

Franklin

The MBG jupyter exercise tool

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1

The student runs a jupyter notebook on their own computer in a way that lets them focus on content and learning without the frustration by library incompatibilities and platform specific dependencies.

On both Mac and Windows, running the following command, prompts the student to select course and exercise and then downloads a folder with a jupyter notebook.

Listing 1.1 Terminal

```
franklin download
```

The student runs the following command, which again prompts for course and exercise and launches JupyterLab from an environment on the student's computer with all required dependencies preinstalled.

Listing 1.2 Terminal

```
franklin jupyter
```

The environment and notebook is exactly the same, wether on Mac or Windows, allowing them to work together, compare results, and receive uniform and unambiguous feedback from instructors.

Part I

Terminal

2 The terminal

 This pages are under construction

A terminal is a text-based interface that allows users to interact with the operating system by typing commands. It provides direct access to the system shell—a program that interprets user input and executes corresponding instructions.

Historically, “terminals” referred to physical devices (e.g., teletypewriters or CRT monitors) connected to mainframe computers. In modern computing, a terminal is typically a software application (e.g., Terminal on macOS, GNOME Terminal on Linux, Command Prompt or PowerShell on Windows) that emulates this interface.

Key characteristics of a terminal include:

Command-Line Interface (CLI): Unlike graphical user interfaces (GUIs), a terminal requires textual input and returns textual output. **Shell Access:** The terminal runs a shell such as `bash`, `zsh`, or `fish`, which interprets and executes user commands (e.g., file manipulation, process control, networking). **Script Execution:** Users can run scripts, automate tasks, and chain commands using control operators (e.g., `&&`, `|`, `>`, etc.). **Remote Access:** Terminals can be used to log into remote systems via protocols such as SSH, providing a low-overhead method for remote system administration and programming. The terminal is a powerful tool, particularly in software development, system administration, and high-performance computing. It enables reproducibility, fine-grained control, and automation, though it requires users to become familiar with a command language and often lacks the immediate feedback and discoverability of graphical interfaces.

Ctrl-C for abort

3 Jupyterlab

Introduction to JupyterLab

JupyterLab is the next-generation web-based user interface for Project Jupyter, designed to offer a flexible and extensible environment for interactive computing. It builds upon the classic Jupyter Notebook interface by integrating a wide range of tools—code consoles, terminals, text editors, data file viewers, and notebooks—into a unified workspace.

The JupyterLab interface is organized into a multi-tab layout, resembling an integrated development environment (IDE). Users can open multiple documents side by side (e.g., a Python script next to a Markdown file and a terminal), drag-and-drop tabs, and link interactive views of the same dataset. It supports live code execution, output rendering (including plots and LaTeX equations), and seamless integration with kernels for many languages, though Python is most common.

Key features of JupyterLab include:

Notebook authoring: Full support for .ipynb notebooks with executable code cells, Markdown, and rich outputs. **Code consoles:** Interactive REPLs connected to notebooks or scripts for testing code snippets. **Text and code editing:** Built-in editor with syntax highlighting, version control integration, and support for many file types. **Terminal access:** Direct command-line interface within the browser for shell-level operations. **Extensibility:** Modular architecture that supports plugins for additional language kernels, visualizations, or custom workflows. JupyterLab preserves all the functionality of the classic notebook interface while offering a more powerful and customizable platform suitable for complex data science workflows, scientific research, and reproducible computing. It is widely used in academia, industry, and education due to its interactive nature and support for literate programming principles.

JupyterLab is a highly extensible, feature-rich notebook authoring application and editing environment, and is a part of Project Jupyter, a large umbrella project centered around the goal of providing tools (and standards) for interactive computing with computational notebooks.

A computational notebook is a shareable document that combines computer code, plain language descriptions, data, rich visualizations like 3D models, charts, graphs and figures, and interactive controls. A notebook, along with an editor like JupyterLab, provides a fast interactive environment for prototyping and explaining code, exploring and visualizing data, and sharing ideas with others.

JupyterLab is a sibling to other notebook authoring applications under the Project Jupyter umbrella, like Jupyter Notebook and Jupyter Desktop. JupyterLab offers a more advanced, feature rich, customizable experience compared to Jupyter Notebook.MM



Figure 3.1: image.png

4 Starting jupyter lab

Terminal commands:

```
conda activate ctib  
jupyter lab
```

It then appears in your default browser. |

5 Side panes



- alks flaksjf laskjdf laskdjf

asdf laksdfj

Jupyter Notebooks are an interactive computing environment that allow users to create and share documents containing live code, equations, visualizations, and narrative text. Originally developed as part of the IPython project, Jupyter (short for Julia, Python, R) now supports over 100 programming languages and has become a standard tool in data science, scientific computing, and education.

At the core of a Jupyter Notebook is a web-based interface that organizes content into “cells.” These cells can contain code (typically in Python, but also in other languages via kernels), formatted text using Markdown, LaTeX for equations, and embedded multimedia elements. Users execute code in-place, and outputs such as plots or tables appear directly below the corresponding cells. This structure enables exploratory data analysis and facilitates reproducibility by interleaving code and its results with documentation.

Notebooks are stored in .ipynb files (JSON format), which preserve the code, outputs, and formatting. They can be run locally using the Jupyter server or hosted in cloud

environments such as Google Colab or Binder. For scientific workflows, notebooks can integrate with tools for version control, containerization, and workflow management, making them a flexible instrument for open and reproducible research.

Despite their strengths, Jupyter Notebooks are not without limitations. Version control can be challenging due to the JSON-based format, and improper use (e.g., out-of-order execution) can compromise reproducibility. Nevertheless, their advantages in accessibility, interactivity, and communication have made them central to modern computational work.

