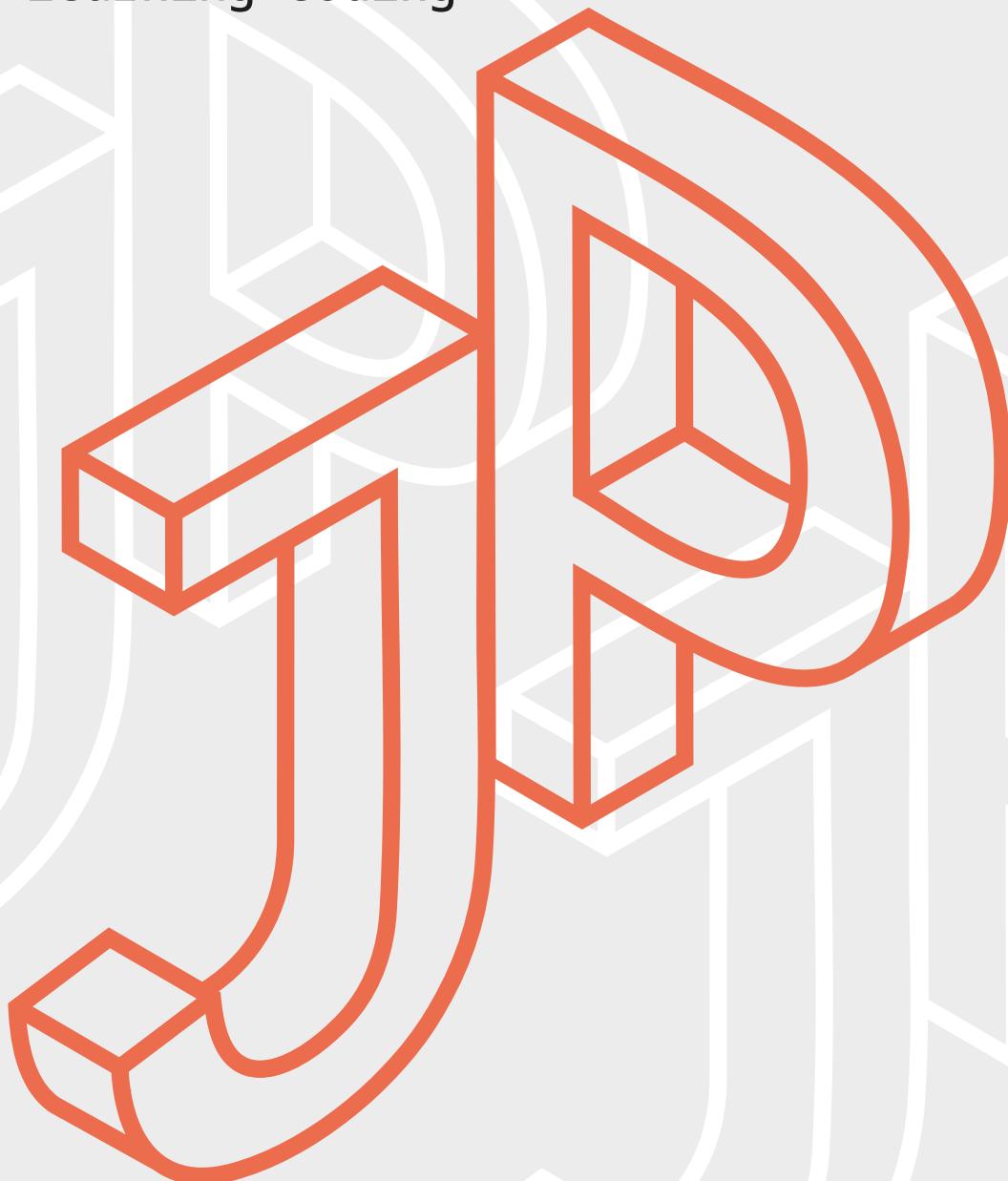


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SERENA BONARETTI

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Thank you for learning with me,

Serena

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Editing and proofreading by John Batson

www.learnpythonwithjupyter.com

To Christof, who loves R

Eccoci nuovamente insieme per imparare a leggere e a scrivere.
Io direi, però, di più: per imparare a conoscere meglio il mondo e noi stessi.
Here we are again together to learn how to read and write.
Actually, I would go further: to learn to better understand the world and ourselves.

—Alberto Manzi, Non è mai troppo tardi, It's never too late

Simple is better than complex.
—Tim Peters, The Zen of Python

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About this book

What will I learn in this book? In this book, you will learn to code in Python using Jupyter Notebook. Even more importantly, you will develop computational thinking, which is the way we think when coding.

What makes this book different? The topic progression in this book is designed according to computational thinking development while focusing on syntax and strategies, rather than listing disconnected language characteristics with isolated examples.

Is this book for me? If you have never coded before, if you are following online courses or videos but feel you can't quite grasp them, or if you need to better structure your Python and coding knowledge, this book is for you. Also, if you are training to become a scientist but are not very strong in coding, if you are transitioning to the Python/Jupyter environment from another programming language, or if you are a teacher looking for material, this book can be for you.

How is this book structured? The book is divided in 11 parts. The first part introduces the computational environment—that is, the Jupyter/Python environment. The following ten parts cover computational thinking and Python syntax. Each part contains two to five chapters, for a total of thirty-eight chapters.

How are chapters structured? Each chapter starts with one or more coding examples embedded in narrative and enriched with detailed explanations. In addition, each contains several theoretical and coding exercises. And they all finish with a recap to summarize the chapter's main concepts, and a *In more depth* section, with coding strategies or curiosities.

Why is code embedded in narratives? Stories provide context and allow long-term memorization. They are extensively used in learning foreign languages. And, in many respects, a programming language is a foreign language.

Why is there code pronunciation? When we code, we pronounce or mumble code within ourselves, and occasionally aloud with a colleague. Although coding has a strong vocal component, there is no defined standard for code pronunciation. The pronunciation proposed in this book is the optimized result of hours of one-on-one interaction with students of various mother tongues.

What kinds of exercises are in the book? In this book, you will find both theory exercises and coding exercises. Theory exercises are meant to strengthen code comprehension and syntax precision. Coding exercises are meant to make you practice and thus learn by doing.

What is on the website? On www.learnpythonwithjupyter.com, you can find Jupyter Notebooks associated with each chapter, so you can test and experiment while learning. You can also find a community, with solutions to both theory and coding exercises. You can ask questions and propose alternative solutions, to deepen your knowledge.

How do I use this book? Start with the first part, *Getting ready*, to install and learn the computational environment. Then, proceed with the chapters. For each chapter, download the corresponding notebook at www.learnpythonwithjupyter.com. Make sure you understand the syntax, play with the code, and do the theoretical exercises. Read the recap and the *In more depth* sections, which will give you useful hints. Finally, do the coding exercises and compare your solutions with the ones you find in the community portal. Obviously, looking at a solution before completing an exercise weakens your

chance of learning. If you do not understand questions or solutions, ask in the community portal. Take your time to solve each exercise. Missing the understanding of one chapter might compromise your understanding of the chapters that follow it.

How is the language used in this book? The language is colloquial and simple—but precise. There are clear definitions and careful explanations. I directly talk to *you*, but I use *we* when explaining syntax. We are in this together! Also, I use the first person when I want to share some hints I learned along the way.

INTRODUCTION

In this part, we will briefly talk about coding environments, language syntax, and computational thinking. If you are eager to start coding, just skip it and come back later!

What do we need to learn when learning coding?

Coding is a lot about telling a computer what to do. We, human beings, need to write commands that computers understand, and to do so, we need to learn to think differently. We have to start from scratch and master a new way of communicating, made of concise and logical instructions. Practically speaking, we have to learn at least three things: a coding environment, language syntax, and computational thinking. Let's see what these are!

A **coding environment** is a **program where we can write and execute code**. There are several environments to code in Python. In this book, we will use the Jupyter/Python environment, which since its release in 2015 has become used increasingly both in industry and academia (Figure 1.1). It allows integrating code with narrative, and it is ideal for creating reports, draft code, and learning to code. Other very common coding environments are the integrated development environments (IDEs). For Python, popular IDEs are PyCharm, Visual Studio, and Spyder (Figure 1.2). IDEs typically embed various components, such as a script editor, a variable environment panel, and a console wherein code is tested and executed. In Chapter 32, you will get familiar with one of them, Spyder, which is commonly used for scientific coding. And finally, the most basic environment is the Python IDLE, which is included in the Python installation. It consists of a shell—which looks very similar to a terminal—where one can type and execute commands (Figure 1.3).

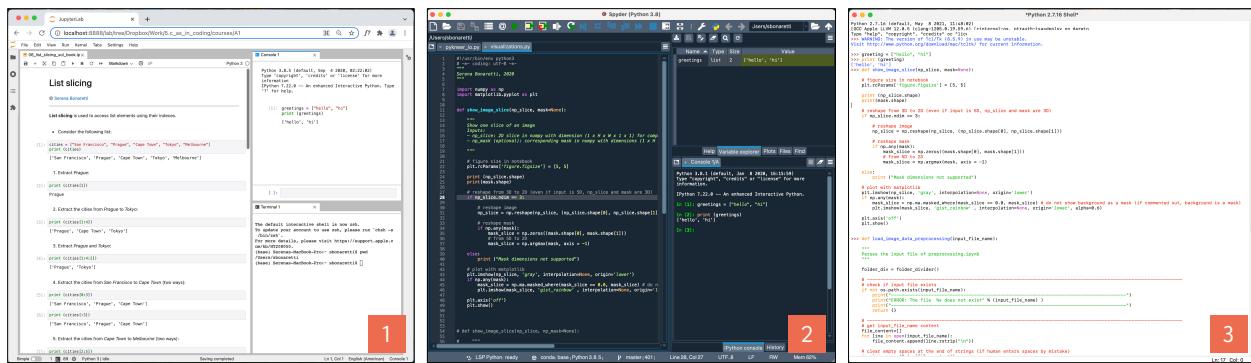


Figure 1. Three IDEs to code in Python: (1) the Jupyter environment, (2) Spyder, and (3) the Python IDLE.

A language **syntax** is a **set of rules defining how to write commands**. You are already very familiar with at least one syntax, which is your native language syntax. In your mother tongue, you know words, punctuation, and how to arrange these elements in sentences to create paragraphs and entire texts. In coding, the pattern is similar. We have to know data types and operators, as well as how to arrange them in `if/else` constructs and loops to create functions and classes. In Table 1, you can see a schematic summary of elements and syntax you will learn in this book. Don't worry if you do not understand most of it—everything will become more and more clear as we progress through the book.

Data types (Words)	Operators (Punctuations)	Constructs and loops (Sentences)	Unit of code (Paragraphs)	Software (Texts)
String, list, integer, float, Boolean, tuple, dictionary, set	Assignment, membership, arithmetic, comparison, logical	<code>if/elif</code> construct, <code>for</code> loop, <code>while</code> loop	Functions	Classes (object-oriented programming)

Table 1. Components of a programming language, from the most basic (left) to the most complex (right). In the column titles, the words in between parentheses show the parallelism with natural language syntax.

Finally, **computational thinking** is the **way we think when coding**. Every time we approach a new subject, we need to learn *how to think* in that subject and develop specific skills. Some of the abilities you will develop in this book are:

- *Creating algorithms*, which means conceiving and implementing a series of sequential instructions to solve a problem.
- *Divide and conquer*, which consists of decomposing problems in sub-problems, and then combining the sub-problem solutions to obtain the main problem solution.
- *Pattern recognition*, which means recognizing in a new problem features of a previously solved problem so that you can apply a similar solution.
- *Solution generalization*, which consists of generalizing solutions from specific cases to broader situations.

As is the case for any subject, developing a way of thinking comes with studying and exercising. Thus, thinking computationally comes with learning syntax and practicing coding. We will start building these abilities in Chapter 1. In the next part, *Getting ready*, you will download, install, and learn how to use the Jupyter/Python environment.

GETTING READY

In this part, we will set up the Jupyter/Python environment and learn how to use it. Let's start this exciting journey!

The Jupyter/Python environment

An easy way to think about the Jupyter/Python environment is to consider it as a Russian doll—those wooden dolls of decreasing size nested one inside another (Figure 2). The largest doll is **JupyterLab**, which is a web-based environment in which we can open, organize, and work on files of various types. In JupyterLab, there is **Jupyter Notebook**, which is a web-based application where we can write code with narrative. Jupyter Notebook supports several programming languages, one of which is **Python**. And finally, Python is enriched by an extraordinary amount of **modules** and **packages** that allow us to add useful functionalities to code. Let's install the Jupyter/Python environment and see how it works!

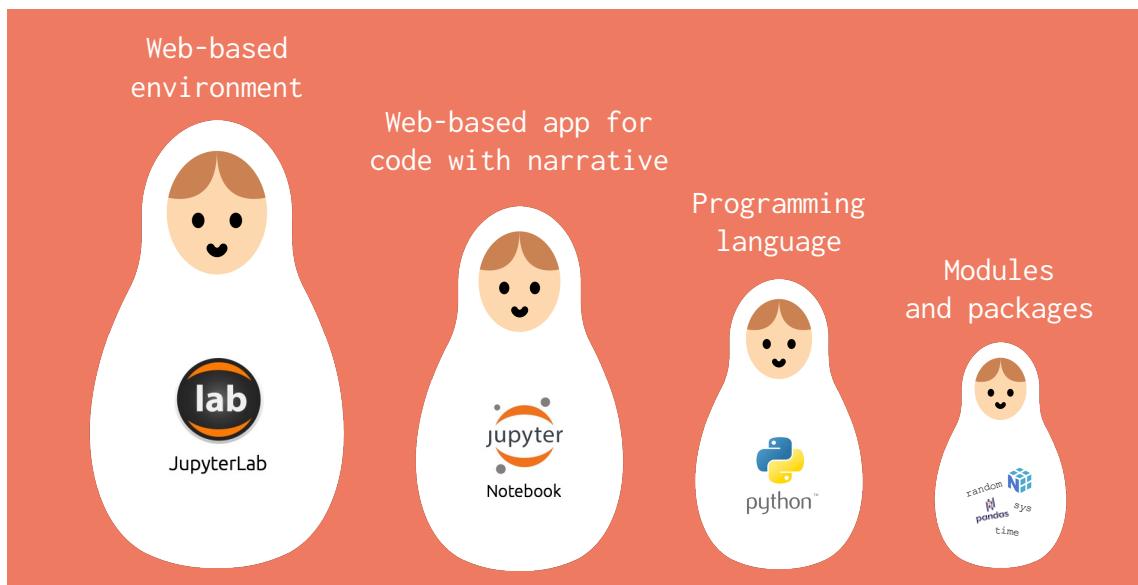


Figure 2. The Jupyter/Python environment represented as a Russian doll, where each component is included in the previous one.

Installing the Jupyter/Python environment

You can install JupyterLab, Jupyter Notebook, Python, and its scientific packages all at once through Anaconda, a commonly used distribution for scientific computing. Go to the Anaconda website, <https://www.anaconda.com/products/individual>, and click *download*. It might take a few minutes. Once downloaded, install Anaconda like any other software: click *next* when required, and leave the default options (unless you have specific requirements). The installation might take a few minutes too. When Anaconda is installed, open the Anaconda Navigator by double-clicking its icon, which looks like the one in Figure 3, box 1. Once opened, you will see all the software contained in Anaconda, including JupyterLab (Figure 3, box 2), Jupyter Notebook (Figure 3, box 3), and Spyder (Figure 3, box 4). In this book, we will code in Python using JupyterLab as a working environment. So let's learn how to use it!

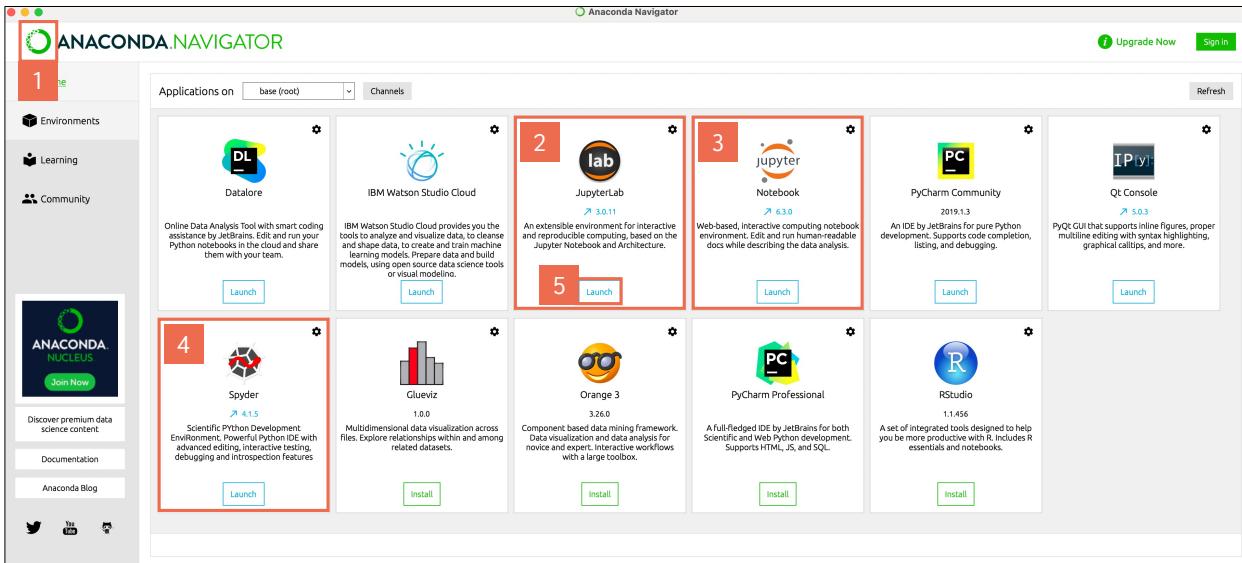


Figure 3. Anaconda interface: (1) icon, (2) JupyterLab, (3) Jupyter Notebook, (4) Spyder, and (5) JupyterLab launch button.

JupyterLab

JupyterLab is an environment where we can code in an organized and efficient way. Open it by clicking the *Launch* button in the JupyterLab tile in Anaconda (Figure 3, box 5). You will see something similar to Figure 4. Below are the most relevant features of JupyterLab and some suggestions on how best to use it.

- **JupyterLab is a web-based environment.** When you launch JupyterLab, the first thing you'll notice is that it starts in the browser. However, its address contains `localhost` (Figure 4, box 1), which means that you are actually working *locally*, that is, on your computer. In other words, you do *not* need to be connected to the internet to use JupyterLab.
- **Top bar** (Figure 4, box 2). The items in the top bar, such as *File*, *Edit*, *View*, etc., are quite intuitive and similar to many other software. We will describe the most relevant items throughout the book, but go ahead and start exploring them! For now, just notice that when clicking some top bar buttons (for example, *File*), some of the items that appear might be light gray because they are disabled (for example, *Save As..*). This is because they refer to Jupyter Notebook, which we will open in the next section. Finally, a fun feature of JupyterLab is that you can set a dark theme. If you want that, go to *Settings*, then *JupyterLab themes*, and click on *JupyterLab Dark*.
- **Browsing and opening files.** On the left side of JupyterLab, you can find a panel with some vertical tabs (Figure 4, box 3). The first tab contains an icon representing a folder, and, for now, we will focus only on this one. The folder tab opens a panel on its right, which contains a few features. The first is a top bar (Figure 4, box 4), containing a symbol, +, which allows us to start a launcher (Figure 4, box 7); an icon representing a folder containing a +, to create a new folder; a vertical arrow pointing up, to upload a new file; and a circular arrow, to refresh the content of the current directory—in coding, we often say **directory** instead of **folder**. Right below, there is a box to search for files. Then, there is the path of the **working directory** (Figure 4, box 5)—that is, the folder where we are currently opening and saving files. And below, there is a list of the directory content (Figure 4, box 6). In

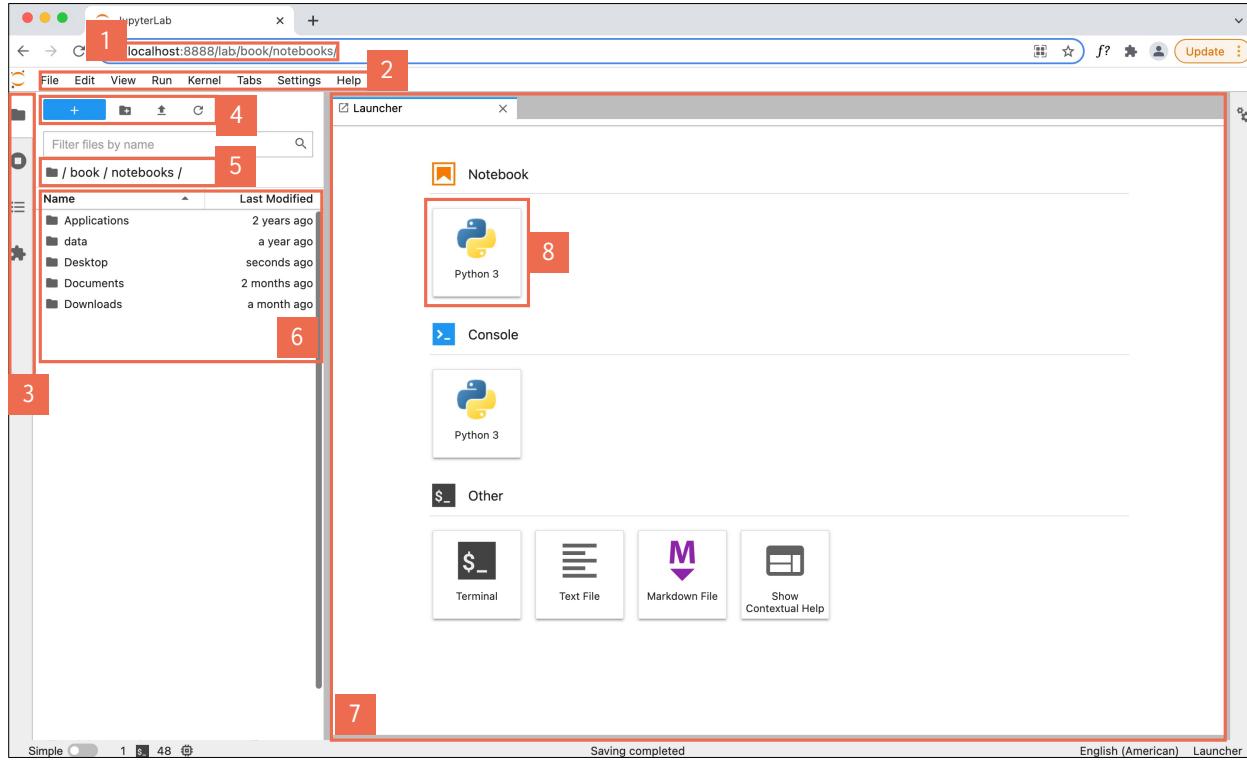


Figure 4. JupyterLab interface, containing: (1) local URL, (2) top bar, (3) lateral tabs, (4) folder browser top bar, (5) folder browser, (6) folder content, (7) launcher, and (8) Jupyter Notebook launch button.

JupyterLab, you can open an *existing* file only from this panel, and not by double-clicking the file in your computer folder. Therefore, you need to know how to navigate folders from JupyterLab. To go back to a previous folder, click on a folder name in Figure 4, box 5 (for example, to go back to the previous folder in this screenshot, you would click on *book*). To go into a sub-folder—a folder in the current folder—just double-click on the sub-folder listed in the folder panel (Figure 4, box 6). Last thing: when clicking on the folder icon (Figure 4, box 3), the whole file browser panel toggles out, meaning it disappears. When re-clicking, the whole panel toggles back in, so it reappears. Toggling out can be convenient if you have a small screen.

- **Launching tools.** The launcher is the place where you can open *new* notebooks, consoles, terminals, text files, etc. (Figure 4, box 7). As an alternative, you can open new files and tools from the top bar (Figure 4, box 2) by clicking on *File*, then *New*, and then selecting the file type you want. It's time to open a Jupyter Notebook!

Jupyter Notebook

To open a Jupyter Notebook, go to the launcher and click the notebook icon (Figure 4, box 8). A new notebook opens in the launcher area (Figure 5, box 2), and it is visible as *Untitled.ipynb* in the browser panel (Figure 5, box 1). Notebooks have the extension *.ipynb*, which stands for *interactive python notebook*. To give the notebook an appropriate name, right-click on *Untitled.ipynb* in the browser panel (Figure 5, box 1). Then, click *Rename*, and change it to any name you want—for example, *practicing_cells.ipynb*. As you might have noticed, by right-clicking on the file name, you can perform several

other actions, such as delete, cut, copy, duplicate, and more.

Let's now focus on a notebook content. A Jupyter Notebook is essentially a file containing a sequence of **cells**, that is, grey rectangles like the ones you see in Figure 5, box 4. Each cell can contain code or narrative, as we will see in a bit. The **blue bar** on the left side of a cell (Figure 5, box 5) indicates that the current cell is the **active cell**. In the presence of multiple cells, we can make a cell active by clicking on the square brackets [] on the cell left side. When a cell is active, we can perform several operations in various ways, either by keyboard commands or via the notebook top bar (Figure 5, box 3, enlarged in Figure 6), the JupyterLab top bar (Figure 4, box 2), or by right-clicking *in* the cell! This might sound redundant, but it is conceived to help coders with different habits—some prefer using keyboard commands, others prefer clicking on the screen—conveniently perform the cell operations they need. If there are too many options for you, then just choose one way and stick to that! Below are some useful cell operations and some of the possible ways to perform them.

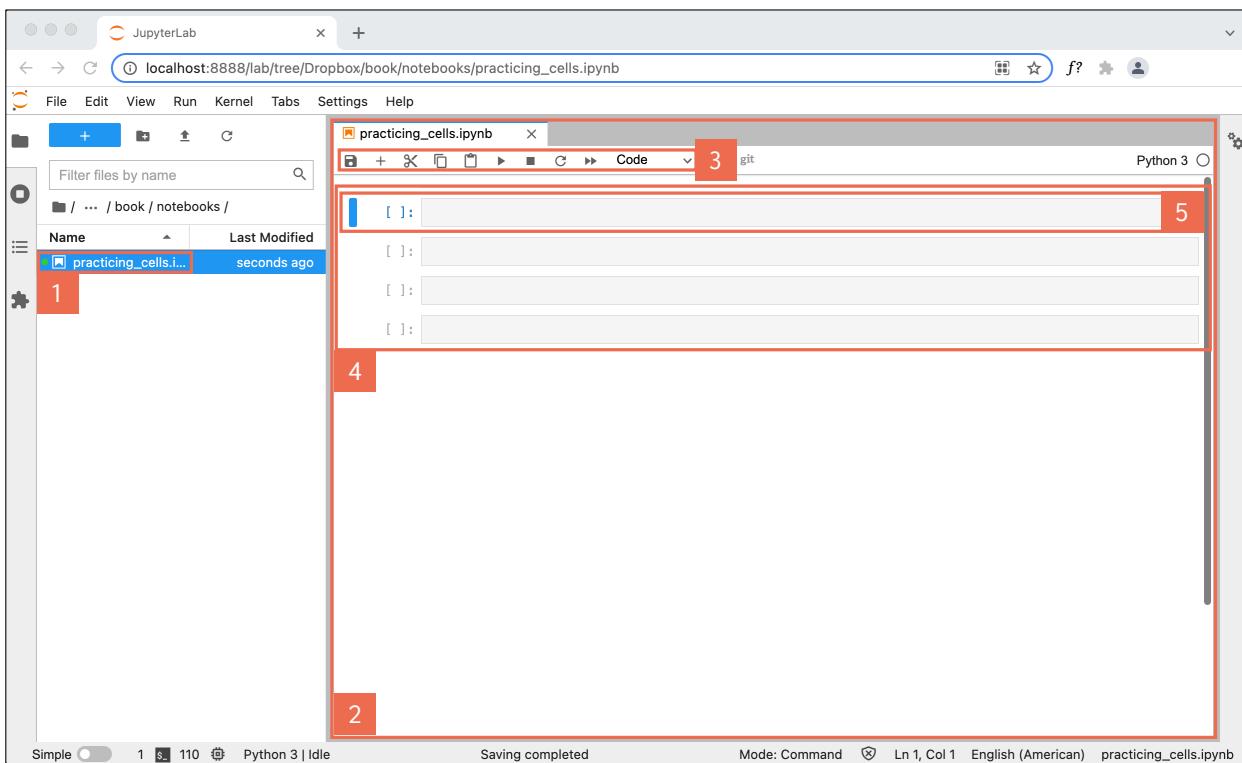


Figure 5. A Jupyter Notebook opened in JupyterLab. (1) Notebook in the folder browser, (2) Jupyter Notebook, (3) Jupyter Notebook top bar, (4) cells, (5) currently active cell.

- *Creating a cell:* To create a new cell below the active cell, press B, for *below*, or the plus button in the notebook top bar (Figure 6, item 2). The newly created cell becomes the active cell. We can also create a new cell above the active cell by pressing A, for *above* (there is no corresponding top bar button).
- *Deleting a cell:* To delete the active cell, press D twice, or click on the scissor button (Figure 6, item 3).
- *Copying a cell:* To copy the active cell, first press C and then V (without command or control!), or item 4 to copy, and then item 5 to paste (Figure 6).

- *Undoing or redoing cell operations:* To undo a cell operation (for example, if you have deleted a cell by mistake), press Z, or in JupyterLab top bar (Figure 4, box 2), go to Edit, and then *Undo cell operation*. Similarly, to redo a cell operation, simultaneously press shift and Z, or in JupyterLab top bar, go to Edit and then *Redo cell operation*.
- *Moving cells:* Left-click on the square brackets [] of the active cell, and while holding down the mouse button, move the cell up or down. When you reach the position you want to move the cell to, release. As an alternative, you can go to Edit in the JupyterLab top bar (Figure 4, box 2) and then click on *Move Cells Up* or *Move Cells Down*.
- *Add line numbers.* Line numbers are very useful when coding—you’ll come to realize this starting in Chapter 1. To add line numbers, go to View in the JupyterLab top bar (Figure 4, box 2), and then click *Show Line Numbers*.
- *Other operations.* You can split or merge cells, enable or disable scrolling for output, etc. by going to the JupyterLab top bar (Figure 4, box 2), and then see the options in Edit, or by right-clicking in a cell and browsing the options that appear. Just explore them!

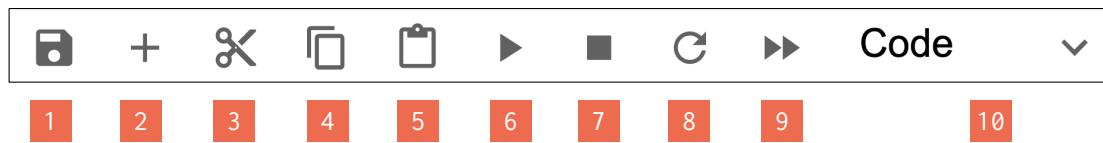


Figure 6. Jupyter Notebook top bar: (1) save notebook, (2) add cell, (3) cut cell, (4) copy cell, (5) paste cell, (6) run cell, (7) interrupt kernel, (8) restart kernel, (9) restart kernel and run whole notebook, and (10) define cell as code or markdown.

What about the remaining buttons in Figure 6? The first button representing a floppy disk—yes, once upon a time we saved data on floppy disks!—is to save the notebook. The buttons 6 to 9 are used to execute code, and you will learn how to use them in Chapter 1 (button 6) and Chapter 7 (buttons 7 to 9).

And finally, time to talk about cell content! As we mentioned before, a cell can contain two things: code or narrative. By default, Jupyter Notebook cells are **code** cells. To transform a cell into a **text** cell, press M on the keyboard, or click the drop-down menu in the Jupyter Notebook top bar (Figure 6, item 10), and select **Markdown**. **Markdown** is a simplified version of HTML, the coding language used to create websites. This is why the Jupyter environment is web-based: to use the rich features of web browsers! Writing the narrative in a notebook is fundamental to embedding code into explanations that make workflows easy to understand. You can learn how to write in Markdown in the *In more depth* session in Chapter 22. And last but not least, cells can contain **code**. The remainder of the book will be about that! So, it’s time to start coding, but before doing that, one last bit: you need to download the Jupyter Notebooks associated with this book.

Downloading the book material

Throughout the rest of the book, you will find 38 chapters. For each chapter, there is a Jupyter Notebook, whose file name includes the corresponding chapter number. Each notebook contains the examples discussed in the text so that you can practice and understand while reading. Download the notebooks at www.learnpythonwithjupyter.com. I highly recommend that you save the notebooks in

a *new folder*—not in the *Download* folder—so that you don’t mix them up with other files you download for other purposes. If you feel like going a step further, I really recommend that you create this folder in a *cloud service*, so that you do not lose your files in case your computer breaks or has issues (yes, computers are machines and they break!). As for cloud services, you can use Google Drive (<https://www.google.com/drive>), Dropbox (<https://www.dropbox.com>), or any others that you prefer. Using these tools is very easy. Download the program that installs the system on your computer. After the installation, you will see a new folder. Just create the folder that is going to contain the notebooks in the newly created cloud folder, and all your files will always be automatically synchronized and saved.

Finally, in each chapter of the book, you will find coding exercises. I recommend that you create a separate folder called *Exercises*, or something similar, and inside this folder, create a Jupyter Notebook for the exercises of each book chapter. Creating notebooks yourself will strengthen your organizational skills and will allow you to become even more familiar with the Jupyter/Python environment.

At this point, we are really ready. Let’s start coding!

PART 1

CREATING THE BASICS

It's time to start coding! In this part, you will learn the basic elements that we will use throughout the whole book. You will learn about strings – that is, a data type that contains text – and the concatenation operation, used to combine strings. You will also learn how to ask questions and how to print out information. And most importantly, you will learn what a variable is. Let's get started!

1. Text, questions, and art

Strings, `input()`, and `print()`

Programming languages are written languages, and the core of written communication is *text*. How is text represented in Python? How can we ask a question to a person? And how can we provide information to a person? To answer these questions, let's open Jupyter Notebook 1 and start!

1. Writing text: Strings

In coding, we use the word *string* to refer to text. We can define strings as follows:

Strings are text in between quotes

Let's look at the two examples below. On the left side, we see the code as it is in Jupyter Notebook 1. On the right side, we see how to pronounce the code. Let's read the code out loud:

[:] 1	"This is a string"	This is a string
[:] 1	'Everything you write between quotes is a string'	Everything you write between quotes is a string

Now let's consider the following statements. Are they true or false?

True or false?

- | | | |
|---|---|---|
| 1. A string contains text | T | F |
| 2. A string is in green in Jupyter Notebook | T | F |
| 3. Quotes can be either single or double | T | F |

Computational thinking and syntax

Let's analyze the code above in detail! In each cell, there is a *string*. As we can see, a string is just some text in between quotes. By text, we mean any **character** we can type on the keyboard: letters, numbers, symbols, and even the space! Quotes can be **double quotes** " ", like in the top example, or **single quotes** ' ', like in the bottom example. Quotes that start a string are called **opening** quotes, whereas quotes that end a string are called **closing** quotes. When writing a string in Python, we can use either double or single quotes; we just have to make sure we do not mix them up. In other words, if we start writing a string with an opening *double* quote, we must finish the string with a closing *double* quote. Similarly, if we start writing a string with an opening *single* quote, we must finish the string with a closing *single* quote. Strings are a Python **data type**, which means that they are one of the core parts of the Python language (see Table 1 in the Introduction). In Jupyter Notebook, Python strings are in red.

Let's run the first cell. **Running a cell** means **executing the code** in that cell. In the notebook, position

the mouse anywhere inside the cell. If you haven't done it already, click the mouse left button. The cursor will become a blinking vertical bar. Then, move to the keyboard. If you are on a MacOS, press *shift* and *return* at the same time. If you are on a Windows, press *shift* and *enter* at the same time (if not explicitly written on any key, *enter* is the key on the right side of the keyboard depicting an angled arrow). As an alternative, you can click the start button in the Jupyter Notebook top bar (Figure 6, icon 6, in the Getting ready part).

This is how the first cell looks when we run it:

```
[1]: 1 "This is a string"  
      'This is a string'
```

This is a string

When we run a cell, two things occur. First, a number appears in between the square brackets on the left side of the cell. In this case, the number is 1 because this is the first cell we ran. Second, we execute the code. In this case, we get to see the content of the cell; that is, 'This is a string'. Jupyter Notebook shows the string in between single quotes, even when the string is written in between double quotes. As mentioned above, single and double quotes are equivalent.

