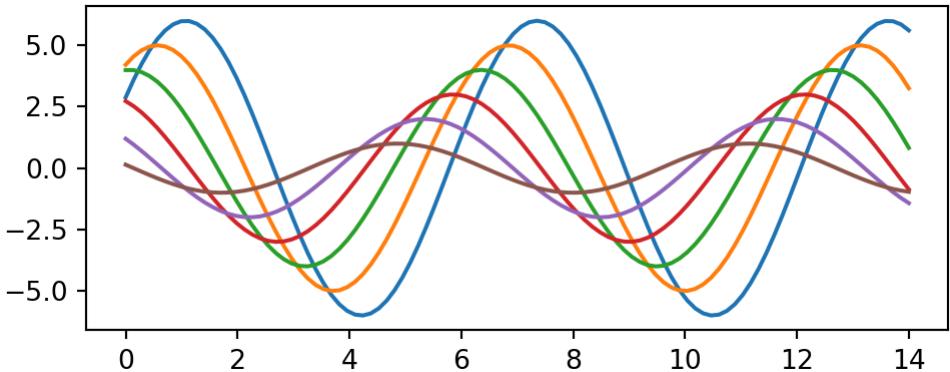
```
1 plt.figure(figsize=(5,5),
2             layout = "constrained")
3
4 sns.kdeplot(
5     data = penguins,
6     x = "bill_length_mm", y = "bill_depth_mm"
7     hue = "species"
8 )
9 sns.scatterplot(
10    data = penguins,
11    x = "bill_length_mm", y = "bill_depth_mm"
12    hue = "species", alpha=0.5
13 )
14 sns.rugplot(
15    data = penguins,
16    x = "bill_length_mm", y = "bill_depth_mm"
17    hue = "species"
18 )
19 plt.legend()
20
21 plt.show()
```



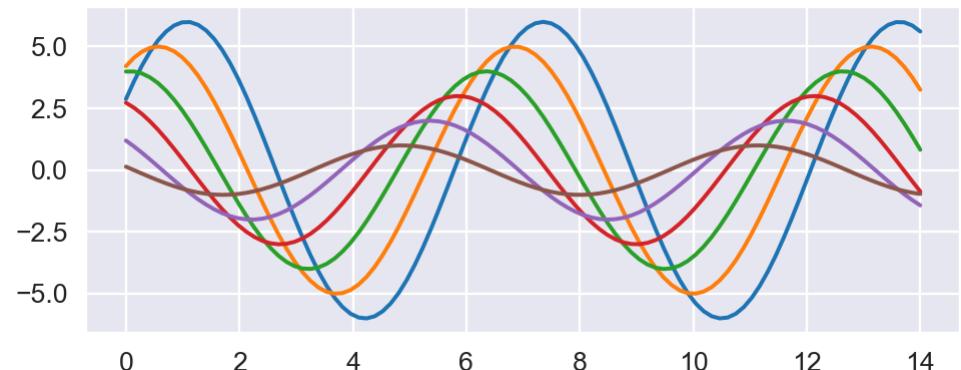
Themes

Seaborn comes with a number of themes (`darkgrid`, `whitegrid`, `dark`, `white`, and `ticks`) which can be enabled at the figure level with `sns.set_theme()` or at the axes level with `sns.axes_style()`.

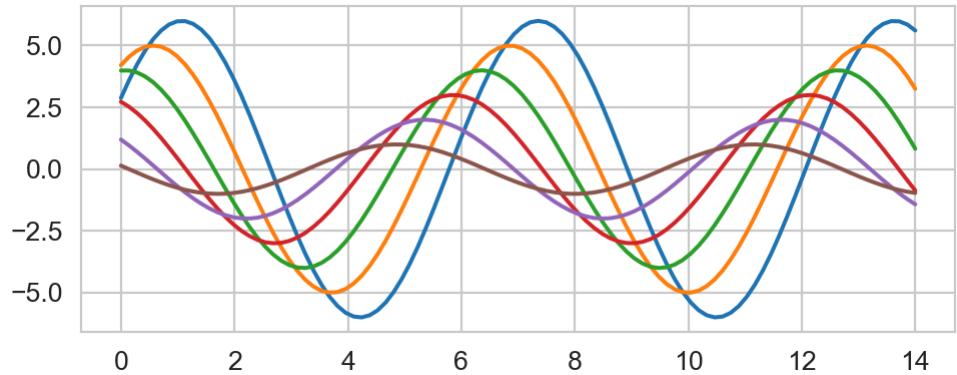
```
1 def sinplot():
2     plt.figure(figsize=(5,2), layout = "constrained")
3     x = np.linspace(0, 14, 100)
4     for i in range(1, 7):
5         plt.plot(x, np.sin(x + i * .5) * (7 - i))
6     plt.show()
7
8 sinplot()
```