5.1 Keyboard shortcuts

5.1.1 Command Mode in Jupyter Notebooks

In Jupyter Notebooks, **Command Mode** is one of the two main interaction modes—the other being **Edit Mode**. Command Mode is active when the cell border is **blue**, indicating that keyboard commands will be interpreted as notebook-level operations rather than editing the cell's content.

Command Mode allows users to manage cells and perform structural modifications without using the mouse. This enhances efficiency, especially when working with large notebooks. Pressing Esc while in a cell activates Command Mode.

Common Keyboard Shortcuts in Command Mode 5-1

| Shortcut | Description |
|--------------------------------|--|
| Enter | Switch to Edit Mode in the selected cell |
| A | Insert a new cell above the current cell |
| B | Insert a new cell below the current cell |
| D, D | Delete the selected cell (press D twice quickly) |
| Z | Undo the last cell deletion |
| Y | Change cell type to code |
| M | Change cell type to Markdown |
| C | Copy the selected cell |
| X | Cut the selected cell |
| V | Paste cell below |
| Shift + V | Paste cell above |
| Shift + Up/Down | Extend selection to multiple cells |
| Ctrl + S (or Cmd + S on macOS) | Save the notebook |
| H | Show all keyboard shortcuts |
| 0, 0 | Restart the kernel (press 0 twice quickly) |

| Shortcut | Description |
|-----------------------------|-----------------------------|
| Shift + M (in Command Mode) | Merge selected cells |

These shortcuts make navigation and cell management significantly faster, enabling an efficient coding and documentation workflow within Jupyter Notebooks.

5.1.2 Edit Mode in Jupyter Notebooks

Edit Mode is activated when a cell's border turns **green**, allowing the user to directly modify the contents of the cell. You can enter Edit Mode by pressing Enter while a cell is selected in Command Mode. This mode is primarily used for writing and editing code or Markdown content within cells.

Common Keyboard Shortcuts in Edit Mode 5-2

| Shortcut | Description |
|-----------------------|--|
| Ctrl + Enter | Run the current cell and remain in Edit Mode |
| Shift + Enter | Run the current cell and move to the next cell |
| Alt + Enter | Run the current cell and insert a new cell below |
| Esc | Switch to Command Mode |
| Ctrl + / | Toggle comment on selected lines (code cells only) |
| Tab | Code completion or indent |
| Shift + Tab | Show tooltip/help for the object under cursor |
| Ctrl +] | Indent the current line or selection |
| Ctrl + [| Dedent the current line or selection |
| Ctrl + A | Select all content in the cell |
| Ctrl + Z | Undo the last change |
| Ctrl + Y | Redo the last undone change |
| Ctrl + Shift + - | Split the current cell at cursor position into two cells |
| Ctrl + S (or Cmd + S) | Save the notebook |
| Ctrl + Shift + - | Split the cell at the current cursor position |

These shortcuts are optimized for efficient coding and content editing, significantly reducing reliance on the mouse and improving productivity within Jupyter Notebooks.

6 Launching a new notebook or terminal

Pick the folder icon in the side pane menu on the left, click the big blue button and launch a notebook

7 Multiple notebooks or terminal views

8 Split windows

9 Controls

9.1 Menu, Toolbar, Context menu

9.2 Command palette: Command/Ctrl Shift C

9.3 Keyboard short-cuts: Command/Ctrl Shift H

10 Three kinds of cells

```
print('hello world')
```

hello world

This is *formatted* markdown

This is raw text

11 Running code in cells

11.1 Code blocks

```
x = 0
```

11.2 Last value is displayed

```
x = 1  
x
```

1

11.3 Everything is one Python process

```
x += 1  
x
```

2

11.4 Restarting the kernel

12 Two kinds of “Undo”

- Edit/Undo to undo stuff in the current cell
- Edit/Undo Cell Operation to undo deleting, moving, merging cells

13 Moving and copy/paste cells

```
print("Move this cell somewhere")
```

Move this cell somewhere

Some other cell

14 Split and merge cells

15 Markdown text

<https://quarto.org/docs/authoring/markdown-basics.html>

This is some more markdown with **bold** text and *italics* and showing that something is a code, like `x = 2 + 2`.

15.1 Lists

- foo
- bar
- baz

15.2 Numbered lists

1. foo
2. bar
3. baz

15.3 Quotes

“ This is a quote

”

15.4 Formulas

$\sum_{i=0}^n i$

HTML

15.5Header 2

15.5.1 Header 3

Header 4 15-1

15.6Formulas

$$\sum_{i=0}^n i$$

15.7Tables

| Name | Value |
|------|-------|
| foo | 2 |
| bar | 3 |

16 HTML magic

```
%%html  
<style>  
table {float:left}  
</style>
```

```
<IPython.core.display.HTML object>
```


17 Images

Make markdown cell and then drag an image into it:

Some other cell

18 Table of content and cell folding

19 Shell commands

```
! ls
```

```
BP TAs.md
ERDA rollout 260923.pptx
FemaleDEGall.pdf
Harmonic mean.xlsx
Marias plots
My Drive 08.10.50
Pictures
Screenshot 2023-09-28 at 14.03.06.png
Screenshot 2023-10-23 at 15.59.13.png
Training project.pdf
Untitled.ipynb
hc38_ECH_90%_regions.txt
jupyter_walk_through.ipynb
nb_20-updated_sweep_enrichments (3).html
nn.png
prob_of_nr_runs.ipynb
rejsUd
runs_of_ones_paper.pdf
timing_code.ipynb
```


20 Developing exercises

20.1 TLDR;

```
conda create -n franklin -c conda-forge munch-group::franklin
conda activate franklin

franklin exercise down
cd <repo>
franklin jupyter run
franklin up
cd ..
```