Let's run the second cell. Like before, left-click anywhere inside the cell. Then, press *shift* and *return* if on MacOS, or *shift* and *enter* if on Windows, or click the start button in the Jupyter Notebook top bar. Here is what we get:

```
[2]: 1 'Everything you write between quotes is a  
      string'  
      'Everything you write between quotes is a string'
```

Everything you write between quotes
is a string

Two things occurred again. First, the number 2 appeared in between the square brackets on the left side of the cell, showing that this is the second cell we ran. As is becoming clear, the **number on the left** side between square brackets indicates the **order of execution** of the cells. Second, we can see the string contained in the cell: 'Everything you write between quotes is a string'.

2. Asking questions: `input()`

In all programming languages there are ways to ask questions to a person, whom we usually call the **user**. This is a very important feature because it allows the interaction between a computer and a human being. What does this mean? Let's look at the code! Read the two cells below out loud (pronunciation on the right):

```
[]: 1 input("What's your name?")  
[]: 1 input("Where are you from?")
```

input what's your name?

input where are you from?

What does the code inside the cells do? Get a first hint by solving the following exercise.

📝 Match the sentence halves

1. What's your name? is
2. `input()` is a built-in function and
3. When running a cell containing `input()`
4. A built-in function is always followed



- a. it is colored green
- b. by round brackets
- c. a string
- d. we can answer a question

Computational thinking and syntax

Let's understand how these lines of code work! Let's run the first cell. We will get a text box:

```
[*]: 1 input("What's your name?")
What's your name? 
```

Type your name in the rectangle (I will write mine!):

```
[*]: 1 input("What's your name?")
What's your name?  Serena
```

And now press *return* or *enter* on the keyboard. You will see the following (you will see your name, of course!):

```
[3]: 1 input("What's your name?")
What's your name? Serena
'Serena' 
```

A few key things have happened here. First, the number on the left side of the cell turned to 3 as expected. But while answering the question, instead of the number 3, there was a **star symbol** (*). This indicates that a cell has started to run but has not finished yet. To complete the cell run and execute the code, we have to press *return* or *enter* after typing the answer. If the cell run is not completed, the code in the cell does not get executed, and in addition, we will not be able to run the following cells. Now, let's look at the code. We know that "What's your name?" is a string, because it is text in between quotes and it is colored red. What about **input()**? It allows us **to ask a question to a user**. In Jupyter Notebook, **input()** creates a text box (a white rectangle) where we can insert some text. **input()** performs a specific task and is called a **built-in function**.

A **built-in function** is a command that performs a specific task

We can recognize if a code element is a built-in function by two characteristics. First, in Jupyter Notebook built-in functions are always *green*. Second, built-in functions are always followed by **parentheses** (). In this book, instead of parentheses, we will call them **round brackets**, to differentiate from other types of brackets that we will encounter in the chapters that follow. In between the round brackets, we often write an **argument**, which for **input()** is a string containing the question we want to ask. Built-in functions are very useful, as they contain code written by the creators of a programming language to facilitate ease-of-use when coding.

Let's run the next cell:

```
[*]: 1 input("Where are you from?")
Where are you from? 
```

Similarly to before, now enter your country of origin in the text box (I will type mine!):

```
[*]: 1 input("Where are you from?")
Where are you from?  Italy
```

Now press *return* or *enter* on the keyboard. You will see an output similar to the following (you will see your country of origin!):

```
[4]: 1 input("Where are you from?")
      Where are you from? Italy
      'Italy'
```

input where are you from?

What happened here is similar to the previous cell. Let's summarize it: the number on the left of the cell turned to 4 because this is the fourth cell we ran. The *built-in function* `input()` created a text box in Jupyter Notebook in which we could answer the question contained in the string we gave as an argument. Too concise? Let's try again: when we run the cell, the *built-in function* `input()` shows us the question, which we put in between the round brackets as a string, and it creates a text box in which we can type the answer. After typing the answer, we press *return* or *enter* to complete the code execution.

At this point we can ask ourselves: where do we see `input()` in action in everyday life? Every time we are asked to type something on a device, there is a function similar to `input()` behind it! For example, this is the case when we write our names to register to a newsletter, enter the amount we want to withdraw from an ATM, or fill out an online form.

Finally, it is important to mention that when we write code, we *wear two hats* – that is, we have two roles: we are at the same time programmer and user! When writing code, we wear the *programmer hat*: we create code to perform a task, design code structure, and define user messages. When testing code, we wear the *user hat*: we check whether the code does what expected, is easy to use, and whether the user interaction is pleasant. When coding, we switch hats continuously!

3. ASCII art: `print()`

We now know how to ask a question to a user, but how do we provide them a piece of information? We use the *built-in function* `print()`! There are several ways to learn about `print()`, and the following one is indeed a lot of fun. It involves a type of digital art called ASCII art, by which images can be created using the symbols on a keyboard. Let's have a look at the following cell:

```
[]: 1 print("/\_\\" )
      2 print(">^.^< ")
      3 print(" / \ ")
      4 print("(____)___")
```

What are we going to print to the screen? The answer is straightforward, but before running the cell, quickly analyze the code by completing the following exercise.

📝 True or false?

- | | | |
|--|---|---|
| 1. <code>print()</code> is a string | T | F |
| 2. <code>print()</code> can have a string as an argument | T | F |
| 3. In coding, we print row by row | T | F |

Computational thinking and syntax

Let's finally run the cell. Here is what we get:

```
[5]: 1 print("/\_/\ ")
      2 print(">^.^< ")
      3 print(" / \ ")
      4 print("(____)__)

/\_/\_
>^.^<
/ \
(____)___
```

The little cat we created using keyboard symbols gets displayed to the screen. To do so, we used a new built-in function `print()`, which **displays on screen the argument** we provide – in this case a *string*. You might ask: But when we ran the cells 1 and 2, we could see the content of the strings; why do we need `print()`? The fact that we could see the strings from cells 1 and 2 is a feature of Jupyter Notebook. After running a cell, Jupyter Notebook displays the content of the last line but not that of the previous lines. If we delete the `print()` function from the code in cell 5, it will display only the very last string:

```
[5]: 1 "/\_/\ "
      2 ">^.^< "
      3 " / \ "
      4 "(____)__
      '____)___'
```

There are a few more things to point out by observing the code in cell 5. In a Jupyter Notebook cell, we can write several lines of code. The lines will get executed **sequentially**. In other words, when we run a cell, Python first executes line number 1, then line number 2, and so on, until the last line of the cell is reached. In addition, **in a string, spaces matter**. Spaces are *characters*, so a space is an element of a *string* and takes its own place. On the other hand, spaces do not matter between code elements. For example, both lines below are executed without error messages:

```
[5]: 1 print("(___)__")
      2 print("(___)__")
      '____)___'
      '____)___'
```

However, the Python style guidelines recommend **avoiding a space between a function and the subsequent round bracket**.

When writing code with some repetition, it is good practice to keep some **parallelism** between the lines of code. Compare the code written in cell 5 as we did above,

```
[]: 1 print("/\_/\ ")
      2 print(">^.^< ")
      3 print(" / \ ")
      4 print("(____)__")
```

to the same code written without aligning closing quotes and closing round brackets, as below:

```
[ ]: 1 print("/\_/\\")
      2 print(">^.^<")
      3 print(" / \")
      4 print("(____)___")
```

We can see that in the second case the code looks somehow more confusing. Instead, when we align quotes, brackets, and other symbols – as you will see in the following chapters – we create code that is more **readable** and **less prone to errors**. We will also talk quite a bit about tricks to minimize the amount of possible errors that we might introduce in code.

One more question before the recap: where do we see the function `print()` in action in everyday life? Every time we see a message on a device! For example: ‘Registration completed’, or ‘Thank you for your purchase’, or ‘Logout successful’. In the underlying code, there is a function similar to `print()`!

Recap

- The type **string** is text in between quotes.
- **input()** is a built-in function to ask a user to enter a value.
- **print()** is a built-in function to display a value to screen.

Our fingers have memory

When learning to code, it is very important to **type every single command**, resisting the temptation of copying/pasting. Typing helps us **memorize** commands in at least two ways. First, when typing a command we mentally spell it, so we repeat it in our minds, and thus we memorize it. Second, our fingers can memorize typing patterns. For example, when typing `print()`, our fingers will automatically remember to type the round brackets right after `print`. Similarly to a pianist who does not look at the keyboard but at the sheet music while playing, we want to look not at the keyboard but at the screen while coding. This way of typing is called **touch typing** (or blind typing). It helps us be faster and **minimize the amount of errors** we make because we do not have to keep moving our eyes between the keyboard and the screen. How can we learn

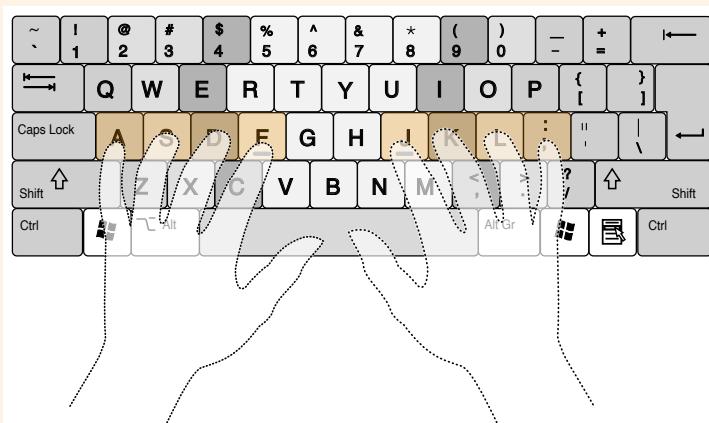


Figure 1.1. Starting finger position on a keyboard

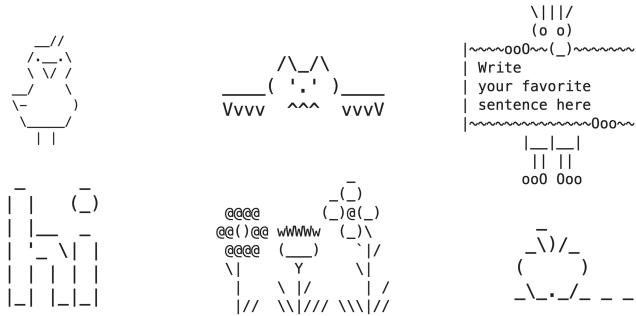
touch typing? It is very easy; it just requires some practice. The idea is that each finger presses some specific keys of the keyboard, as in Figure 1.1. We position the left index finger on the letter F and the right index finger on the letter J – the two little bumps on these keys define the starting point. The remaining fingers will go on the keys in the same row. For the left hand, the middle finger will go on the letter D, the ring finger on S, and the small finger on A. Similarly, for the right hand, the middle finger will go on the letter K, the ring finger on L, and the small finger on the semicolon. What about the letters G and H that are in between? When needed, the left index finger will move from F to G, and the right index finger from J to H. The fingers will then move upward and downward for the other letters, maintaining the same reciprocal positions.

There are plenty of websites to learn touch typing in a fun way, such as www.typing.com and www.typingclub.com. They are free, and creating an account is not compulsory. They provide gradual exercises starting from typing single letters, to syllables, to words, up to whole sentences. Give it a try?

Ready for some coding exercises? Create a new notebook and solve the following exercises below. If you do not remember how to create a new notebook or new cells, have a look at pages at the *Getting Ready* part.

Let's code!

1. *Writing strings.* Write a string using *double quotes*. Then, run the cell and observe what happens. Then write a string using *single quotes*. Run the cell and observe what happens.
2. *Asking questions.* Write two questions using the *built-in function* `input()` and then answer them.
3. *ASCII art.* Reproduce at least one of the following pieces of ASCII art:



2. Events and favorites

Variables, assignment, and string concatenation

Let's continue building our basics by learning about *variables* and *string concatenation*. What are they? Let's find out together using Notebook 2! Read the example below aloud and try to understand what the code does:

1. Organizing an event

- You are organizing an event, and you have created the following registration form for the participants:

The registration form is titled "REGISTRATION FORM". It contains two input fields: "first_name = _____" and "last_name = _____".

Figure 2.1. Registration form for the event participants.

- The first participant comes in and you fill out the form:

```
[]: 1 first_name = "Fernando"           first name is assigned Fernando  
      2 last_name = "Pérez"             last name is assigned Pérez
```

- Then you print out what you entered in the registration form:

```
[]: 1 print(first_name)           print first_name  
      2 print(last_name)            print last_name
```

What does the code in these cells do? Let's get some hints by completing the following exercise.

📝 True or false?

1. The command `first_name = "Fernando"` assigns the string "Fernando" to the variable `first_name` T F
2. The command `print(first_name)` will print out Fernando T F
3. The command `print(last_name)` will print out `last_name` T F

Computational thinking and syntax

Any guesses about what happens? Let's run the first cell:

[1]:	1 first_name = "Fernando" 2 last_name = "Pérez"	first name is assigned Fernando last name is assigned Pérez
------	--	--

At line 1 we create a **variable** called `first_name`. To the variable `first_name` we **assign** the string "Fernando", which is the **value**. Similarly, at line 2 we create a variable called `last_name`, to which we assign the string "Pérez" as a value. In general, we can assign any value to a variable. For example, we can register our second guest, Guido van Rossum, by writing:

[]:	1 first_name = "Guido" 2 last_name = "van Rossum"	first name is assigned Guido last name is assigned van Rossum
-----	--	--

As you can see, the *variable* names remain the same (`first_name` and `last_name`), whereas the assigned *values* can be different ("Fernando" or "Guido", "Pérez" or "van Rossum"). We can define variables as follows:

A **variable** is a label associated to a value

In Python, variables are *lowercase*. When composed of multiple words, these are connected by *underline*, like in `first_name`. In Jupyter Notebook, variables are *black*. The symbol `=` is called **assignment operator**. This has nothing to do with the *equals* we learned in math! *equals* has a different symbol in coding, which we will see in Chapter 9. In coding we use the symbol `=` to **assign a value to a variable**, and we pronounce it as *is assigned*. This is a very important concept to remember, and it's one of the most counter-intuitive! Symbols are colored *purple* in Jupyter Notebook.

Let's now run the second cell:

[2]:	1 print(first_name) 2 print(last_name)	print first_name print last_name
	Fernando Pérez	

As you might expect, at line 1 we print to the screen the *value* assigned to the variable `first_name`, which is Fernando. At line 2 we print the value assigned to the variable `last_name`, which is Pérez. Who is Fernando Pérez? The creator of Jupyter Notebook! And Guido van Rossum? The creator of Python!

2. Favorites

Time to put together what we have learned so far! Let's read the following code:

[]:	1 name = input("What's your name?")	name is assigned input what's your name?
[]:	1 favorite_food = input("What's your favorite food?")	favorite_food is assigned input what's your favorite food?

```
[1]: 1 print("Hi! My name is " + name)
      2 print("My favorite food is " +
            favorite_food)
      2 print(name + "'s favorite food is " +
            favorite_food)
```

```
print Hi! My name is concatenated with
      name
print My favorite food is concatenated
      with favorite_food
print name concatenated with 's favorite
      food is concatenated with favorite_food
```

What happens in this code? Let's get some hints by completing the following exercise!

📝 True or false?

1. The answer to the question What's your name? is assigned to the variable name T F
2. The question What's your favorite food? is asked before the question What's your name? T F
3. If the answer to the first question is Terry and the answer to the second question is mango, then the third print will show Terry's favorite food is pizza T F
4. The symbol + can combine a string and a variable containing a string T F

Computational thinking and syntax

Let's run the first cell:

```
[3]: 1 name = input("What's your name?")
      What's your name? Serena
```

name is assigned input what's your name?

The name we enter in the text box will be assigned to the variable name.

Let's run the second cell:

```
[4]: 1 favorite_food = input("What's your
      favorite food?")
      What's your favorite food? pasta
```

favorite_food is assigned input what's
 your favorite food?

Similarly to the above example, what we enter in the text box will be assigned to the variable favorite_food.

Let's now run the last cell of this notebook. What do we expect the prints to be?

```
[5]: 1 print("Hi! My name is " + name)
      2 print("My favorite food is " +
            favorite_food)
      2 print(name + "'s favorite food is " +
            favorite_food)
```

```
Hi! My name is Serena
My favorite food is pasta
Serena's favorite food is pasta
```

```
print Hi! My name is concatenated with
      name
print My favorite food is concatenated
      with favorite_food
print name concatenated with 's favorite
      food is concatenated with favorite_food
```

At line 1, we print out the union of the string "Hi! My name is " and the value assigned to the variable name. When dealing with strings, the symbol + is called a **concatenation symbol**, not plus! Concatenating simply means *chaining together*. + allows us to **merge strings**, and we can pronounce it as concatenated with.

We have now learned the very basics on which we will build our coding skills and knowledge. Now let's

take just a few minutes to complete the following exercise, which will help us summarize clearly the syntax we have learned so far!

Fill in the gaps

Fill in the gaps by inserting what each word is and its color in Jupyter Notebook. See the example in the first sentence:

1. `input()` is a built-in function and is colored green.
2. `Also print()` is a and is colored .
3. `name` is a and is colored .
4. `"My favorite food is"` is a and is colored .
5. `=` is the and is colored .
6. `+` is the and is colored too.

Recap

- In coding, we assign **values** to **variables**.
- The symbol `=` is the **assignment operator** (and not the `equals` symbol!), and it can be pronounced `is assigned`.
- The symbol `+` is the **concatenation symbol** when dealing with strings (and not the `plus` symbol!), and it can be pronounced concatenated with.

Dealing with `NameError` and `SyntaxError`

When we write code, we inevitably make mistakes, and we get error messages. Getting error messages is *normal* when coding. It's important to learn how to read error messages so that we can fix errors quickly and keep coding. There are different kinds of errors, and we'll learn how to fix them over the course of the book. This is an example of an error:

```
NameError                                                 Traceback (most recent call last)
Cell In[5], line 1
----> 1 print ("Hi! My name is " + ame )
      2 print ("My favorite food is " + favorite_food )
      3 print ( name + "'s favorite food is " + favorite_food )
NameError: name 'ame' is not defined
```

When encountering an error, we have to perform two steps:

1. **Read the last line of the message**, which tells us what type of errors we have made
2. **Look for the green arrow**, which shows us the line where the error is.

In this case we are dealing with a **Name error**. The last line of the message says: `NameError: name 'ame' is not defined`. This is a very common error message. It means that there is not variable `'ame'` in your code. This error message usually pops up in two cases: when we misspell a variable name, or when we have not run a previous Jupyter Notebook cell containing

the initialization (or creation) of the variable. In this example we have misspelled the variable 'name'. This variable is present at lines 1 and 3. Which line should we look at? The arrow pointing at line number 1 shows us that the error is at line 1, where we can see that we typed 'ame' instead of 'name'. So we can correct the typo, rerun the cell, and quickly move on with coding! Another very common error message is the following:

```
Cell In[5], line 1
    print("Hi! My name is " name)
                           ^
SyntaxError: invalid syntax
```

In this case we have made a **syntax error**. The last line of the message says: `SyntaxError: invalid syntax`, which means that we have forgotten some symbol or punctuation. Where is the error? For syntax errors, we look at two lines in the message: at the end of the very first line, we see that we made the error at line 1; after the line of code, we see a hat symbol ^ that shows us the part of the command where there is something missing.

Ready to exercise? Let's go!

Let's code!

1. At *the gym*. You are the manager of a gym and you have to register a new person. What variables would you create? Write three variables, assign a value to each of them (make sure they are strings!), and print them out.
2. At *a bookstore*. You are the owner of a bookstore and you want to create a book catalog. You start with the first book: *Code Girls* by Liza Mundy. You create two variables, *book title* and *author*, assign them the actual title and author, and print them out. Then, pick a book of your choice, create the two variables again, assign the corresponding values, and print them out.
3. *Where are you from?* Ask a person what country they come from and where they live. Then print out three sentences like in cell 5 of the code in this chapter.
4. *What's your favorite song?* Ask a person their favorite song and favorite singer. Then print out three sentences like in cell 5 of the code in this chapter.

PART 2

INTRODUCTION TO LISTS AND IF/ELSE CONSTRUCTS

In this part, you will learn about lists, which are simply sequences of elements of various types—for example, strings. You will also learn how to manipulate them, that is, how to add, remove, or replace one or more elements. And finally, you will learn if/else constructs, which allow for executing code based on conditions. Ready? Let's go!

3. In a bookstore

Lists and if... in... / else...

What does a list look like? And how do we use `if/else` conditions? To answer these questions, let's open Jupyter Notebook 3 and begin! Read the following example aloud and try to understand it:

- You are the owner of a bookstore. On the programming shelf there are:

```
[:] 1 books = ["Learn Python", "Python for all", "Intro  
      to Python"]  
    2 print(books)
```

```
books is assigned Learn Python,  
Python for all, Intro to Python  
print books
```

- A new customer comes in, and you ask what book she wants:

```
[:] 1 wanted_book = input("Hi! What book would you like  
      to buy?")  
    2 print(wanted_book)
```

```
wanted book is assigned input Hi!  
What book would you like to buy?  
print wanted book
```

- You check if you have the book, and you reply accordingly:

```
[:] 1 if wanted_book in books:  
      2     print("Yes, we sell it!")  
    3 else:  
      4     print("Sorry, we do not sell that book")
```

```
if wanted book in books  
print Yes, we sell it!  
else  
print Sorry, we do not sell that  
book
```

What does the code above do? Get some hints by completing the following exercise.

True or false?

1. On the programming shelf there are 2 books T F
2. If the customer wants a book that is in the programming shelf, you print: Yes, we sell it! T F
3. The `if/else` block allows us to execute commands based on conditions T F

Computational thinking and syntax

Let's analyze the code line by line, starting with the first cell:

```
[1]: 1 books = ["Learn Python", "Python for all", "Intro  
      to Python"]  
    2 print(books)
```

```
books is assigned Learn Python,  
Python for all, Intro to Python  
print books
```

```
['Learn Python', 'Python for all', 'Intro to Python']
```

On line 1 there is a variable called `books`, to which we assign a sequence of elements of type string: "Learn Python", "Python for all", and "Intro to Python". The elements are separated by commas and they are in between square brackets. A variable with this syntax is called **list**. In our code, `books` is a **variable of type list** whose elements are of type string. In other words, we can say that `books` is a list of

strings. A list is defined as follows:

A **list** is a sequence of elements separated by commas ,
and in between square brackets []

As its name says, a list is literally a list of elements, similar to a shopping list or a to-do list. It can contain elements of various types, such as strings, numbers, etc. For now, we will consider only lists of strings.

Let's run the second cell:

[2]:	<pre>1 wanted_book = input("Hi! What book would you like 2 to buy?") 3 print(wanted_book)</pre>	<pre>wanted book is assigned input Hi! What book would you like to buy? print wanted book</pre>
	<pre>Hi! What book would you like to buy? Learn Python Learn Python</pre>	

You are now familiar with the code in this cell. Briefly summarized, on line 1 we created a variable called `wanted_book`, which contains the user's answer to the question: `Hi! What book would you like to buy?` Then, on line 2, we printed the value contained in the variable `wanted_book`.

Let's run the third cell:

[3]:	<pre>1 if wanted_book in books: 2 print("Yes, we sell it!") 3 else: 4 print("Sorry, we do not sell that book")</pre>	<pre>if wanted book in books print "Yes, we sell it!" else print "Sorry, we do not sell that book"</pre>
	<pre>Yes, we sell it!</pre>	

Here, we finally meet the `if/else` construct. Let's learn how it works by starting from lines 1 and 2. These lines say `if wanted_book`, which is `"Learn Python"`, is in `books`, which is `["Learn Python", "Python for all", "Intro to Python"]` (line 1), `print "Yes, we sell it!"` (line 2). In line 1, we check whether the value assigned to the variable `wanted_book` is one of the elements of the list `books`. If that is the case, then we move to line 2 and print out a positive answer to the user.

What if `wanted_book` is not in the list? Let's rerun cell 2 and enter a book that is not in the list:

[4]:	<pre>1 wanted_book = input("Hi! What book would you like 2 to buy?") 3 print(wanted_book)</pre>	<pre>wanted book is assigned input Hi! What book would you like to buy? print wanted book</pre>
	<pre>Hi! What book would you like to buy? Basic Python Basic Python</pre>	

In this case, what do you expect when running the cell below? Let's run it:

[5]:	<pre>1 if wanted_book in books: 2 print("Yes, we sell it!") 3 else: 4 print("Sorry, we do not sell that book")</pre>	<pre>if wanted book in books print Yes, we sell it! else print Sorry, we do not sell that book</pre>
	<pre>Sorry, we do not sell that book</pre>	

We start again from line 1, where we read `wanted_book`, which now is `"Basic Python"`, is in `books`,

which is ["Learn Python", "Python for all", "Intro to Python"]. But this time, "Basic Python" is not in the list books. So we skip line 2, go directly to line 3—where there is `else`—and proceed to line 4, where we print the string "Sorry, we do not sell that book".

As you can deduce from the example above, in an `if/else` construct, code is executed depending on the **truthfulness of a condition**. If the condition in the `if` line is met, or true, we execute the underlying code. Otherwise, if the condition in the `if` line is not met, or false, then we execute the code under `else`. Therefore, we can define the `if/else` construct as follows:

An **`if/else` construct** checks whether a condition is true or false,
and executes code accordingly:

if the condition is met, the code under the `if` condition is executed;
if the condition is not met, the code under `else` is executed.

Let's now focus on the syntax. An `if/else` construct is composed of four parts, explained below:

- **`if condition`** (line 1) contains a condition that determines code execution. It is made up of three components: (1) the **keyword `if`**, colored bold green in Jupyter Notebook (2) the condition itself and (3) the punctuation mark colon `:`.
- **`Statement`** (line 2) contains the code that gets executed if the condition at line 1 is met.
- **`else`** (line 3) implicitly contains the alternative to the condition on line 1. This line is always composed of the **keyword `else`** followed by the colon `:`.
- **`Statement`** (line 4) contains the code that gets executed if the condition at line 1 is not met.

Note: `else` and its following statements are not mandatory. There are cases when we do not want to do anything if the conditions are not met. Some examples of this scenario are provided in the following chapters.

Before concluding, let's zoom even more into these lines and focus on two more aspects: membership conditions and indentation. In coding, we can use various types of conditions, and you will see these throughout the book. In this case, we have a **membership condition**: `wanted_book in books` (line 1), where we check whether a variable contains one of the elements of a list. In a membership condition, we write: (1) variable name, (2) `in`, and (3) the list in which we want to find the element. `in` is a **membership operator**. In Jupyter Notebook, this is colored bold green, like keywords. In general, make sure not to confuse keywords, in bold green, with built-in functions, in fainter green.

Finally, notice that the statements under the `if` condition (line 2) and under the `else` (line 4) are always indented, which means shifted toward the right. An **indentation** consists of 4 spaces, or 1 tab. In Jupyter Notebook, when pressing enter or return after writing the `if` or `else` lines, the cursor is always automatically placed at the right indented position. Under an `if` or an `else` condition, we can write as many commands as we want, but they must be indented correctly to be executed.

Complete the table

Up to this point, you have already learned quite a lot of syntax. Complete the following table by using the example in the first row to summarize the syntax you know so far.

Code element	What it is	What it does
books	A variable of type list	It contains a sequence of strings
wanted_book		
"Learn Python"		
if		
in		
else		
=		
+		
input()		
print()		

Recap

- **Lists** are a Python type that contain a sequence of elements (for example, strings) separated by commas , and in between square brackets [].
- The **if/else construct** allows us to execute code based on conditions.
- The **membership operator in** verifies whether an element is in a list.
- In Python, we use **indentation** for statements below if or else.

Let's give variables meaningful names!

One of the fundamental criteria when writing code is **readability**. It is important to write code that is easy to read both for our future selves and for others. One of the ways to make code readable is to create **meaningful variable name**. As an example, let's consider the code we analyzed in this chapter. On line 1 of cell 2 we created the variable wanted_book:

```
[2]: 1 wanted_book = input("Hi! What book would you like
to buy?") answer is assigned input
Hi! What book would you
like to buy?
```

Instead of wanted_book, we could have named the variable answer:

```
[2]: 1 answer = input("Hi! What book would you like to
buy?") answer is assigned input
Hi! What book would you
like to buy?
```

The name answer is logically consistent because this variable contains the answer to the question "Hi! What book would you like to buy?". However, answer is not the best choice because it is a very *generic* variable name. Variable names should be **pertinent**, representing the information they contain. Consider having 10 input() commands in the code. What do we call the corresponding variables? We don't want to call them answer_1, answer_2, ..., answer_10; it would

be hard to remember what we assigned to `answer_7`, for example. Or, if we later decide to reshuffle some questions, then we will have to rename the variables to make sure the numbers increase consistently. This would generate a lot of confusion and increase the possibility of errors.

Back to the previous example, the name `answer` would also not be meaningful in the following line of code from cell 3:

```
[3]: 1 if answer in books: if answer in books
```

It does not make much sense to look for an answer in a list of books! But it makes more sense to look for a wanted book in a list of books:

```
[3]: 1 if wanted_book in books: if wanted book in books
```

Let's code!

For each of the following scenarios, create code similar to that presented in this chapter.

1. *In an art gallery.* You are the owner of an art gallery. Write a list of some paintings you sell. A new customer comes in, and you ask what painting she wants to buy. You check whether you have that painting and reply accordingly.
2. *In a travel agency.* You are the owner of a travel agency. Write a list of some travel destinations you sell tickets for. A new customer comes in, and you ask where he wants to go. You check whether you offer that travel destination and reply accordingly.
3. *In a chemical lab.* You are the manager of a lab. On a shelf there some jars containing chemicals. Write a list containing the names of the chemicals. One of the lab members comes to you and you ask what chemical she wants. You check in your system whether you have that chemical and reply accordingly.
4. *In a tea room.* You are the owner of a tea room. Write a list of teas you offer. A new customer comes in, and you ask what tea he wants. You check on the menu whether you serve that tea and reply accordingly.

4. Grocery shopping

List methods: `.append()` and `.remove()`

What are methods? And what do `.append()` and `.remove()` do? To answer this questions, open Jupyter Notebook 4 and follow along. Let's start with the following example:

- You are going to a grocery store where you have to buy some food:

```
[]: 1 shopping_list = ["carrots", "chocolate", "olives"]      shopping list is assigned  
      carrots, chocolate, olives  
2 print(shopping_list)                                     print shopping list
```

- Right before leaving home, you ask yourself if you have to buy something else. If the item is not in the list, you add it:

```
[]: 1 new_item = input("What else do I have to buy?")      new item is assigned input What  
2 if new_item in shopping_list:                            else do I have to buy?  
3     print (new_item + " is/are already in the           if new item in shopping list  
        shopping list")                                print new item concatenated with  
4     print(shopping_list)                               is/are already in the shopping  
5 else:                                                 list  
6     shopping_list.append(new_item)                   print shopping list dot append new item  
7     print(shopping_list)                           print shopping list
```

- Finally, you ask yourself if you have to remove an item. If so, you remove the item from the list:

```
[]: 1 item_to_remove = input("What do I have to           item to remove is assigned input  
remove?")                                         what do I have to remove?  
2 if item_to_remove in shopping list:                if item to remove in shopping  
3     shopping_list.remove(item_to_remove)          list  
4     print(shopping_list)                         shopping list dot remove item to  
5 else:                                              remove  
6     print (item_to_remove + " is/are not in the    print item to remove concatenated  
        shopping list")                           with is/are not in the shopping  
7     print(shopping_list)                         list  
                                         print shopping list
```

To get a better idea of what happens in this code, match the sentence halves in the following exercise.

Match the sentence halves

- | | |
|---|---|
| 1. The variable <code>shopping_list</code> contains | a. we remove it from the shopping list |
| 2. If the new item is not in the shopping list | b. to remove an element from a list |
| 3. If the item to remove is in the shopping list | c. "carrots", "chocolate", and "olives" |
| 4. The method <code>.append()</code> allows us | d. we add it to the shopping list |
| 5. The method <code>.remove()</code> allows us | e. to add an element at the end of a list |

Computational thinking and syntax

Let's dig into the code by running the first cell:

```
[1]: 1 shopping_list = ["carrots", "chocolate", "olives"]
      2 print(shopping_list)
      ['carrots', 'chocolate', 'olives']
```

shopping list is assigned
carrots, chocolate, olives
print shopping list

We start with a list called `shopping_list`, which contains three strings: "carrots", "chocolate", and "olives" (line 1). Then, we print the shopping list to the screen (line 2).

What does `.append()` do? Let's run the second cell:

```
[2]: 1 new_item = input("What else do I have to buy?")
      2 if new_item in shopping_list:
          3     print (new_item + " is/are already in the
                  shopping list")
      4     print(shopping_list)
      5 else:
          6     shopping_list.append(new_item)
          7     print(shopping_list)
```

new item is assigned input What
else do I have to buy?
if new item in shopping list
print new item concatenated with
is/are already in the shopping
list
print shopping list
else
shopping list dot append new item
print shopping list

What else do I have to buy? carrots
carrots is/are already in the shopping list
['carrots', 'chocolate', 'olives']

In this cell, we ask the user to input a new item to buy, and the answer is saved in the variable `new_item` (line 1). Then, we act according to the value contained in `new_item`. If `new_item` is already in `shopping_list` (line 2), we print out a message saying that the item is already in the shopping list (line 3). To make the message more precise, we concatenate the string in `new_item` with the string "is/are already in the shopping list". Then, we print out the shopping list to check that the item is actually in the list (line 4).

What if the item is *not* in the shopping list? Let's rerun the cell and enter an item that is not in the list:

```
[3]: 1 new_item = input("What else do I have to buy?")  
2  
3     if new_item in shopping_list:  
4         print (new_item + " is/are already in the  
5             shopping list")  
6  
7     print(shopping_list)  
8 else:  
9     shopping_list.append(new_item)  
10    print(shopping_list)  
  
What else do I have to buy? apples  
['carrots', 'chocolate', 'olives', 'apples']
```

new item is assigned input What
else do I have to buy?
if new item in shopping list
print new item concatenated with
is/are already in the shopping
list
print shopping list
else
shopping list dot append new item
print shopping list

This time, we entered *apples* in the text box created by `input()` (line 1). Because *apples* is not in the shopping list (line 2), we skip the commands at lines 3 and 4 and jump directly to the `else` (line 5) to execute the commands below. We add the new item to the list (line 6), and we print out the list to check whether we added the element correctly (line 7).

How do we add a new element to a list? Let's have a closer look at line 6. Here, the method `.append()` adds the element `new_item` to the `shopping_list`. Note that `.append()` always **adds an element at the end of a list**. As we said, `.append()` is a method. But what is a method? A preliminary definition (we'll redefine it when we talk about object-oriented programming, at the end of the book) is as follows:

A **method** is a built-in function for a specific variable type

You can recognize that methods are functions because they are followed by round brackets. However, a method has its own syntax, which is composed of four elements: (1) variable name, (2) dot, (3) method name, and (4) round brackets. In the round brackets, there can be an **argument**, such as `new_item` in this case. Different data types have different methods. For example, `.append()` can be used for lists but not for strings. Lists have a total of eleven methods, and we will learn all of them throughout this book. Methods are colored *blue* in Jupyter Notebook.

Finally, what does `.remove()` do? Let's run the last cell:

```
[4]: 1 item_to_remove = input("What do I have to  
2     remove?")  
3  
4     if item_to_remove in shopping list:  
5  
6         shopping_list.remove(item_to_remove)  
7  
8     print(shopping_list)  
9 else:  
10    print (item_to_remove + " is/are not in the  
11        shopping list")  
12  
13    print(shopping_list)  
  
What do I have to remove? olives  
['carrots', 'chocolate', 'apples']
```

item to remove is assigned input
what do I have to remove?
if item to remove in shopping
list
shopping list dot remove item to
remove
print shopping list
else
print item to remove concatenated
with is/are not in the shopping
list
print shopping list

This time, we ask the user what item they want to remove (line 1). If the item to remove is in the shopping list (line 2), then we remove the item (line 3) and print out the resulting list (line 4). How do we remove an item? We use `.remove()`, which is the list method **to remove an item from a list**. The

syntax is the same as for `.append()` and any other method: list name followed by dot, method name, and round brackets, which can contain an argument. As an argument, `.remove()` takes the element to be removed from the list.

What if we answer the question "What do I have to remove?" with an element that is not in the list? Let's have a look:

<pre>[5]: 1 item_to_remove = input("What do I have to remove?") 2 if item_to_remove in shopping_list: 3 shopping_list.remove(item_to_remove) 4 print(shopping_list) 5 else: 6 print(item_to_remove + " is/are not in the shopping list") 7 print(shopping_list)</pre>	<pre>item to remove is assigned input what do I have to remove? if item to remove in shopping list shopping list dot remove item to remove print shopping list else print item to remove concatenated with is/are not in the shopping list print shopping list</pre>
<pre>What do I have to remove? grapes grapes is/are not in the list ['carrots', 'chocolate', 'apples']</pre>	

In the text box created by `input()`, we entered *grapes* (line 1), which is not in `shopping_list` (line 2). Therefore, we skip lines 3 and 4 and jump to the `else` at line 5. There, we print out a message saying that `item_to_remove` is not in the shopping list (line 6) and print out the shopping list for final check (line 7).