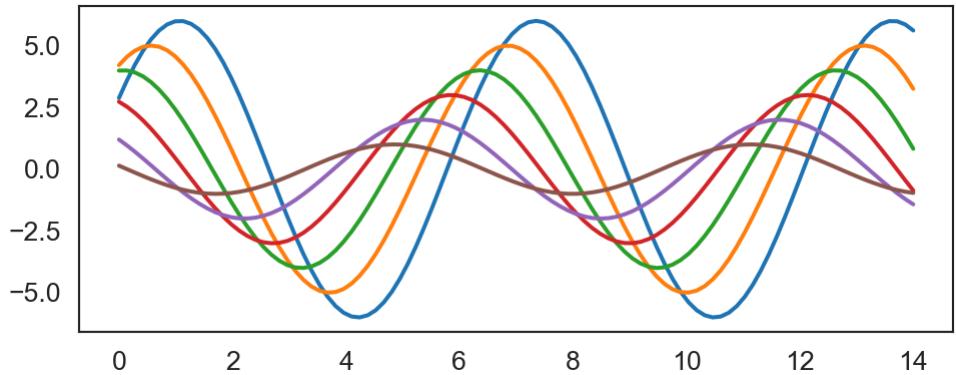
```
1 with sns.axes_style("darkgrid"):
2     sinplot()
```



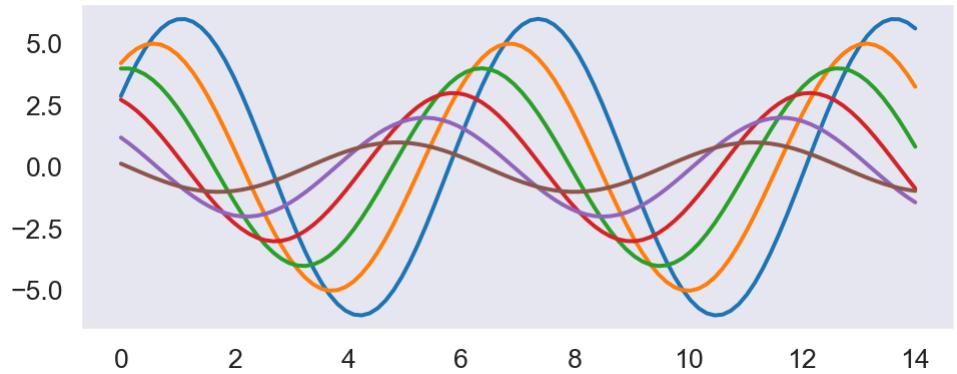
```
1 with sns.axes_style("whitegrid"):
2     sinplot()
```



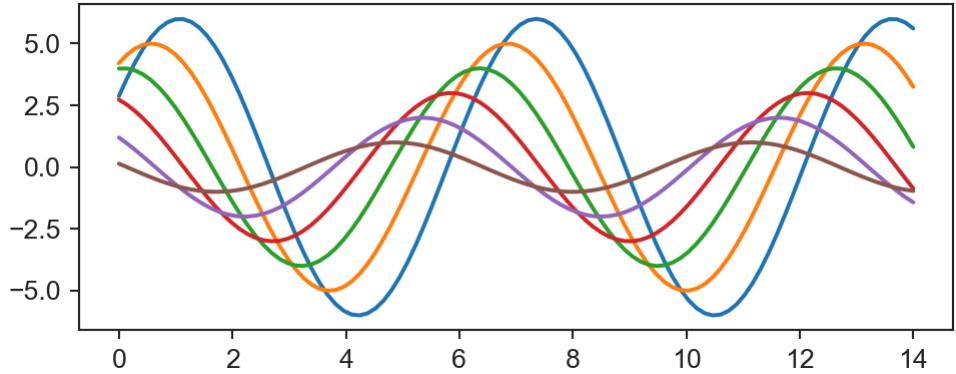
```
1 with sns.axes_style("white"):
2     sinplot()
```



```
1 with sns.axes_style("dark"):
2     sinplot()
```