20.2 Create an exercise repository

A git repository is where an exercise lives

- **exercise.ipynb::** blah blah
- **Dockerfile:** blah blah
- **README.md::** blah blah
- **docker-entrypoint.sh::** blah blah
- **tagged-release.sh::** blah blah

20.3 Develop/change a new exercise on GitLab

21 Data analysis in Python and R

21.1R

```
fizz_buzz <- function(fbnums = 1:50) {  
  output <- dplyr::case_when(  
    fbnums %% 15 == 0 ~ "FizzBuzz",  
    fbnums %% 3 == 0 ~ "Fizz",  
    fbnums %% 5 == 0 ~ "Buzz",  
    TRUE ~ as.character(fbnums)  
  )  
  print(output)  
}
```

21.2Python

```
def fizz_buzz(num):  
    if num % 15 == 0:  
        print("FizzBuzz")  
    elif num % 5 == 0:  
        print("Buzz")  
    elif num % 3 == 0:  
        print("Fizz")  
    else:  
        print(num)
```

21.3R

```
fizz_buzz <- function(fbnums = 1:50) {  
  output <- dplyr::case_when(  
    fbnums %% 15 == 0 ~ "FizzBuzz",  
    fbnums %% 3 == 0 ~ "Fizz",
```

```
    fbnums %% 5 == 0 ~ "Buzz",  
    TRUE ~ as.character(fbnums)  
  )  
  print(output)  
}
```

21.4Python

```
def fizz_buzz(num):  
    if num % 15 == 0:  
        print("FizzBuzz")  
    elif num % 5 == 0:  
        print("Buzz")  
    elif num % 3 == 0:  
        print("Fizz")  
    else:  
        print(num)
```

22 Numpy and Pandas

Fast computation using vectors and matrices

```
list1 = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
list2 = [9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

```
summed = []
for i in range(len(list1)):
    summed.append(list1[i] + list2[i])
summed
```

```
[9, 9, 9, 9, 9, 9, 9, 9, 9, 9]
```

22.1 Arrays

```
import numpy as np
```

```
a = np.array(list1)
b = np.array(list2)
a, b
```

```
(array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9]), array([9, 8, 7, 6, 5, 4, 3, 2, 1, 0]))
```

22.2 Broadcasting

```
a + b
```

```
array([9, 9, 9, 9, 9, 9, 9, 9, 9, 9])
```

```
a * b
```

```
array([ 0,  8, 14, 18, 20, 20, 18, 14,  8,  0])
```

```
a - 10
```

```
array([-10,  -9,  -8,  -7,  -6,  -5,  -4,  -3,  -2,  -1])
```

```
a.sum()
```

```
45
```

```
a.mean()
```

```
4.5
```

22.3 Multidimensional arrays

```
list_of_lists = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]  
list_of_lists
```

```
[[1, 2, 3], [4, 5, 6], [7, 8, 9]]
```

```
list_of_lists[1][1]
```

```
5
```

```
matrix = np.array(list_of_lists)  
matrix
```

```
array([[1, 2, 3],  
       [4, 5, 6],  
       [7, 8, 9]])
```

```
48
```

```
matrix[1][1] # not efficient
```

5

```
matrix[1, 1] # efficient
```

5

```
matrix - 10
```

```
array([[ -9,  -8,  -7],
       [ -6,  -5,  -4],
       [ -3,  -2,  -1]])
```

```
matrix.sum()
```

45

```
list_of_lists_of_lists = [[[1, 2, 3], [4, 5, 6], [7, 8, 9]], [[1, 2, 3], [4, 5, 6], [7, 8, 9]]]
list_of_lists_of_lists
```

```
[[[1, 2, 3], [4, 5, 6], [7, 8, 9]], [[1, 2, 3], [4, 5, 6], [7, 8, 9]]]
```

```
tensor = np.array(list_of_lists_of_lists)
tensor
```

```
array([[[1, 2, 3],
        [4, 5, 6],
        [7, 8, 9]],
       [[1, 2, 3],
        [4, 5, 6],
        [7, 8, 9]]])
```

```
tensor[1, 1, 1]
```

5

23 Pandas

Fast computations on data tables (on top of Numpy).

```
import pandas as pd
```

23.1 DataFrame

```
df = pd.DataFrame({'name': ['Mike', 'Mia', 'Jake'], 'weight': [82, 62, 75]})
df
```

| | name | weight |
|---|------|--------|
| 0 | Mike | 82 |
| 1 | Mia | 62 |
| 2 | Jake | 75 |

```
type(df)
```

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

```
df = pd.DataFrame(dict(name=['Mike', 'Mia', 'Jake'], weight=[82, 62, 75]))
df
```

| | name | weight |
|---|------|--------|
| 0 | Mike | 82 |
| 1 | Mia | 62 |
| 2 | Jake | 75 |

```
records = [('Mike', 82), ('Mia', 62), ('Jake', 75)]
```

```
df = pd.DataFrame().from_records(records, columns=['age', 'weight'])
df
```

| | age | weight |
|---|------|--------|
| 0 | Mike | 82 |
| 1 | Mia | 62 |
| 2 | Jake | 75 |

```
df.index
```

```
RangeIndex(start=0, stop=3, step=1)
```

```
df.index.values
```

```
array([0, 1, 2])
```

```
df.columns
```

```
Index(['age', 'weight'], dtype='object')
```

```
df.dtypes
```

```
age      object
weight   int64
dtype: object
```

Add a column to an existing dataframe:

```
df['height'] = [182.5, 173.0, 192.5]
df
```

| | age | weight | height |
|---|------|--------|--------|
| 0 | Mike | 82 | 182.5 |
| 1 | Mia | 62 | 173.0 |
| 2 | Jake | 75 | 192.5 |

Add another, categorical, column:

```
df['sex'] = pd.Categorical(['male', 'female', 'male'], categories=['female', 'male'], ordered=True)
df
```

| | | age | weight | height | sex |
|---|------|-----|--------|--------|--------|
| 0 | Mike | 82 | | 182.5 | male |
| 1 | Mia | 62 | | 173.0 | female |
| 2 | Jake | 75 | | 192.5 | male |

```
df.dtypes
```

```
age          object
weight       int64
height       float64
sex          category
dtype: object
```

A Series just wraps an array:

```
df.height.to_numpy()
```

```
array([182.5, 173. , 192.5])
```

23.2 Example penguin data set

```
import seaborn as sns
```

```
penguins = sns.load_dataset('penguins')
```

```
penguins
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|---|---------|-----------|----------------|---------------|-------------------|-------------|--------|
| 0 | Adelie | Torgersen | 39.1 | 18.7 | 181.0 | 3750.0 | Male |
| 1 | Adelie | Torgersen | 39.5 | 17.4 | 186.0 | 3800.0 | Female |
| 2 | Adelie | Torgersen | 40.3 | 18.0 | 195.0 | 3250.0 | Female |
| 3 | Adelie | Torgersen | NaN | NaN | NaN | NaN | NaN |

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----|---------|-----------|----------------|---------------|-------------------|-------------|
| 4 | Adelie | Torgersen | 36.7 | 19.3 | 193.0 | 3450.0 |
| ... | ... | ... | ... | ... | ... | ... |
| 339 | Gentoo | Biscoe | NaN | NaN | NaN | NaN |
| 340 | Gentoo | Biscoe | 46.8 | 14.3 | 215.0 | 4850.0 |
| 341 | Gentoo | Biscoe | 50.4 | 15.7 | 222.0 | 5750.0 |
| 342 | Gentoo | Biscoe | 45.2 | 14.8 | 212.0 | 5200.0 |
| 343 | Gentoo | Biscoe | 49.9 | 16.1 | 213.0 | 5400.0 |

penguins.dtypes

```

species          object
island           object
bill_length_mm   float64
bill_depth_mm    float64
flipper_length_mm float64
body_mass_g      float64
sex              object
dtype: object

```

penguins.head()

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|---|---------|-----------|----------------|---------------|-------------------|-------------|
| 0 | Adelie | Torgersen | 39.1 | 18.7 | 181.0 | 3750.0 |
| 1 | Adelie | Torgersen | 39.5 | 17.4 | 186.0 | 3800.0 |
| 2 | Adelie | Torgersen | 40.3 | 18.0 | 195.0 | 3250.0 |
| 3 | Adelie | Torgersen | NaN | NaN | NaN | NaN |
| 4 | Adelie | Torgersen | 36.7 | 19.3 | 193.0 | 3450.0 |

penguins.tail()

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----|---------|--------|----------------|---------------|-------------------|-------------|
| 339 | Gentoo | Biscoe | NaN | NaN | NaN | NaN |
| 340 | Gentoo | Biscoe | 46.8 | 14.3 | 215.0 | 4850.0 |
| 341 | Gentoo | Biscoe | 50.4 | 15.7 | 222.0 | 5750.0 |
| 342 | Gentoo | Biscoe | 45.2 | 14.8 | 212.0 | 5200.0 |
| 343 | Gentoo | Biscoe | 49.9 | 16.1 | 213.0 | 5400.0 |

23.3Series

```
penguins['flipper_length_mm']
```

```
0      181.0
1      186.0
2      195.0
3         NaN
4      193.0
...
339     NaN
340     215.0
341     222.0
342     212.0
343     213.0
Name: flipper_length_mm, Length: 344, dtype: float64
```

```
penguins.flipper_length_mm
```

```
0      181.0
1      186.0
2      195.0
3         NaN
4      193.0
...
339     NaN
340     215.0
341     222.0
342     212.0
343     213.0
Name: flipper_length_mm, Length: 344, dtype: float64
```

```
type(penguins.flipper_length_mm)
```

```
pandas.core.series.Series
```

23.4Broadcasting

```
penguins.bill_depth_mm - 1000
```

```
0      -981.3
1      -982.6
2      -982.0
3         NaN
4      -980.7
...
339      NaN
340     -985.7
341     -984.3
342     -985.2
343     -983.9
Name: bill_depth_mm, Length: 344, dtype: float64
```

```
penguins.bill_depth_mm * penguins.flipper_length_mm
```

```
0      3384.7
1      3236.4
2      3510.0
3         NaN
4      3724.9
...
339      NaN
340     3074.5
341     3485.4
342     3137.6
343     3429.3
Length: 344, dtype: float64
```

23.5 Indexing

23.5.1 Get a cell

```
penguins.loc[4, 'island']
```

```
'Torgersen'
```

23.5.2 Get a row

```
penguins.loc[4]
```

```
species      Adelie
island       Torgersen
bill_length_mm  36.7
bill_depth_mm  19.3
flipper_length_mm 193.0
body_mass_g  3450.0
sex          Female
Name: 4, dtype: object
```

23.5.3 Get a column

```
penguins['bill_depth_mm']
```

```
0      18.7
1      17.4
2      18.0
3       NaN
4      19.3
...
339    NaN
340     14.3
341     15.7
342     14.8
343     16.1
Name: bill_depth_mm, Length: 344, dtype: float64
```

```
penguins.bill_depth_mm
```

```
0      18.7
1      17.4
2      18.0
3       NaN
4      19.3
...
339    NaN
```

```

340    14.3
341    15.7
342    14.8
343    16.1
Name: bill_depth_mm, Length: 344, dtype: float64