Complete the table

In Python, we use a lot of punctuation marks. Sum up what you have seen so far by completing the following table, using the example in row 1.

Punctuation symbol	What it's called	What it does
<code>''</code> or <code>""</code>	Single quotes or double quotes	They contain a strings
<code>()</code>		
<code>[]</code>		
<code>:</code>		
<code>,</code>		
<code>.</code>		

Recap

- The method `.append()` **adds an element** at the **end** of a list.
- The method `.remove()` **removes an element** from a list.

Why do we print so much?

When coding, it is important to **keep control of variable's values**. And particularly when learning to code, every time we create or modify a variable, it's important to make sure the code does what it is intended to do. Printing is an easy way to check that variable modifications correspond to our intentions. As an example, consider the code in cell 4, and let's focus on the `if` condition and its statements (lines 2–4). Let's rewrite it without the printing command:

<pre>[4]: 1 item_to_remove = input("What do I have to remove?") 2 if item_to_remove in shopping_list: 3 shopping_list.remove(item_to_remove)</pre>	<pre>item to remove is assigned input what do I have to remove? if item to remove in shopping list shopping list dot remove item to remove</pre>
<pre>What do I have to remove? olives</pre>	

How do we know that the code actually worked correctly? That is, how do we know whether 'olives' was actually removed from `shopping_list`? We can assume that it happened, but we cannot be sure until we see it with our eyes. So, we need to print. Let's rewrite the code by adding `print()` back to line 4:

<pre>[4]: 1 item_to_remove = input("What do I have to remove?") 2 if item_to_remove in shopping_list: 3 shopping_list.remove(item_to_remove) 4 print(shopping_list)</pre>	<pre>item to remove is assigned input what do I have to remove? if item to remove in shopping list shopping list dot remove item to remove print shopping list</pre>
<pre>What do I have to remove? olives ['carrots', 'chocolate', 'apples']</pre>	

Because we printed, we can make sure that 'olives' is not in the `shopping_list`. Therefore, our code accomplished what we intended. Always print extensively when coding; you can always remove the `print()` function later on.

Let's code!

1. For each of the following scenarios, create code similar to the one presented in this chapter.
 - a. *Organizing an event.* You are organizing an event. Write a list of what you need to buy. Then ask your co-organizer what else you have to buy. If the item is not in the list, add it. Finally, ask your co-organizer if there is anything you need to remove from the list. If so, remove the item from the list.
 - b. *Favorite cities.* Write a list containing names of cities. Ask a friend their favorite city. If the city is not in the list, add it. Then, ask your friend if they do not like one of the cities you listed. If so, remove the city from your list.
2. *Shoe store.* You are the owner of a shoe store, and you have to place a new order for the next summer season. You go to the storage room, and you create a list of the remaining shoes: sneakers, boots, ballerinas. You know that in summer your customers will want sandals, so you add them to the list. However, they are not going to buy boots, so you remove them from the list. After you get the new supplies, a new customer comes in. You ask what shoes he wants to try, and he replies that he'd like

to try sandals. You check in your list and reply accordingly. Then you ask if he wants to have a look at something else, and he replies that he'd like to try boots. You check in your list again and reply accordingly.

3. *Currency exchange office.* You work at a currency exchange office. The available currencies are Euros, Canadian Dollars, and Yen, whereas the Swiss Franc is unavailable, so you will have to order it. Create a list of available currencies and a list of currencies to order. A new customer comes in; you ask what currency she wants. After she replies, you check in the list of available currencies. If the currency she wants is available, you tell her that you have it, remove the currency from the list of available currencies, and add the currency to the list of currencies to order. If the currency she wants is not available, you tell her that you do not have that currency, and add the currency to the list of currencies to order.

5. Customizing the burger menu

List methods: `.index()`, `.pop()`, and `.insert()`

Let's learn three more list methods: `.index()`, `.pop()`, and `.insert()`. Open Jupyter Notebook 5, and read the following example aloud.

- You are at a food court, ready to order. Today's menu includes a burger, a side dish, and a drink:

```
[1]: 1 todays_menu = ["burger", "salad", "coke"]  
      2 print(todays_menu)
```

today's menu is assigned burger, salad,
coke
print today's menu

- You are happy with burger and coke, but you want to change the side dish from salad to fries. To do so, you:

1. Look at the position of the side dish in the menu:

```
[2]: 1 side_dish_index = todays_menu.index("salad")  
      2 print(side_dish_index)
```

side dish index is assigned today's
menu dot index of salad
print side dish index

2. Remove salad from the side dish position:

```
[3]: 1 todays_menu.pop(side_dish_index)  
      2 print(todays_menu)
```

today's menu dot pop side_dish_index
print today's menu

3. Add fries to the side dish position:

```
[4]: 1 todays_menu.insert(side_dish_index, "fries")  
      2 print(todays_menu)
```

today's menu dot insert at side dish
index fries
print today's menu

What happens in this code? Get some hints by completing the following exercise.

True or false?

- | | | |
|---|---|---|
| 1. The method <code>.index()</code> gives us the position of an element in a list | T | F |
| 2. The position of salad is 2 | T | F |
| 3. We remove the element in position <code>side_dish_index</code> and insert a new element in the same position | T | F |
| 4. <code>.index()</code> , <code>.pop()</code> , and <code>.insert()</code> are three string methods | T | F |

Computational thinking and syntax

Let's analyze the details of the code! Let's run the first cell:

```
[1]: 1 todays_menu = ["burger", "salad", "coke"]  
      2 print(todays_menu)
```

today's menu is assigned burger, salad,
coke
print today's menu

['burger', 'salad', 'coke']

We create a list called `todays_menu` containing three elements of type string—"burger", "salad", and "coke" (line 1)—and we print it out (line 2).

In the second cell, we meet the new list method `.index()`. What does it do? Let's run the cell:

```
[2]: 1 side_dish_index = todays_menu.index("salad")
      2 print(side_dish_index)
```

side dish index is assigned today's
menu dot `index` of `salad`
`print` side dish index

1

The method `.index()` looks for the element "salad" in the list `todays_menu` and tells us its position. More technically, we say that `.index()` **takes the argument** "salad" and **returns** its index. The position of "salad" is then assigned to the variable `side_dish_index` (line 1), which we print out (line 2). Note that in coding, we use the two synonyms **index** and **position** interchangeably.

Why is "salad" in position 1 and not 2? This is because in Python we count elements starting **from 0**, as you can see in Figure 5.1: "burger" is in position 0, "salad" in position 1, and "coke" in position 2.

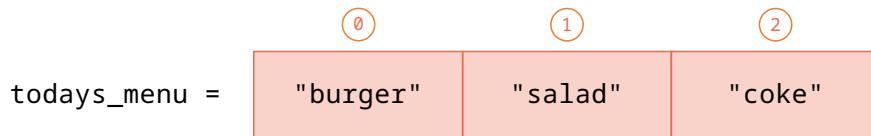


Figure 5.1. Representation of the list `todays_menu`: each square is a list element, and the number above is the corresponding index.

Finally, note that an element position is a number. In Python, zero, positive, and negative whole numbers are called **integers**, abbreviated as **int**. In our example, the variable `side_dish_index` contains the number 1, and it is of **type integer**.

Let's discover what `.pop()` does by running the next cell:

```
[3]: 1 todays_menu.pop(side_dish_index)
      2 print(todays_menu)
```

today's menu dot `pop` `side_dish_index`
`print` today's menu

['burger', 'coke']

The method `.pop()` removes the element in position `side_dish_index` from the list `todays_menu`. In other words, `.pop()` takes `side_dish_index` as an argument and **removes the element at that index**, which is "salad". In the previous chapter, we saw another method that deletes an element from a list: `.remove()`. What is the difference between the two methods? The method `.remove()` deletes an element of a certain *value*, whereas `.pop()` deletes an element in a *specific position*.

And finally, let's learn the method `.insert()`. Let's run the last cell:

```
[4]: 1 todays_menu.insert(side_dish_index, "fries")
      2 print(todays_menu)
```

today's menu dot `insert` at `side dish`
index `fries`
`print` today's menu

['burger', 'fries', 'coke']

The method `.insert()` allows us to **add an element at a specific index**. It takes two arguments: (1) the *index* where we want to insert the new element and (2) the *value* of the new element. In this case, we want to insert at position `side_dish_index`, which is position 1, the string "fries". Similarly, in the

previous chapter we saw another method to add an element to a list: `.append()`. What's the difference? The method `.append()` adds an element *at the end* of a list, whereas `.insert()` adds an element in a specific position of a list.

Finally, when dealing with lists, we must always be aware of that **each element has a position**. In some cases, it is more convenient to work directly on the elements and use methods like `.append()` and `.remove()`. In other cases, it is more appropriate to work on elements' positions, so we use methods such as `.index()`, `.pop()`, and `.insert()`. Note that `.append()`, `.remove()`, `.pop()`, and `.insert()` modify the list. On the other side, `.index()` gives us some information about the list, and we can save this information in a separate variable. Lastly, `.append()`, `.remove()`, `.index()`, and `.pop()` take only one argument, whereas `.insert()` takes two arguments, which are position and new element.

Complete the table

So far you have learned five list methods. Summarize what they do by completing the following table.

List method	What it does
<code>.append()</code>	
<code>.remove()</code>	
<code>.index()</code>	
<code>.pop()</code>	
<code>.insert()</code>	

Recap

- The method `.index()` returns the **position of an element** in a list.
- The method `.pop()` **removes an element in a certain position** from a list.
- The method `.insert()` **adds an element in a certain position** to a list.
- **Indices** (or positions) of elements start from **0** and increase in increments of one unit; they are of type **integer**.

We code in English!

During a coffee break, a colleague once told me, “Isn’t it crazy that when English speaking people code, they actually do it in their own mother tongue? I mean, when they say `if`, they actually mean `if`!” I had never thought about it. For me, an Italian mother tongue, `if` was just a keyword composed of two symbols. Reading `if book in books` or `ab book in books` was exactly the same. I had learned to look at keywords and variable names as abstract symbols with no intrinsic meaning; they were just entities with a specific function. After that conversation, I mentally translated keywords and variable names into my mother tongue, and everything acquired much more meaning and made so much more sense! I grasped the importance of variable

names (they actually have a meaning in English!), and thus, I started writing commands like `if book in books`, instead of `if variable_1 in list_1`. Now, when I code, I mainly think in English. But that translation process helped me acquire more awareness and make my code much more readable. In Chapters 4 and 5, we learned five list methods. Their names actually have a meaning in English. `Remove`, `insert`, and `index` are pretty straightforward. To remember that `append` adds new elements at the end of a list, one can think of the appendix of a book, which is always at the end, or of the appendix in the intestine, which is somewhere at the end of the abdomen. To remember `pop`, one can think of making popcorn, like little explosions, that here remove elements from a certain position. Whether English is your native tongue or not, remember that we code in English!



Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter:
 - a. *Getting a new bike.* You go to a bike store to buy your new bike. There you find a bike you like: it is blue, electric, and has gears. Write a list with these characteristics. You are happy with the bike being electric and having gears, but you would like to change its color. To do so, you (1) look at the position of the *blue* color in the bike option list, (2) remove the *blue* color, and (3) add the color you want.
 - b. *Ordering a T-shirt online.* You are ordering a new T-shirt online. You find a T-shirt you like, which is red, with a round neck, and with a print *add your text here*. Write a list with these characteristics. Now you want to add your own text to the T-shirt. To do so, you (1) look at the position of *add your text here*, (2) remove *add your text here*, and (3) add the text you want to be printed on your T-shirt. After completing the exercise, can you think of an alternative way to change the T-shirt print?
2. *Steve Jobs.* Given the following list:

```
steve_jobs = ["somebody", "learn", "use", "a computer", "it teaches us"]
```

Find out a famous quote by Steve Jobs by doing the following:

- a. Add the new string "think" at the end of the list.
- b. Add "should" in position 1.
- c. Add "how to" in position 3. Then also add it in position 7.
- d. Replace "use" with "program".
- e. Add "because" after "a computer".
- f. Replace "somebody" with "everybody".
- g. Add " - Steve Jobs" at the end.

3. *Grace Hopper.* Do you know why we say *debugging* in coding? Let's find out! Given the following list:

```
grace_hopper = ["In 1946", "a moth", "caused", "a malfunction", "in an early", "electromechanical", "computer"]
```

Modify it by doing the following:

- a. Replace "In 1946" with "From then on".

- b. Add "we said" after "computer".
- c. Remove the string in position 5 (6th element) and add "with a" in the same position.
- d. Remove the string in position 3 (4th element).
- e. Substitute (or replace) "a moth" with "when anything".
- f. Remove "in an early".
- g. Add "it had bugs in it" at the end of the list.
- h. Substitute "caused" with "went wrong".
- i. Add " - Grace Hopper" at the end of the list.

6. Traveling around the world

List slicing

In the previous two chapters, you learned five methods to manipulate lists: `.append()`, `.remove()`, `.index()`, `.pop()`, and `.insert()`. These list methods are very convenient and easy to remember; however, they can make code quite cumbersome. In Python, there is an alternative and more compact way to change, add, and remove list elements, which you will see in the next chapter. This alternative method is based on *slicing*; therefore, in this chapter, we will focus on this topic. Ready to get to know everything about slicing? Open Jupyter Notebook 6 and follow along! First of all, what is slicing?

Slicing means accessing list elements through their indices

If you have a sweet tooth, the word “slicing” immediately reminds you of a slice of cake. And in fact, there is quite a similarity between slicing a cake and slicing a list! In the first case, you “extract” one or more cake slices for your guests—and yourself! In the second case, you extract one or more list elements for subsequent lines of code.

- Let's meet the list we will slice:

```
[1]: 1 cities = ["San Diego", "Prague", "Cape Town", "Tokyo",
      "Melbourne"]
      2 print(cities)
      ['San Diego', 'Prague', 'Cape Town', 'Tokyo', 'Melbourne']
```

cities is assigned San
Diego, Prague, Cape
Town, Tokyo, Melbourne
print cities

In this cell, there is a list called `cities` containing five strings: "San Diego", "Prague", "Cape Town", "Tokyo", and "Melbourne" (line 1), and we print it out (line 2).

How are we going to slice `cities`? The **syntax** for slicing is very easy. It consists of the **list name followed by opening and closing square brackets**, like this: `cities[]`. In between the square brackets, we write the **positions of the elements** we want to slice. For this reason, it's crucial to be aware of the positions of each element within a list. In the list `cities`, the elements have the following positions:

	①	②	③	④	
cities =	"San Diego"	"Prague"	"Cape Town"	"Tokyo"	"Melbourne"

Figure 6.1. Representation of the list `cities`: each square is a list element, and the number above is the corresponding index.

Now, how do we write element positions in between the square brackets? There are various rules depending on how many elements we want to slice, where they are, and in which direction we want to extract them. We are going to learn all these rules in the coming pages.

A last note before starting: to better learn about slicing, I suggest this method. Every time you read a slicing task (for example: Slice "Prague"), cover the following code with a piece of paper. Try to guess

the code, and compare your guess with the solution. Then carefully read the explanation. Make sure you fully understand the current example before proceeding to the next one. Enough words, time to slice!

1. Slice "Prague":

```
[2]: 1 print(cities[1])          print cities in position one  
      'Prague'
```

In this cell, we slice (or access) "Prague", which is in position 1, and we print it. As you can see, when we slice **one single element** from a list, we write the position of the element itself in between the square brackets. Thus, we can summarize this syntax as **list_name[element_position]**, and we can read it as *list name in position element position*.

Note: For simplicity, in this example and those that follow, we just print the sliced elements. However, one could assign a sliced element to a variable, like this:

```
[2]: 1 sliced_city = cities[1]          sliced_city is assigned cities in position  
      2 print(sliced_city)           one  
      'Prague'                   print sliced_city
```

We will assign sliced list elements to variables in the following chapters. For now, let's focus on understanding how slicing works!

2. Slice the cities from "Prague" to "Tokyo":

```
[3]: 1 print(cities[1:4])          print cities in positions from one to four  
      ['Prague', 'Cape Town', 'Tokyo']
```

In this cell, we slice and print three consecutive elements—"Prague", "Cape Town", and "Tokyo"—that are at positions 1, 2, and 3, respectively. In between the square brackets, we write two numbers, separated by a colon :. The first number is the position of the *first* element we want to slice, and we call it **start**. In this case, the start is 1, which corresponds to "Prague". The second number is the position of the *last* element we want to slice, to which we must add 1. We call it **stop**. The stop always follows the **plus one rule**, which simply says that **we must add 1 to the position of the last element we want to slice** (you can learn the reasoning behind this rule in the *In more depth* section at the end of this chapter). In this example, the position of the last element ("Tokyo") is 3, to which we must add 1 because of the plus one rule, so the stop is 4. We can summarize the syntax to slice consecutive elements as **list_name[start:stop]**, and we can read it as *list name in positions from start to stop*.

3. Slice "Prague" and "Tokyo":

```
[4]: 1 print(cities[1:4:2])          print cities in positions from one to four  
      ['Prague', 'Tokyo']           with a step of two
```

In this case, we want to slice and print two non-consecutive elements—"Prague" and "Tokyo"—which are at positions 1 and 3, respectively. In the code above, you might recognize that 1 is the start, 4 is the stop (because of the plus-one rule), and 2? That is the **step**! As you can see, "Tokyo" is positioned 2 steps after "Prague": there is 1 step from "Prague" to "Cape Town", and 1 step from "Cape Town" to "Tokyo", for a total of 2 steps. Therefore, the syntax to slice **non-consecutive elements** is an extension

of the rule we saw in the example above: `list_name[start:stop:step]`, which you can read as *list name from start to stop with step*. We can call it the **three-s rule**, where the three s's are the initials of `start`, `stop`, and `step`, respectively.

The most convenient aspect of the three-s rule is that we can simplify it in several situations. For example, you might wonder: why didn't we write the step in the example 2, where we sliced the cities from "Prague" to "Tokyo"? Because **when elements are consecutive, the step is 1**—"Cape Town" is 1 step after "Prague", and "Tokyo" is 1 step after "Cape Town"—and when the step is 1 we can simply omit it. Obviously, we could have written the code specifying the step as follows:

[3]:	<pre>1 print(cities[1:4:1])</pre>	<code>print cities in positions from one to four with a step of one</code>
	<pre>['Prague', 'Cape Town', 'Tokyo']</pre>	

However, adding the step here is a redundancy, so we simply avoid it.

4. Slice the cities from "San Diego" to "Cape Town":

[5]:	<pre>1 print(cities[0:3])</pre>	<code>print cities in positions from zero to three</code>
	<pre>['San Diego', 'Prague', 'Cape Town']</pre>	

Here we have to slice consecutive elements. So, we specify the start, which is `0` for "San Diego", and the stop, which is `3` for "Cape Town", but we can omit the step because it is `1`. Interestingly, in this case we can simplify the three-s rule even more! Because the **start coincides with the first element of the list**, we can simply omit it:

[6]:	<pre>1 print(cities[:3])</pre>	<code>print cities from the beginning of the list to position three</code>
	<pre>['San Diego', 'Prague', 'Cape Town']</pre>	

5. Slice the cities from "Cape Town" to "Melbourne":

[7]:	<pre>1 print(cities[2:5])</pre>	<code>print cities in positions from two to five</code>
	<pre>['Cape Town', 'Tokyo', 'Melbourne']</pre>	

Again, we have to slice consecutive elements. Therefore, we specify the start, which is `2` for "Cape Town", and the stop, which is `5` (because of the plus-one rule) for "Melbourne", but we omit the step because it is `1`. And once more, we can simplify the three-s rule! How? The **stop coincides with the last element of the list**, so we can just omit it:

[8]:	<pre>1 print(cities[2:])</pre>	<code>print cities from position two to the end of the list</code>
	<pre>['Cape Town', 'Tokyo', 'Melbourne']</pre>	

So far, we have seen the three-s rule applied in its entirety (example 3), and without start (example 4), stop (example 5), and step (example 2). How else can we simplify it? Let's look at the following example. How do you think the code will look?

6. Slice "San Diego", "Cape Town", and "Melbourne":

[9]:	<pre>1 print(cities[0:5:2])</pre>	<code>print cities in positions from zero to five with a step of two</code>
	<pre>['San Diego', 'Cape Town', 'Melbourne']</pre>	

This time, the elements to slice are not consecutive. We start at 0, which is the position of "San Diego", we stop at 5 (because of the plus-one rule) for "Melbourne", and we specify the step, which is 2, because we are slicing every second element. However, as you might have guessed, because the start coincides with the beginning of the list, and the stop coincides with the last element of the list, we can omit both, and rewrite the code above as follows:

[10]: 1	<code>print(cities[::2])</code>	<code>print cities from the beginning to the end of the list with a step of two</code>
		'San Diego', 'Cape Town', 'Melbourne'

You have now mastered the three-s rule and learned how to simplify it. How else can we play with it? Let's look at this further representation of the list `cities`:

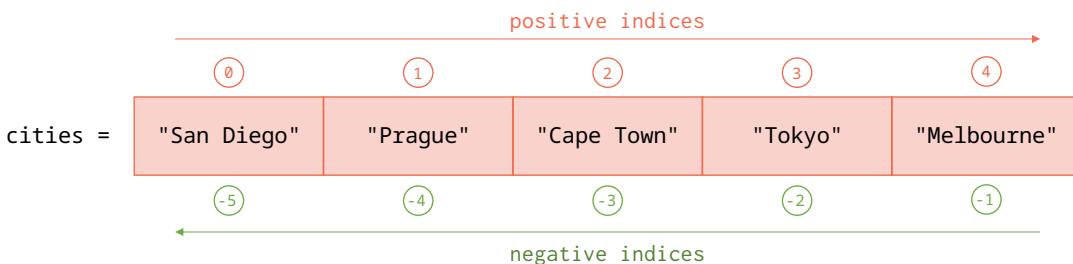


Figure 6.2. In a list, indices can be positive (from left to right) or negative (from right to left).

In Python, each element of a list can be identified by a positive or a negative index. We use **positive indices** when we consider elements **from left to right** and **negative indices** when we consider elements **from right to left**. Positive indices start from 0 and increase of 1 unit (0, 1, 2, etc.). Negative indices start from -1 and decrease of 1 unit (-1, -2, -3, etc.). Note that negative indices do not start from 0 to avoid ambiguity: the element in position 0 is always the first element of the list starting from the left side. When are negative indices convenient? For example, when we are dealing with a very long list. In that case, it would be tedious to count through all elements starting from 0. So we can just count backwards starting from the last element!

How do we use negative indices in slicing? Let's have a look!

7. Slice "Melbourne":

[11]: 1	<code>print(cities[4])</code>	<code>print cities in positions 4</code>
		Melbourne

In this example, we extracted "Melbourne" as we learned in example 1: by writing its *positive* index, which is 4, in between the square brackets. However, "Melbourne" is the last element of the list; therefore, it is much more convenient to use its *negative* index to slice it, like this:

[12]: 1	<code>print(cities[-1])</code>	<code>print cities in position minus one</code>
		Melbourne

The advantage of using the negative index is that we do not need to count through all the list elements to get to know the position of "Melbourne". Since "Melbourne" is the last element of the list, we can just write -1. This saves us time and eliminates possible errors due to miscounting.

8. Slice all the cities from "Prague" to "Tokyo" using negative indices:

[13]: 1 print(cities[-4:-1])	print cities in positions from minus four to minus one ['Prague', 'Cape Town', 'Tokyo']
------------------------------	--

This is in an alternative to example 2. There, we extracted the cities from "Prague" to "Tokyo" using positive indices, whereas here we want to use negative indices. It might look intimidating, but the reasoning is always the same. The first element we want to extract is Prague, which is in position -4, therefore the start is -4. The last element we want to extract is Tokyo, which is in position -2, thus the stop is -1 because of the *plus one* rule. Like in the previous example, using negative indices can be very convenient when extracting elements from the end of a long list.

In this example, we saw how to use negative indices for the start and the stop. What about the step? A **negative step** allows us to slice elements in reverse order, which means from the right to the left. Negative steps can be used with both positive or negative start and stop. This might sound confusing, but we'll clarify it in the next three examples. Slicing in reverse order is a very powerful feature, and it's the last thing you need to know to master slicing. Let's have a look!

9. Slice all the cities from "Tokyo" to "Prague" using positive indices (reverse order):

[14]: 1 print(cities[3:0:-1])	print cities in positions from three to zero with a step of minus one ['Tokyo', 'Cape Town', 'Prague']
-------------------------------	---

When slicing—and coding, in general—it is extremely important to be aware of the result we expect. When slicing in reverse order, having the result in mind can really avoid confusion. So, let's start from there. We want to print out "Tokyo", "Cape Town", and "Prague". The first element is "Tokyo", which is in position 3, so the start is 3. The last element is "Prague", which is in position 1. When we slice in reverse order, instead of the plus-one rule, we have to use the **minus one rule**, which says that **we must subtract 1 from the position of the last element we want to slice**. Why? This is very intuitive. As we know, for the stop, we always want to take the *next* position. When slicing in direct order, the next position is on the *right* side of the last element. Therefore, we add 1 to its index. On the other side, when slicing in reverse order, the next position is on the *left* side of the last element. Therefore, we subtract 1 from its index. Now, back to our example. The last element is "Prague", which is in position 1. And because of the minus one rule, the stop is 0. Finally, we need to define the step. Because the elements are consecutive, the step should be 1, but because we are going in reverse order, we have to put a minus in front of it, so the step becomes -1.

In summary, when slicing in reverse order, we have to: (1) make sure we have the first and the last elements clearly in our minds, (2) apply the minus one rule to the stop, and (3) use a negative step.

Let's raise the bar even more now! Look at the next example.

10. Slice all the cities from "Tokyo" to "Prague" using negative indices (reverse order):

[15]: 1 print(cities[-2:-5:-1])	print cities in positions from minus two to minus five with a step of minus one ['Tokyo', 'Cape Town', 'Prague']
---------------------------------	---

When using negative indices for the start and the stop, the rules are exactly the same as when using positive indices. The first element we want to slice is "Tokyo", which is in position -2, so the start is -2. The last element is "Prague", which is in position -4. Because of the minus one rule, we have to

subtract 1 from -4, therefore the stop is -5. And finally, because we are slicing consecutive elements in reverse order, the step is -1. As you can now imagine, using negative indices can be very convenient when slicing elements at the end of a very long list in reverse order.

11. Slice all the cities (in reverse order):

```
[16]: 1 print(cities[::-1])
```

`print` from the beginning of the list to the
end of the list with a step of `minus 1`

```
['Melbourne', 'Tokyo', 'Cape Town',  
'Prague', 'San Diego']
```

The first element to slice is "Melbourne", which is the last element of the list. Therefore, we can omit the start. The last element to slices is "San Diego", which is the first element of the list. Therefore, we can omit the stop too. We just must write the step, which is -1 because we are slicing consecutive elements in reverse order. Easy to remember!

Last note. Learning slicing might feel overwhelming at first because of all the rules, the use of positive and negative indices, and thinking of lists in direct and reverse order. However, learning slicing properly is fundamental not only because it is often used in coding, but also because it allows you to exercise your brain and strengthen your logical thinking. Take your time to learn the rules and do the exercises below. You will greatly benefit from it in the following chapters!

📝 Complete the table

Complete the following table to create an overview of slicing in your own words:

Slicing syntax	What it does
<code>list_name[index]</code>	
<code>list_name[start:stop:step]</code>	
<code>list_name[:stop:step]</code>	
<code>list_name[start::step]</code>	
<code>list_name[start:stop]</code>	
<code>list_name[negative_index]</code>	
<code>list_name[::-negative_step]</code>	
<code>list_name[::-1]</code>	

Recap

- To slice one element, we use the rule: `list_name[element_position]`.
- To slice multiple elements, we use the **three-s rule**: `list_name[start:stop:step]`, where:
 - We can omit: Start when we slice from the first element of a list. Stop when we slice to the last element of a list. Step when we slice consecutive elements of a list.
 - The stop follows the **plus one** rule when slicing from left to right (direct order), and the **minus one** rule when slicing from right to left (reverse order).

- The values of `element_position`, `start`, `stop`, and `step` can be:
 - Positive: when considering elements from left to right (*direct order*).
 - Negative: when considering elements from right to left (*reverse order*).
- Negative steps are used to invert lists.

Why the plus one rule?

So far, we have learned that each list element is associated with an index or position. However, in Python, each element is actually considered between two positions, as represented in Figure 6.3.



Figure 6.3. List representation where each element is in between indices.

Let's re-consider example 2, where we extracted the cities from "Prague" to "Tokyo":

[3]:	1	print(cities[1:4])		print cities in positions from one to four
			['Prague', 'Cape Town', 'Tokyo']	

Using the representation above, we can see that the start is 1 because that is the index that precedes "Prague", the first element to slice. And the stop is 4 because that is the index that follows "Tokyo", the last element to slice.

For many people, considering elements in-between indices is pretty straightforward. For other people, considering that elements have one single index—as we have done so far—is easier. My recommendation is to pick one representation and stick to that. In this book, we will continue to represent list elements with one single index.

💻 Let's code!

- Fruits and veggies.* Given the following list:

```
fruits_and_veggies = ["peppers", "apricots", "carrots", "apples", "zucchini",
                      "grapes", "cabbage", "oranges", "asparagus", "pears"]
```

Use slicing to extract:

- The produce between apples and grapes (included);
- All the vegetables;
- All the fruits;
- The vegetables between carrots and asparagus (included);
- The fruits between apples and oranges (included).

2. Clothes, stationery, and electronics. Given the following list:

```
objects = ["mobile", "t_shirt", "pencil", "laptop", "hat", "ruler", "tv", "pants",  
"pen"]
```

Use slicing to extract:

- a. All the clothes;
- b. All the stationery;
- c. All the electronics;
- d. The second and the last stationery items;
- e. The first and the last electronics items;
- f. The first and the second clothing items.

3. Interior design. Given the following list: `interior_design = ["sofa", "curtain", "lamp", "table", "carpet", "plant", "armchair", "blanket", "vase"]`

Use slicing to extract the following elements in *direct* order (from left to right), once using *positive* indices and once using *negative* indices:

- a. All furniture;
- b. All textiles;
- c. All decorative elements;
- d. The pieces composed of 5 letters (count them by hand, no coding required).

4. Botanic garden. Given the following list:

```
botanic_garden = ["tulip", "pine", "poppy", "palm", "rose", "oak", "daisy",  
"eucalyptus"]
```

Use slicing to extract the following elements, once in *direct* order (from left to right) and once in *inverse* order (from right to left):

- a. All flowers;
- b. All trees;
- c. All flowers and trees starting with p (find them by hand, no coding required);
- d. "pine", "rose", and "eucalyptus";
- e. All flowers and trees.

5. Travel agency. You are the owner of a travel agency and these are the destinations you offer:

```
destinations = ["Boston", "Madrid", "Shanghai", "Cairo", "Mexico City", "Copenhagen",  
"Seoul", "Casablanca", "Lima", "Vienna", "Bangkok", "Nairobi", "Buenos Aires",  
"Athens", "Manila", "Cape Town"]
```

You also have a list containing additional destinations you want to offer in the future:

```
future_destinations = ["Tunis"]
```

- a. A new customer comes in and you ask where he would like to go. He replies: Berlin. You check whether Berlin is part of the destination list. If Berlin is part of the list, you say that you sell tickets for Berlin. If Berlin is not part of the destination list, you: (1) tell the customer that you do not sell tickets for Berlin; (2) tell him what European cities are in the destination list; and (3) add Berlin to the list of future destinations.
- b. Because tickets for Berlin are not available, your customer is now thinking about going to Asia. So you tell him the destinations in Asia. He tells you that he forgot the last two Asian places you mentioned; so you tell them again. Then, he says he would have enjoyed going to Hong Kong. But Hong Kong is not an available destination, so you add it to the list of future destinations.

- c. Now you ask your customer if he is interested in going to the American continent, and he replies: Toronto. You check whether Toronto is part of the list. Similarly to what you did for Berlin, if Toronto is part of the list, you say that you sell tickets for Toronto. If Toronto is not part of the destination list, you: (1) tell your customer that you do not sell tickets for Toronto, (2) tell him what cities on the American continent are in the destination list, and (3) add Toronto to the list of future destinations.
- d. The customer is still undecided. You think he might be interested in a trip to Africa, so you tell him all the destinations in Africa. He finally tells you that he wants to go to Cape Town! So you replace Cape Town from the list of destinations with Tunis from the list of future destinations, and remove Tunis from the future destination list.
- e. The customer is finally gone, and you want to create a flyer with all the destinations you offer. To do so, you add the three new future destinations to the list of current destinations (in what order?), and you print out the destinations you offer for each continent. While doing so, you notice that Africa only has four destinations. So you add one African destination to the destination list before printing out the African destinations. And, finally, you close the shop, go home, and enjoy your evening after a hard day of work!

7. Senses, planets, and a house

Changing, adding, and removing list elements using slicing

Now that you know everything about slicing, let's see how to use it to manipulate lists—that is, how to change, add, or remove list elements. Download and open Jupyter Notebook number 7 from www.learnpythonwithjupyter.com and follow along. Similarly to the previous chapter, cover the code in these pages with a sheet of paper. First, try to guess the commands to execute, and then compare with the code below. Don't forget to read the code aloud!

1. Senses

Let's first learn how to **change list elements** using **slicing** and **assignment**.

- Given the following list:

```
[1]: 1 senses = ["eyes", "nose", "ears", "tongue",
      "skin"]
  2 print(senses)
['eyes', 'nose', 'ears', 'tongue', 'skin']
```

senses is assigned eyes, nose, ears,
tongue, skin
print senses

The list `senses` contains five strings: "eyes", "nose", "ears", "tongue", and "skin" (line 1), and we print it out (line 2).

- Replace "nose" with "smell":

```
[2]: 1 senses[1] = "smell"
  2 print(senses)
['eyes', 'smell', 'ears', 'tongue', 'skin']
```

senses in position one is assigned
smell
print senses

To change **one list element**, we assign the new value to the list sliced in the element's position. In this case, the element we want to replace—"nose"—is in position 1. So, we slice the list in position 1, and we assign the new string "smell" (line 1). Then, we print the list to check whether the change is correct (line 2).

At this point, you might ask: Why do I have to learn list manipulation using slicing when I already know how to do it with methods? For at least three reasons! First reason: to **reduce the possibility of errors**. The code at line 1 is an alternative to the code we learned in Chapter 5, where we used three methods to replace an element, that is:

```
[]: 1 nose_index = senses.index("nose")
  2 senses.pop(nose_index)
  3 senses.insert(nose_index, "smell")
```

nose index is assigned senses dot index
of nose
senses dot pop nose index
senses dot insert at position nose
index smell

By using slicing, we reduce the number of commands from 3 to 1, and we do not need to create an extra variable—`nose_index`. By writing less code, we minimize the possibility of making errors! Second reason: **slicing makes code writing faster**. Imagine you have to replace 4 elements. With slicing, you would have to write just 4 lines of code; instead, with list methods, the number of lines required would

be 12! And finally, the third reason: transitioning from list methods to list slicing allows us to shift from a more concrete to a more **abstract way of thinking**. As you know, when using list methods, we use a *coding* language that is more similar to a *natural* language. Method names, in fact, are words in the English vocabulary, such as *remove*, *insert*, etc. Instead, when slicing, we use numbers—which represent element positions—and thus we use (numerical) symbols in place of words. As you can see, we are building more and more the abstract thinking that coding requires. So let's keep going!

- Replace "tongue" and "skin" with "taste" and "touch":

<pre>[3]: 1 senses[3:5] = ["taste", "touch"] 2 print(senses)</pre>	<pre>senses in positions from three to five is assigned taste, touch print senses</pre>
--	---

To change **several elements** in a list, first we slice the elements we want to substitute, and then we assign them a list containing the new values. In this case, we want to replace two elements, so we slice using the three-s rule. The start is the position of "tongue", which is 3, and the stop is the position of "skin", which is 4, but it becomes 5 because of the plus one rule. The step is 1, so we can omit it. To the sliced list, we assign a list containing the new elements, which are the strings "taste" and "touch" (line 1). Finally, we print the list to make sure that the change occurred correctly (line 2).

- Replace "eyes" and "ears" with "sight" and "hearing":

<pre>[4]: 1 senses[0:3:2] = ["sight", "hearing"] 2 print(senses)</pre>	<pre>senses in positions from zero to three with a step of two is assigned sight, hearing print senses</pre>
--	--

Like in the previous example, we want to replace several elements. So, we begin by slicing the list. The start is the position of "eyes", which is 0 (and can be omitted). The stop is the position of "ears", which is 2, but it becomes 3 because of the plus one rule. The two elements are not consecutive, thus we have to write the step, which is 2. Finally, we assign the list containing the two strings we want to add: "sight" and "hearing". Note that the two elements we want to replace are not consecutive, but Python takes care of placing "sight" and "hearing" in the right positions (line 1). At the end, we print the final list to check the changes we made (line 2).