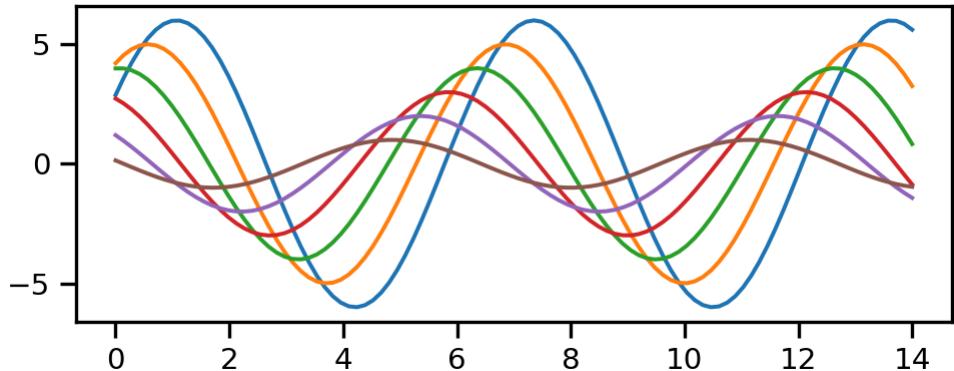


```
1 with sns.axes_style("ticks"):
2     sinplot()
```

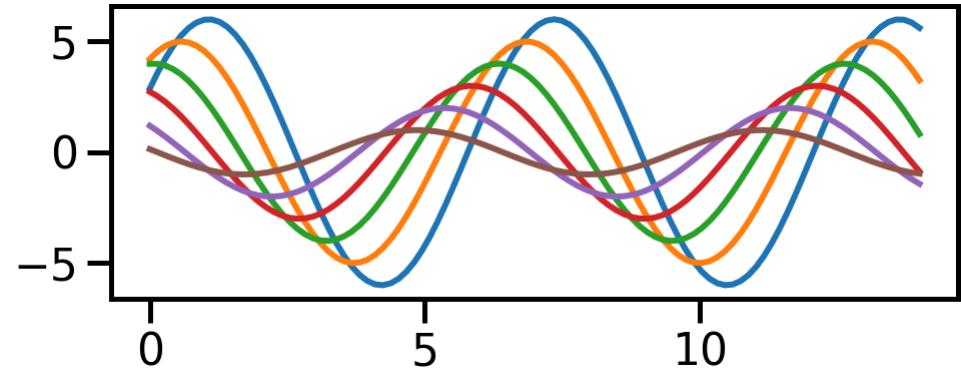


Context

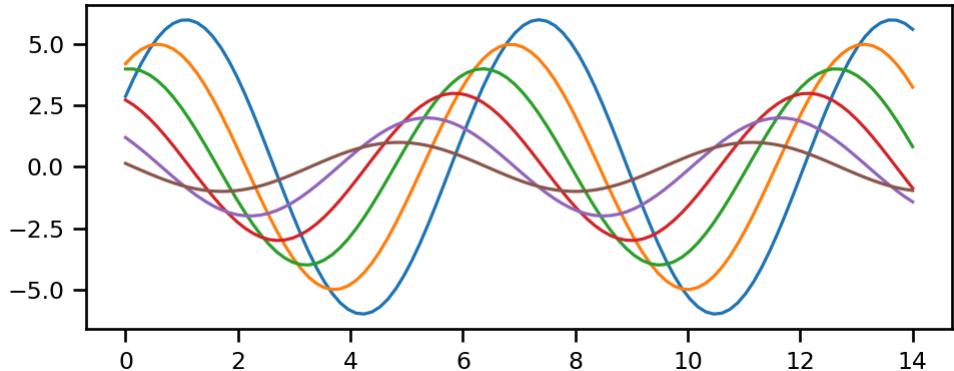
```
1 sns.set_context("notebook")
2 sinplot()
```



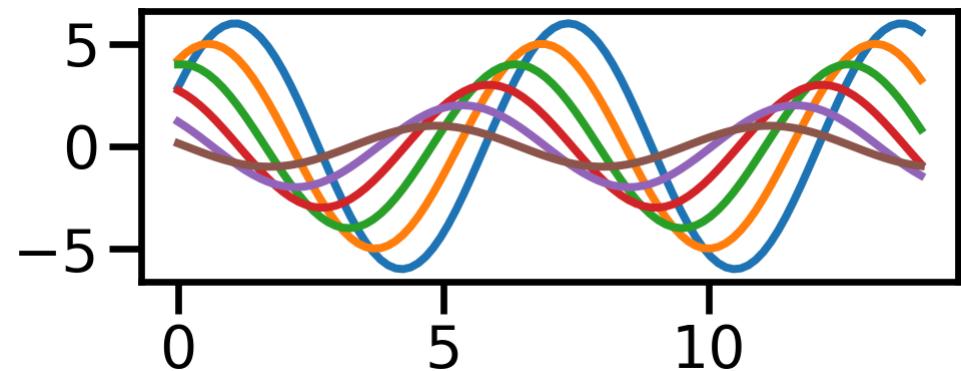
```
1 sns.set_context("talk")
2 sinplot()
```



```
1
2 sns.set_context("paper")
3 sinplot()
```



```
1 sns.set_context("poster")
2 sinplot()
```