```

23.5.4 Get a range of rows and multiple columns

```
penguins.loc[40:45, ['island', 'body_mass_g']]
```

| | island | body_mass_g |
|----|--------|-------------|
| 40 | Dream | 3150.0 |
| 41 | Dream | 3900.0 |
| 42 | Dream | 3100.0 |
| 43 | Dream | 4400.0 |
| 44 | Dream | 3000.0 |
| 45 | Dream | 4600.0 |

23.5.5 Use boolean series as index to subset data

```

idx = penguins.bill_length_mm > 55
idx

```

```

0      False
1      False
2      False
3      False
4      False
...
339    False
340    False
341    False
342    False
343    False
Name: bill_length_mm, Length: 344, dtype: bool

```



```
penguins.loc[idx]
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|-----|-----------|--------|----------------|---------------|-------------------|-------------|--------|
| 169 | Chinstrap | Dream | 58.0 | 17.8 | 181.0 | 3700.0 | Female |
| 215 | Chinstrap | Dream | 55.8 | 19.8 | 207.0 | 4000.0 | Male |
| 253 | Gentoo | Biscoe | 59.6 | 17.0 | 230.0 | 6050.0 | Male |
| 321 | Gentoo | Biscoe | 55.9 | 17.0 | 228.0 | 5600.0 | Male |
| 335 | Gentoo | Biscoe | 55.1 | 16.0 | 230.0 | 5850.0 | Male |

```
penguins.loc[(penguins.bill_length_mm > 55) & (penguins.sex == 'Female')]
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|-----|-----------|--------|----------------|---------------|-------------------|-------------|--------|
| 169 | Chinstrap | Dream | 58.0 | 17.8 | 181.0 | 3700.0 | Female |

23.5.6 Setting and resetting the index

```
penguins
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|-----|---------|-----------|----------------|---------------|-------------------|-------------|--------|
| 0 | Adelie | Torgersen | 39.1 | 18.7 | 181.0 | 3750.0 | Male |
| 1 | Adelie | Torgersen | 39.5 | 17.4 | 186.0 | 3800.0 | Female |
| 2 | Adelie | Torgersen | 40.3 | 18.0 | 195.0 | 3250.0 | Female |
| 3 | Adelie | Torgersen | NaN | NaN | NaN | NaN | NaN |
| 4 | Adelie | Torgersen | 36.7 | 19.3 | 193.0 | 3450.0 | Female |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 339 | Gentoo | Biscoe | NaN | NaN | NaN | NaN | NaN |
| 340 | Gentoo | Biscoe | 46.8 | 14.3 | 215.0 | 4850.0 | Female |
| 341 | Gentoo | Biscoe | 50.4 | 15.7 | 222.0 | 5750.0 | Male |
| 342 | Gentoo | Biscoe | 45.2 | 14.8 | 212.0 | 5200.0 | Female |
| 343 | Gentoo | Biscoe | 49.9 | 16.1 | 213.0 | 5400.0 | Male |

```
df = penguins.set_index(['species', 'sex', 'island'])  
df.head(10)
```

| species | sex |
|---------|--------|
| Adelie | Male |
| | Female |
| | NaN |
| | Female |
| | Male |
| | Female |
| | Male |
| | |
| NaN | |

df.reset_index()

| | species | sex | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----|---------|--------|-----------|----------------|---------------|-------------------|-------------|
| 0 | Adelie | Male | Torgersen | 39.1 | 18.7 | 181.0 | 3750 |
| 1 | Adelie | Female | Torgersen | 39.5 | 17.4 | 186.0 | 3800 |
| 2 | Adelie | Female | Torgersen | 40.3 | 18.0 | 195.0 | 3250 |
| 3 | Adelie | NaN | Torgersen | NaN | NaN | NaN | NaN |
| 4 | Adelie | Female | Torgersen | 36.7 | 19.3 | 193.0 | 3450 |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 339 | Gentoo | NaN | Biscoe | NaN | NaN | NaN | NaN |
| 340 | Gentoo | Female | Biscoe | 46.8 | 14.3 | 215.0 | 4850 |
| 341 | Gentoo | Male | Biscoe | 50.4 | 15.7 | 222.0 | 5750 |
| 342 | Gentoo | Female | Biscoe | 45.2 | 14.8 | 212.0 | 5200 |
| 343 | Gentoo | Male | Biscoe | 49.9 | 16.1 | 213.0 | 5400 |

23.6Sorting rows

```
sorted_df = penguins.sort_values(by="bill_length_mm")
sorted_df.head()
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----|---------|-----------|----------------|---------------|-------------------|-------------|
| 142 | Adelie | Dream | 32.1 | 15.5 | 188.0 | 3050.0 |
| 98 | Adelie | Dream | 33.1 | 16.1 | 178.0 | 2900.0 |
| 70 | Adelie | Torgersen | 33.5 | 19.0 | 190.0 | 3600.0 |