2. Planets

To **add new elements** to a list, we can use **slicing combined with list concatenation and assignment**. How? Let's have a look at the following examples!

- Given the following list:

<pre>[5]: 1 planets = ["Mercury", "Mars", "Earth", "Neptune"] 2 print(planets)</pre>	<pre>planets is assigned Mercury, Mars, Earth, Neptune print planets</pre>
--	--

We begin with the list `planets`, which contains four strings: "Mercury", "Mars", "Earth", and "Neptune" (line 1), and we print it out (line 2).

- Add "Jupiter" at the end of the list:

```
[6]: 1 planets = planets + ["Jupiter"]
      2 print(planets)
      ['Mercury', 'Mars', 'Earth', 'Neptune', 'Jupiter']
```

planets is assigned planets concatenated with Jupiter
print planets

To add **an element at the end of a list**, we (1) embed it in a list, (2) concatenate it to the original list, and (3) assign the result to the original list. It's less complicated than it sounds! Let's start from the far right of line 1. We take the new element "Jupiter"—which is a string—and we enclose it in square brackets to transform it into a list: `["Jupiter"]`. Why do we need to change "Jupiter" data type? Because we want to add it to the list `planets` using concatenation. And, as in string concatenation, we can concatenate only strings with strings; in **list concatenation**, we can concatenate only **lists with lists**. Note that list concatenation works the same way as string concatenation. Finally, we **assign the result of the operation to the original list** `planets` to actually change it. It is common to say that we **reassign** the result to the original list. This whole operation constitutes an alternative to the method `.append()`. Finally, we print out the modified list to check the correctness of our code (line 2).

You may have realized that in this example there is no slicing! This is because it's a special case, where we add an element at the end of a list—it would be similar if we added an element at the beginning of a list. We could write `planets[0:4] + ["Jupiter"]`, where `planets[0:4]` slices all the elements in the list, but that would be redundant. Let's see slicing in action in the next two examples!

- Add "Venus" between "Mars" and "Earth":

```
[7]: 1 planets = planets[0:2] + ["Venus"] + planets[2:5]
      2 print(planets)
      ['Mercury', 'Mars', 'Venus', 'Earth', 'Neptune',
       'Jupiter']
```

planets is assigned planets from zero to two concatenated with venus concatenated with planets from two to five
print planets

In this case, we want to add an element **in the middle** of a list. To do so, we (1) split the list in two segments at the position where we want to insert the new element, (2) insert the new element as a list by concatenating it with the two list segments, and (3) assign the result to the original list. Like before, it's easier than it sounds! We want to split the list between "Mars" and "Earth". So, the first list segment will contain "Mercury" and "Mars". Thus, we slice `planets` starting from position 0, corresponding to "Mercury", and stopping in position 2 for the plus one rule; "Mars" is in position 1. The second list segment will contain "Earth", "Neptune", and "Jupiter". So, we slice starting from position 2, corresponding to "Earth", and stopping in position 5 for the plus one rule; "Jupiter" is in position 4. In between the two list segments, we concatenate a new list containing the string "Venus"—like before, we have to change "Venus" from a string to a list. We conclude the operation by assigning the concatenation result to the original list. As you may have realized, this line is an alternative to the method `.insert()` (line 1). Finally, we print out the obtained list to check the correctness of the operation (line 2).

A nice way to think about the whole procedure is to consider a list like a **toy train**, where each list element is a car. When we want to insert a new car, for example a restaurant car, we split the train into two parts in the position where we want the new car to be. Then, we add the first part of the train to

the left side of the restaurant car, and the second part of the train to the right side of the restaurant car. Thus, we obtain our modified train!

- Add "Uranus" and "Saturn" between "Neptune" and "Jupiter":

```
[8]: 1 planets = planets[:5] + ["Uranus", "Saturn"] + planets[5:]
2 print(planets)
['Mercury', 'Mars', 'Venus', 'Earth', 'Neptune',
 'Uranus', 'Saturn', 'Jupiter']
```

planets is assigned planets from the beginning of the list to position five concatenated with Uranus, Saturn concatenated with planets from position five to the end of the list
print planets

To insert **several consecutive elements in the middle of a list**, we use the same approach as the one above. We slice the first part of the list planets from the beginning (start omitted) to 5, which corresponds to the position of "Neptune" plus 1. Then, we concatenate the two new elements "Uranus" and "Saturn" embedded in a list. Finally, we concatenate the remaining part of the list planets, starting from the position of "Jupiter", which is 5, and stopping at the end of the list (stop omitted). As you'll probably notice, when we want to insert several consecutive elements in the middle of a list, we just **embed all the elements in a list** (line 1). Finally, we print out the modified list to check whether we added the new elements correctly (line 2).

Now a trick! We saw that the start of the first list segment and the stop of the second list segment are omitted. In addition, you may have noticed that the stop of the first list segment coincides with the start of the second list segment—they are both 5. This is because of the plus one rule applied to the stop of the first list segment. Therefore, when adding new elements using slicing, we can **just count the stop of the first list segment**. That will coincide with the start of the second list segment. The remaining start and stop can be omitted!

An important note before continuing: in the past three examples, we started analyzing code from the right side of the assignment symbol. Focusing on that side is quite common because it is where we define variable changes and operations. Sometimes, we can even start writing code on the right side of the assignment symbol, and then type the appropriate variable name on the left side. It's very common to start **analyzing or writing code backwards!**

3. A house

To **delete** list elements, we can use the **keyword del combined with list slicing**. This is very easy. Let's have a look!

- Given the following list:

```
[9]: 1 house = ["kitchen", "dining room", "living room",
2      "bedroom", "bathroom", "garden", "balcony",
3      "terrace"]
4 print(house)
['kitchen', 'dining room', 'living room', 'bedroom',
 'bathroom', 'garden', 'balcony', 'terrace']
```

house is assigned kitchen, dining room, living room, bedroom, bathroom, garden, balcony, terrace, print house

We start with a list called `house` containing 8 strings (line 1), and we print it out (line 2).

- Delete "dining room":

```
[10]: 1 del house[1]
        2 print(house)
['kitchen', 'living room', 'bedroom', 'bathroom',
 'garden', 'balcony', 'terrace']
```

`del` house in position one
`print` house

To **delete one element** in a list, we can use `del` followed by the list sliced at the position of the element we want to delete. In this case, we want to remove the string "dining room", which is in position 1, so we write the keyword `del` followed by `house[1]`. `del` is a **keyword** that allows us to **delete a variable or some elements in a variable**—in this case, some elements in a list. Like the other keywords we have seen so far—for example, `if` and `else`—`del` is written in *bold green* in Jupyter Notebook. As you may have realized, using `del` and slicing is an alternative to using the list methods `.pop()` or `.remove()` (line 1). After removing the element, we print out the list for checking (line 2).

- Delete "garden" and "balcony":

```
[11]: 1 del house[4:6]
        2 print(house)
['kitchen', 'living room', 'bedroom', 'bathroom',
 'terrace']
```

`del` house in positions from four
to six
`print` house

To **delete consecutive elements** from a list, we use the same syntax as above: we write the keyword `del` followed by the list sliced at the positions of the elements we want to delete. In this example, the start is the position of "garden", which is 4, and the stop is the position of "balcony", which is 5, and it becomes 6 because of the plus one rule (line 1). Then we print out the reduced list (line 2).

- Delete "kitchen", "bedroom" and "terrace":

```
[12]: 1 del house[::2]
        2 print(house)
['living room', 'bathroom']
```

`del` house in positions from the
beginning to the end of the list
with a step of two
`print` house

To **delete non-consecutive elements** in a list, we use the same procedure as the one above: we write the keyword `del`, followed by the list sliced at the positions of the elements we want to remove. In this example, the start corresponds to "kitchen", which is the first element of the list, so we can omit it. The stop corresponds to "terrace", which is the last element in the list, so we can omit it as well. And the step is 2 because we want to delete every second element (line 1). Finally, we print the remaining list (line 2).

- Delete "house":

```
[13]: 1 del house
        2 print(house)

NameError           Traceback (most recent call last)
Cell In[13], line 2
      1 del house
      ----> 2 print (house)
NameError: name 'house' is not defined
```

del house
print house

Finally, we want to delete the whole house! So we write the keyword `del` followed by the variable name `house` (line 1). This time, we get an error when we print out the list `house`. It's a *Name Error*, telling us that the variable does not exist anymore (line 2). This is a good error, telling us that we succeeded in our aim: we deleted the *whole* variable `house`!

Complete the table

In the previous four chapters, you learned how to manipulate lists using methods or slicing. Complete the table below to compare the two different techniques:

List operation	List methods	List slicing
Adding an element at the beginning of a list		
Adding an element in the middle of a list		
Adding an element at the end of a list		
Changing an element in a list		
Deleting an element in a list		

- What is different if you want to add, change, or delete several elements? Write your answer here:
-
-

Recap

- To *change* list elements, we can use slicing and assignment.
- To *add* list elements, we can combine slicing, concatenation, and assignment.
- To *delete* list elements, we can use the keyword `del` and slicing.
- List concatenation is performed using the `+` symbol and works the same way as string concatenation.

What is a Jupyter Notebook kernel?

The kernel is the component of Jupyter Notebook that executes code. When we run a cell, the kernel tells Python to execute computations and save variables. Every notebook has its own kernel. And when we open a notebook, a new kernel is automatically created and is ready to execute code. Now you may ask: Why do we care about the kernel? Because sometimes we need to interrupt it or restart it to continue running code. Let's see what this means.

Interrupting the kernel. Consider two cells containing code. In the first cell, we ask a question using the function `input()`. In the second cell, we print the variable containing the answer. We want to execute the code, so we run the first cell. On the left side, we get the star symbol between the square brackets, indicating that the code is being executed. But before entering the answer, we mistakenly run the second cell! Now the second cell also gets the star symbol between the square brackets on the left side, like this:

```
[*]: 1 name = input("What's your name?")
      name is assigned input what's your
      name?
      What's your name?  
```



```
[*]: 1 print(name)           print name
```

In this case, the situation is frozen and no code gets executed! So we need to interrupt the kernel. To do that, we can either go to the JupyterLab top bar, then to *Kernel*, and then *Interrupt Kernel*, or we can go to the Jupyter Notebook top bar and press the interrupt kernel button—that is, item 7 in Figure 7.1.

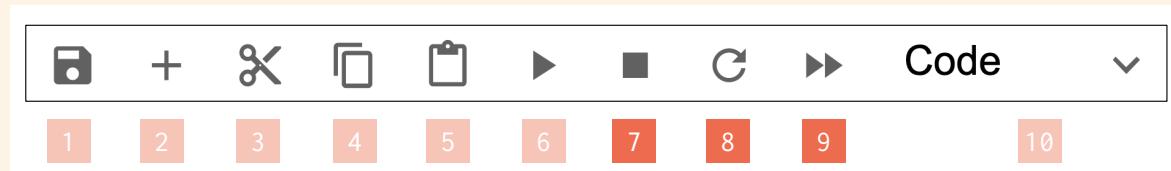


Figure 7.1. Jupyter Notebook top bar: (1) save notebook, (2) add cell, (3) cut cell, (4) copy cell, (5) paste cell, (6) run cell, (7) interrupt kernel, (8) restart kernel, (9) restart kernel and run whole notebook, and (10) define cell as code or markdown.

After interrupting the kernel, the star symbols in between square brackets disappear, and we can run each cell again.

Restarting the kernel. Consider the list house from this chapter. Let's say that we want to delete the element "dining room", as we did in one of the examples above. But, by mistake, we type the wrong slicing index—that is, `0` instead of `1`—deleting "kitchen" in place of "dining room", like this:

```
[9]: 1 house = ["kitchen", "dining room",
            "living room", "bedroom", "bathroom",
            "garden", "balcony", "terrace"]
      house is assigned kitchen, dining
      room, living room, bedroom,
      bathroom, garden, balcony, terrace,
```



```
[10]: 1 del house[0]
      2 print(house)
      ['dining room', 'living room', 'bedroom',
      'bathroom', 'garden', 'balcony', 'terrace']
```

We want to restore the original variable `house` and rerun the corrected version of our code—`del house[1]`—to obtain the correct result. How do we go back? By restarting the kernel! To do that, we can either go to the JupyterLab top bar, then *Kernel*, and then *Restart Kernel*; or we can go to the Jupyter Notebook top bar and press the curved arrow (item 8 in Figure 7.1). Then, we can rerun the cells of the notebook. As an alternative, we can restart the kernel and rerun all notebook cells at once by going to the JupyterLab top bar, then *Kernel*, and then *Restart Kernel and Run all Cells*, or to the Jupyter Notebook top bar and pressing the symbol with two arrow tips (item 9 in Figure 7.1). You may ask: do I really have to restart the kernel every time I make a mistake? Not really. In this case, one could just rerun the first cell to bring the variable `house` back to its original value, and rerun the second cell with the corrected code. However, when dealing with multiple variables, or if we make several mistakes for a single variable, it is good practice to reset the kernel and start from scratch.



Let's code!

1. *Stephanie Shirley*. Do you know the story of Stephanie Shirley? Let's see what she did! Given the following list:

```
stefanie_shirley = ["In 1962", "Stephanie Shirley", "founded", "a software company", "employing", "only women", "working from home"]
```

Do the following using *list slicing*:

- Replace "founded" with "thrived".
- Remove the element in position 0 (first element).
- Replace "employing" with "transferred ownership".
- Add "and over the years" between "thrived" and "a software company".
- Replace "only women" with "to her staff".
- Insert "gradually" in position 4 (fifth element).
- Replace "a software company" with "she".
- Add "70 millionaires" at the end of the list.
- Remove "Stephanie Shirley".
- Replace "working from home" with *creating*".
- Insert "The business" at the beginning of the list.

Then, redo the same using *list methods*.

2. *Tim Berners-Lee*. What did Tim Berners-Lee invent? Let's find it out! Given the following list:

```
tim_bernarslee = ["Tim Berners-Lee", "invented", "the World Wide Web", "in 1989", "at CERN in Geneva", "info.cern.ch", "was", "the address of", "the world's first website and Web server"]
```

Do the following using *list slicing*:

- Remove "info.cern.ch".
- Replace "was" with "consists of".
- Remove the element in position 1 (second element).
- Add "all over the world" at the end of the list.
- Replace "the world's first website and Web server" with "about 75 million servers".

- f. Remove the element in position 0 (first element).
- g. Replace "in 1989" with "Nowadays".
- h. Remove the element in position 0 (first element).
- i. Replace "at CERN in Geneva" with "it is estimated that".
- j. Add "the internet" in position 2 (third element).
- k. Remove the element in position 4 (fifth element).

Then, redo the same using *list methods*.

3. Alan Turing. What happened thanks to Alan Turing's contributions? Let's discover it! Given the following list:

```
alan_turing = ["Turing", "created", "an electromechanical machine", "to crack",
"the Nazi Navy's", "Enigma Code"]
```

Do the following using *list slicing*:

- a. Replace "the Nazi Navy's" with "shortened the war".
- b. Insert "by two years" in position 5 (sixth element).
- c. Replace "an electromechanical machine" with "his contribution".
- d. Add "saving millions of lives" to the end.
- e. Replace "created" with "that".
- f. Remove "to crack".
- g. Replace "Turing" with "It is estimated".
- h. Remove the element in position 5 (sixth element).

Then, redo the same using *list methods*.

PART 3

INTRODUCTION TO THE FOR LOOP

In this part, you will learn about the for loop, which is one of the two loops in coding—the other is the while loop. We will learn its syntax and how to use it to search elements in a list, modify a list, and automatically create new lists. Let's go!

8. My friends' favorite dishes

for... in range()

The **for loop** is one of the most important constructs in coding because it allows us to **repeatedly execute commands**. What does this mean and how does it work? Time to open Jupyter Notebook 8 and answer these questions! Read the following example out loud and try to understand it:

- Here are a list of my friends and a list of their favorite dishes:

```
[:] 1 friends = ["Geetha", "Luca", "Daisy", "Juhan"]  
     friends is assigned Geetha, Luca,  
     Daisy, Juhan  
    2 dishes = ["sushi", "burgers", "tacos", "pizza"]  
     dishes is assigned sushi, burgers,  
     tacos, pizza
```

- These are all my friends:

```
[:] 1 print("My friends' names are:")  
     print My friends' names are:  
    2 print(friends)  
     print friends
```

- These are my friends one by one:

```
[:] 1 for index in range(0,4):  
     print("index:" + str(index))  
  
    2 print("friend:" + friends[index])  
     for index in range from zero to four  
     print index: concatenated with  
     string of index  
     print friend: concatenated with  
     friends in position index
```

- These are all their favorite dishes:

```
[:] 1 print("Their favorite dishes are:")  
     print Their favorite dishes are:  
    2 print(dishes)  
     print dishes
```

- These are their favorite dishes one by one:

```
[:] 1 for index in range(0,4):  
     print("index:" + str(index))  
  
    2 print("dish:" + dishes[index])  
     for index in range from zero to four  
     print index: concatenated with  
     string of index  
     print dish: concatenated with dishes  
     in position index
```

- These are my friends, with their favorite dishes one by one:

```
[:] 1 for index in range(0,4):  
     print ("My friend " + friends[index] +  
           "'s favorite dish is " + dishes[index])  
     for index in range from zero to four  
     print My friend concatenated  
     with friends in position index  
     concatenated with 's favorite dish  
     is concatenated with dishes in  
     position index
```

Get some hints about what the code does by completing the next exercise.

Match the sentence halves

- | | |
|--|--|
| <ol style="list-style-type: none"> 1. The for loop allows us 2. The variable index 3. In the first loop, the variable index 4. The built-in function range() determines 5. The built-in function range() can take | <ol style="list-style-type: none"> a. a start and a stop as an argument b. how many times commands are repeated c. to repeat the indented commands d. changes value at each loop e. is assigned the value 0 |
|--|--|

Computational thinking and syntax

Let's start by running the first cell:

```
[1]: 1 friends = ["Geetha", "Luca", "Daisy", "Juhan"]
      2 dishes = ["sushi", "burgers", "tacos", "pizza"]
```

friends is assigned Geetha, Luca,
Daisy, Juhan
dishes is assigned sushi, burgers,
tacos, pizza

There are two lists—friends and dishes—and each contains four strings.

Let's run the second cell:

```
[2]: 1 print("My friends' names are:")
      2 print(friends)
```

My friends' names are:
['Geetha', 'Luca', 'Daisy', 'Juhan']
print My friends' names are:
print friends

We print out the string `My friends' names are:` (line 1) and the content of the list `friends` (line 2).

Let's now run the third cell, which contains the first for loop:

```
[3]: 1 for index in range(0,4):
      2     print("index:" + str(index))
      3     print("friend:" + friends[index])
```

index: 0
friend: Geetha
index: 1
friend: Luca
index: 2
friend: Daisy
index: 3
friend: Juhan
for index in range from zero to four
print index: concatenated with
string of index
print friend: concatenated with
friends in position index

The code prints the position and the value of each list element by repeating lines 2 and 3 four times. How does this happen? Let's start from line 1, which is the **header** of the for loop. It consists of five components:

- **for**: The keyword starting a for loop. Like all keywords, it is bold green in Jupyter Notebook.
- **index**: A variable that is assigned a different value at each loop iteration (we'll talk more about this in a bit).
- **in**: A membership operator, the same that you learned in the construct `if...in/else` in Chapter 3.
- **range()**: A built-in Python function. You can recognize this as a function because it is followed by

round brackets and is colored green in Jupyter Notebook—like `input()` and `print()`. We'll talk more about `range()` in a bit too.

- : that is, the colon punctuation.

To better understand what this line does, let's begin from the built-in function `range()`. It takes two arguments: `0` and `4`. They are two integers that we can call—guess what?—start and stop! So, what does `range()` do? Create a separate cell in the notebook, and then write and run the following code:

[4]:	1	list(range(0,4))	list of range from zero to four
		[0,1,2,3]	

The built-in function **range()** returns a sequence of integers spanning from the start (included) to the stop (excluded because of the plus one rule). In this example, the integers go from `0` to `3`, and—guess what again?—they correspond to the indices of the elements of the list `friends!` Why is there `list()`? This is another built-in function that we write here for a proper print out. Don't worry too much about it for now. Let's focus on understanding the `for` loop!

What do we do with the list of integers created by `range()`? We assign them to the variable `index`! At each code repetition—or **loop**, or **iteration**—`index` is subsequently assigned a number created by `range()`. That is, in the first loop, `index` is assigned `0`; in the second loop, `index` is assigned `1`; and so on. We could call the variable `index` any name—for example, `loop_id`, `iteration_number`. However, it is convention to call it `index`, so we will adopt it. Now, what can we do with the variable `index`? At least two things!

First, we can print `index` to keep track of which loop is getting executed, like we do at line 2. In the first loop, `index` is assigned `0`, so we print "index: 0". In the second loop, `index` is assigned `1`, so we print "index: 1"—and so on. Why is `str()` here? Because we can concatenate only strings with strings, and `index` is an integer! So, we need to change the variable type of `index` from integer to string. And to do that, we can use the built-in function **str()**, which transforms a variable into a string.

Second, we can use `index` to automatically slice list elements one by one. As you now know, `index` changes at every iteration, and it can be assigned values that go from the beginning of a list—that is, `0`—to the end of a list—in this case `3`. Let's look at line 3 of the cell above. In the first loop, when `index` is assigned `0`, `friends[index]` is the same as `friends[0]`—that is, "Geetha". In the second loop, when `index` is assigned `1`, `friends[index]` is the same as `friends[1]`, i.e., "Luca". And so on.

The lines below the header—in this example, lines 2 and 3—are called the **body** of the `for` loop. They are always **indented**, and there can be as many as we want. They get executed for a number of times determined by the sequence of numbers created by the function `range()`.

Before moving to the next cell, let's summarize what the code at cell 3 does. We have to go through the three lines of code for a total of four times, like this:

- In the first iteration, `index` is assigned `0` (line 1), so we print `index: 0` (line 2), and then `friends` in position `index`—which is `0`—and thus friend: Geetha (line 3).
- In the second iteration, `index` is assigned `1` (line 1), so we print `index: 1` (line 2), and then `friends` in position `index`—which is `1`—and therefore friend: Luca (line 3).
- In the third iteration, `index` is assigned `2` (line 1), so we print `index: 2` (line 2), and then `friends` in position `index`—which is `2`—and therefore friend: Daisy (line 3).
- In the fourth iteration, `index` is assigned `3` (line 1), so we print `index: 3` (line 2), and then `friends` in position `index`—which is `3`—and therefore friend: Juhan (line 3).

Being aware of what happens at each loop is fundamental to make sure that our code does what we expect. Any time you are uncertain about what is happening in a for loop, **think about your code line by line and iteration by iteration**, like we did right above. If the code is particularly complicated, you can also **create a table**, where you can keep track of each line at each iteration, like this:

Loop	<code>for index in range(0,4):</code>	<code>print("index:" +str(index))</code>	<code>print("friend:"+friends[index])</code>
First	<code>index = 0</code>	<code>index: 0</code>	<code>friend: friends[0] → Geetha</code>
Second	<code>index = 1</code>	<code>index: 1</code>	<code>friend: friends[1] → Luca</code>
Third	<code>index = 2</code>	<code>index: 2</code>	<code>friend: friends[2] → Daisy</code>
Fourth	<code>index = 3</code>	<code>index: 3</code>	<code>friend: friends[3] → Juhan</code>

Before going to the next cell, let's define the for loop:

A **for loop** is the repetition of a group of commands for a **determined** number of times.

This definition summarizes the two main features of a for loop.

1. We execute the **lines of code that are in the body** of the for loop several times
2. The **number of times is known** and is determined by a sequence of numbers created by the built-in function `range()`

Let's continue with cell 4:

[4]:	<pre>1 print("Their favorite dishes are:") 2 print(dishes)</pre> <p>Their favorite dishes are: ['sushi', 'burgers', 'tacos', 'pizza']</p>	<pre>print Their favorite dishes are: print dishes</pre>
------	---	--

We print out the string `Their favorite dishes are:` (line 1) and the content of the list `dishes` (line 2).

Let's run cell 5, which contains another for loop:

[5]:	<pre>1 for index in range(0,4): 2 print("index:" + str(index)) 3 4 print("dish:" + dishes[index])</pre> <p>index: 0 friend: sushi index: 1 friend: burgers index: 2 friend: tacos index: 3 friend: pizza</p>	<pre>for index in range from 0 to 4 print index: concatenated with string of index print dish: concatenated with dishes in position index</pre>
------	--	---

The header is the same as that of the for loop we met at cell 3, including the start and the stop of the built-in function `range()`. Also, line 2—where we print the index value at each iteration—is the same. However, at line 3 we print out the dish names one by one. Once again, let's go through the code one iteration at a time:

- In the first iteration, `index` is assigned `0` (line 1), so we print `index: 0` (line 2), and then we print dishes in position `index`—which is `0`—and thus `dish: sushi` (line 3).
 - In the second iteration, `index` is assigned `1` (line 1), so we print `index: 1` (line 2), and then we print dishes in position `index`—which is `1`—and thus `burgers` (line 3).
 - In the third iteration, `index` is assigned `2` (line 1), so we print `index: 2` (line 2), and then we print dishes in position `index`—which is `2`—and thus `tacos` (line 3).
 - In the fourth iteration, `index` is assigned `3` (line 1), so we print `index: 3` (line 2), and then we print dishes in position `index`—which is `3`—and thus `pizza` (line 3).

Finally, let's run the last cell:

```
[6]: 1 for index in range(0,4):
2     print ("My friend " + friends[index] +
       "'s favorite dish is " + dishes[index])
```

for index in range from zero to four
print My friend concatenated
with friends in position index
concatenated with 's favorite dish
is concatenated with dishes in
position index

My friend Geetha's favorite dish is sushi
My friend Luca's favorite dish is burgers
My friend Daisy's favorite dish is tacos
My friend Juhan's favorite dish is pizza

Once again, there is a `for` loop. The header is the same as that in the two previous examples: we create a sequence of integers that go from 0 to 3, and we assign them to the variable `index`, one by one at each iteration (line 1). Just one note: beyond the start and the stop, the built-in function `range()` can also take a step as an argument, like so:

```
[6]: 1 for index in range(0,4,1): for index in range from zero to four  
with a step of one
```

As for the start and the stop, the step also works exactly the same way as it does in slicing (Chapter 6). In these examples, we omitted the step because it is 1—that is, we take all the elements of the list. You will play with different step values in the coding exercises at the end of this chapter.

Finally, the body of the for loop is constituted of one line of code, where we print out a sentence composed of four parts, concatenated to each other. The first and the third parts are two strings—"My friend " and "'s favorite dish is ". The second and the fourth parts are the elements of the lists friends and dishes sliced at position index (line 2). As you'll notice, we can use index to **simultaneously slice several lists of the same length at the same position** within one for loop.



Fill in the gaps

Complete the following sentences to summarize the for loop syntax and functionality in your own words:

1. A for loop is _____.
 2. A for loop header is _____.
 3. A for loop body is _____.
 4. for is a _____ and is colored _____ in Jupyter Notebook.

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5. index is a _____ and is colored _____ in Jupyter Notebook. It is assigned _____.
6. range() is a _____ and is colored _____ in Jupyter Notebook. It can take three arguments: _____, _____, and _____. It returns _____.
7. An iteration or loop is _____.

Recap

- A for loop is the repetition of commands for a defined number of times.
- When the for loop is used to slice a list, the number of times coincides with the list length.
- The generic syntax of a for loop header is: `for index in range(start, stop, step):`.
- The body of a for loop is indented and can contain as many lines of code as needed.
- `range()` is a built-in Python function that creates a sequence of integers spanning from the start (included) to the stop (excluded).
- `str()` is a built-in Python function that converts a variable into a string.

Dealing with IndexError and IndentationError

When executing a for loop, we might encounter two errors: index errors and indentation errors. Let's see why they happen and how to fix them!

Index error. Let's modify the example in cell 3 by changing the stop to 5 (instead of 4). When we run the cell, we get the following error.

```
[3]: 1 for index in range(0,5):
      2     print("index:" + str(index))
      3     print("friend:" + friends[index])
index: 0
friend: Geetha
index: 1
friend: Luca
index: 2
friend: Daisy
index: 3
friend: Juhan
index: 4
-----
IndexError      Traceback (most recent call last)
Cell In[3], line 3
      1 for index in range (0,5):
      2     print ("index: " + str(index))
----> 3     print ("friend: " + friends[index])
IndexError: list index out of range
```

for index in range from zero
to five
print index: concatenated
with string of index
print friend: concatenated
with friends in position
index

Let's decipher the error message. As you know from Chapter 2, we start reading from the last line, which informs us about the type of error: `IndexError: list index out of range`. This means that we are **trying to slice a list in a position that does not exist**. Where do we do this? Let's look for the arrow. It points to line 3, where we slice `friends` in position `index`. What's the value of `index`? From the last line of the printouts, we can see that `index` is 4. Thus, we are trying to slice the list `friends` in position 4, which does not exist. Fixing this error is easy: we just correct the stop in `range()` to 4.

IndentationError. The indentation error is very easy to recognize and fix. Let's look into this example:

```
[3]: 1 for index in range(0,4):
      2     print("index: " + str(index))

Cell In[3], line 2
print("index: " + str(index))
^

IndentationError: expected an indented block
```

`for index in range from zero
to four
print index: concatenated
with string of index`

Again, we start reading from the last line of the error message, which says: `IndentationError: expected an indented block`. This means that we **did not indent a line of code**. Where? The message says line 2 at the end of its first line. The fix is straightforward: we just indent line 2. A last note: Jupyter Notebook (and other editors) help us avoid the indentation error by positioning the cursor correctly when we press `enter` after a line terminated by a colon (`:`)—that is, after a `for` loop header, an `if/else` condition, a `while` loop header (Chapter 17), a function definition (Chapter 28), or a class definition (Chapter 35).



Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter.
 - a. *Capitals of the world.* Write two lists, one containing countries of the world and the other containing their capital cities. First, print out all the countries as a list and all the countries one by one. Then, print out all the cities as a list and all the cities one by one. Finally, print out each country with its capital.
 - b. *Animals of the world.* Write two lists, one containing animals of the world and one containing the continents (or countries) where they live. First, print out all the animals as a list and all the animals one by one. Then, print out all the continents as a list and all the continents one by one. Finally, print out each animal with the continent where it lives.

2. *Mountains and rivers.* Given the following list:

```
mountains_rivers = ["everest", "mississippi", "yosemite", "nile", "mont blanc",
"amazon"]
```

Print:

- a. All elements as a list;
- b. All elements one by one using a `for` loop;
- c. Mountains using slicing;

- d. Mountains one by one using a `for` loop (tip: remember that `range()` can have three arguments: `start, stop, step`);
- e. Rivers using slicing;
- f. Rivers one by one using a `for` loop (what start do you use?);
- g. All elements in reverse order using slicing;
- h. All elements in reverse order, one by one, using a `for` loop (what start, stop, and step do you use?).

3. Wild animals. Given the following list:

```
wild_animals = ["eagle", "bear", "parrot", "tiger", "pelican", "coyote"]
```

Print:

- a. All animals as a list;
- b. All animals one by one using a `for` loop;
- c. Mammals using slicing;
- d. Mammals one by one using a `for` loop;
- e. Birds using slicing;
- f. Birds one by one using a `for` loop (what start do you use?);
- g. All animals in reverse order using slicing;
- h. All animals, one by one, in reverse order using a `for` loop.

9. At the zoo

For loop with if... ==... / else...

Can we combine for loops and if/else constructs? Yes! How? Open Jupyter Notebook 9 and follow along. Read the following example aloud, and try to understand how it works:

- You are at the zoo and you write down a list of some animals you see:

```
[:] 1 animals = ["giraffe", "penguin",
                 "dolphin"]
    2 print(animals)
```

animals is assigned giraffe, penguin, dolphin
print animals

- Then you print out the animals one by one:

```
[:] 1 # for each position in the list
    2 for i in range(0, len(animals)):
        3     print("--- Beginning of loop ---")
        4     # print each element and its position
        5     print ("The element in position " +
               str(i) + " is " + animals[i])
```

for each position in the list
for i in range from zero to len of animals
print beginning of loop
print each element and its position
print the element in position concatenated
with string of i concatenated with is
concatenated with animals in position i

- You really wanted to see a penguin:

```
[:] 1 wanted_to_see = "penguin"
```

wanted to see is assigned penguin

- Once home, you tell your friend the animals you saw, specifying which one you really wanted to see:

```
[:] 1 # for each position in the list
    2 for i in range(0, len(animals)):
        3     # if the current animal is
        4         what you really wanted to see
        5         if animals[i] == wanted_to_see:
            6             # print out that that's the animal
            7             you really wanted to see
            8             print("I saw a " + animals[i] +
                  " and I really wanted to see it!")
        9     else:
            10        # just print out what you saw
            11        print("I saw a " + animals[i])
```

for each position in the list
for i in range from zero to len of animals
if the current animal is what you really
wanted to see
if animals in position i equals wanted to
see
print out that that's the animal you
really wanted to see
print I saw a concatenated with animals in
position i concatenated with and I really
wanted to see it!
else
just print out what you saw
print I saw a concatenated with animals in
position i

What's happening in this code? Get some hints by completing the following exercise.

 True or false?

- | | | |
|---|---|---|
| 1. We can include a condition in a for loop using an if/elif construct | T | F |
| 2. The built-in function len() returns the number of elements in a list | T | F |
| 3. The hash symbol # starts a new line of code | T | F |
| 4. The == symbol checks whether two variables are different | T | F |

Computational thinking and syntax

Let's start by running the first cell:

```
[1]: 1 animals = ["giraffe", "penguin",
              "dolphin"]
      2 print(animals)
      ['giraffe', 'penguin', 'dolphin']
```

animals is assigned giraffe, penguin, dolphin
print animals

We consider a list called animals containing three strings: "giraffe", "penguin", and "dolphin" (line 1), and we print it out (line 2).

Let's run the second cell:

```
[2]: 1 # for each position in the list
      2 for i in range(0, len(animals)):
          3     print("--- Beginning of loop ---")
          4     # print each element and its position
          5     print ("The element in position " +
                  str(i) + " is " + animals[i])
      --- Beginning of loop ---
      The element in position 0 is giraffe
      --- Beginning of loop ---
      The element in position 1 is penguin
      --- Beginning of loop ---
      The element in position 2 is dolphin
```

for each position in the list
for i in range from zero to len of animals
print beginning of loop
print each element and its position
print the element in position concatenated with string of i concatenated with is concatenated with animals in position i

We run the for loop three times, and each time we print out the lines 3 and 5. Let's dig into the code to understand it better! The header of the for loop at line 2 contains two changes from the syntax we saw in the previous chapter. First, we use the abbreviation `i` for the variable `index`. Shortening names of frequently used variables is common in coding because it reduces the amount of typing required. Some abbreviations become conventions—like in this case—so, from this point on we will use `i`. Second, instead of an integer, we use `len(animals)` as the stop in the built-in function `range()`. If we used an integer, then the stop would be 3, because the last element—"dolphin"—is in position 2, to which we add 1 for the plus one rule. But what if we added another element to the list? We would have to remember to modify the stop from 3 to 4. As you can imagine, this practice is very prone to error, as it's easy to forget to update the stop or miscount the last element position. Therefore, we do **not** want to **hard-code** the stop—that is, to explicitly write its value. We want to make it **dependent on the variable** we are dealing with so that we do not have to take care of possible variations. To do so, we use `len()`, which is a built-in function that **returns the length of a variable**—that is, 3 for the list `animals`. We can use this trick because **the length of a list is always one unit more than the index of the last element**; therefore, it coincides with the stop. From this point on, we will not need to count to find

the stop—`len()` will do it for us!

Let's analyze the body of the `for` loop. At line 3, we print a string stating that we are at the beginning of a loop. It is meant to be **visually different** to make the printouts of each iteration **easy to identify**. Beyond *Beginning of loop*, we could use sentences like *New iteration*, *New loop*, etc. To increase the visibility, we can also use symbols before and/or after the text—such as dashes (---) in this example. Alternatives can be arrows (-->), tildes (~~~), or any other character on the keyboard. At line 5, we print out each element and its position in a sentence composed of four parts concatenated to each other. The first and the third parts—"The element in position " and " is"—are two hard-coded strings. The second element is the index of the current loop. It's an integer, so we use the built-in function `str()` to convert it into a string. Finally, the last element (`animals[i]`) is a string, containing a list element sliced in a different position `i` at each iteration—that is, "giraffe", "penguin", or "dolphin".