Color palettes

All of the examples below are the result of calls to `sns.color_palette()` with `as_cmap=True` for the continuous case,

```
1 show_palette()
```



```
1 show_palette("husl")
```



```
1 show_palette("tab10")
```



```
1 show_palette("Set2")
```



```
1 show_palette("hls")
```



```
1 show_palette("Paired")
```



Continuous palettes

```
1 show_cont_palette("viridis")
```



```
1 show_cont_palette("YlOrBr")
```



```
1 show_cont_palette("cubehelix")
```



```
1 show_cont_palette("vlag")
```



```
1 show_cont_palette("light:b")
```



```
1 show_cont_palette("mako")
```



```
1 show_cont_palette("dark:salmon_r")
```



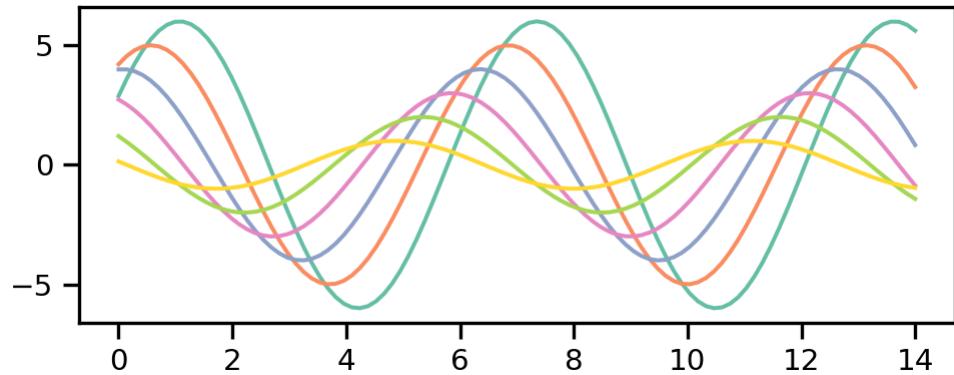
```
1 show_cont_palette("rocket")
```



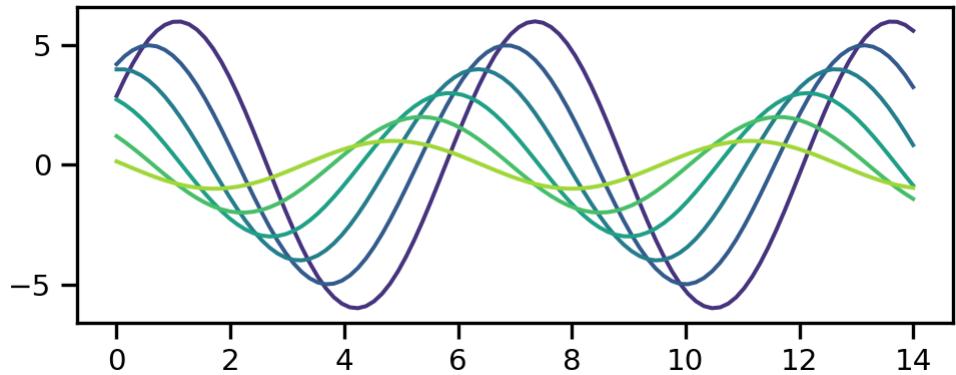
Applying palettes

Palettes are applied via the `set_palette()` function,

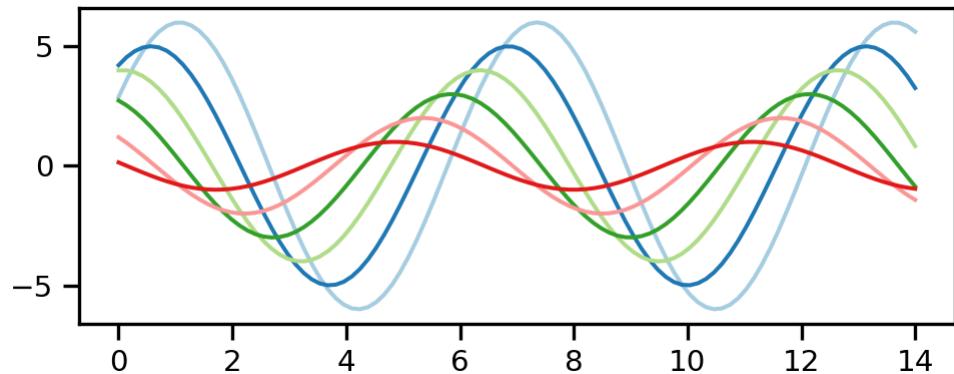
```
1 sns.set_palette("Set2")
2 sinplot()
```



```
1 sns.set_palette("viridis")
2 sinplot()
```



```
1 sns.set_palette("Paired")
2 sinplot()
```



```
1 sns.set_palette("rocket")
2 sinplot()
```