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|----|---------|-----------|----------------|---------------|-------------------|-------------|--------|
| 92 | Adelie | Dream | 34.0 | 17.1 | 185.0 | 3400.0 | Female |
| 8 | Adelie | Torgersen | 34.1 | 18.1 | 193.0 | 3475.0 | NaN |

sorted_df.index.values

```
array([142, 98, 70, 92, 8, 18, 54, 80, 14, 100, 52, 83, 124,
       25, 66, 74, 136, 60, 90, 118, 68, 22, 42, 48, 150, 148,
       78, 94, 120, 86, 34, 64, 58, 40, 15, 147, 4, 82, 132,
       87, 44, 138, 77, 31, 144, 117, 84, 47, 133, 62, 38, 59,
       21, 121, 102, 103, 10, 20, 11, 149, 104, 28, 96, 108, 134,
       110, 107, 23, 88, 130, 13, 106, 116, 16, 24, 126, 36, 89,
       6, 128, 145, 56, 0, 35, 146, 7, 5, 30, 1, 32, 114,
       45, 50, 72, 93, 112, 105, 139, 71, 39, 51, 137, 140, 122,
       97, 2, 27, 29, 125, 141, 26, 57, 143, 95, 41, 230, 182,
       33, 76, 101, 135, 119, 46, 63, 91, 67, 12, 61, 85, 123,
       55, 127, 151, 65, 326, 69, 236, 53, 9, 79, 113, 37, 49,
       172, 184, 206, 17, 256, 115, 260, 75, 251, 81, 244, 131, 278,
       109, 174, 99, 228, 328, 306, 216, 332, 288, 265, 276, 258, 129,
       43, 257, 246, 336, 314, 268, 304, 275, 241, 252, 272, 208, 298,
       299, 269, 342, 157, 280, 262, 226, 155, 232, 277, 195, 312, 266,
       111, 211, 214, 204, 282, 73, 284, 234, 166, 160, 19, 158, 245,
       220, 286, 238, 334, 281, 193, 243, 170, 180, 291, 294, 293, 225,
       274, 152, 242, 162, 270, 227, 176, 325, 229, 340, 213, 317, 190,
       164, 338, 322, 324, 250, 302, 310, 296, 187, 308, 188, 224, 290,
       247, 329, 202, 248, 292, 318, 233, 255, 271, 173, 320, 295, 259,
       239, 222, 337, 192, 199, 231, 300, 323, 254, 171, 237, 235, 209,
       316, 313, 179, 287, 263, 261, 217, 186, 331, 201, 285, 343, 303,
       153, 221, 223, 249, 198, 273, 210, 219, 240, 168, 279, 341, 267,
       330, 167, 178, 264, 175, 289, 205, 305, 218, 197, 315, 196, 194,
       185, 297, 319, 154, 159, 161, 307, 203, 333, 200, 163, 212, 165,
       177, 189, 309, 207, 311, 301, 156, 181, 327, 191, 183, 283, 335,
       215, 321, 169, 253, 3, 339])
```

Click to the left of an output cell to enable/disable scrolling of the output (usefull for large amounts of output).

sorted_df.loc[0]

```
species      Adelie
island      Torgersen
```

```

bill_length_mm      39.1
bill_depth_mm       18.7
flipper_length_mm   181.0
body_mass_g         3750.0
sex                 Male
Name: 0, dtype: object

```

```
sorted_df.flipper_length_mm[0]
```

```
181.0
```

```
sorted_df.iloc[0] # iloc !!!
```

```

species      Adelie
island       Dream
bill_length_mm  32.1
bill_depth_mm  15.5
flipper_length_mm  188.0
body_mass_g  3050.0
sex          Female
Name: 142, dtype: object

```

```
sorted_df.flipper_length_mm.iloc[0]
```

```
188.0
```

23.7 Summary stats

```
penguins.describe()
```

| | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-------|----------------|---------------|-------------------|-------------|
| count | 342.000000 | 342.000000 | 342.000000 | 342.000000 |
| mean | 43.921930 | 17.151170 | 200.915205 | 4201.754386 |
| std | 5.459584 | 1.974793 | 14.061714 | 801.954536 |
| min | 32.100000 | 13.100000 | 172.000000 | 2700.000000 |
| 25% | 39.225000 | 15.600000 | 190.000000 | 3550.000000 |
| 50% | 44.450000 | 17.300000 | 197.000000 | 4050.000000 |

| | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----|----------------|---------------|-------------------|-------------|
| 75% | 48.500000 | 18.700000 | 213.000000 | 4750.000000 |
| max | 59.600000 | 21.500000 | 231.000000 | 6300.000000 |

```
penguins.bill_length_mm.mean()
```

```
43.9219298245614
```

```
penguins.bill_length_mm.count()
```

```
342
```

23.8 Grouping

```
penguins.groupby('island')
```

```
<pandas.core.groupby.generic.DataFrameGroupBy object at 0x15cc9e5e0>
```

23.8.1 Aggregate

Aggregating produces a **single** value for each variable in each group:

Means for all numeric variables for each island:

```
penguins.groupby('island').aggregate("mean", numeric_only=True)
```

| | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----------|----------------|---------------|-------------------|-------------|
| island | | | | |
| Biscoe | 45.257485 | 15.874850 | 209.706587 | 4716.017964 |
| Dream | 44.167742 | 18.344355 | 193.072581 | 3712.903226 |
| Torgersen | 38.950980 | 18.429412 | 191.196078 | 3706.372549 |

```
penguins.groupby('island').mean(numeric_only=True)
```

| | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g |
|-----------|----------------|---------------|-------------------|-------------|
| island | | | | |
| Biscoe | 45.257485 | 15.874850 | 209.706587 | 4716.017964 |
| Dream | 44.167742 | 18.344355 | 193.072581 | 3712.903226 |
| Torgersen | 38.950980 | 18.429412 | 191.196078 | 3706.372549 |

Means for bill_length_mm and flipper_length_mm:

```
penguins.groupby('island')[['bill_length_mm', 'flipper_length_mm']].mean()
```

| | bill_length_mm | flipper_length_mm |
|-----------|----------------|-------------------|
| island | | |
| Biscoe | 45.257485 | 209.706587 |
| Dream | 44.167742 | 193.072581 |
| Torgersen | 38.950980 | 191.196078 |