Finally, lines 1 and 4 start with the **hash symbol** (#) and are followed by text. These lines are called **comments**. What are they? Let's give a definition:

Comments are code descriptions or explanations.

Comments are a **fundamental component** of coding. They can contain **descriptions** of the code, or **explanations** about why we made a certain coding choice, or any other **information** that is relevant to understand the code they refer to. Comments are in light green in Jupyter Notebook, and they are above and aligned with the line/s they explain. For example, the comment at line 4 refers to the code at line 5, so it is indented and aligned with line 5. You might wonder why we write comments. For at least two reasons. First reason: **to make code readable** for us and others. When reading old code, we rarely remember why we wrote what we wrote—yes, even if we wrote it ourselves! Similarly, when we read somebody else's code, it is often hard to understand what they did and why, if the code is not well commented. Second reason: **to keep track of what we are doing**. When writing code, we sometimes concentrate on small details and lose the big picture. In these cases, we can end up asking ourselves: why am I writing this again? Using comments to outline code can help us keep track of the steps we have to **implement**—that is, to write. Finally, how do we write useful comments? That's simple: **use precise language**. Writing # here is a for loop does not add any information to code because a loop is clearly visible. It is more meaningful to describe what the for loop does and why; for example, # using a for loop to browse a list and print out its elements one by one. Also, don't take any line of code for granted. It's really so easy to forget why we wrote that line of code that way! In general, remember that **comments are written for human beings**, not for Python. As a matter of fact, Python skips comments when it reads our code. Try to add an hash front of a line of code yourself: Python is not going to execute it!

Let's run the next cell:

```
[3]: 1 wanted_to_see = "penguin"           wanted to see is assigned penguin
```

We create a variable called `wanted_to_see` to which we assign the string "penguin".

Let's run the last cell:

<pre>[4]: 1 # for each position in the list 2 for i in range(0, len(animals)): 3 # if the current animal is 4 # what you really wanted to see 5 if animals[i] == wanted_to_see: 6 # print out that that's the animal 7 # you really wanted to see 8 print("I saw a " + animals[i] + 9 " and I really wanted to see it!") 10 else: 11 # just print out that you saw it 12 print("I saw a " + animals[i]) 13 I saw a giraffe 14 I saw a penguin and I really wanted to see it! 15 I saw a dolphin</pre>	<pre>for each position in the list for i in range from zero to len of animals if the current animal is what you really wanted to see if animals in position i equals wanted to see print out that that's the animal you really wanted to see print I saw a concatenated with animals in position i concatenated with and I really wanted to see it! else just print out that you saw it print I saw a concatenated with animals in position i</pre>
--	---

Once more, we use the `for` loop to browse the list elements. But this time, **we apply a condition to each element**. Let's analyze line by line. The header of the `for` loop is the same as the one in cell 2. Then, at line 4, we start an `if/else` construct. It is similar to the one we learned in Chapter 3: it's composed of an `if` condition (line 4), a statement (line 6), an `else` (line 7), and another statement (line 9). However, the condition after the keyword `if` is different. In Chapter 3, we checked if an element was in a list by using the membership operator `in`. In this case, we check if the values assigned to two variables `animals[i]` and `wanted_to_see` are equal. To do so, we write (1) the keyword `if`; (2) the first variable, that is, `animals[i]`; (3) the comparison operator `==`, and (4) the second variable, that is, `wanted_to_see`. The **comparison operator `==`** is pronounced *equals* or *is equal to*. Note that **`==` is very different from `=`**. The symbol `==` is a **comparison operator** and is used in conditions to check if the values assigned to two variables are the same. The symbol `=` is the assignment operator, and it is used to assign a value to a variable.

To make sure that what this code does is clear, let's go through the `for` loop step-by-step:

- In the first loop: at line 2, `i` is assigned `0`. At line 4, we check if `animals` in position `i`—where `i` is `0`, so `animals[0]` is "giraffe"—is equal to the value assigned to the variable `wanted_to_see`, which is "penguin". Because "giraffe" is not equal to "penguin", we skip the statement under the `if` at line 6, and we jump directly to the statement under the `else`, which is at line 9. There, we print "I saw a giraffe".
- In the second loop: at line 2, `i` is assigned `1`. At line 4, we check again if `animals` in position `i`—where `i` is `1`, so `animals[1]` is "penguin"—is equal to the value assigned to the variable `wanted_to_see`. In this case, the values of the two variables `animals[i]` and `wanted_to_see` are equal, so we execute the statement under the `if` condition (line 6), where we print "I saw a penguin and I really wanted to see it!".
- Finally, in the third loop: at line 2, `i` is assigned `2`. At line 4, we check once more if `animals` in position `i`—where `i` is `2`, thus `animals[2]` is "dolphin"—is equal to the value assigned to the variable `wanted_to_see`, which is "penguin". Because "dolphin" is not equal to "penguin", we skip the statement at line 6, and we jump directly to the statement under the `else`, which is at line 9. There, we

```
print "I saw a dolphin".
```

 Complete the table

In coding there is a lot of jargon—that is, technical words or expressions that are typically used, but whose meaning is not always clear. Have you familiarized yourself with the jargon introduced so far? Complete the table by writing the meaning of the following expressions:

Expression	Meaning
To run a cell (Chapter 1)	
To write readable code (Chapter 3)	
The function takes one argument (Chapter 5)	
The function returns an integer (Chapter 5)	
To reassign to a variable (Chapter 7)	
The element is hard-coded (Chapter 8)	
To comment code (Chapter 9)	
To hard-code (Chapter 9)	
To implement code (Chapter 9)	

Recap

- In a `for` loop, the variable `index` is commonly abbreviated with `i`.
- The built-in function `len()` returns the length of a variable.
- We can use the `if/else` construct in a `for` loop.
- We can use the comparison operator `==` (*equals* or *is equal to*) in an `if` condition.
- Comments start with the hash symbol `#`, and they are descriptions or explanations.

Dealing with TypeError

Type error is common when we try to concatenate variables of different types. Let's look at this example, modified from cell 2 in this chapter:

<pre>[2]: 1 # for each position in the list 2 for i in range(0, len(animals)): 3 print("--- Beginning of loop ---") 4 # print each element and its position 5 print ("The element in position " + i + " is " + animals[i]) </pre>	<pre>for each position in the list for i in range from zero to len of animals print beginning of loop print each element and its position print the element in position concatenated with i concatenated with is concatenated with animals in position i</pre>
<pre>--- Beginning of loop ---</pre> <hr/>	
<pre>TypeError Traceback (most recent call last) Cell In[2], line 5 3 print ("-- Beginning of loop --") 4 # print each element and its position ----> 5 print ("The element in position " + i + " is " + animals [i]) TypeError: can only concatenate str (not "int") to str</pre>	

The last line of the error message says `TypeError: can only concatenate str (not "int") to str`. It means that somewhere in our code we are trying to concatenate an integer with one or more strings. Where? The green arrow points to line 5, where there are three concatenations. As mentioned in the text above, the components are "The element in position" and " is ", which are two hard-coded strings; the list element `animals[i]`—that is, "giraffe", "penguin", or "dolphin"—which is a string, too; and the variable `i`, which is an integer between 0 and 2. So `i` is the issue! Solving the error is very easy: we just transform `i` into a string with the built-in function `str()`, like this: `str(i)`.

Let's look at another example, modified from Chapter 7:

<pre>[6]: 1 planets = planets + "Jupyter" 2 print(planets)</pre>	<pre>planets is assigned planets concatenated with jupyter print planets</pre>
<pre>TypeError Traceback (most recent call last) Cell In[6], line 1 ----> 1 planets = planets + "Jupyter" 2 print (planets) TypeError: can only concatenate list (not "str") to list</pre>	

This time, the last line of the error message says: `TypeError: can only concatenate list (not "str") with list`. We are trying to concatenate a string to a list. Where? The green arrow points to line 1. Around the concatenation symbol, there are `planets`—which is a list—

and "Jupyter"—which is a string! Correcting this error is easy: we simply transform "Jupyter" into a list by embedding it in between square brackets, like this: ["Jupyter"]. When getting a type error, remember to **analyze the type of each variable** located in the line of code where the error occurs. Also, remember that we can only concatenate lists with lists, and strings with strings!

Let's code!

Note: Starting from this chapter, write code comments wherever pertinent.

1. For each of the following scenarios, create code similar to that presented in this chapter:
 - a. Sports. Write a list of sports you like, and print them out one by one. What is your favorite sport? Create a variable for it. Finally, print out all sports one by one, specifying if they are your favorite sports.
 - b. An astronaut's next destination. You are an astronaut and you write down the list of the planets of the solar system: Mercury, Mars, Venus, Earth, Neptune, Uranus, Saturn, Jupiter. Print out the planets one by one. Then, create a variable for your next destination. Finally, print out all the planets, specifying if they are your next destination.
2. Months. Given the following list:

```
months = ["February", "July", "January", "August", "December", "June"]
```

Print out the names of winter months using a `for` loop. Then, print out the names of summer months using a `for` loop. Choose a month you like and assign it to a variable. Print out all the months one by one, specifying if the current month is your favorite. Finally, what alternative way could you use to check if your favorite month is in the list?

3. Mary K. Keller. Given the following list:

```
mary_k_keller = ['a nun', 'She was also', 'in Computer Science.',  
'to receive a Ph.D.', 'American woman', 'the first', 'was', 'Mary K. Keller']
```

Print out all the elements in reverse order, first using slicing, and then using a `for` loop. Then, consider the following variable: `name = 'Mary K. Keller'`. Check if this variable is in the list in two ways: first, using the `if/else` construct; and then, using the `if/else` construct in a `for` loop. What are the differences between the two methods?

10. Where are my gloves?

For loop for searching

When combined with lists, a `for` loop is typically used for at least three operations: searching elements, changing elements, and creating new lists, as you will learn in the next three chapters. In this chapter, we will start with learning how to use the `for` loop to search elements in a list. Ready? Open Jupyter Notebook 10 and follow along. Cover the code after each task with a piece of paper, and try to guess the answer. Then compare and read the explanation. Let's get started!

- Who doesn't have a messy drawer? Here is ours! It contains some accessories:

```
[1]: 1 accessories = ["belt", "hat", "gloves",
      "sunglasses", "ring"]
2 print(accessories)
['belt', 'hat', 'gloves', 'sunglasses', 'ring']
```

```
accessories is assigned belt, hat,
gloves, sunglasses, ring
print accessories
```

We start with the list `accessories` composed of 5 strings (line 1), and we print it out (line 2).

- Print all accessories one by one, as well as their positions in the list. Use a sentence like *The element x is in position y*:

```
[2]: 1 # for each position in the list
2 for i in range(len(accessories)):
3     # print each element and its position
4     print ("The element " + accessories[i] +
      " is in position" + str(i))
```

```
for each position in the list
for i in range len of accessories
print each element and its position
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
```

```
The element belt is in position 0
The element hat is in position 1
The element gloves is in position 2
The element sunglasses is in position 3
The element ring is in position 4
```

We warm up by using a `for` loop to print each list element and its position, as we learned in Chapters 8 and 9. The syntax of the `for` loop is the same as we saw previously, with one last simplification in the header: we **omit the start**. When the start is 0—that is, the beginning of the list—we don't need to write it. Can we also omit the stop when it coincides with the end of the list? Not really: the built-in function `range()` would not know where to stop creating consecutive integers (if you need to refresh your memory that `range()` creates a list of integers, see cell 4 in Chapter 8). Finally, note that we keep commenting each command to increase code readability.

Now it's time to look for items in the drawer. How do we do it? To search list elements, we have to (1) create a **for loop to browse all elements** of a list and (2) **use an if/else construct** to check if the current element has the characteristics we want, like we did at cell 4 of Chapter 9. In general, we can search for elements based on various conditions. In the previous chapters, we searched if elements are present in a list (Chapter 3) and for elements equal to a given variable (Chapter 9). In this chapter, we will search for elements with a certain length and in a certain list position. To do that, we will use the **comparison operators**. Ready? Let's go!

1. Print the accessory whose name is **composed of** 6 characters and its position in the list. Use a sentence like *The element x is in position y and it has n characters*:

```
[3]: 1 # for each position in the list
2 for i in range(len(accessories)):
3     # if the length of the element equals 6
4
4     if len(accessories[i]) == 6:
5
5         # print the element, its position,
6         # and its number of characters
6         print ("The element " + accessories[i] +
7             " is in position" + str(i)) +
8             " and it has 6 characters")
9
9
for each position in the list
for i in range len of accessories
if the length of the element equals
six
if len of accessories in position i
equals six
print the element, its position,
and its number of characters
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with and it has six
characters
```

The element gloves is in position 2 and it has 6 characters

We want to find the list element composed of 6 characters. As mentioned above, we create a for loop to browse all elements in the list (line 2), and we write an if/else construct to evaluate if the current element—that is, `accessories[i]`—is composed of 6 characters (lines 4 and 6). How do we know how many characters a string has? The **number of characters coincides with the length of the string**; therefore, we can use the built-in function `len()`. Thus, in the if condition, we compare the length of the current element of the list—`len(accessories[i])`—to the number of characters we want—that is, 6. The comparison operator that we use is `==` (equals or is equal to), which checks if two values are identical, like you learned in Chapter 9 at cell 4. If the current element satisfies the condition, we print out the sentence at line 6, like we do for the element "gloves". What about the other elements? We do not want to do anything, so we simply omit the else part of the if/else construct. Note the comments on lines 1,3, and 5.

2. Print the accessories whose names are composed of **less than** 6 characters:

```
[4]: 1 # for each position in the list
2 for i in range(len(accessories)):
3     # if the length of the element is less
4     # than 6
4
4     if len(accessories[i]) < 6:
5
5         # print the element, its position,
6         # and its number of characters
6         print ("The element " + accessories[i] +
7             " is in position" + str(i)) +
8             " and it has less than 6 characters")
9
9
for each position in the list
for i in range len of accessories
if the length of the element is
less than six
if len of accessories in position i
less than 6
print the element, its position,
and its number of characters
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with and it has less
than 6 characters
```

The element belt is in position 0 and it has less than 6 characters

The element hat is in position 1 and it has less than 6 characters

The element ring is in position 4 and it has less than 6 characters

The structure of the code is the same as that in example 1. What changes is the comparison operator, which is `<` and is pronounced **less than** (line 4). By using this operator, we check if the length of the

current element is less than 6. For the elements composed of less than 6 characters, we print out the sentence at line 6—that is, for the strings "belt", "hat", and "ring".

3. Print the accessories whose name is composed of **more than** 6 characters. Also, assign 6 to a variable:

```
[5]: 1 # defining the threshold
2 n_of_characters = 6
3 # for each position in the list
4 for i in range(len(accessories)):
5     # if the length of the element is greater
      # than the threshold
6     if len(accessories[i]) > n_of_characters:
7
8         # print the element, its position,
          # and its number of characters
9         print ("The element " + accessories[i] +
10             " is in position" + str(i) +
11             " and it has more than " +
12             str(n_of_characters) + " characters")
```

defining the threshold
n of characters is assigned six
for each position in the list
for i in range len of accessories
if the length of the element is
greater than the threshold
if len of accessories in position i
greater than n of characters
print the element, its position,
and its number of characters
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with and it has more
than concatenated with string of
n of characters concatenated with
characters

The element sunglasses is in position 3 and it has more than 6 characters

In this example, we add two novelties. The first is straightforward: we use the comparison operator `>`, which is pronounced **greater than** (line 6). In this case, only one string has more than 6 characters—that is, "sunglasses"—so we print out line 8 for that element.

The second novelty is the variable `n_of_characters` (line 2). It is assigned 6—that is, the threshold length above which we want to print list elements. Why do we create `n_of_characters` instead of simply using 6? Because we use it in two lines of code—in the condition (line 6) and in the print (line 8)—and this implies the possibility of errors. What if instead of considering 6 characters, we wanted to consider 4? We would have to modify the number both at lines 6 and 8, and we could forget to change in both places. Instead, by using the variable `n_of_characters`, we change the value in just one place (line 2). It is **good practice to create variables** containing values instead of hard-coding within a block of code. Variables are usually written **at the beginning of a block of code** so that they are easy to find, especially when the code is composed of several lines.

4. Print the accessories whose name is composed of a number of characters **different from** 6:

```
[6]: 1 # defining the threshold
2 n_of_characters = 6
3 # for each position in the list
4 for i in range(len(accessories)):
5     # if the length of the element is not equal
          # to the threshold
```

defining the threshold
n of characters is assigned six
for each position in the list
for i in range len of accessories
if the length of the element is not
equal to the threshold

```

6   if len(accessories[i]) != n_of_characters:
7       # print the element, its position,
8       # and its number of characters
9       print ("The element " + accessories[i] +
10          " is in position" + str(i) +
11          " and it has a number of characters
12          different from " +
13          str(n_of_characters))

```

if len of accessories in position i
not equal to n of characters
print the element, its position,
and its number of characters
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with and it has a
number of characters different from
concatenated with string of n of
characters

```

The element belt is in position 0 and it has a number of characters different from 6
The element hat is in position 1 and it has a number of characters different from 6
The element sunglasses is in position 3 and it has a number of characters different
from 6
The element ring is in position 4 and it has a number of characters different from 6

```

The comparison operator for *different from* is `!=` and is pronounced **not equal to** (line 6). The structure of the code is the same as that above: we use the variable `n_of_characters` to avoid hard coding (line 2); we create a `for` loop to browse all list elements (line 4); we create an `if` condition to check what strings have lengths not equal to the threshold (line 6); and, finally, we print out a sentence for those elements that satisfy the condition (line 8)—that is, “belt”, “hat”, “sunglasses”, and “ring”. Before each command, we write a comment to explain what the command does (lines 1,3,5, and 7).

5. Print the accessories whose position is **less than or equal to** 2:

```

[7]: 1 # defining the threshold
2 position = 2
3 # for each position in the list
4 for i in range(len(accessories)):
5     # if the position of the element is less
6     # than or equal to the threshold
7     if i <= position:
8         # print the element, its position,
9         # and its position characteristic
10        print ("The element " + accessories[i] +
11           " is in position" + str(i) +
12           ", which is less than or equal to " +
13           str(position))

```

defining the threshold
position is assigned two
for each position in the list
for i in range len of accessories
if the position of the element is
less than or equal to the threshold
if i less than or equal to position
print the element, its position,
and its position characteristic
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with which is less
than or equal to concatenated with
string of position

```

The element belt is in position 0, which is less than or equal to 2
The element hat is in position 1, which is less than or equal to 2
The element gloves is in position 2, which is less than or equal to 2

```

In this example, we introduce two novelties again. The first novelty is the comparison operator `<=`, which is pronounced **less than or equal to** (line 6). What is the difference between the two comparison operators `<` (less than or equal to) and `<` (less than)? When using `<=`, we *include* the threshold—that is, we consider all the elements whose position is equal to 2 or less. When using `<`, we *exclude* the threshold—that is, we consider only the elements whose position is strictly less than 2.

The second novelty is that we want to search for elements based on their position. How do we do it?

First, we create a variable called `position` to which we assign the threshold—that is, 2 (line 2). Then, we need to write the comparison. How do we know the position of each element? **In a for loop, the position of the current list element is `i`!** Remember the following from the previous chapters?

- In the first loop, `i` is assigned 0, thus `accessories[i]` is `accessories[0]`, which is "belt".
- In the second loop, `i` is assigned 1, thus `accessories[i]` is `accessories[1]`, which is "hat".
- In the third loop, `i` is assigned 2, thus...

Therefore, in the `if` condition, we compare the current element position `i` to the threshold position in the variable `position` (line 6). For all those elements whose position `i` is less than or equal to `position`, we print line 8—that is, for "belt", "hat", and "gloves".

6. Print the accessories whose position is **at least** 2:

```
[8]: 1 # defining the threshold
2 position = 2
3 # for each position in the list
4 for i in range(len(accessories)):
5     # if the position of the element is greater
      # than or equal to the threshold
6
7         if i >= position:
8             # print the element, its position,
               # and its position characteristic
9             print ("The element " + accessories[i] +
10                 " is in position " + str(i) +
11                 ", which is at least " + str(position))
```

defining the threshold
position is assigned two
for each position in the list
for i in range len of accessories
if the position of the element
is greater than or equal to the
threshold
if i greater than or equal to
position
print the element, its position,
and its position characteristic
print The element concatenated
with accessories in position i
concatenated with is in position
concatenated with string of i
concatenated with which is at
least concatenated with string of
position

```
The element gloves is in position 2, which is at least 2
The element sunglasses is in position 3, which is at least 2
The element ring is in position 4, which is at least 2
```

In this last example, the code structure remains the same, but we use the comparison operator `>=`, pronounced **greater than or equal to** (line 6). Similarly to before, the difference between `>=` (*greater than or equal to*) and `>` (*greater than*) is that when using `>=`, we include the threshold, whereas when using `>`, we exclude the threshold. In this case, we print the sentence at line 8 for all the elements whose position is at least—that is, greater than or equal to—`position`, which are "gloves", "sunglasses", and "ring" (line 8).

Finally, a trick to remember the spelling of comparison operators composed of two symbols: the symbol `=` is always in the second position, as you'll notice for `!=` (example 4), `<=` (example 5), and `>=` (example 6).

 Complete the table

In this chapter, you learned the six comparison operators. Sum up their characteristics in your own words in the table below:

Comparison operator	What it does	Pronunciation
==		
!=		
>		
>=		
<		
<=		

 Insert into the right column

Up to now, you have learned several coding elements: data types, built-in functions, keywords, and list methods. Do you remember which is which? Insert the following elements into the right column:

```
string, else, input(), if, .remove(), print(), .index(), len(),
str(), del, list, .append(), range(), for, .insert(), integer, .pop()
```

Data types	Built-in functions	Keywords	List methods

Recap

- We can use a `for` loop combined with an `if/else` construct to search for elements in a list.
- It is good practice to create variables instead of hard-coded values in a block of code to reduce the possibility of errors. Variables are usually located at the beginning of a block of code.
- In Python, there are six comparison operators: `==`, `!=`, `>`, `>=`, `<`, `<=`.

Let's use keyboard shortcuts!

While coding, it can be very practical to use keyboard shortcuts to minimize typing interruptions. Although it might sound like a bit of an exaggeration, using the mouse can really be distracting at times because it slows down the typing rhythm and interrupts the writing flow. Shortcuts, on the other hand, allow us to never leave the keyboard! They are **combinations of keys pressed simultaneously** that can perform various operations. Let's have a look at the most common ones. In the following examples, we will use the keys that are colored in Figure 10.1.

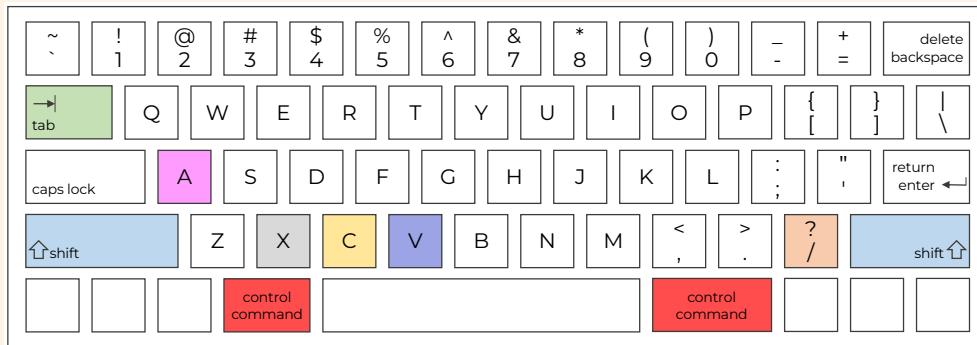


Figure 10.1. Example of keyboard. The colored keys are commonly used for shortcuts.

In the following shortcut combinations, *control/command* means that you will have to press they key *control* if you are using a Windows operating system, or the key *command* if you are using a MacOS operating system (that is, one of the red keys in Figure 10.1). In addition, the symbol *+* means that you have to press the listed keys simultaneously. What shortcuts do you know among the following ones?

- *control/command + A* (red key + pink key): selects all the lines of code in a cell—the letter *A* stands for *all*;
- *control/command + X* (red key + grey key): cuts selected lines of code;
- *control/command + C* (red key + yellow key): copies selected lines of code;
- *control/command + V* (red key + purple key): pastes selected lines of code;
- *control/command + /* (red key + orange key): adds a *#* in front of the selected lines of code—that is, it comments them out. If the key combination is re-pressed, the *#* is removed, and the code is un-commented;
- *tab* (green key): indents the selected lines of code—that is, it moves the lines four spaces towards right;
- *shift + tab* (blue key + green key): outdents the selected lines of code—that is, it moves the lines four spaces towards the left.

Note that these shortcuts can be used for several lines of code at once, thus speeding up the writing. Together with learning to type with ten fingers (see the *In more depth* session in Chapter 1), using shortcuts is an efficient way to write code faster and without interruptions!

 Let's code!

1. *Seasons.* Given the following list:

```
seasons = ["spring", "summer", "fall", "winter"]
```

Print:

- All seasons whose names are composed of at least 5 characters;
- All seasons whose names are composed of a number of characters that is equal to or less than 4;
- All seasons whose position is less than 2;
- All seasons whose position is at least 2.

2. *Word search.* You are working for a magazine and you have just created a new word search game for your readers. Here are the words hidden in the game:

```
words = ["cards", "park", "pets", "football", "golf", "crosswords", "toys",
"exercise", "hobbies", "riding", "biking", "games", "reading", "movies",
>walking", "concerts"]
```

After the grid is completed:

- Create a variable called title containing the number of words to find, and then print it out (e.g., Word search with 16 words).
- Find words composed of 5 letters. More specifically, print out a title, which has to contain the number of letters of this word group, and the words.
- Are there words with less than 5 characters? If so, for each word, print out a sentence containing the word itself, its position in the list, and its number of characters.
- Similarly, are there words with more than 8 characters? If so, for each word, print out a sentence containing the word itself, its position in the list, and its number of characters.
- What are the words in the second part of the list that have a number of characters different than 7? What's their position? And their number of characters?
- Finally, what are the words in the first fourth of the list that are composed of 4 characters? What's their position?

You can download the word search game for this exercise solution on the community website!

3. *Spelling competition.* Here are some words of the category musculoskeletal (msk) system that you have to memorize for the next spelling competition:

```
msk_words = ["ankle", "patella", "rib", "femur", "sternocleidomastoid", "tendon",
"sternum", "abdominal external oblique", "muscle", "scapula", "radius", "bone",
>vertebra", "ligament", "ulna", "skull", "clavicle"]
```

- How many words do you have to learn? Compute it and print it out.
- What is the length of each word? (including spaces if any).
- Let's now group words based on their length. Here is a list of short words:

```
short = ["leg"]
```

Add all words with 6 characters or less to the list and print out the result. How many words are in the list?

- Here is a list of words of intermediate length:

```
intermediate = ["cartilage"]
```

Add all words with 7, 8, and 9 characters. Then print out the result. How many words are in the list?

- e. And finally, here is a list of long words:

```
long = ["pectoralis major"]
```

Add all the remaining words and print out the result. How many words are in the list?

11. Cleaning the mailing list

For loop to change list elements

Time to learn how to use the `for` loop to change list elements! Open Jupyter Notebook 11 and follow along. Don't forget to pay attention to code pronunciation. Let's go!

- You are responsible for a newsletter, and you have to send an email to the following addresses:

```
[:] 1 emails = ["SARAH.BROWN@GMAIL.com",
              "Pablo.Hernandez@live.com",
              "LI.Min@hotmail.com"]
```

emails is assigned
SARAH.BROWN@GMAIL.com,
Pablo.Hernandez@live.com,
LI.Min@hotmail.com

- For the sake of consistency, you want all email addresses to be lowercase. So you change them:

```
[:] 1 # for each position in the list
2 for i in range(len(emails)):
3
4     print("-> Loop: " + str(i))
5
6     # print element before the change
7     print ("Before the change, the element in
position " + str(i) + " is " + emails[i])
8
9     # change element and reassign
10    emails[i] = emails[i].lower()
11
12    # print element after the change
13    print ("After the change, the element in
position " + str(i) + " is " + emails[i])
14
15    # print the modified list
16    print("Now the list is: " + str(emails[i]))
```

for each position in the list
`for i in range len of emails`

`print -> loop: concatenated with string of i`

`print element before the change`
`print Before the change, the element in position concatenated with string of i concatenated with is concatenated with emails in position i`

`change element and reassign`
`emails in position i is assigned`
`emails in position i dot lower`

`print element after the change`
`print After the change, the element in position concatenated with string of i concatenated with is concatenated with emails in position i`

`print the modified list`
`print Now the list is: concatenated with string of emails in position i`

What's new in the code above? Get some hints by completing the following exercise.

💡 True or false?

- | | | |
|---|---|---|
| 1. To change a list element, we need to reassign after the change | T | F |
| 2. The method <code>.lower()</code> is a list method | T | F |
| 3. The method <code>.lower()</code> changes a string to uppercase | T | F |
| 4. Comments and empty lines make code more readable | T | F |

Computational thinking and syntax

Let's run the first cell:

```
[1]: 1 emails = ["SARAH.BROWN@GMAIL.com",
             "Pablo.Hernandez@live.com",
             "LI.Min@hotmail.com"]
```

emails is assigned
SARAH.BROWN@GMAIL.com,
Pablo.Hernandez@live.com,
LI.Min@hotmail.com

We consider a list composed of three strings, each corresponding to an email address (line 1).

Let's run the second cell:

```
[2]: 1 # for each position in the list
2 for i in range(len(emails)):
3
4     print("-> Loop: " + str(i))
5
6     # print element before the change
7     print ("Before the change, the element in
position " + str(i) + " is " + emails[i])
8
9     # change element and reassign
10    emails[i] = emails[i].lower()
11
12    # print element after the change
13    print ("After the change, the element in
position " + str(i) + " is " + emails[i])
14
15 # print the modified list
16 print("Now the list is: " + str(emails))
```

for each position in the list
for i in range to len of emails

print -> loop: concatenated with
string of i

print element before the change
print Before the change, the element
in position concatenated with string
of i concatenated with is concatenated
with emails in position i

change element and reassign
emails in position i **is assigned**
emails in position i dot lower

print element after the change
print After the change, the element in
position concatenated with string of i
concatenated with is concatenated with
emails in position i

print the modified list
print Now the list is: concatenated
with string of emails

-> Loop: 0
Before the change, the element in position 0 is: SARAH.BROWN@GMAIL.com
After the change, the element in position 0 is: sarah.brown@gmail.com
-> Loop: 1
Before the change, the element in position 0 is: Pablo.Hernandez@live.com
After the change, the element in position 0 is: pablo.hernandez@live.com
-> Loop: 2
Before the change, the element in position 0 is: LI.Min@hotmail.com
After the change, the element in position 0 is: li.min@hotmail.com
Now the list is: ['sarah.brown@gmail.com', 'pablo.hernandez@live.com',
'li.min@hotmail.com']

We use a for loop to browse all the elements in the list (line 2). Within the for loop, there are four commands. Let's have a look at them one by one.

At line 3, we print a title for each iteration of the for loop, as we learned at cell 2 of Chapter 9. The title is composed of a symbol (i.e., ->) and the number of the current loop—represented by the variable i.

The symbol makes the title easy to visually identify, and the loop number favors checking what happens at each specific iteration.

At line 5, we print the current element (`emails[i]`) before the change, as it is in the list. This will be convenient for comparing the current element before and after the change.

At line 7, we change the current element. How do we do it? We take the current element `emails[i]`, and we change it to lowercase using the **string method** `.lower()`. You might remember that methods are functions for specific data types, they are colored blue in Jupyter Notebook, and their syntax is: (1) variable name, (2) dot, (3) method name, and (4) round brackets, in which there can be an argument (see Chapter 4). How do we know that `.lower()` is a string method? Because `emails[i]` is a string! Python has at least four methods to change character cases:

- `.lower()` to change all characters of a string to lowercase;
- `.upper()` to change all characters of a string to uppercase;
- `.title()` to change the first character of a string to uppercase and all the remaining characters to lowercase;
- `.capitalize()` to change the first character of each word in a string to uppercase, and all the remaining characters to lowercase.

Finally, to actually change a list element, we need to **re-assign the changed element to itself**. In other words, we need to **overwrite the current element with its new version**. If we do not do that, then the list element will remain unchanged.

At line 9, we print out a sentence containing the modified element to check that the change actually occurred. For a double check, we can also compare this sentence with the sentence containing the element before the change, which we printed at line 5.

At line 10, we print out the new list. We need to transform the list `emails` to a string because of the concatenation. Thus, we use the built-in function `str()`, like we do for integers.

Finally, we use two techniques to increase code readability. First, we add comments before each major command to explain what the code does (lines 1, 6, 9, 12, and 15). Second, we add empty lines to visually separate units of thought corresponding to one or more commands, like we would do for paragraphs in a text (lines 3, 5, 8, 11, and 14).

Match the code

Given the following string:

```
greeting = "hElLo, How arE YoU?"
```

Connect each command with the correct output:

- | | |
|--|--------------------------|
| 1. <code>print(greeting.lower())</code> | a. 'HELLO, HOW ARE YOU?' |
| 2. <code>print(greeting.upper())</code> | b. 'Hello, how are you?' |
| 3. <code>print(greeting.title())</code> | c. 'hello, how are you?' |
| 4. <code>print(greeting.capitalize())</code> | d. 'Hello, How Are You?' |

Recap

- To change list elements, we always need to reassign the changed element to itself
- String methods to change cases are: `.lower()`, `.upper()`, `.title()`, and `.capitalize()`

In what list am I changing the element?

Sometimes, we have to change a list element before adding it to an existing list. This can create confusion about *where* to change the list element. Let's consider this example:

- Given the following list:

```
[1]: 1 sports = ["diving", "hiking"] sports is assigned diving, hiking
```

- Add the mountain sport to the following list, making sure the string is uppercase:

```
[2]: 1 mountain_sports = ["CLIMBING"] mountain_sports is assigned CLIMBING
```

We want to take the string "hiking" from the list `sports`, transform it into "HIKING", and add it to the list `mountain_sports`. Where do we change the string to uppercase? Let's have a look at these two cases.

Case 1: *Changing the element both in the original list and in the new list.*

Consider the following code:

```
[3]: 1 sports[1] = sports[1].upper() sports in position 1 is assigned
      2 mountain_sports.append(sports[1]) sports in position 1 dot upper
      3 print(sports) mountain_sports dot append sports
      4 print(mountain_sports) in position 1
                           print sports
                           print mountain_sports
['diving', 'HIKING']
['CLIMBING', 'HIKING']
```

In this example, we first change the element in position 1 to uppercase (line 1), and then we append the changed element to the list `mountain_sports` (line 2). When we print out the two lists (lines 3 and 4), we see that the element "HIKING" is uppercase in both lists. As you can imagine, changing the element in the original list is not the best option because we might need the original list `sports` for further computations. How do we make "hiking" uppercase only in `mountain_sports`? Let's have a look at the next example.

Case 2: *Changing the element only in the new list.*

Consider the following code:

<pre>[3]: 1 current_sport = sports[1].upper() 2 mountain_sports.append(current_sport) 3 print(sports) 4 print(mountain_sports) ['diving', 'hiking'] ['CLIMBING', 'HIKING']</pre>	<pre>current_sport is assigned sports in position 1 dot upper mountain_sports dot append current_sport print sports print mountain_sports</pre>
--	---

In this example, we assign the transformed element—that is, 'HIKING', created with the command `sports[1].upper()`—to a new variable. This new variable is `current_sport`(line 1). Then, we append the variable `current_sport` to the list `mountain_sports` (line 2). When we print out both lists (lines 3 and 4), we see that "HIKING" is only in the list `mountain_sports`. We can call `current_sport` an **intermediary**, **auxiliary**, or **temporary** variable. Its role is to temporarily store a value that we will use in subsequent code. Although they are very convenient, temporary variables are generally not recommended because they occupy computer memory. Can we avoid using `current_sport`? Yes, let's have a look at this last example:

<pre>[3]: 1 mountain_sports.append(sports[1].upper()) 2 print(sports) 3 print(mountain_sports) ['diving', 'hiking'] ['CLIMBING', 'HIKING']</pre>	<pre>mountain_sports dot append sports in position 1 dot upper() print sports print mountain_sports</pre>
--	---

In this final example, there is a **nested command**, which is a command containing one or more commands, like in a Russian doll (line 1). To break down nested commands, we usually start from the inner command and move outwards. In this example, the inner command is `sports[1].upper()`, where we modify the string 'hiking' to be uppercase. The outer command is `mountain_sports.append()`, where we add the modified element—that is, 'HIKING'—to the list. As you can see, the inner command is what we assigned to the variable `current_sport` in the previous example. Therefore, we can avoid a temporary variable by directly substituting its content in a nested command. Finally, when we print out both lists (lines 2 and 3), we see that we changed "hiking" to uppercase only in the list `mountain_sports`.