Just for flipper_length_mm:

```
penguins.groupby('island').flipper_length_mm.mean()
```

```
island
Biscoe      209.706587
Dream       193.072581
Torgersen   191.196078
Name: flipper_length_mm, dtype: float64
```

23.8.2 Transform

Transforming produces new columns with the *same length* as the input:

```
penguins.groupby('island')[['bill_length_mm', 'flipper_length_mm']].transform("mean")
```

| | bill_length_mm | flipper_length_mm |
|---|----------------|-------------------|
| 0 | 38.950980 | 191.196078 |
| 1 | 38.950980 | 191.196078 |
| 2 | 38.950980 | 191.196078 |
| 3 | 38.950980 | 191.196078 |

| | bill_length_mm | flipper_length_mm |
|-----|----------------|-------------------|
| 4 | 38.950980 | 191.196078 |
| ... | ... | ... |
| 339 | 45.257485 | 209.706587 |
| 340 | 45.257485 | 209.706587 |
| 341 | 45.257485 | 209.706587 |
| 342 | 45.257485 | 209.706587 |
| 343 | 45.257485 | 209.706587 |

```
def z_value(sr):
    return (sr - sr.mean()) / sr.std()
```

```
penguins.groupby('island')[['bill_length_mm', 'flipper_length_mm']].transform(z_value)
```

| | bill_length_mm | flipper_length_mm |
|-----|----------------|-------------------|
| 0 | 0.049258 | -1.636022 |
| 1 | 0.181475 | -0.833742 |
| 2 | 0.445910 | 0.610362 |
| 3 | NaN | NaN |
| 4 | -0.744048 | 0.289450 |
| ... | ... | ... |
| 339 | NaN | NaN |
| 340 | 0.323193 | 0.374297 |
| 341 | 1.077478 | 0.869267 |
| 342 | -0.012044 | 0.162167 |
| 343 | 0.972717 | 0.232877 |

23.8.3 Apply

Flexible method allowing any operation on grouped data.

Return a single value:

```
def fun(df):
    return df.bill_length_mm + df.flipper_length_mm.mean() / df.body_mass_g
```

```
penguins.groupby('island').apply(fun)#.to_frame('my_stat')
```

```
island
Biscoe    20    37.861678
```

```

21      37.758252
22      35.955186
23      38.253090
24      38.855186
...
Torgersen 127      41.544464
          128      39.062687
          129      44.147799
          130      38.557503
          131      43.154627
Length: 344, dtype: float64

```

Return a dataframe:

```

def fun(df):
    return pd.DataFrame({'sqrt_bill': np.sqrt(df.bill_length_mm),
                        'bill_squared': df.bill_length_mm**2})

penguins.groupby('island').apply(fun)

```

| island | | sqrt_bill |
|-----------|-----|-----------|
| Biscoe | 20 | 6.14 |
| | 21 | 6.14 |
| | 22 | 5.99 |
| | 23 | 6.18 |
| | 24 | 6.22 |
| ... | ... | ... |
| | 127 | 6.44 |
| | 128 | 6.24 |
| Torgersen | 129 | 6.64 |
| | 130 | 6.20 |
| | 131 | 6.56 |

24 Plots with matplotlib

```
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
sns.set_style("darkgrid")

# make graphics sharper on a good screen
from matplotlib_inline.backend_inline import set_matplotlib_formats
set_matplotlib_formats('retina', 'png')

penguins = sns.load_dataset("penguins")
penguins.head()
```

| | species | island | bill_length_mm | bill_depth_mm | flipper_length_mm | body_mass_g | sex |
|---|---------|-----------|----------------|---------------|-------------------|-------------|--------|
| 0 | Adelie | Torgersen | 39.1 | 18.7 | 181.0 | 3750.0 | Male |
| 1 | Adelie | Torgersen | 39.5 | 17.4 | 186.0 | 3800.0 | Female |
| 2 | Adelie | Torgersen | 40.3 | 18.0 | 195.0 | 3250.0 | Female |
| 3 | Adelie | Torgersen | NaN | NaN | NaN | NaN | NaN |
| 4 | Adelie | Torgersen | 36.7 | 19.3 | 193.0 | 3450.0 | Female |

```
plt.scatter(penguins.bill_length_mm, penguins.flipper_length_mm) ; # semi colon makes last value
```

```
sns.set_style("ticks")
# sns.set_style("darkgrid")
# sns.set_style("whitegrid")
# sns.set_style("white")
# sns.set_style("dark")
```

```
plt.scatter(penguins.bill_length_mm, penguins.flipper_length_mm)
sns.despine()
```

```
plt.hist(penguins.bill_length_mm) ;
```

25 Better plotting with seaborn (on top of matplotlib)

```
sns.scatterplot(data=penguins, x="bill_length_mm", y="flipper_length_mm") ;

sns.scatterplot(data=penguins, x="bill_length_mm", y="flipper_length_mm", hue="species") ;

sns.scatterplot(data=penguins, x="bill_length_mm", y="flipper_length_mm", hue="species", style="species") ;

sns.scatterplot(data=penguins, x="bill_length_mm", y="flipper_length_mm", hue="species",
                style="sex", size="body_mass_g") ;

def legend_outside():
    plt.legend(bbox_to_anchor=(1.05, 1), loc='upper left', borderaxespad=0)

sns.scatterplot(data=penguins, x="bill_length_mm", y="flipper_length_mm", hue="species", style="species")

legend_outside()

plt.title("Penguin measurements")
plt.ylabel("flipper length (mm)")
plt.xlabel("bill length in (mm)") ;
```