Nested commands are a convenient way to write compact code. How many commands can we nest into each other? Theoretically, as many as we want! In practice, we want to keep nested commands to a minimum for a good balance between code efficiency and code readability.



Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter:
 - a. *Editing an article.* You work at a newspaper, and you have to edit a paper that has plenty of acronyms:
`acronyms = ["asap", "faq", "fyi", "diy"]`

All the acronyms are lowercase, so you change them to uppercase.

- b. Name tags. You are organizing an event, and you have the following list of names:

```
names = ["JOHN", "geetha", "xiao", "LAURA"]
```

You want to print out nice name tags, so you capitalize all names.

2. Colors. Given the following list:

```
colors = ["yellow", "beige", "green", "red", "ultramarine", "coral", "lavender",
"silver", "cyan", "blue", "black", "magenta", "gold", "pink", "scarlet", "brown"]
```

- How many colors are there? Compute it!
- Starting from the second element (position 1), change every third word to uppercase.
- Starting from the third element (position 2), capitalize every third word.
- Add all the colors of the first half of the list `colors` to the following list using a `for` loop, making sure they are lowercase:

```
some_colors = ["white"]
```

How many colors are there in `some_colors` now?

- Add all the colors of the second half of the list `colors` to the following list using slicing:

```
more_colors = ["purple"]
```

How many colors are there in `more_colors` now? Change them to uppercase.

3. Camping. Given the following list:

```
camping = ["tent", "adventure", "boots", "hiking", "hat", "nature", "path", "lake",
"mountain_sports", "fire", "water bottle", "fishing", "national park", "beach",
"compass", "forest", "trail", "sleeping bag"]
```

- How many elements are in there?
- Get all the words composed of less than (including) 6 letters and add them to the following list, capitalizing each word:
`short_camping = ["Trip"]`
- Slice every second word of the list `camping` starting from the first word (position 0) and assign them to a new variable called `some_camping_words`.
- Capitalize each word of the strings in `some_camping_words` composed of a number of characters other than 4.
- In `some_camping_words`, remove the first word (position 0) using a list method.
- In `some_camping_words` remove "path" using a list method.
- Are there more words in `short_camping` or `some_camping_words`? Use an `if/else` construct to print out which list has more words, as well as how many words they contain.

12. What a mess at the bookstore!

For loop to create new lists

Let's finally learn how to use a `for` loop to create new lists. Open Jupyter Notebook 12 and follow along. Once more, don't forget to read the code out loud!

- There were many customers in the shop today, and they mixed up the books whose authors' last names start with A and S:

```
[:] 1 authors = ["Alcott", "Saint-Exupéry",
    "Arendt", "Sepulveda", "Shakespeare"]  
authors is assigned Alcott,  
Saint-Exupéry Arendt, Sepulveda,  
Shakespeare
```

- So you have to put the books whose authors' last name starts with A on one shelf, and the books whose authors' last name starts with S on another shelf:

```
[:] 1 # initialize the variables as empty lists  
2 shelf_a = []  
3 shelf_s = []  
4  
5 # for each position in the list  
6 for i in range(len(authors)):  
7  
8     # print out the current element  
9     print("The current author is: " +  
10       authors[i])  
11  
12     # get the initial of the current author  
13     author_initial = authors[i][0]  
14  
15     print("The author's initial is: " +  
16       author_initial)  
17  
18     # if the author's initial is A  
19     if author_initial == "A":  
20         # add the author to the shelf a  
21         shelf_a.append(authors[i])  
22         print ("The shelf A now contains: " +  
23             str(shelf_a) + "\n")  
24  
25     # otherwise (author's initial is not A)  
26     else:  
27         # add the author to the shelf s  
28         shelf_s = shelf_s + [authors[i]]  
29  
30         print ("The shelf S now contains: " +  
31             str(shelf_s) + "\n")  
  
initialize the variables as empty lists  
shelf a is assigned an empty list  
shelf s is assigned an empty list  
  
for each position in the list  
for i in range len of authors  
  
print out the current element  
print The current author is:  
concatenated with authors in position  
i  
  
get the initial of the current author  
author initial is assigned authors in  
position i in position zero  
print The author's initial is:  
concatenated with author_initial  
  
if the author's initial is A  
if author_initial equals A  
add the author to the shelf a  
shelf a dot append authors in position i  
print The shelf A now contains:  
concatenated with str of shelf a  
concatenated with backslash n  
  
otherwise (author's initial is not A)  
else  
add the author to the shelf s  
shelf s is assigned shelf_s concatenated  
with authors in position i  
print The shelf S now contains:  
concatenated with str of shelf s  
concatenated with backslash n
```

```

27 # print out the final shelves
28 print ("The authors on the shelf A are: " +
str(shelf_a)
29 print ("The authors on the shelf S are: " +
str(shelf_s)

```

```

print out the final shelves
print The authors on the shelf A are:
concatenated with str of shelf a
print The authors on the shelf S are:
concatenated with str of shelf s

```

What are the new concepts in this code? Complete the following exercise to get some hints.

True or false?

- | | | |
|--|---|---|
| 1. We initialize an empty list by assigning a pair of square brackets | T | F |
| 2. We can compose several slicings in one command | T | F |
| 3. The method .append() and list concatenation perform two different actions | T | F |
| 4. The special character "\n" creates an empty line after a print | T | F |

Computational thinking and syntax

Let's run the first cell:

```
[1]: 1 authors = ["Alcott", "Saint-Exupéry",
"arendt", "Sepulveda", "Shakespeare"]
```

```
authors is assigned Alcott,
Saint-Exupéry Arendt, Sepulveda,
Shakespeare
```

The list `authors` is composed of five strings, each of them corresponding to the last name of a book author. The last names start with either A or S.

Let's run the second cell. The code is long, so we break it in pieces. Here are lines 1–3:

```
[2]: 1 # initialize the variables as empty lists
2 shelf_a = []
3 shelf_s = []
```

```
initialize the variables as empty lists
shelf a is assigned an empty list
shelf s is assigned an empty list
```

We create two new lists, `shelf_a` and `shelf_s`, to which we assign a pair of empty square brackets. Technically, we say that we **initialize two empty lists**—meaning that we create the two lists `shelf_a` and `shelf_s`, but they don't have any content yet. Why do we do that? We will answer this question when we analyze lines 18 and 24. So, let's keep going!

Let's analyze lines 5–9:

```

5 # for each position in the list
6 for i in range(len(authors)):
7
8     # print out the current element
9     print("The current author is: " +
authors[i])

```

```

for each position in the list
for i in range len of authors

print out the current element
print The current author is:
concatenated with authors in position
i

```

We create a `for` loop to browse all the elements in the list `authors` (line 6), and we print out a sentence to keep track of the list element sliced at each iteration (line 9).

Let's continue with lines 11–13:

```

11     # get the initial of the current author
12     author_initial = authors[i][0]
13
14     print("The author's initial is: " +
15         author_initial)

```

get the initial of the current author
author initial is assigned authors in
position i in position zero
print The author's initial is:
concatenated with author_initial

At each iteration, we obtain the initial of the current author (line 12), and we print it out (line 13). How do we get an author's initial? Let's focus on the right side of the assignment symbol—`authors[i][0]`—at line 12. There are two pairs of square brackets, indicating two consecutive slicings. To understand how this works, let's substitute the variables with their corresponding values. In the first loop, `i` is 0; thus, we get `authors[0][0]`. `authors[0]` is "Alcott", and "Alcott"[0] is "A". Similarly, in the second loop, `i` is 1, thus we get `authors[1][0]`. `authors[1]` is "Saint-Exupéry", and "Saint-Exupéry"[0] is "S". And so on. With the first pair of square brackets `[i]`, we slice a list obtaining a string, whereas with the second pair of square brackets `[0]`, we slice a string obtaining a character. In summary, when dealing with **several consecutive slicings**, we execute one at the time, starting from the left. Note that **string slicing works the same way as list slicing**.

Let's have a look at lines 15–25:

```

15     # if the author's initial is A
16     if author_initial == "A":
17         # add the author to the shelf a
18         shelf_a.append(authors[i])
19         print ("The shelf A now contains: " +
20             str(shelf_a) + "\n")
21
22     # otherwise (author's initial is not A)
23     else:
24         # add the author to the shelf s
25         shelf_s = shelf_s + [authors[i]]
26
27         print ("The shelf S now contains: " +
28             str(shelf_s) + "\n")

```

if the author's initial is A
if author_initial equals A
add the author to the shelf a
shelf a dot append authors in position i
print The shelf A now contains:
concatenated with str of shelf a
concatenated with backslash n

otherwise (author's initial is not A)
else
add the author to the shelf s
shelf s is assigned shelf_s concatenated
with authors in position i
print The shelf S now contains:
concatenated with str of shelf s
concatenated with backslash n

We are still in the `for` loop whose header is at line 6, and we find an `if/else` construct. If the author's initial is equal to A (line 16), we append the current author `authors[i]` to the list `shelf_a` (line 18). Then, we print out the current status of `shelf_a` (line 19). If the author's initial is not A, then we go to the `else` (line 22), and we concatenate the current author `authors[i]` to the list `shelf_s` (line 24). Note that `authors[i]` is in between square brackets for type compatibility: `authors[i]` is a string, so it must be transformed into a list to be concatenated to the list `shelf_s` (we learned this at cell 6 of Chapter 7). Finally, we print the current status of `shelf_s` (line 25). Let's now look at a few more details.

At lines 18 and 24, we add an element to a list. In the first case, we use the list method `.append()`, whereas in the second case, we use concatenation. The two approaches perform exactly the same operation and can be used interchangeably.

At the end of the print commands at lines 19 and 24, you'll notice "`\n`". What's that? It's a **special character** that creates an empty line after a print. The backslash \ tells Python to consider `n` not as a letter of the alphabet, but as a special character meaning *new line*. Printing an empty line is another way to increase code readability in a `for` loop, in addition to printing loop titles (see Chapter 9, cell 2).

You will see more special characters in the *In more depth* section of Chapter 27.

Finally, we can answer the question we asked at lines 1–3: why do we need to initialize `shelf_a` and `shelf_s` as empty lists? Because it would be impossible to add new elements to a list that does not exist!

As a general rule, **when using a `for` loop to create and fill an empty list**, we have to:

1. Initialize an empty list before the `for` loop
2. Concatenate or append new elements within the `for` loop

Let's conclude with lines 27–29:

```
27 # print out the final shelves
28 print ("The authors on the shelf A are: " +
str(shelf_a)
29 print ("The authors on the shelf S are: " +
str(shelf_s))
```

print out the final shelves
print The authors on the shelf A are:
concatenated with str of shelf a
print The authors on the shelf S are:
concatenated with str of shelf s

Above, we print out the final versions of the created lists—`shelf_a` (line 28) and `shelf_s` (line 29). In both cases, we transform the list to a string using the built-in function `str()` to concatenate.

Finally, let's look at the printouts:

```
The current author is: Alcott
The author's initial is: A
The shelf A now contains: ['Alcott']

The current author is: Saint-Exupéry
The author's initial is: S
The shelf S now contains: ['Saint-Exupéry']

The current author is: Arendt
The author's initial is: A
The shelf A now contains: ['Alcott', 'Arendt']

The current author is: Sepulveda
The author's initial is: S
The shelf S now contains: ['Saint-Exupéry', 'Sepulveda']

The current author is: Shakespeare
The author's initial is: S
The shelf S now contains: ['Saint-Exupéry', 'Sepulveda', 'Shakespeare']

The authors on the shelf A are: ['Alcott', 'Arendt']
The authors on the shelf S are: ['Saint-Exupéry', 'Sepulveda', 'Shakespeare']
```

Each triplet of lines of code is printed during a `for` loop iteration. The first line is printed at line 9 (e.g., `The current author is: Alcott`), the second line is printed at line 13 (e.g., `The author's initial is: A`), and the third line is printed at line 19 if the author's initial is A (e.g., `The shelf A now contains: ['Alcott']`), or at line 25 if the author's initial is S (e.g., `The shelf S now contains: ['Saint-Exupéry']`). After each group of 3 lines, there is an empty line because of "`\n`" at the end of the print commands at lines 19 and 25. The last two lines containing the final content of `shelf_a` and

`shelf_s` come from the prints at lines 28 and 29. Finally, the code contains several comments and empty lines between blocks of code to improve readability.

Match the code

Before starting coding, let's summarize what we learned about `for` loops! Given the following list:

```
hot_drinks = ["tea", "coffee", "hot chocolate"]
```

Connect each command with the correct output and the corresponding action:

- | | | |
|--|--|------------------------|
| 1. <code>for i in range(len(hot_drinks)):</code> | a. <code>['TEA', 'coffee', 'hot chocolate']</code> | ★.create list elements |
| <code>print(hot_drinks[i])</code> | | |
| 2. <code>for i in range(len(hot_drinks)):</code> | b. tea | ♣.change list elements |
| <code>if hot_drinks[i][0] == "c":</code> | coffee | |
| <code>print(hot_drinks[i])</code> | hot chocolate | |
| 3. <code>for i in range(len(hot_drinks)):</code> | c. <code>['coffee', 'hot chocolate']</code> | ■.print list elements |
| <code>if len(hot_drinks[i]) == 3:</code> | | one by one |
| <code>hot_drinks[i] = hot_drinks[i].upper()</code> | | |
| <code>print(hot_drinks)</code> | | |
| 4. <code>long_words = []</code> | d. coffee | ▲.find list elements |
| <code>for i in range(len(hot_drinks)):</code> | | |
| <code>if len(hot_drinks[i]) >= 6:</code> | | |
| <code>long_words.append(hot_drinks[i])</code> | | |
| <code>print(long_words)</code> | | |

Recap

- To create and fill a list in a `for` loop, we have to: (1) initialize an empty list *before* the `for` loop and (2) fill the list using `.append()` or list concatenation *in* the `for` loop.
- String slicing works the same way as list slicing.
- In multiple consecutive slicings, we execute one slicing at a time, starting from the left.
- The special character "`\n`" creates an empty line after a `print`.

Append or concatenate. Don't assign!

When creating a new list within a `for` loop, a common mistake is to assign a new element to the list instead of appending it or concatenating it. Let's see what this means with the following example. Here is the same list as the one used earlier in this chapter:

<pre>[1]: 1 authors = ["Alcott", "Saint-Exupéry", "Arendt", "Sepulveda", "Shakespeare"]</pre>	<code>authors</code> is assigned Alcott, Saint-Exupéry Arendt, Sepulveda, Shakespeare
---	---

Let's simplify the code by creating only the list containing author last names starting with A. To show how an error can occur, at line 10 we assign `authors[i]` to the new list `shelf_a`, instead of appending it (or concatenating it). What happens to `shelf_a` throughout the code?

<pre>[2]: 1 # initialize the variable 2 shelf_a = [] 3 # for each position in the list 4 for i in range(len(authors)): 5 # get the author's initial 6 author_initial = authors[i][0] 7 8 # if the author's initial is A 9 if author_initial == "A": 10 # add the author to the shelf a 11 shelf_a = authors[i] 12 13 print ("The shelf A now 14 "contains: " + str(shelf_a)) 15 # print out the final shelves 16 print ("The authors on the shelf A are: " 17 + str(shelf_a))</pre>	<code>initialize the variable</code> <code>shelf_a</code> is assigned an empty list for each position in the list <code>for i in range len of authors</code> get the author's initial <code>author_initial</code> is assigned <code>authors</code> in position <code>i</code> in position zero if the author's initial is A <code>if author_initial equals A</code> add the author to the shelf a <code>shelf_a</code> is assigned <code>authors</code> in position <code>i</code> <code>print The shelf A now contains:</code> <code>concatenated with str of shelf_a</code> <code>print out the final shelves</code> <code>print The authors on the shelf A</code> <code>are: concatenated with str of shelf</code> <code>a</code>
---	---

```
The shelf A now contains: Alcott
The shelf A now contains: Arendt
The authors on the shelf A are: Arendt
```

Let's go through the `for` loop and focus on the names starting with A:

- When `i` is 0 (line 4), `author_initial` is "A" (line 6); the `if` condition is true (line 8), so we assign `authors[i]`—that is, "Alcott"—to `shelf_a` (line 10), and we print out `The shelf A now contains: Alcott` (line 11). With the assignment at line 10, we implicitly transform `shelf_a` from a list—which we initialized at line 2—into a string—because we assign it the string "Alcott".
- When `i` is 2 (line 4), `author_initial` is "A" (line 6); the `if` condition is true (line 8), we assign `authors[i]`—that is, "Arendt"—to `shelf_a` (line 10), and we print out: `The shelf A now contains: Arendt` (line 11). In this case, in the assignment at line 10, we overwrite the value "Alcott"—which we assigned in the previous loop—with the value "Arendt"; thus, `shelf_a` remains a string.

At line 13, we print the final version of `shelf_a`, which is a string with value "Arendt".

In conclusion, assigning a variable to a list (e.g., `shelf_a = authors[i]`) changes the type of the list itself to the variable type (e.g., `shelf_a` becomes a string). In addition, the value is overwritten at each loop, and the final value is the one assigned in the last loop. Thus, the correct way to add

elements to a list is either to append—e.g., `shelf_a.append(authors[i])`—or concatenate—e.g., `shelf_a = shelf_a + [authors[i]]`.

Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter.
 - a. *Selling electric cars.* You work at a famous car company, and you have to ship new electric cars that have just arrived. Your colleagues plated the cars destined to Spain and to Portugal, but they mixed them up:
`e_cars = ["PT-754J", "ES-096L", "PT-536G", "ES-543H", "PT-653H"]`
 Separate the two groups of cars according to their destinations.
 - b. *Teaching English verbs.* You are an English teacher for foreign students. Some of them have difficulties understanding when a present verb is conjugated in the third person singular (he/she/it), or in other persons (I/you/we/they). So you provide a list of verbs:
`english_verbs = ["eat", "drink", "eats", "sleep", "drinks", "sleeps"]`
 and you help your students separate the verbs between third person and other persons.

2. *Desserts.* Given the following list:

```
desserts = ["meringue", "apple pie", "clair", "rice pudding", "chocolate",
"english pudding", "cake", "icing"]
```

Get all the initials, change them to uppercase, and concatenate them in a new list. Then invert the list. What dessert do you get?

3. *Guess the jobs.* Given the following list:

```
jobs = ["photog", "bal", "mu", "inve", "ambas", "si", "ler", "stig", "rapher", "ci",
"ator", "ina", "an", "sador"]
```

Group strings composed of 2, 3, 4, 5, and 6 letters in new lists. What jobs do you get? Make sure that the first letter of each job is uppercase.

4. *Art.* Given the following list:

```
art = ["apor", "refsscu", "atwat", "fetes", "erta", "jtylpt", "aprco", "srap",
"ruolo", "texture", "gitp", "puors"]
```

Create new lists for each of the following:

- If the string length is 4, then get two letters starting from the second (positions 1 and 2).
- If the string length is 5, then get the third and fourth letters (positions 2 and 3).
- If the string length is at least 6, then get the last three letters.

What art words do you get? Make sure all strings are uppercase!

PART 4

NUMBERS AND ALGORITHMS

In this part, you will learn how to perform arithmetic operations, play with random numbers, and implement your first algorithms. Ready? Let's start!

13. Implementing a calculator

Integers, floats, and arithmetic operations

In the previous chapters, you have developed quite a bit of computational thinking, so now you are ready for numbers, some easy math, and algorithms! There is a general misconception that in order to be good at coding one has to be very good at math. However, that's not necessarily true, as you will see in the coming chapters!

In this chapter, you will start becoming familiar with numbers in coding by implementing a calculator. To do that, you first need to learn arithmetic operators in Python and how to ask a user for a number. As in previous chapters, try first to solve the task by yourself and then compare your answer with the code below. You will find the code also in Jupyter Notebook 13. Let's start!

1. What are the arithmetic operations in Python?

In Python, there are 7 arithmetic operations. Let's quickly explore them one by one. Which ones do you already know, and which ones are new?

1. Addition:

```
[1]: 1 4 + 3          four plus three  
      7
```

To sum two numbers, we use the arithmetic operator `+`, pronounced *plus*. As you know, the same symbol `+` is used as a concatenation symbol when merging strings or lists; in that case, it is pronounced *concatenated with*.

2. Subtraction:

```
[2]: 1 6 - 2          six minus two  
      4
```

To subtract one number from another, we use the arithmetic operator `-`, pronounced *minus*.

3. Multiplication:

```
[3]: 1 6 * 5          six times five  
      30
```

To multiply two numbers, we use the multiplication operator `*`, which is pronounced *times*. Note that in Python (and in other programming languages), the multiplication symbol is different from the symbol used in paper-and-pencil computations, which can be the cross symbol `x` or the mid-line dot operator `.`.

4. Exponentiation:

```
[4]: 1 2 ** 3          two to the power of three  
      8
```

To calculate the power of a number, we use the exponentiation operator `**`, which is pronounced *to the power of*. The operation `2**3` corresponds to 2^3 in paper-and-pencil.

5. Division:

[5]:	4	10	/	5
		2.0		

ten divided by five

To divide a number by another number, we use a forward slash `/`, and we pronounce it *divided by*. Note that the result of a division is always a decimal number.

6. Floor division:

[6]:	5	7	//	4
		1		

seven floor division four

To execute a floor division, we use the operator `//`, composed of two forward slashes and pronounced *floor division*. A floor division is a division where the result is rounded to the **closest lower integer**. In this example, the result of the corresponding division `/` would be 1.75, thus the result of the floor division is 1, which is the closest lower integer to 1.75. The word *floor* indicates that we round the result down, that is—using a metaphor—to the floor of a house.

7. Modulo:

[7]:	7	7	%	4
		3		

seven modulo four

To calculate a modulus, we use the operator `%`, which is pronounced *modulo*. This operation calculates a **remainder** (or modulus), which is the number needed to go back to the dividend after a floor division. For example, from cell 6 we know that the result of the floor division `7//4` is 1. If we multiply 1 (the result) times 4 (the divisor), we get 4 ($4 \times 1 = 4$). To get to 7 (the dividend), we need 3, which is the modulus ($4 + 3 = 7$). Note that modulo is the name of the operator, while modulus is the name of the operation and a synonym for remainder. The modulus operation is used quite often in coding, as you will see in the next chapter.

To summarize, Python provides seven arithmetic operators:

- 1 for addition (+);
- 1 for subtraction (-);
- 2 for the “multiplication family”, which are multiplication (*) and exponentiation (**);
- 3 for the “division family”, which are division (/), floor division (//), and modulo (%).

Note that the division operators can provide *whole numbers* or *decimal numbers* as results, independently of the characteristics of dividend and divisor. Discover more nuance by solving the following exercise. Test your answers in Python!

 True or false?

1. The result of a division is always a whole number (e.g., without decimals). For T F
example, the result of `11/5` is the whole number 2
2. The result of `7//2` is 3, but the result of `-7//2` is -4. This is because the floor T F
division rounds to the closest lower integer
3. The result of `7.5 % 3` is 1.5. Therefore, the result of a modulus operation can be T F
a decimal number

2. How do we ask a user to input a number?

When asking a user to input a number, it's important to be careful about variable types. Let's see what this means!

- Ask a user to input a number, assign it to a variable, and print out the variable:

<pre>[8]: 1 number = input("Insert a number:") 2 print(number)</pre>	number is assigned input Insert a number: print number
<pre>Insert a number: 9</pre>	9

We use the built-in function `input()` to ask the user to type a number, and we save the answer in the variable `number` (line 1). Then, we print out the variable value (line 2). What type do you expect the variable `number` to be? Let's find out!

- Check the type of the variable `number`:

<pre>[9]: 1 type(number) 2 str</pre>	type number
--	-------------

To know the type of a variable, we use the built-in function `type()`, which **takes a variable as an input and returns its type**. In the printout, we see that the type of `number` is `str`, which is an abbreviation for string. But shouldn't 9 be an integer? Yes! However, `number` is a string because the built-in function **input() returns strings**, regardless of what a user types on a keyboard (characters, numbers, or symbols). To transform the value of `number` into an actual number that we can use in calculations, we have to transform its type from string to integer.

- Transform `number` into an integer, print it out, and check its type:

<pre>[10]: 1 number = int(number) 2 print(number) 3 type(number)</pre>	number is assigned int of number print number type number
<pre>9</pre>	int

The built-in function **int() takes a non-integer variable as an input and returns it as an integer**. Note that to actually transform a variable type, we need to **reassign** the output of the built-in function `int()` to the variable itself (line 1). At line 2, we print `number`, which is still 9. However, this time `number` is of type `int`, as we can see from `type(number)` at line 3. What if we want a decimal number? In that case, we have to transform the variable type into `float`!

- Transform `number` into a float, print it out, and check its type:

<pre>[11]: 1 number = float(number) 2 print(number) 3 type(number)</pre>	number is assigned float of number print number type number
<pre>9.0</pre>	float

The built-in function **float() takes a non-decimal variable as an input and returns it as a decimal**. Also in this case, we need to reassign the output of `float()` to the variable itself to actually change the data type (line 1). From the print at line 2, we see that the variable `number` is now `9.0`, that is, a decimal number. And from the command at line 3, we can see that `number` is now of type `float`. Let's close the circle, and go back to the variable `number` being a string! How would you do that?

- Transform number back into a string, print it out, and check its type:

```
[12]: 1 number = str(number)
        2 print(number)
        3 type(number)
```

9.0	number is assigned str of number
str	print number
	type number

To transform a variable into a string, we use the built-in function `str()`, which we learned in Chapter 8. Note that because we transform `number` into a string from a float (and not an integer), the value is now `9.0`—that is, it contains the decimal component.

Numerical variables can be of three types:

- **Integers** (whole numbers), used in computations;
- **Floats** (decimal numbers), used in computations;
- **Strings**, when we need numbers as text—for example, when concatenating them to strings.

We finally know arithmetic operations in Python and how to ask a number to a user. So we are ready to create a calculator! Where do we start? From the user inputs! Let's find out the inputs in the following exercise.

Complete the sentences

Complete the following sentences with the inputs you need from a user to implement a calculator. If you are not sure, think about what you enter when using a calculator:

1. The first input is _____ .
2. The second input is _____ .
3. The third input is _____ .

3. Let's create the calculator!

- Ask the user for the first input, which is the first number. What type should it be?

```
[13]: 1 first_number = input("Insert the first
        2     number:")
        3     first_number = float(first_number)

        type(first_number)
Insert the first number: 4
float
```

first_number is assigned input Insert the first number:
first_number is assigned float of first_number
type first number

We ask the user to input the first number using the built-in function `input()`, and we assign the user's choice to the variable `first_number` (line 1). Then, we need to transform the type of `first_number` from a string into a numerical type to perform calculations. Which type do we choose: integer or float? If the user enters a whole number, we need to transform `first_number` into an integer. But what if the user enters a decimal number? Then, we need to transform `first_number` into a float! So we

go for an inclusive solution, that is, transforming `first_number` into a float to comprehend both whole numbers and decimal numbers. Thus, we use the built-in function `float()`, and we reassign to the variable `first_number` (line 2). Finally, we print out `first_number`'s type to check that it's correct (line 3).

- Ask the user for the second input, which is the arithmetic operator:

<pre>[14]: 1 operator = input("Insert an arithmetic operator:") 2 type(operator)</pre>	<pre>operator is assigned input Insert an arithmetic operator: type operator</pre>
<pre>Insert the arithmetic operator: + str</pre>	

We ask the user for an arithmetic operator and we save the value in the variable `operator` (line 1). Because an arithmetic operator is a symbol, we keep it as a string, and we print out its type to check for correctness (line 2).

- Finally, ask the user for the third and final input, which is the second number. What type should it be?

<pre>[15]: 1 second_number = float(input("Insert the second number:")) 2 type(second_number)</pre>	<pre>second_number is assigned float of input Insert the second number: type second number</pre>
<pre>Insert the second number: 3 float</pre>	

As we did for `first_number`, we ask the user for the second number using the built-in function `input()`. Then, we need to transform the user's choice from string to float using the built-in function `float()`. Instead of using two separate commands like we did at cell 13 (lines 1 and 2), we **nest the two built-in functions one into the other**: we transform the user's choice into a float before assigning it to the variable `second_number` (line 1). Then, we print out the `second_number`'s type to make sure that it's a float (line 2).

- Let's write the core of the calculator! How would you do it? Try out some ideas before looking at the implementation below:

<pre>[16]: 1 if operator == "+": 2 result = first_number + second_number 3 4 elif operator == "-": 5 result = first_number - second_number 6 7 elif operator == "*": 8 result = first_number * second_number 9 10 elif operator == "**": 11 result = first_number ** second_number 12 13 elif operator == "/": 14 result = first_number / second_number</pre>	<pre>if operator is equal to plus result is assigned first number plus second number elif operator is equal to minus result is assigned first number minus second number elif operator is equal to times result is assigned first number times second number elif operator is equal to to the power of result is assigned first number to the power of second number elif operator is equal to divided by result is assigned first number divided by second number</pre>
---	--

```
11 elif operator == "//":  
12     result = first_number // second_number  
  
13 elif operator == "%":  
14     result = first_number % second_number  
  
15 else:  
16     print("You didn't enter an  
         arithmetic operator")  
  
17 print(result)  
7.0
```

elif operator is equal to floor division
result is assigned first number floor
division second number
elif operator is equal to modulo
result is assigned first number modulo
second number
else
print You didn't enter an arithmetic
operator
print result

The operation that our code will execute depends on the arithmetic operator entered by the user; thus, we need to take into account all possibilities. To do that, we create a long list of conditions for the arithmetic operator, with the corresponding calculations. We start by considering addition (lines 1 and 2). In the `if` condition, we check if the variable `operator` from cell 14 is equal to the symbol `+`. Because `operator` is a string, we need to consider the addition operator as a string as well, so we embed it in between quotes (i.e., `"+"`) (line 1). In the subsequent statement, we calculate the sum between the two numerical variables (`first_number` and `second_number`) entered by the user, and we assign the result to the variable `result` (line 2). Then, we consider subtraction (lines 3 and 4). We structure the code as we did above: first, we write a condition where we check that the variable `operator` is equal to the string `" - "` (line 3); then, we execute the difference between the two numbers entered by the user, and we assign the result to the variable `result` (line 4).

As you might have noticed, the condition at line 3 started with the keyword `elif`, which is an abbreviation for `else if`. We use `elif` when we check **several conditions on one single variable**, which is `operator` in this case. We continue the code with a similar structure for the remaining arithmetic operations (lines 5-14). When using an `if/elif/else` construct, make sure to **always test code under all conditions**. To do that in our example, re-enter the variables `first_number`, `operator`, and `second_number` for each condition and make sure that what gets printed is the one you expected. We conclude the list of conditions with an `else` (line 15), which prints out a warning in case the user did not enter a valid arithmetic operator (line 16). Finally, we print out the variable `result` to check that our code is correct (line 17). Note that we print `result` at the end of the `if/elif/else` construct instead of after each statement (lines 2,4,6,8,10,12,14) to avoid redundancy.

- Finally, let's print out the result:

```
[17]: 1 print (str(first_number) + " " + operator  
      + " " + str(second_number) + " = " +  
      str(result))  
  
4.0 + 3.0 = 7.0
```

print str of first_number concatenated
with space concatenated with operator
concatenated with space concatenated with
str of second_number concatenated with
equals concatenated with str of result

We print the result, concatenating `first_number`, `operator`, `second_number`, and `result`. Note that we convert the numerical variables into strings for the concatenation.

Finally, let's put together our code to create a real calculator by merging all lines from the code above into one single cell. This will allow us to run only one cell (instead of multiple cells) when executing the code:

```
[18]: 1 # first input
2 first_number = float(input("Insert the
3   first number:"))
4
5 # operator
6 operator = input("Insert an arithmetic
7   operator:")
8
9 # second input
10 second_number = float(input("Insert the
11   second number:"))
12
13 # computations
14 if operator == "+":
15     result = first_number + second_number
16
17 elif operator == "-":
18     result = first_number - second_number
19
20 elif operator == "*":
21     result = first_number * second_number
22
23 elif operator == "**":
24     result = first_number ** second_number
25
26 elif operator == "/":
27     result = first_number / second_number
28
29 elif operator == "//":
30     result = first_number // second_number
31
32 elif operator == "%":
33     result = first_number % second_number
34
35 else:
36     print("You didn't enter an
37       arithmetic operator")
38
39 # print the result
40 print(str(first_number) + " " + operator
41 + " " + str(second_number) + " = " +
42 str(result))
```

first input
first_number is assigned float of input
Insert the first number:

operator
operator is assigned input Insert an arithmetic operator:

second input
second_number is assigned float of input
Insert the second number:

computations
if operator is equal to plus
result is assigned first number plus second number
elif operator is equal to minus
result is assigned first number minus second number
elif operator is equal to times
result is assigned first number times second number
elif operator is equal to to the power of
result is assigned first number to the power of second number
elif operator is equal to divided by
result is assigned first number divided by second number
elif operator is equal to floor division
result is assigned first number floor division second number
elif operator is equal to modulo
result is assigned first number modulo second number
else
print You didn't enter an arithmetic operator

print the result
print str of first_number concatenated with space concatenated with operator concatenated with space concatenated with str of second_number concatenated with equals concatenated with str of result

When we merge code in one cell at the end of an implementation, we usually edit and clean it up for better **readability**. In this example, we directly transform `first_number` in a float by nesting the built-in function `input()` into the built-in function `float()` (line 2); we delete all the intermediate prints (i.e., we remove line 3 from cell 13, line 2 from cells 14 and 15, and line 17 from cell 16); and we add comments (lines 1, 4, 7, 10, and 28) and lines spaces (lines 3, 6, 9, 27).

Complete the table

In this chapter, you learned the seven arithmetic operators. Sum up their characteristics in your own words in the table below:

Arithmetic operator	Operation	Pronunciation
+		
-		
*		
**		
/		
//		
%		

Recap

- There are seven arithmetic operators in Python: `+`, `-`, `*`, `**`, `/`, `//`, `%`.
- Numbers can be represented by three data types: integers for whole numbers, floats for decimal numbers, and strings as text.
- To transform a variable into an integer, we use the built-in function `int()`; to transform a variable into a float, we use the built-in function `float()`.
- To check the type of a variable, we use the built-in function `type()`.
- We use the keyword `elif` to check multiple conditions on the same variable.

Solving arithmetic expressions

Arithmetic expressions are combinations of arithmetic operations. As we do in paper-and-pencil expressions, we execute operations in a specific order, which is summarized by the acronym BEDMAS. First, we perform operations between brackets, then we compute exponentiation, division, multiplication, addition, and subtraction. Here is an example:

```
[1]: 1 6 + 2 * 3           six plus two times three
      12
```

First we execute the multiplication, followed by the addition. Thus, we first calculate $2 * 3$, which is 6, and then $6 + 6$, which is 12.

Here is another example:

```
[2]: 1 (6 + 2) * 3           open round bracket six plus two close round
      24                           bracket times three
```

First, we execute the operation between round brackets $(6 + 2)$, which is 8, and then the multiplication $8 * 3$, which is 24. Note that brackets can only be round in coding.

Let's code!

1. **Math competition.** You are holding a math competition where participants have to choose among three envelopes and solve the arithmetic operation contained in the chosen envelope:
 - If the participant chooses envelope 1, she will have to solve: $(3 \times 5^2 \div 15) - (5 - 2^2)$.
 - If the participant chooses envelope 2, she will have to solve: $-1 \times [(3 - 4 \times 7) \div 5] - 2^3 \times 24 \div 6$.
 - If the participant chooses envelope 3, she will have to solve: $\frac{(36 - 3) \times 4}{(15 - 9) \div 3}$.Compute the solutions.
2. **Geometry tutoring.** You are helping your neighbor's kid with some geometry exercises. He has to calculate the area and volume of a cylinder, and you want to test result correctness using Python. Ask the kid for cylinder radius and height. Then calculate area and volume of a cylinder using these formulas: $area = 2\pi r^2 + 2\pi r h$ and $volume = \pi r^2 h$. Hint: What is the value of π ? Assign it to a variable! He also has to calculate surface and area of a cube of edge length $a = 4$. He does not have the right formulas, so you look for them on the internet. Write code to test whether his calculations are correct.
3. **What's the temperature out there?** You are traveling between Europe and North America, and you need to pack the right clothes. Write a temperature converter, knowing that the relation between Celsius and Fahrenheit degrees is $C = 5 \div 9 \times (F - 32)$. Answer these two questions:
 - a. The temperature in Miami is 75°F. What is the temperature in Celsius?
 - b. The temperature in Lisbon is 17°C. What is the temperature in Fahrenheit?