26 Wide or long data

Wide format data:

```
penguins[['bill_length_mm', 'bill_depth_mm']]
```

| | bill_length_mm | bill_depth_mm |
|-----|----------------|---------------|
| 0 | 39.1 | 18.7 |
| 1 | 39.5 | 17.4 |
| 2 | 40.3 | 18.0 |
| 3 | NaN | NaN |
| 4 | 36.7 | 19.3 |
| ... | ... | ... |
| 339 | NaN | NaN |
| 340 | 46.8 | 14.3 |
| 341 | 50.4 | 15.7 |
| 342 | 45.2 | 14.8 |
| 343 | 49.9 | 16.1 |

Long format data:

```
long_df = penguins.melt(value_vars=['bill_length_mm', 'bill_depth_mm'])  
long_df
```

| | variable | value |
|-----|----------------|-------|
| 0 | bill_length_mm | 39.1 |
| 1 | bill_length_mm | 39.5 |
| 2 | bill_length_mm | 40.3 |
| 3 | bill_length_mm | NaN |
| 4 | bill_length_mm | 36.7 |
| ... | ... | ... |
| 683 | bill_depth_mm | NaN |
| 684 | bill_depth_mm | 14.3 |
| 685 | bill_depth_mm | 15.7 |

| | variable | value |
|-----|---------------|-------|
| 686 | bill_depth_mm | 14.8 |
| 687 | bill_depth_mm | 16.1 |

long format is required when you want a number of columns to appear as a “variable” in the plot. As in the example below where the color “variable” reflects whether the point is bill_depth_mm or bill_length_mm.

Retain other information for each observation:

```
long_df = penguins.melt(id_vars=['species', 'body_mass_g', 'island'], value_vars=['bill_length_mm', 'bill_depth_mm'],
                        var_name='variable', value_name='value')
long_df
```

| | species | body_mass_g | island | variable | value |
|-----|---------|-------------|-----------|----------------|-------|
| 0 | Adelie | 3750.0 | Torgersen | bill_length_mm | 39.1 |
| 1 | Adelie | 3800.0 | Torgersen | bill_length_mm | 39.5 |
| 2 | Adelie | 3250.0 | Torgersen | bill_length_mm | 40.3 |
| 3 | Adelie | NaN | Torgersen | bill_length_mm | NaN |
| 4 | Adelie | 3450.0 | Torgersen | bill_length_mm | 36.7 |
| ... | ... | ... | ... | ... | ... |
| 683 | Gentoo | NaN | Biscoe | bill_depth_mm | NaN |
| 684 | Gentoo | 4850.0 | Biscoe | bill_depth_mm | 14.3 |
| 685 | Gentoo | 5750.0 | Biscoe | bill_depth_mm | 15.7 |
| 686 | Gentoo | 5200.0 | Biscoe | bill_depth_mm | 14.8 |
| 687 | Gentoo | 5400.0 | Biscoe | bill_depth_mm | 16.1 |

```
sns.scatterplot(data=long_df, x='body_mass_g', y='value', hue='variable', style='species',
                legend_outside())
```

```
sns.boxplot(data=long_df, x='species', y='value', hue='variable') ;
```

```
sns.boxplot(data=long_df, x='variable', y='value', hue='species') ;
```

```
sns.boxplot(data=long_df, x='species', y='value', hue='variable') ;
```

27 Plots with multiple facets

```
g = sns.FacetGrid(penguins, col="island")
g ;
```

Map plotting to each facet:

```
g = sns.FacetGrid(penguins, col="island", hue="species", height=3)
g.map(sns.scatterplot, "bill_length_mm", "flipper_length_mm") ;
```

Grid of facets representing combinations of two variables:

```
g = sns.FacetGrid(penguins, row="sex", col="island", hue="species", height=3) ;
g.map(sns.scatterplot, "bill_length_mm", "flipper_length_mm") ;
```

```
g = sns.FacetGrid(penguins, row="sex", col="island", hue="species", height=3) ;
g.map(sns.regplot, "bill_length_mm", "flipper_length_mm") ;
```

```
sns.lmplot(data=penguins, x="bill_length_mm", y="flipper_length_mm", row="sex", col="island", hue=
```

27.1 FacetGrid.map vs. FacetGrid.map_dataframe

When you use `FacetGrid.map(func, "col1", "col2", ...)`, the function `func` is passed the values of the columns `"col1"` and `"col2"` (and more if needed) as parameters 1 and 2 (`args[0]`, `args[1]`, ...). In addition, the function always receives a keyword argument named `color=`.

```
def scatter(*args, **kwargs):
    return plt.scatter(args[0], args[1], **kwargs)
```

```
g = sns.FacetGrid(penguins, row="sex", col="island", hue="species") ;
g.map(scatter, "bill_length_mm", "flipper_length_mm") ;
```

When you use `FacetGrid.map_dataframe(func, "col1", "col2", ...)`, the function `func` is passed the names `"col1"` and `"col2"` (and more if needed) as parameters 1 and 2 (`args[0]`, `args[1]`, ...), and the filtered dataframe as keyword argument `data=`. In addition, the function always receives a keyword argument named `color=`.

```
def scatterplot(*args, **kwargs):
    return sns.scatterplot(x=args[0], y=args[1], **kwargs)

g = sns.FacetGrid(penguins, row="sex", col="island", hue="species") ;
g.map_dataframe(scatterplot, "bill_length_mm", "flipper_length_mm") ;
```




```
g = sns.FacetGrid(penguins, row="sex", col="island", hue="species") ;
g.map(sns.histplot, "bill_length_mm") ;
```



```
g = sns.FacetGrid(penguins, row="sex", col="island", hue="species") ;
g.map(sns.kdeplot, "bill_length_mm") ;
```



```
sns.pairplot(penguins, hue="species") ;
```



```
sns.pairplot(penguins, hue="sex") ;
```