14. Playing with numbers

Common operations with lists of numbers

Lists of numbers are one of the most used data structures in coding. They follow the same rules as lists of strings—that is, we can use slicing and methods (e.g., `.append()`, `.remove()`, etc.) to manipulate them. In this chapter, we will explore some typical tasks performed with lists of numbers. Open Jupyter Notebook 14 and follow along. As we've done previously, try first to solve the task by yourself: start by defining the expected solution, outline the steps to reach it, and then write the code to solve it. When you are done, compare your implementation with the one proposed here.

1. Changing numbers based on conditions

One of the most common tasks in coding is changing numbers in a list based on some conditions. Let's have a look at this example!

- Given the following list of numbers:

```
[1]: 1 numbers = [12, 3, 15, 7, 18] numbers is assigned twelve, three, fifteen, seven, eighteen
```

We start with a list containing five integers.

- Subtract 1 from the numbers greater than or equal to 10, and add 2 to the numbers that are less than 10:

```
[2]: 1 # for each position in the list for i in range(len(numbers)): for each position in the list for i in range len of numbers

2     # if current number >= 10 if numbers[i] >= 10:

3         # subtract 1 numbers[i] = numbers[i] - 1 if current number is greater than or equal to ten
if numbers in position i is greater than or equal to ten
subtract one
numbers in position i is assigned numbers in
position i minus one

4     # otherwise
5     else: otherwise
6         # add 2 add two
7         numbers[i] = numbers[i] + 2 numbers in position i is assigned numbers in
position i plus two

8
9
10
11
12
13
14 # print the final result
15 print(numbers) print the final result
print numbers

[11, 5, 14, 9, 17]
```

We implement a `for` loop to browse all the elements of the list `numbers` (line 2). Then, we use an `if/else` construct to define a condition and compute accordingly. If the current number—that is, `numbers[i]`—is greater than 10 (line 5), we subtract 1, and we reassign the result to `numbers[i]` (line 7), similarly to what we saw in Chapter 11 (cell 2, line 10). If the current number is not greater than or

equal to 10, we jump to the `else` (line 10). Then, we add 2 to the current number, and we reassign (line 12). Let's see how this works step by step:

- In the first loop, `i` is 0 (line 2), `numbers` in position 0 is 12, which is greater than 10 (line 5), so we subtract 1, obtaining 11, and we replace 12 with 11 by reassigning (line 7).
- In the second loop, `i` is 1 (line 2), `numbers` in position 1 is 3, which is not greater than or equal to 10 (line 5), so we jump to the `else` (line 10). There, we add 2 to 3, obtaining 5, and we replace 3 with 5 by reassigning (line 12).
- Etc.

Finally, we print the obtained list to check its correctness (line 15).

2. Separating numbers based on conditions

Another very common task with lists of numbers is to separate numbers into new lists based on given conditions. Let's see an example here!

- Given the following list of numbers:

[3]:	<pre>3 numbers = [2, 10, 7, 5, 0, 9]</pre>	<code>numbers</code> is assigned two, ten, seven, five, zero, nine
------	--	--

We start with a list containing six integers.

- Separate the numbers into two different lists—one for odd numbers, and one for even numbers:

<pre>[4]: 1 # initialize the empty lists 2 even = [] 3 odd = [] 4 5 # for each position in the list 6 for i in range(len(numbers)): 7 8 # if the current number is even 9 if numbers[i] % 2 == 0: 10 # add it to the list even 11 even.append(numbers[i]) 12 # otherwise 13 else: 14 # add it to the list odd 15 odd.append(numbers[i]) 16 17 # check the final results 18 print(even) 19 print(odd)</pre>	<code>initialize empty lists</code> <code>even</code> is assigned an empty list <code>odd</code> is assigned an empty list <code>for each position in the list</code> <code>for i in range len of numbers</code> <code>if the current number is even</code> <code>if numbers in position i modulo two equals zero</code> <code>add it to the list even</code> <code>even dot append numbers in position i</code> <code>otherwise</code> <code>else</code> <code>add it to the list odd</code> <code>odd dot append numbers in position i</code> <code>check the final results</code> <code>print even</code> <code>print odd</code>
---	--

`[2,10,0]`

`[7,5,9]`

We create two empty lists, one that will contain the even numbers (line 2) and one that will contain the odd numbers (line 3). To fill them up, we need a `for` loop together with the list method `.append()` (or with concatenation), as we learned in Chapter 13. Thus, we create a `for` loop that browses all the list numbers one by one (line 6). Then, we use an `if/else` construct to determine whether each element of the list `numbers` will go to even or odd (lines 8–15). How do we **decide if a number is even or odd?**

We know that even numbers are divisible by 2, whereas odd numbers are not. Thus, we can use the **modulo**, one of the seven arithmetic operators we learned in the previous chapter. When divided by 2, even numbers have a modulus (or remainder) equal to 0, whereas odd numbers don't (the remainder is 1!). Therefore, if the remainder of the current list number (e.g., `numbers[i]`) divided by 2 is 0 (line 9), then we append `numbers[i]` to the list `even` (line 11). Otherwise (line 13), we append `numbers[i]` to the list `odd` (line 15). Finally, we print the two lists to check the results (lines 18 and 19).

3. Finding the maximum of a list of numbers

A third very common task when dealing with lists of numbers is to find the maximum (or minimum) number in a list. Try to find the maximum of the list below by yourself, drafting and experimenting with code, before looking into the solution.

- Given the following list of numbers:

```
[5]: 3 numbers = [2, -5, 34, 70, 22]
```

`numbers` is assigned two, minus five, thirty-four, seventy, twenty-two

- Find the maximum number in the list:

```
[6]: 1 # initialize the maximum with the
      first element of the list
  2 maximum = numbers[0]
  3
  4 # for each position in the list
      starting from the second
  5 for i in range(1, len(numbers)):
  6
  7 # if the current number is greater
      than the current maximum
  8     if numbers[i] > maximum:
  9
 10         # assign the number to maximum
 11         maximum = numbers[i]
 12
 13 # print the maximum of the list
 14 print(maximum)
 70
```

initialize the maximum with the first element of the list
`maximum` is assigned `numbers` in position 0

for each position in the list starting from the second
`for i in range one len of numbers`

if the current number is greater than the current maximum
`if numbers in position i is greater than maximum`
assign the number to `maximum`
`maximum` is assigned `numbers` in position i

print the maximum of the list
`print maximum`

We create a variable called `maximum` that will contain the maximum number in the list, and we initialize it with the first number in the list, which is `numbers[0]` (line 2). Then, we employ a `for` loop starting from the second position to the last position of the elements in the list (line 5)—we do not start from 0 because it is not very meaningful to compare the value of `numbers[0]` (from the `for` loop) to itself (assigned to `maximum`). Then, we check if the current number is greater than the maximum (line 8). If so, we assign the number to the maximum (line 10). If not, we do not need to perform any action; therefore, we can skip the `else` and a following statement. Finally, we print out the maximum (line 13). In other words, we assign the first number of the list—that is, 2—to a variable that we call `maximum` (line 1). Then, we compare all the subsequent numbers of the list to the value of `maximum`, and if the list number is greater than `maximum`, we assign the list number to `maximum` (lines 5–10). When we look into each iteration, this is what happens:

- When `i` is 1, `numbers[1]` is -5, which is not greater than 2, so we don't do anything.
- When `i` is 2, `numbers[2]` is 34, which is greater than 2. Thus, 34 is the new maximum and we assign it to the variable `maximum`.
- When `i` is 3, `numbers[3]` is 70, which is greater than 34. Thus, 70 is the new maximum and we assign it to the variable `maximum`.
- When `i` is 4, `numbers[4]` is 22, which is not greater than 70, so we don't do anything. Since the `for` loop is over, the value of `maximum` is 70, as we found in the previous iteration.

Finally, why do we initialize the variable `maximum` with the first element of the list and not with a very small number? Suppose that we initialize the variable `maximum` with a small number like `0.000005`. If we try to find the maximum value in the list `[0.000001, 0.000002, 0.000003]` by comparing each element to `maximum`, we won't succeed because all elements in the list are smaller than `0.000005`. As a result, we will incorrectly conclude that the maximum is `0.000005`, while the correct maximum should be `0.000003`. When we look for a maximum, picking a specific number as the initial `maximum` does not allow us to generalize our code. We want to **compare the numbers within the list**.

True or false?

1. To change a number in a list, we need to reassign the new value to the same list T F position.
2. To calculate whether a number is divisible or multiple of another number, we used T F the arithmetic operation floor division.
3. To calculate the maximum of a number in a list, we compare the list numbers with T F each other.

Recap

- When dealing with lists of numbers, some of the basic tasks are:
 - Changing numbers in a list depending on conditions;
 - Separating numbers into new lists based on conditions;
 - Finding the maximum (or minimum) number in a list.

Don't name variables with reserved words!

When naming variables, it's important not to use reserved words, that is, names of built-in functions or keywords. How do we know if a name is a reserved word? And what happens if we used it as a variable name? Consider the following example:

```
[1]: 1 len = 10
      2 print(len)
          10
```

```
len is assigned ten
print len
```

We create a variable called `len` to which we assign the number ten (line 1). As you can see, the **variable name** is colored **green**, which means it is a **reserve word**—we know that `len()` is a Python built-in function, and that variable names are colored black. When we print the variable (line 2), we do not encounter any issue. However, if we want to calculate the length of a list in

subsequent code, we get an error:

```
[2]: 1 numbers = [1, 2, 3]
      2 len(numbers)
-----
TypeError      Traceback (most recent call last)
Cell In[2], line 2
      1 numbers = [1, 2, 3]
----> 2 len (numbers)
TypeError: 'int' object is not callable
```

numbers is assigned one, two,
three
len numbers

The error message says: 'int' object is not callable, which means that we want to use `len` as a function; however, now `len` is an integer! In other words, by naming the variable `len` (cell 1, line 1), we overwrote the function `len` with an integer, and we cannot use it as a function anymore. To solve this issue, we have to restart the kernel, that is, we need to erase all variables and start from scratch (see the *In more depth* section in Chapter 7).



Let's code!

1. *Finding the minimum in a list of numbers.* Given the following list of numbers:

```
numbers = [78, -900, 356, -103, 0, -78]
```

find the minimum number in the list.

2. *Grouping numbers by position.* Given the following list of numbers:

```
numbers = [4, 25, 7, -8, 59, 63, -10, 74]
```

separate the numbers in odd positions from the numbers in even positions using a `for` loop.

3. *Number multiples.* Given the following list of numbers:

```
numbers = [20, 24, 69, 15, 100, 16, 40, 80, 33, 57, 2, 200]
```

create a list for the numbers that are multiples of 10, a list for the numbers that are multiples of 3, and a list for the remaining numbers. Finally, delete the list `numbers`.

4. *Longest and shortest string.* Given the following list of strings:

```
dogs = ["labrador", "chihuahua", "basset hound", "bernese shepherd", "poodle",
"cocker spaniel"]
```

find the longest and the shortest strings. Print out the two strings and their lengths.

5. *Summing numbers in a list.* Given the following list of numbers:

```
numbers = [3, 5, 2]
```

calculate the sum.

6. *Fibonacci sequence.* The Fibonacci sequence is a sequence of numbers where the current number is the sum of the two previous numbers. Write code that asks the user for a number n and prints out the Fibonacci sequence of n .

Hint: Start the sequence as [1,1]

Example:

- User input: 10
- Output: [1, 1, 2, 3, 5, 8, 13, 21, 34, 55].

15. Fortune cookies

The Python module random

Let's continue our discovery of numbers in Python by learning how to generate random numbers. Randomness is quite useful in coding, for example to create games or in scientific simulations. Read the following example and try to understand it. You can find the code in Notebook 15. Let's start!

- You are at a Chinese restaurant, and at the end of the meal, you get a fortune cookie. There are only three fortune cookies left. Each of them contains a message:

```
[]: 1 fortune_cookies = ["The man on the top of the  
mountain did not fall there", "If winter comes,  
can spring be far behind?", "Land is always on  
the mind of a flying bird"]
```

fortune cookies is assigned The
man on the top of the mountain did
not fall there, If winter comes,
can spring be far behind?, Land
is always on the mind of a flying
bird

- Which fortune cookie will you get? Let the computer decide! To do so, the computer needs a Python module called *random*:

```
[]: 1 import random
```

- Here is your message when the computer picks an index:

```
[]: 1 # pick a message index  
2 message_index =  
    random.randint(len(fortune_cookies)-1)  
  
3 print(message_index)  
  
5 # get the message  
6 message = fortune_cookies[message_index]  
  
7 print(message)
```

pick a message index
message index is assigned random
dot randint len of fortune cookies
minus one
print message index

get the message
message is assigned fortune
cookies at message index
print message

- And here is your message when the computer directly picks an element:

```
[]: 1 # pick a message  
2 message = random.choice(fortune_cookies)  
3 print(message)
```

pick a message
message is assigned random dot
choice fortune cookies
print message

✍ True or false?

- | | | |
|--|---|---|
| 1. <code>import</code> is a function | T | F |
| 2. <code>random</code> is a Python module | T | F |
| 3. <code>.randint()</code> and <code>.choice()</code> are functions of the package <code>random</code> | T | F |
| 4. The arguments of the functions <code>.randint()</code> and <code>.choice()</code> are of type <code>string</code> | T | F |

Computational thinking and syntax

Let's begin by running the first cell:

```
[1]: 1 fortune_cookies = ["The man on the top of the
mountain did not fall there", "If winter comes,
can spring be far behind?", "Land is always on
the mind of a flying bird"]
```

fortune cookies is assigned The
man on the top of the mountain did
not fall there, If winter comes,
can spring be far behind?, Land
is always on the mind of a flying
bird

The variable `fortune_cookies` is a list containing 3 strings.

Let's continue with the second cell:

```
[2]: 1 import random import random
```

We use the keyword `import` to import the module `random`. What does this mean? As you know, Python contains basic built-in functions, such as `print()`, `input()`, `len()`, `range()`, etc. However, when we code, we often need tools for recurrent tasks, such as generating random numbers, browsing directories, computing statistics, etc. For this reason, Python contains additional units called **modules**. We will talk about modules in greater detail in Chapter 32. For now, let's keep in mind this definition:

A **module** is a **unit** containing **functions** for a **specific task**

Because in Python there are plenty of modules—which could slow down our computer if imported all at once—we usually import only the module (or modules) that we are planning to use. To import a module, we use the **keyword import** followed by the **module name**.

Let's now run cell number 3:

```
[3]: 1 # pick a message index
2 message_index =
    random.randint(len(fortune_cookies)-1)
3 print(message_index)
4
5 # get the message
6 message = fortune_cookies[message_index]
7 print(message)
2
Land is always on the mind of a flying bird
```

pick a message index
message index is assigned random
dot randint len of fortune cookies
minus one
print message index

get the message
message is assigned fortune
cookies at message index
print message

The module `random` contains several functions, and in this cell we use `.randint()` (line 2). As you can see, the **syntax to call a module function** is as follows: **(1) module name; (2) dot; (3) function name; and (4) function inputs in between round brackets**. The function `.randint()` takes two integers as inputs—which we can call `a` and `b` (`.randint(a,b)`)—and returns a random number between them included—that is, `a` and `b` can be the generated random number. In our example, we want to pick a random number representing the index (or position) of an element in the list `fortune_cookies`. Thus, we could write `.randint(0,2)`. But what if we added or removed some strings to or from the list? We would have to manually change the endpoint `b`, and this could be prone to error! Similarly to what we do for the stop in a `for` loop, we **parameterise** `b`, that is, we write `b` as a function of the length of a list. Thus,

we type `len(fortune_cookies)`, from which we subtract 1 because list indexes start from zero (i.e., `len(fortune_cookies)` is 3, but the index of the last element is 2). After creating the random number, we assign it to `message_index`, and we print it (line 3). Finally, we slice the list `fortune_cookies` in position `message_index` to extract a string that we assign to the variable `message` (line 6) and print to the screen (line 7). One last note: try to run the cell several times. What happens? Every time `.randint()` returns a different number (0, 1, or 2), and thus we get a different fortune cookie message!

Let's have a look at the last cell:

```
[4]: 1 # pick a message
      2 message = random.choice(fortune_cookies)
      3 print(message)
The man on the top of the mountain did not fall there
```

pick a message
message is assigned random dot
choice fortune cookies
print message

In this case, we use another function from the module `random` called `.choice()`, which takes a list as an input and returns a randomly selected element of the list (line 2). Finally, we print the message (line 3).

What is the difference between `.choice()` and `.randint()`? When using `.choice()`, we do not know the position of the element the computer randomly selects, whereas when using `.randint()`, we know where the element is in the list.

Match the sentence halves

- | | |
|---|---|
| 1. In <code>range(start, stop, step)</code> | a. module name, dot, function name() |
| 2. In <code>.randint(a,b)</code> | b. returns a random element from a list |
| 3. The function <code>.randint(a,b)</code> | c. stop is excluded |
| 4. The function <code>.choice(list)</code> | d. variable name, dot, method name() |
| 5. The syntax to use a string or list method
is | e. the endpoint b is included |
| 6. The syntax to use a function from a module
is | f. returns a random integer between a and
b (included) |

Recap

- A module is a unit containing functions for a specific task.
- To import a module, we use the keyword `import`. Imports are usually written at the beginning of code, and only once.
- When calling a module function, we use the following syntax: `module_name.function_name()`.
- `random` is a module to generate random numbers. It contains several functions, including:
 - `.randint(a,b)`: returns a random integer between the endpoints *a* and *b* (included);
 - `.choice(list_name)`: returns an element of a list.

What if I don't use the index in a for loop?

As we know from the previous chapters, in a `for` loop, the variable `i` changes its value from the start to the stop (minus 1!) of the interval created by the function `range()`. Within the loop, we use `i` to either print out the current loop number (e.g., `print("This is loop number " + str(i))`) or to automatically slice list elements (e.g., `print(friends[i])`). However, in some cases, we do not need `i`. Let's look at an example:

<pre>[1]: 1 import random 2 3 # repeat the commands 3 times (index not 4 needed) 4 for _ in range(3): 5 # create a random number between 10 6 and 20 7 random_number = random.randint(10,20) 8 9 # print the number 10 print("The random number is" + 11 random_number)</pre>	<pre>import random repeat the commands 3 times (index not needed) for underscore in range three create a random number between ten and twenty random_number is assigned random dot randint ten twenty print the number print The random number is concatenated with random_number</pre>
--	---

```
The random numbers is: 14
The random numbers is: 17
The random numbers is: 12
```

We use a `for` loop to generate and print three random numbers (lines 4–8). As you can see, we use the `for` loop to repeat commands that do not contain `i`. In this case, it is a Python style convention to substitute `i` with an underscore (i.e., `_`) in the header of the `for` loop (line 4), to signal that we do not need an index in the loop. Using `i` in the loop header would not be an error, but it would decrease code readability.



Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter:
 - a. *Tossing a coin.* What are the two possibilities when tossing a coin? Write them in a list. Then, toss the coin, once using `.randint()` and once using `.choice()`. What do you get?
 - b. *Rolling dice.* What are the possibilities when rolling a die? Write them in a list. Then, roll the die, once using `.randint()` and once using `.choice()`. What numbers do you get? Finally, choose one method and roll the die three times. What numbers do you get?
2. *Ten random numbers.* Create a list of 10 random numbers between 0 and 100 using a `for` loop.
3. *Unique random numbers multiple of a number.* Create a list of 100 random numbers between 5 and 60. Divide them into two lists depending on whether they are a multiple of 4 or not. Then, create another list called `unique`, where you add unique multiples of 4 from the previous list. This means that, for example, that if 42 is present more than once, it will appear only once in `unique`. If the number is already present in `unique`, print out a sentence like: *The number x is already in unique.* How many unique multiples of 4 could you generate randomly?

4. *Playing with prime numbers.* Create a list of 150 random numbers between 50 and 100, and divide them into lists depending on whether they are multiple of the prime numbers 2, 3, 5, or 7 (a number can be added to more than one lists if it is multiple of several prime numbers). Then, sum up all the elements for each list separately (do not use built-in functions you might find online!). Is each sum a multiple of the original prime number? That is, is the sum of all the multiples of 3 a multiple of 3 itself?

16. Rock paper scissors

Introduction to algorithms

Everybody knows the game rock paper scissors! Kids in every corner of the world play this game originating at least 2,000 years ago in China¹. In this chapter, we will learn how to implement this game in Python. How would you do it? Write your ideas in the next exercise and try to write your own implementation. Then, have a look at the computational solution below, implemented also in Notebook 16.



Complete the sentences

Think about three steps you need to implement rock paper scissors and write them below. Consider that you will play against the computer: it will pick either paper, rock, or scissors, and you will do the same. Who wins?

1. _____ .
2. _____ .
3. _____ .

1. Computer pick

In the first step, the computer picks among paper, rock, and scissors. How? Let's have a look at the code below.

- Make the computer pick rock, paper, or scissors:

```
[1]: 1 import random
      2
      3 # list of game possibilities
      4 possibilities = ["rock", "paper", "scissors"]
      5
      6 # computer random pick
      7 computer_pick = random.choice(possibilities)
      8 print(computer_pick)
      rock
```

import random	import random
# list of game possibilities	list of game possibilities
possibilities = ["rock", "paper", "scissors"]	possibilities is assigned rock, paper, scissors
# computer random pick	computer random pick
computer_pick = random.choice(possibilities)	computer pick is assigned random dot choice possibilities
print(computer_pick)	print computer pick
rock	

We import the package `random`, which we learned in the previous chapter (line 1). Then, we create a list containing the possible choices—that is, the three strings "`rock`", "`paper`" and "`scissors`" (line 4). We use the function `.choice()` from the package `random` to randomly pick an element from the list `possibilities`. Finally, we save the pick in the variable `computer_pick` (line 7) and we print it out (line 8). In this case, `computer_pick` is `rock`.

¹https://en.wikipedia.org/wiki/Rock_paper_scissors

2. Player choice

In the second step, it's the player's turn to choose among rock, paper, and scissors. Let's have a look below.

- Make the player choose among rock, paper, or scissors:

```
[2]: 1 # asking the player to make their choice
      2 player_choice = input("Rock, paper, or
      3   scissors?")
      print(player_choice)
rock, paper, or scissors? rock
rock
```

asking the player to make their choice
player choice is assigned input rock,
paper, or scissors?
print player choice

We use the built-in function `input` to ask the player to choose among rock, paper, or scissors, and we save the choice in the variable `player_choice` (line 2). Then, we print it out as a check (line 3). In our example, the player chooses `rock`.

3. Determine who wins

It's time to determine who wins! How do we do it? The computer has three possible picks, and so does the player. Thus, there are nine possible scenarios. How do we code them without forgetting any? One option is to define three situations where the computer's pick is fixed and the player's choice varies. Let's see the implementation!

- If the computer picks `rock`:

```
[3]: 1 if computer_pick == "rock":
      2
      3     # compare to the player's choice
      4     if player_choice == "rock":
      5         print("Tie!")
      6     elif player_choice == "paper":
      7         print("You win!")
      8     else:
      9         print("The computer wins!")
Tie!
```

if computer pick equals rock
compare to the player's choice
if player choice equals rock
print Tie!
elif player choice equals paper
print You win!
else
print The computer wins!

We start with an `if` condition to check if the computer pick equals "`rock`" (line 1). Then we evaluate the player's choice. If the player's choice equals "`rock`" (line 4), then we print that it's a tie (line 5). If the player's choice equals "`paper`" (line 6), then we print that the player wins (line 7). Finally, in the remaining case—the player's choice is "`scissors`"—(line 8), we print that the computer wins (line 9). The code is very simple: an `if` condition containing an `if/elif/else` construct with prints in the statements. As you can see, we **print a message directly to the player**, not to the coder. You might remember that when we code, we alternate two hats: the coder hat or the player hat (see Chapter 1). If we print "`The player wins`" (line 7), we tell the coder that the code works. But if we print `You win!`, we talk to the `player`, who is the person we are coding for! Think about when you play a computer game: what kind of messages do you get?

In an `if/elif/else` construct, it is important to **test all conditions**. We want to make sure that all statements execute correctly, as we mentioned when we implemented a calculator (Chapter 13). What does testing mean exactly?

Testing means to **evaluate and verify** that the **code does what it is supposed** to do

How do we test the code in this example? We rerun cell 2—where we ask the player to choose among rock, paper, and scissors—two times: once entering `paper` and once entering `scissors`. After each run, we rerun cell 3 to check that the corresponding printout is correct. It is important to enter the strings in the same order as they appear in the conditions: first `rock`, then `paper`, and finally `scissors`. **Keeping the same order helps us make sure that we test all conditions**, without skipping any.

Sometimes testing is confused with **debugging**, but they are two very different concepts. You might have heard the word **debugging** many times. What is its exact meaning?

Debugging means **identifying** and **removing errors** from code

Debugging is a bit of a detective job. When we get error messages, or we do not obtain the result that we expect, we need to understand **where** the error is so that we can fix it. A very common way to debug is to **print** variables after every line of code, to check the value they are assigned. When the variable value is not the expected one, that's where the error happens! Once we have found the error, we can fix it, and then we can keep coding. To understand further why we use the word debugging, read the *In more depth* section at the end of this chapter.

Let's continue implementing rock paper scissors, looking at the second computer pick possibility.

- If the computer picks `paper`:

[4]:	<pre> 1 if computer_pick == "paper": 2 3 # compare to the player's choice 4 if player_choice == "paper": 5 print("Tie!") 6 elif player_choice == "scissors": 7 print("You win!") 8 else: 9 print("The computer wins!") </pre>	<pre> if computer pick equals paper compare to the player's choice if player choice equals paper print Tie! elif player choice equals scissors print You win! else print The computer wins! </pre>
------	---	--

The structure of the code is the same as in the previous cell: an `if` condition (line 1) containing an `if/elif/else` construct (lines 4–9). What changes are the terms of comparison—that is, the strings—in the conditions: we check if the computer picks "`paper`", and we change the conditions for the player according to the printed messages.

When we write code with a repetitive structure—like in our example—it is crucial to use parallelism. Do you know what it is?

Parallelism means maintaining a **corresponding structure**
for subsequent lines or blocks of code

In our example, we can either keep the *conditions* in the same order—e.g., the first term of comparison is always "`rock`", the second is always "`paper`", and the third is always "`scissors`"—or we can keep the *statements* in the same order—that is, the first message is always "`Tie!`" (line 5 in both cells 3 and 4), the second is always "`You win!`" (line 7 in both cells), and the third is always "`The computer wins!`" (line 9

in both cells). Parallelism helps us remember to **list all conditions** in every construct, and it improves code **readability**.

Once more, let's not forget to **test all conditions**. We first have to make sure that the computer pick is paper. Since we have only three options, a simple way is to rerun cell 1 until we get what we need—that is, "paper". Then, we re-run cells 2 and 4 three times, each time entering the player choice and testing the corresponding print, **in the same order as** in the if/elif/else construct. In other words, first we enter "paper" at cell 2, and run cell 4 to test lines 4–5. Then, we enter "scissors" at cell 2, and run cell 4 testing lines 6–7. And finally, we enter "scissors" at cell 2, and run cell 4 to test lines 8–9.

Let's finally look into the third scenario.

- If the computer picks scissors:

```
[5]: 1 if computer_pick == "scissors"
2
3     # compare to the player's choice
4     if player_choice == "scissors":
5         print("Tie!")
6     elif player_choice == "rock":
7         print("You win!")
8     else:
9         print("The computer wins!")
```

```
if computer pick equals scissors
compare to the player's choice
if player choice equals scissors
print Tie!
elif player choice equals rock
print You win!
else
print The computer wins!
```

Also in this last case, the code structure is similar: an if condition (line 1) nesting an if/elif/else construct (lines 4–9). We check if the computer picked "scissors" and if the player chose "scissors" (line 4), "rock" (line 6), or "paper" (the else in line 8). As in cell 4, we construct the conditions so that the print statements are **parallel** to the conditions in cell 3. Finally, once more, we want to make sure we **test the code**. Thus, first we re-run cell 1, making sure that the computer_pick is "scissors". Then, we re-run cells 2 and 5, subsequently entering and testing for "scissors", "rock", and "paper".

Note that we considered a **well-behaved player**, that is, a player that enters rock, paper, or scissors correctly, without any misspelling. We will assume that we are dealing with well-behaved players in all coming chapters to focus on computational thinking and coding syntax. We will learn to check for input correctness in Chapter 30.

At this point, the code is completed! As coders, we have taken care of the various parts of the code, writing and testing them. Now it's time to put all the code together for the player!

Merging the code

- Let's merge the code:

```
[6]: 1 import random
2
3     # list of game possibilities
4     possibilities = ["rock", "paper", "scissors"]
5
6     # computer random pick
7     computer_pick = random.choice(possibilities)
```

```
import random
list of game possibilities
possibilities is assigned rock, paper,
scissors
computer random pick
computer_pick is assigned random dot
choice possibilities
```

<pre> 7 # asking the player to make their choice 8 player_choice = input("Rock, paper, or 9 scissors?") 10 11 # determine who wins 12 # if the computer picks rock 13 if computer_pick == "rock": 14 # compare to the player's choice 15 if player_choice == "rock": 16 print("Tie!") 17 elif player_choice == "paper": 18 print("You win!") 19 else: 20 print("The computer wins!") 21 22 # if the computer picks paper 23 if computer_pick == "paper": 24 # compare to the player's choice 25 if player_choice == "paper": 26 print("Tie!") 27 elif player_choice == "scissors": 28 print("You win!") 29 else: 30 print("The computer wins!") 31 32 # if the computer picks scissors 33 if computer_pick == "scissors": 34 # compare to the player's choice 35 if player_choice == "scissors": 36 print("Tie!") 37 elif player_choice == "rock": 38 print("You win!") 39 else: 40 print("The computer wins!") </pre> <p>Rock, paper, or scissors? rock You win!</p>	<p>asking the player to make their choice player choice is assigned input rock, paper, or scissors?</p> <p>determine who wins if the computer picks rock if computer pick equals rock compare to the player's choice if player choice equals rock print Tie! elif player choice equals paper print You win! else print The computer wins!</p> <p>if the computer picks paper if computer pick equals paper compare to the player's choice if player choice equals paper print Tie! elif player choice equals scissors print You win! else print The computer wins!</p> <p>if the computer picks scissors if computer pick equals scissors compare to the player's choice if player choice equals scissors print Tie! elif player choice equals rock print You win! else print The computer wins!</p>
---	--

When merging code, we usually do some **editing to improve code use and readability**. In this case, we erased the print of `computer_pick` (which was in cell 1, line 8) because we do not want the player to know the computer choice in advance. Similarly, we delete the print of `player_choice` (which was in cell 2, line 3), as the player already sees their choice from the entry at line 9. Other editing might include improving comments, making variable names more meaningful, restructuring parts of the code, etc.

Let's now zoom out and observe the procedure we use to implement the game. We first defined three steps—see the exercise *Complete the sentences*. Then, we implemented each step separately—see paragraphs 1. Computer pick, 2. Player choice, and 3. Determine who wins. Finally, we merged all the code together and edited it—see *Merging the code*. This way of approaching a task is called *divide and conquer*.

Divide and conquer means **dividing** a project into **sub-projects**, **solving** the sub-projects, and **combining the solutions** of the sub-projects to obtain the solution of the whole project

In other words, there are three steps to solve a computational task:

1. Break the project into subprojects
2. Solve the subprojects separately
3. Merge the solutions of the subprojects to obtain the solution of the whole project

Last but not least, let's talk about algorithms! You have surely heard this word many times. What is an algorithm?

An **algorithm** is a **sequence of rigorous steps** to **execute and complete a task**

Algorithms are just procedures to solve tasks, problems, or assignments. They do not have to be complicated. They can actually be pretty simple. There are plenty of algorithms in everyday life! Think about the sequence of steps you make to brush your teeth: taking the toothpaste tube, opening and squeezing it, placing toothpaste on the toothbrush, etc. This is an algorithm! Or think about cooking recipes, especially printed recipes. At the top, there is a list of ingredients (e.g., 2 carrots, 3 onions), which are the variables (e.g., carrots = 2, onions = 3). Then, there is the execution of the recipe, that is, the steps to process the ingredients into the final dish. In programming, many algorithms have been developed in the past few decades. The most famous algorithms were designed to sort lists, find prime numbers, find elements in a list, etc. We will not look into them in this book, but you can find plenty of examples and explanations in more advanced books and on the internet.

Complete the table

In this chapter, you learned several more important concepts in coding. Write their definitions in your own words:

Concept	Definition
Testing	
Debugging	
Parallelism	
Divide and conquer	
Algorithm	

Recap

- An algorithms is a sequence of steps to execute a task.
- When writing an algorithm (and code in general), we largely use parallelism, testing, debugging, and divide and conquer.

Why do we say Debugging, Divide and conquer, and Algorithms?

Do you know why we say *debugging*, *divide and conquer*, and *algorithms*? The term *debugging* originated in 1947, when a moth was found in a relay of Mark II computer at Harvard University, causing the computer to malfunction. The moth was then taped to a log sheet, with the annotation *Relay 70 Panel F (moth) in relay*. *First actual case of a bug being found* (see Figure 16.1). Although the word *debugging* is not mentioned in the annotation, it became popular thanks to Grace Hopper, who worked on the same computer^{a,b}. *Divide and conquer* is attributed to Philip II of Macedon, and it was reused by the Roman ruler Julius Caesar, the French emperor Napoleon, and many more^c. It refers to a military strategy where the invaders divide the enemy forces to defeat them more easily and conquer them as a whole. Finally, the term *algorithm* derives from al-Khwarizmi, the last name of Muhammad ibn Musa al-Khwarizmi, a 9th-century Persian mathematician and astronomer whose books were widely read in Europe in the late Middle Ages. He wrote a book on the Hindu–Arabic numeral system, which was translated into Latin in the 12th century. The latin manuscript starts with the phrase *Dixit Algorizmi* ("Thus spoke Al-Khwarizmi"), where "Algorizmi" was the translator's Latinization of Al-Khwarizmi's last name^d.

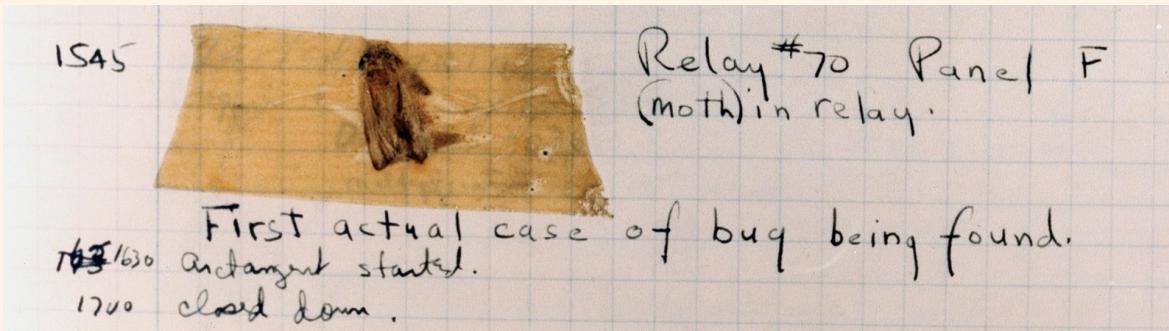


Figure 16.1. The page of the log from the Mark II with the moth taped on it. It dates 9 September 1947. The time is 15:45 as visible on the top left. The log book is at the Smithsonian Institution's National Museum of American History in Washington, D.C., United States.

^a<https://en.wikipedia.org/wiki/Debugging>

^bhttps://en.wikipedia.org/wiki/Grace_Hopper

^c[https://en.wikipedia.org/wiki/Divide_and_rule](https://en.wikipedia.org/wiki/Divide_and_conquer_algorithm)

^d<https://en.wikipedia.org/wiki/Algorithm>

💻 Let's code!

1. Trivia night! Trivia is a quiz game where players have to answer questions about various subjects. For this implementation of Trivia, prepare 3 questions and their corresponding answers for 3 different topics. Ask the player to pick a topic, and then ask a randomly picked question about that topic. Finally, tell the player whether the answer is correct. If not, print out the correct answer. Here are some hints:

- How do you organize your questions and answers? What Python data types do you use?
- What is the sequence of actions you need to perform? Write them down before coding. You can always update them while implementing.
- How do you test that your code is correct?
- Remember to divide and conquer!

PART 5

THE WHILE LOOP AND CONDITIONS

In part 5, you will learn the last construct in coding: the while loop. You will also learn various types of conditions that you can use in while loops and if/elif/else statements. Let's go!

17. Do you want more candies?

The *while* loop

In coding, there are three constructs: `if/elif/else`, `for` loops, and `while` loops. You have now mastered the first two, and in this chapter, you will finally learn the `while` loop! Read the code below, and try to understand what it does. Follow along with Notebook 17!

1	# initialize variable	initialize variable
2	number_of_candies = 0	number_of_candies is assigned zero
3		
4	# print the initial number of candies	print the initial number of candies
5	print("You have " + str(number_of_candies) + " candies")	print You have concatenated with str number of candies concatenated with candies
6		
7	# ask if one wants a candy	ask if one wants a candy
8	answer = input("Do you want a candy? (yes/no)")	answer is assigned input Do you want a candy? (yes/no)
9		
10	# as long as the answer is yes	as long as the answer is yes
11	while answer == "yes":	while answer equals yes:
12		
13	# add a candy	add a candy
14	number_of_candies += 1	number_of_candies is incremented by one
15		
16	# print the current number of candies	print the current number of candies
17	print("You have " + str(number_of_candies) + " candies")	print You have concatenated with str number of candies concatenated with candies
18		
19	# ask again if they want more candies	ask again if they want more candies
20	answer = input("Do you want more candies? (yes/no)")	answer is assigned input Do you want more candies? (yes/no)
21		
22	# print the final number of candies	print the final number of candies
23	print("You have a total of " + str(number_of_candies) + " candies")	print You have a total of concatenated with str number of candies concatenated with candies

Complete the following exercise to start getting to know the syntax and functionality of the `while` loop!

True or false?

- | | | |
|--|---|---|
| 1. while is a variable | T | F |
| 2. The while loop header contains a condition | T | F |
| 3. The variable answer appears 2 times in the code | T | F |
| 4. The variable number_of_candies increases by one unit at each loop | T | F |
| 5. The while loop continues as long as the player inputs yes and stops when the player inputs no | T | F |

Computational thinking and syntax

Let's run the cell, and let's analyze the code in two separate blocks. We'll start with the first block:

<pre>[1]: 1 # initialize variable 2 number_of_candies = 0 3 4 # print the initial number of candies 5 print("You have " + str(number_of_candies) + " candies")</pre>	<pre>initialize variable number_of_candies is assigned zero print the initial number of candies print You have concatenated with str number of candies concatenated with candies</pre>
---	---

We create a variable called `number_of_candies` and initialize it to `0` (line 2). This variable will keep count of the number of candies we want. It is a very important variable, and we will talk about it again when analyzing the second block of code. At line 5, we print out the number of candies we have, which is zero.

Let's look into the next block, which is the core of the whole code:

<pre>7 # ask if one wants a candy 8 answer = input("Do you want a candy? (yes/no)") 9 10 # as long as the answer is yes 11 while answer == "yes": 12 13 # add a candy 14 number_of_candies += 1 15 16 # print the current number of candies 17 print("You have " + str(number_of_candies) + " candies") 18 19 # ask again if they want more candies 20 answer = input("Do you want more candies? (yes/no)")</pre>	<pre>ask if one wants a candy answer is assigned input Do you want a candy? (yes/no) as long as the answer is yes while answer equals yes: add a candy number_of_candies is incremented by one print the current number of candies print You have concatenated with str number of candies concatenated with candies ask again if they want more candies answer is assigned input Do you want more candies? (yes/no)</pre>
--	---

```

22 # print the final number of candies
23 print("You have a total of " +
      str(number_of_candies) + " candies")

You have 0 candies
Do you want a candy? (yes/no) yes
You have 1 candies
Do you want more candies? (yes/no) yes
You have 2 candies
Do you want more candies? (yes/no) no
You have a total of 2 candies

```

```

print the final number of candies
print You have a total of concatenated
with str number of candies concatenated
with candies

```

Let's see how the `while` loop works. We ask the player whether they want a candy, and we save the reply in the variable `answer` (line 8). Then, we continue with the `while` loop header, which says something like: as long as the variable `answer` is equal to yes, do the following (line 11): add a unit to the variable `number_of_candies` (line 14); print out the current number of candies (line 17), and ask again the player if they want more candies (line 20). Then, we go back to the `while` loop header (line 11). If the answer at line 20 was yes, we'll do the same as above, that is: add a unit to the variable `number_of_candies` (line 14); print out the current number of candies (line 17), and ask again the player if they want more candies (line 20). Then, we will go back to the `while` loop header again (line 11). If the answer at line 20 was yes again, we will do the same as above once more, that is: add a unit to the variable `number_of_candies` (line 14), ... We'll keep doing this **as long as** the variable `answer` is equal to yes. What if the player answers no at line 20? When we go back to the `while` loop header (line 11), the condition is not valid anymore, because `answer` is not equal to yes! So the loop stops, and we go directly to the first line after the `while` loop body (line 23). There, we print out the total number of candies.

Let's now look into the syntax. The `while` loop starts with a **header** (line 11), which is composed of three parts: (1) the keyword `while`, (2) a condition, and (3) colon : (every construct header ends with a colon!). In this example, we check whether the value assigned to the variable `answer` equals the string "yes". We will see other kinds of conditions in the next chapter. After the header, there is the **body** of the `while` loop (lines 13–20). The body is **indented**, similarly to the `for` loop body and `if/elif/else` statements. Let's now focus our attention on two variables: `answer` and `number_of_candies`.

How many times do you see the variable `answer` and where? `answer` is in **three** different places: (1) **before** the `while` loop (line 8), (2) **in the condition** of the `while` loop, and (3) **in the body** of the `while` loop. Why do we need it three times? Before a `while` loop, we always have to initialize the variable contained in the condition of the `while` loop header; otherwise, we cannot evaluate the condition itself when the loop starts. In our example, we initialize `answer` with the first player's answer (line 8). Then, we have to check the condition involving the variable `answer`. In this case, we check if `answer` is equal to yes (line 11). Finally, we have to allow the variable to change (line 20), so that the loop can terminate; otherwise, the loop will keep going indefinitely. Sooner or later, we all forget this last part, and we get into an **infinite loop!** If that happens to you, just stop the cell (if it takes too long, restart the kernel!).

Let's finally look into the variable `number_of_candies`. How many times do you see it and where? `number_of_candies` is in **two** places: (1) **before** the `while` loop, where it is **initialized** (line 2), and (2) **in** the `while` loop, where it is **incremented** by one unit at every loop (line 14). The variable `number_of_candies` is generally called **counter** because **it keeps count of the number of loops**. The symbol `+=` is an **assignment symbol**, and we can pronounce it as *incremented by*. It is a compact way of writing `number_of_candies = number_of_candies + 1`. For any arithmetic operator, there is the

associated assignment operator, that is, `-=` (*decrease by*), `*=` (*multiply by and reassign*), `/=` (*divide by and reassign*), etc. Note that in assignment operators, the symbol `=` is always in the second position, after an arithmetic operator.

What is the difference between a `for` loop and a `while` loop? In Chapter 8, we defined the `while` loop as follows:

A **for loop** is the repetition of a group of commands for a **determined** number of times

In a **for loop**, we know exactly how many times we are going to run the commands in the loop body. Conversely, in a **while loop** we do not know how many times we are going to run the commands in the loop body because the duration of a while loop depends on the validity of the condition in the header. Let's define the while loop and summarize its characteristics:

A **while loop** is the repetition of a group of commands
as long as a condition holds

A while loop stops when the condition in the header is not true anymore. We always have to give the variable in the condition the possibility to change so that the condition in the header can be false and the loop can stop. If the variable in the condition (answer in our example) cannot change in the while loop body, then we will get an infinite loop. Finally, to know how many times we run the loop, we can use a counter (number_of_candies in our example) to keep track of the number of iterations. The presence of a counter is not compulsory.



Insert into the right column

So far, you have learned several operators: arithmetic, assignment, and comparison operators. Insert each symbol in the right column:

+, ==, *=, <, /, *, <=, =, // =, /=, //, !=, -=, -, +=, >=, %=, **, %, ***, >

Recap

- A while loop is the repetition of a bunch of commands as long as a condition holds.
- The variable in the condition must be initialized before the condition. It also has to change somewhere in the loop body so that the loop can stop when the condition does not hold anymore.
- A while loop can have a counter. Counters keep track of the number of loops and must be initialized before the loop header.
- When updating a variable with an arithmetic operation, we can use the corresponding assignment operator, that is, `+=`, `-=`, etc.

Writing code is like writing an email!

What steps do we do when writing an email? We start with recipient's address and email subject, then we continue with the salutation, the body of the email, greetings, and we finish with signature (an algorithm, isn't it?). Once we are done, we read the email again for a check. We correct some misspellings, and we quickly edit a few things here and there. Often, we go deeper: we reformulate some sentences or we completely rearrange some paragraphs. Without realizing it, we have gone through the email a couple of times! Now, think about the steps we make when writing code. First, we write the imports, the variables, and the implementation of an algorithm. Then we test it to we check whether it works, and if not, we correct it. Once it finally works, we remove unused variables, compact some code lines, improve variable names, and clean comments. Like we do for emails, we look at our code circularly, that is, from top to bottom a couple of times, exactly like when we re-read an email. But for some reason, when we code, we often want the first draft to be the final implementation, and we get frustrated if this doesn't happen. When writing code, **consider the time you spend testing, debugging, and improving the code as part of the process**, not as some extra time that prevents you from doing something else! It's all part of the process!



Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter:
 - a. Do you want more cookies?
 - b. Do you want less exercises?
2. At the cheese shop. You own a cheese shop, and you sell slices of cheese at 50c each. A new customer comes in, and you ask if they want cheese. The customer is uncertain of how much cheese to buy, so after every slice, you ask again if they want another slice of cheese. As long as the customer says yes, then you add a slice of cheese, update the final price, and tell them the amount of slices of cheese and the price so far. How many slices of cheese did you sell? And what was the final price?
3. Playing with numbers. Given the following list: `numbers = [0]`, ask the player if you should add another number to the list. As long as the player says yes, add to the list the sum of the last number you added and the counter of the current loop. Example: If you run the while loop 7 times, you will get the following list: `[0, 1, 3, 6, 10, 15, 21, 28]`

4. *Generating even numbers.* Given an empty list, ask the player if you should add another number to the list. As long as the player says yes, create a random number between 0 and 100, and if the number is even, then add it to the list. How many numbers did you generate? How many even? How many odd? What is the ratio between the amount of even and odd numbers you generated?

18. Animals, unique numbers, and sum

Various kinds of conditions

In the previous chapter, we saw only one kind of condition in a `while` loop—that is, that a variable is equal to "yes". Let's now take a look at three examples with other kinds of conditions. First, try to solve each task by yourself: read the requirements carefully, list the steps to execute, implement them one by one, and merge the code to the solution (divide and conquer!). This time, also try to take it one step further: keep an eye on the processes that your mind goes through while solving the tasks. **You will often find recurring thinking patterns when coding.** Knowing and recognizing them will give you awareness and thus speed up your work. For each of the following examples, you will see a possible way to approach the coding task at hand. Maybe it will be similar to your thinking, or maybe it will be different. In any case, it will give you an idea of possible thinking pathways. You can play with the proposed solutions on Notebook 18. Enough talk—let's start coding!

1. Guess the animal!

- Given the following list:

```
1 animals = ["giraffe", "dolphin", "penguin"] animals is assigned giraffe, dolphin,  
penguin
```

- Create a game in which the computer randomly picks one of the three animals and the player has to guess the animal picked by the computer. Make sure that the player keeps playing until they guess the animal picked by the computer. At the end of the game, tell the player how many attempts it took to guess the animal.

The game has four requirements: (1) the computer randomly picks one of the three animals; (2) the player has to guess the animal picked by the computer; (3) the player keeps playing until they guess the animal picked by the computer; and (4) at the end of the game, tell the player how many attempts it took to guess the animal. Let's see how to implement each requirement!

- The computer randomly picks one of the three animals. This is pretty straightforward:

1 import random 2 3 # computer pick 4 computer_pick = random.choice(animals) 5 print(computer_pick)	import random computer pick computer pick is assigned random dot choice animals print computer pick
---	---

We import the package `random` (line 1), and we use its function `.choice()` to make the computer pick a random element from the list `animals` (line 4). Then, we print `computer_pick` as a check (line 5).

2. The player has to guess the animal picked by the computer. This task is also easy:

```

1 # player guess
2 player_guess = input("Guess the animal!
Choices: giraffe, dolphin, penguin:")
3
4 Guess the animal! Choices: giraffe, dolphin, penguin: giraffe

```

We use the function `input()` to ask the player to input their guess (line 2). We assume that the player's input is `giraffe`.

3. The player keeps playing until they guess the animal picked by the computer. The phrase "until they guess the animal" is equivalent to "as long as they guess the animal", which immediately suggests to us that we should use a `while` loop. What condition do we write in the header? Let's see:

```

1 # as long as the player's guess and the
2   computer's pick are different
3
4   while player_guess != computer_pick:
5
6     # tell the player that the animal is
7       not right
8     print("That's not the right animal!")
9
10    # ask the player to guess again
11    player_guess = input("Try again! Guess
12      the animal! Choices: giraffe, dolphin,
13        penguin:")
14
15    # tell the player that they guessed the
16      right animal
17    print("Well done! You guessed " +
18      computer_pick)
19
20 That's not the right animal!
21 Try again! Guess the animal! Choices: giraffe, dolphin, penguin: dolphin
22 Well done! You guessed dolphin

```

The loop must stop when the player guesses the animal, that is, until `player_guess` and `computer_pick` are the same. In general, **when a requirement defines the condition that stops a while loop**, we have to think the opposite way: **we need to find the condition that allows the while loop to keep going**. In our example, the loop must keep going as long as `player_guess` is not equal to `computer_pick` (line 2). In the loop body, we provide a feedback to the player saying that the animal they picked is not right (line 5), and we ask the player to guess the animal again (line 8) so that the while loop can continue. Finally, after the loop, we print out a message confirming that the player guessed the right animal (line 12).

4. At the end of the game, tell the player how many attempts it took to guess the animal. We definitely need a counter!

<pre> 1 # initializing the counter 2 n_of_attempts = 1 3 4 # as long as the player's guess and the 5 # computer's pick are different 6 while player_guess != computer_pick: 7 8 # tell the player that the animal is 9 # not right 10 print("That's not the right animal!") 11 # print the numbers of attempts so far 12 print("Number of attempts so far: " + 13 str(n_of_attempts)) 14 15 # increase the number of attempts 16 n_of_attempts += 1 17 18 # ask the player to guess again 19 player_guess = input("Try again! Guess 20 the animal! Choices: giraffe, dolphin, 21 penguin:") 22 23 # tell the player that they guessed the 24 # right animal 25 print("Well done! You guessed " + 26 computer_pick + " at attempt number " + 27 str(n_of_attempts)) </pre>	<pre> initializing the counter n of attempts is assigned one as long as the player's guess and the computer's pick are different while player guess is not equal to computer pick: tell the player that the animal is not right print That's not the right animal! print the numbers of attempts so far print Number of attempts so far: concatenated with str n of attempts increase the number of attempts n of attempts is incremented by one ask the player to guess again player guess is assigned input Try again! Guess the animal! Choices: giraffe, dolphin, penguin: tell the player that they guessed the right animal print Well done! You guessed concatenated with computer pick concatenated with at attempt number concatenated with str(n of attempts) </pre>
<pre> That's not the right animal! Number of attempts so far: 1 Try again! Guess the animal! Choices: giraffe, dolphin, penguin: dolphin Well done! You guessed dolphin at attempt number 2 </pre>	

We create the counter `n_of_attempts` (line 2), and we initialize it to 1. Why 1 and not to 0? Because the player enters the first input before the `while` loop (see requirement 2. The player has to guess the animal picked by the computer), and that is the first attempt! Then, we tell the player the current number of attempts (line 11) and increase `n_of_attempts` by one unit at every loop (line 14). Finally, we include the total number of attempts to the last print (line 20).

After solving the four tasks, we can merge the code together! Here is the complete solution:

<pre> [1]: 1 import random 2 3 # computer pick 4 computer_pick = random.choice(animals) 5 6 # player guess 7 player_guess = input("Guess the animal! 8 Choices: giraffe, dolphin, penguin:") </pre>	<pre> import random computer pick computer pick is assigned random dot choice animals print computer pick computer pick player guess is assigned input Guess the animal! Choices: giraffe, dolphin, penguin: </pre>
---	---

```

9
10 # initializing the counter
11 n_of_attempts = 1
12
13 # as long as the player's guess and the
14 computer's pick are different
15 while player_guess != computer_pick:
16
17     # tell the player that the animal is
18     # not right
19     print("That's not the right animal!")
20
21     # print the numbers of attempts so far
22     print("Number of attempts so far: " +
23           str(n_of_attempts))
24
25     # increase the number of attempts
26     n_of_attempts += 1
27
28     # ask the player to guess again
29     player_guess = input("Try again! Guess
            the animal! Choices: giraffe, dolphin,
            penguin:")
30
31     # tell the player that they guessed the
32     # right animal
33     print("Well done! You guessed " +
            computer_pick)

```

Guess the animal! Choices: giraffe, dolphin, penguin: giraffe
 That's not the right animal!
 Number of attempts so far: 1
 Try again! Guess the animal! Choices: giraffe, dolphin, penguin: dolphin
 Well done! You guessed dolphin at attempt number 2

initializing the counter
 n of attempts is assigned 1
 as long as the player's guess and the
 computer's pick are different
 while player guess is not equal to
 computer pick:
 tell the player that the animal is not
 right
 print That's not the right animal!
 print the numbers of attempts so far
 print Number of attempts so far:
 concatenated with str n of attempts
 increase the number of attempts
 n of attempts is incremented by one
 ask the player to guess again
 player guess is assigned input Try
 again! Guess the animal! Choices:
 giraffe, dolphin, penguin:
 tell the player that they guessed the
 right animal
 print Well done! You guessed
 concatenated with computer pick

Note that we commented out the print of the `computer_pick` (line 5), as the final code is for a player and not for a coder!

2. Create a list of 8 unique random numbers!

Here is our next task:

- Create a list of 8 random numbers between 0 and 10. Make sure they are unique, meaning each number is present only once in the list. If the number is already in the list, then print the following: *The number x is already in the list.* How many numbers did you generate before finding 8 unique numbers?

The task has four requirements: (1) create a list of 8 random numbers between 0 and 10; (2) make sure they are unique, that is, each number is present only once in the list; (3) if the number is already in the list, then print *The number x is already in the list*; and (4) how many numbers did you generate before finding 8 unique numbers? Let's go through the requirements one by one!

1. Create a list of 8 random numbers between 0 and 10.

According to this requirement only, we can create a list of 8 numbers using a `for` loop and the function `.randint()` from the module `.random`:

<pre> 1 import random 2 3 # initialize the number list 4 unique_random_numbers = [] 5 6 # for 8 times 7 for _ in range(8): 8 9 # create a random number between 0 and 10 10 unique_random_numbers.append(11 random.randint(0,10)) 12 13 # print the list 14 print(unique_random_numbers) </pre>	<pre> import random initialize the number list unique random numbers is assigned an empty list for eight times for underscore in range eight create a random number between zero and ten unique random numbers dot append random dot randint zero ten print the list print unique random numbers </pre>
[7, 9, 3, 2, 3, 0, 9, 6]	

We import the package `random` (line 1), and we initialize `unique_random_numbers`—which will contain the created numbers—to an empty list (line 4). Then, we create a `for` loop, where we generate eight random numbers between 0 and 10, and we append them to `unique_random_numbers` (lines 6–10). Note that we use an underscore instead of the variable `i` in the loop header because we do not need `i` in the loop body (see the *In more depth* section *What if I don't use the index in a for loop?* in Chapter 15). Finally, we print `unique_random_numbers` to check that it actually contains eight random numbers (line 13). Let's go to the next requirement!

2. Make sure they are unique, which means each number is present only once in the list. In the list we printed out above, the numbers are not unique: both 3 and 9 are present twice. Thus, we need to modify our code. How? We do not know how many random numbers we need to generate before obtaining 8 unique numbers, that is, we do not know how many times we need to run the command `unique_random_numbers.append(random.randint(0,10))` (line 9 in the cell above). For this reason, we cannot use a `for` loop—which we use when we know the exact number of iterations—but we need to use a `while` loop, which we use when the number of iterations is determined by a condition. **Making changes in code during the drafting process is normal**, as we mentioned in the *In more depth* section of the previous chapter *Writing code is like writing an email!* What condition do we use in this `while` loop? The list must be composed of 8 elements, thus its length has to be 8! Let's see how we can transform the code:

<pre>1 import random 2 3 # initialize the number list 4 unique_random_numbers = [] 5 6 # as long as the length of the list is not 8 7 while len(unique_random_numbers) != 8: 8 9 # create a random number between 0 and 10 10 number = random.randint(0,10) 11 12 # if the number is already in the list 13 if number in unique_random_numbers: 14 # place holder 15 a = 0 16 # otherwise 17 else: 18 # add the new number to the list 19 unique_random_numbers.append(number) 20 21 # print the list 22 print(unique_random_numbers) [1, 8, 10, 7, 3, 0, 5, 9]</pre>	<pre>import random initialize the number list unique random numbers is assigned an empty list as long as the length of the list is not eight while len of unique random numbers is not equal to eight create a random number between zero and ten number is assigned random dot randint zero ten if the number is already in the list if number in unique random numbers: place holder a is assigned zero otherwise else add the new number to the list unique random numbers dot append number print the list print unique random numbers</pre>
--	--

At line 7, we substitute the header of the for loop with the header of a while loop, with the condition that the loop **keeps going** as long as the length of the list is not equal to 8. Then, we generate a random number (line 10). We need to make sure that the random number is a new one (or unique!) before adding it to the list. Thus, we create an if ... in / else construct (lines 12–19), which we learned in Chapter 3. If the number is already in the list (line 13), then we do not want to add it to the list. The next requirement will tell us what to do, so right now we can just use a placeholder, or a nonfunctional command in our code that we plan to substitute (a=0, line 15). Using placeholders is not very good coding practice, but sometimes we can make an exception in the very early drafting phase. If the number is not in the list (else at line 17), then we append it to the list (line 19).

3. If the number is already in the list, then print: The number x is already in the list

We substitute the placeholder a=0 with the print commands (line 15):

<pre> 1 import random 2 3 # initialize the number list 4 unique_random_numbers = [] 5 6 # as long as the length of the list is not 8 7 while len(unique_random_numbers) != 8: 8 9 # create a random number between 0 and 10 10 number = random.randint(0,10) 11 12 # if the number is already in the list 13 if number in unique_random_numbers: 14 # print that the number is in the list 15 print("The number " + str(number) + 16 " is already in the list") 17 18 # otherwise 19 else: 20 # add the new number to the list 21 unique_random_numbers.append(number) 22 23 # print the list 24 print(unique_random_numbers) </pre> <p>The number 1 is already in the list The number 10 is already in the list The number 7 is already in the list The number 5 is already in the list [1, 8, 10, 7, 3, 0, 5, 9]</p>	<pre> import random initialize the number list unique random numbers is assigned an empty list as long as the length of the list is not eight while len of unique random numbers is not equal to eight create a random number between zero and ten number is assigned random dot randint eight ten if the number is already in the list if number in unique random numbers: print that the number is in the list print The number concatenated with str number concatenated with is already in the list otherwise else add the new number to the list unique random numbers dot append number print the list print unique random numbers </pre>
--	---

As we can see in the printouts, the numbers 1, 10, 7, and 5 were generated twice, but they are in the list only once!

4. How many numbers did you generate before finding 8 unique numbers?

To satisfy this last requirement, we need a counter. It will keep track of the amount of numbers we generated, which coincides with the number of iterations of the `while` loop!

```

[2]: import random

2
3 # initialize the number list
4 unique_random_numbers = []

5
6 # initialize the counter
7 counter = 0
8

9 # as long as the length of the list is not 8

10 while len(unique_random_numbers) != 8:
11
12     # create a random number between 0 and 10
13
14     number = random.randint(0,10)
15
16     # increase the counter by 1
17     counter += 1
18
19     # if the number is already in the list
20     if number in unique_random_numbers:
21         # print that the number is in the list
22         print("The number " + str(number) +
23             " is already in the list")
24
25     # otherwise
26     else:
27         # add the new number to the list
28         unique_random_numbers.append(number)
29
30
31     # print the final list and the total amount
32     # of generated numbers
33     print(unique_random_numbers)
34     print("The total amount of generated numbers
35         is: " + str(counter))

```

The number 1 is already in the list
 The number 10 is already in the list
 The number 7 is already in the list
 The number 5 is already in the list
 [1, 8, 10, 7, 3, 0, 5, 9]
 The total amount of generated numbers is: 12

```

import random

initialize the number list
unique random numbers is assigned an
empty list

initialize the counter
counter is assigned zero

as long as the length of the list is
not eight
while len of unique random numbers is
not equal to eight

create a random number between zero
and ten
number is assigned random dot randint
zero ten

increase the counter by one
counter is incremented by one

if the number is already in the list
if number in unique random numbers:
print that the number is in the list
print The number concatenated with
str number concatenated with is
already in the list
otherwise
else
add the new number to the list
unique random numbers dot append
number

print the final list and the total
amount of generated numbers
print unique random numbers
print The total amount of generated
numbers is: concatenated with str
counter

```

We initialize the counter (line 7), increment it by one unit at each iteration (line 16), and print it out (line 29).

3. Sum up the multiples of 3

- Write code that continues asking a player to enter an integer until they enter a negative number. At the end, print the sum of all entered integers that are multiples of 3.

The task has two requests: (1) keep asking a player to enter an integer until they enter a negative number, and (2) at the end, print the sum of all entered integers that are multiples of 3. Let's see how to implement them!

1. *Keep asking a player to enter an integer until they enter a negative number.* The requirement is straightforward: we use the `input` function to ask the player to enter numbers and a `while` loop to keep asking. Which condition do we use in the header? Let's have a look:

<pre> 1 # ask the user for an integer 2 number = int(input("Enter an integer: ")) 3 4 # as long as the number is positive 5 while number >= 0: 6 # ask for the next new integer 7 number = int(input("Enter another integer: ")) Enter an integer: 3 Enter another integer: 6 Enter another integer: 4 Enter another integer: -1 </pre>	<i>ask the user for an integer number is assigned int input Enter an integer:</i> <i>as long as the number positive while number is greater than or equal to zero</i> <i>ask for the next new integer number is assigned int input Enter another integer:</i>
--	---

The loop must continue as long as the player enters a negative number, that is, as long as `number` is positive—greater than or equal to zero (line 5). As we learned in the previous chapter, the variable in the condition has to be in three places: before the loop, in the loop header, and within the loop. Thus, first we initialize the variable `number` with the integer entered by the player (line 2). Then, we condition the variable in the `while` loop header (as we saw in line 5). And finally, to avoid an infinite loop, we ask the player to enter a new number (line 7). Let's implement the second requirement!

2. *At the end, print the sum of all entered integers that are multiples of 3.*

We need to check whether the numbers the user enters are multiples of 3, and, if they are, then sum them up. Ideas on how to do it? Let's start drafting the code:

Part 5. The while loop and conditions

```
1 # list containing the numbers to sum
2 numbers = []
3
4 # ask the user for an integer
5 number = int(input("Enter an integer: "))
6
7 # as long as the number is positive
8 while numbers >= 0:
9
10    # if the number is multiple of 3
11    if numbers % 3 == 0:
12
13        # add the number to the list
14        numbers.append(number)
15
16        # ask for the next integer
17        number = int(input("Enter another
18                      integer: "))
19
20    # print the list of multiples of 3
21    print(numbers)
22
23    # initialize the sum to 0
24    sum_of_numbers = 0
25
26    # calculate the sum of numbers
27    for i in range(len(numbers)):
28        sum_of_numbers = numbers[i] +
29        sum_of_numbers
30
31    # print the final sum
32    print("The sum of the multiples of 3 is: " +
33          str(sum_of_numbers))
```

list containing the numbers to sum
numbers is assigned empty list

ask the user for an integer
number is assigned int input Enter an integer:

as long as the number positive
while number is greater than or equal to zero:

if the number is multiple of 3
if number modulus three is equal to zero:
add the number to the list
numbers dot append number

ask for the next integer
number is assigned int input Enter another integer:

print the list of multiples of 3
print numbers

initialize the sum to zero
sum of numbers is assigned zero

calculate the sum of numbers
for i in range len of numbers
sum of numbers is assigned numbers in position i plus sum of numbers

print the final sum
print The sum of the multiples of 3 is: concatenated with str sum of numbers

```
Enter an integer: 3
Enter another integer: 6
Enter another integer: 4
Enter another integer: -1
[3, 6]
The sum of the entered multiples of 3 is: 9
```

We can create an empty list called `numbers` that will contain the multiples of 3 (line 2). Then, within the `while` loop, we add an `if` construct, in which we check whether the current number is a multiple of 3 by using the modulo operator. If the condition is met, then we append the number to the list `numbers` (line 13). At the end of the `while` loop (i.e., after the player has entered a negative number), we sum up the numbers in the list, similarly to what we did in the exercise 5 of Chapter 14. First, we create the variable `sum_of_numbers`, which will contain the final sum, and we initialize it to zero (line 22). Then, we use a `for` loop through the list `numbers`—containing the multiples of 3—to add the current list element (`numbers[i]`) to the amount in `sum_of_numbers` (line 26). Finally, we print out the sum at

line 29.

We solved the task, but can we improve our code? Let's read the following requirement again: *at the end, print the sum of all entered integers that are multiples of 3*. We are not asked to save the multiples of 3 in a list—just to print out their sum. Do we need to create the list? Not really! So, how do we do it? Let's see this alternative solution:

<pre>[3]: 1 # initialize the sum to 0 2 sum_of_numbers = 0 3 4 # ask the user for an integer 5 number = int(input("Enter an integer: ")) 6 7 # as long as the number is positive 8 while numbers >= 0: 9 10 # if the number is a multiple of 3 11 if numbers % 3 == 0: 12 13 # add the number to the sum 14 sum_of_numbers += number 15 16 # ask for the next integer 17 number = int(input("Enter another 18 integer: ")) 19 20 # print the final sum 21 print("The sum of the multiples of 3 is: + + 22 str(sum_of_numbers))</pre>	<pre>initialize the sum to zero sum of numbers is assigned zero ask the user for an integer number is assigned int input Enter an integer: as long as the number positive while number is greater than or equal to zero if the number is a multiple of 3 if number modulus three is equal to zero: add the number to the sum sum of numbers is incremented by number ask for the next integer number is assigned int input Enter another integer: print the final sum print The sum of the multiples of 3 is: concatenated with str sum of numbers Enter an integer: 3 Enter another integer: 6 Enter another integer: 4 Enter another integer: -1 The sum of the entered multiples of 3 is: 9</pre>
--	--

We remove all the code related to the list `numbers`. We initialize `sum_of_numbers` to zero before the `while` loop (line 2). Then, within the loop, we sum the current multiple of 3 (i.e., `number`) to the total sum (line 13)—without saving it to a list. With this trick, we improve our code in two ways: (1) we do not create a list, which occupies space in computer memory, and (2) we avoid a `for` loop that occupies memory and time during the execution. The code thus becomes shorter, faster, and more elegant.

Match the sentence halves

- | | |
|---|-------------------------------------|
| 1. An if/elif construct checks whether a condition is true or false | a. for a determined number of times |
| 2. A for loop is the repetition of a group of commands | b. as long as a condition holds |
| 3. A while loop is the repetition of a group of commands | c. and executes code accordingly |

Recap

- In a while loop header, we can write various kinds of conditions. The correct condition is the one that keeps the loop going (not stopping!)
- When solving a task, it is common to decompose and analyze the requirements, solve the subtasks, and merge the code to the solution (divide and conquer!)
- When coding, we often write a first draft, and then we improve the draft to make the code faster and robust (writing code is like writing an email!)

Don't confuse the while loop with if/elif!

When learning coding constructs, it can be easy to confuse the while loop with the if/else construct. If this happened to you while learning the past two chapters, read the following paragraph. If you feel like you mastered the difference between while loops and if/else constructs, feel free to skip the coming lines!

Consider the following example, similar to the first one in this chapter.

- Given the following list:

```
[1]: 1 fruits = ["mango", "orange", "banana"] fruits is assigned mango, orange, banana
```

- Create a game where the computer randomly picks a fruit and the player has to guess the fruit picked by the computer. Make sure that the player keeps playing until they guess the fruit picked by the computer.

We have to solve 3 tasks: (1) the computer randomly picks a fruit, (2) the player has to guess the fruit picked by the computer, and (3) we must make sure that the player keeps playing until they guess the fruit picked by the computer. The first two requirements are straightforward, and we will solve them quickly. We will focus on the third requirement.

1. The computer randomly picks a fruit.

[2]:	<pre> 1 import random 2 3 # computer pick 4 computer_pick = random.choice(fruits) 5 </pre>	<pre> import random computer pick computer pick is assigned random dot choice fruits </pre>
------	--	--

We import the package random (line 1) and we use the method `.choice()` to make the computer randomly pick an element of the list `fruits`.

2. The player has to guess the fruit picked by the computer.

6	<pre> # player guess player_guess = input("Guess the fruit! Choices: mango, orange, banana: ") </pre>	<pre> player guess player guess is assigned input Guess the fruit! Choices: mango, orange, banana: </pre>
---	---	---

We use the built-in function `input()` to ask the player to enter a fruit (line 7).

3. Make sure that the player keeps playing until they guess the animal picked by the computer. The first instinct would be to do the following:

9	<pre> # check the player guess if player_guess == computer_pick: print("That's right! The fruit is " + computer_pick) else: print(" Nope! Try again!") </pre>	<pre> check the player guess if player guess is equal to computer pick print That's right! The fruit is concatenated with computer pick else print Nope! Try again! </pre>
---	---	--

We check if `player_guess` is equal to `computer_pick` with an `if/else` construct, and we print messages accordingly (lines 9–11). If the player did not guess the right fruit, we have to ask them to guess again (like at line 7). Then, we have to check once more if the guess is correct (like at lines 9–11), and so on. This is not feasible because we cannot know how many times it is going to take the player to guess the correct fruit! In addition, we would repeat code, which means that we can use a loop! So, here is the correct solution with the `while` loop:

9	<pre> while player_guess != computer_pick: # as long as the player's guess and the # not right player_guess = input(" Nope! Try again! Guess the fruit! Choices: mango, orange banana: ") </pre>	<pre> while player guess is not equal to computer pick: as long as the player's guess and the computer's pick are different player guess is assigned input Nope! Try again! Guess the fruit! Choices: mango, orange, banana: </pre>
---	---	---

As long as the `player_guess` is not equal to `computer_pick` (line 9), we ask the player to make a guess (line 11), which we check in the condition of the `while` loop header (line 9), and the loop keeps going as long as the condition holds.

 Let's code!

1. *Guess the number!* Create a game where the computer picks a number between 0 and 10, and the player has to guess it. If the player guesses a number that is too high or too low, then the computer tells the player. The game stops when the player guesses the number. At the end, tell the player how many attempts it took to guess the number.
2. *12 even random numbers.* Create a list of 12 even random numbers between 0 and 30. How many odd numbers did you exclude?
3. *Spelling game for kids.* Create a game that helps kids learn spelling. The game has the following requirements: (1) Create a list of words to be spelled. Among these words, choose a word randomly, and tell the kid the chosen word (e.g., “Spell the word ‘hello’”). (2) The kid has to enter one letter at the time. If the kid enters the correct letter, then provide positive reinforcement (e.g., “Well done!”), and ask for the next letter. If the kid does not enter the correct letter, then tell them that the letter is not correct, and ask for a letter again.

Challenge 1: Instead of creating only 1 list of words, create 3 lists, one per topic, so that the kid can choose a topic before spelling a word.

Challenge 2: The game continues as long as the kid wants to spell a new word.

19. And, or, not, not in

Combining and reversing conditions

Up to now, we have considered only one condition in `if/else` constructs and `while` loops. What if we need more than one condition? And what if we need to reverse a condition? In this chapter, we will learn how to combine or reverse conditions using the logical operators `and`, `or`, `not`, and the membership operator `not in`. As usual, try to solve the tasks yourself before looking at the solutions, which you can also find in Notebook 19. Let's start!

1. and

- Given the following list of integers:

```
[1]: 1 numbers = [1, 5, 7, 2, 8, 19] numbers is assigned one, five, seven, two, eight, nineteen
```

- Print out the numbers that are between 5 **and** 10:

```
[2]: 1 # for each position in the list for i in range(len(numbers)): for each position in the list for i in range len of numbers
3
4     # if the current number is between 5
      # if the current number is between
      # and 10
      # and ten
5     if numbers[i] >= 5 and numbers[i] <= 10:
6
6         # print the current number
7         print("The number " + str(numbers[i])
      print The number concatenated with
      + " is between 5 and 10") str numbers in position i concatenated
      + is between five and ten
The number 5 is between 5 and 10
The number 7 is between 5 and 10
The number 8 is between 5 and 10
```

We use a `for` loop to browse all the elements in the list (line 2). Then, we check if each number is between 5 and 10 (line 5). To be in between two numbers, a number must be greater than or equal to the smaller number *and* smaller than or equal to the greater number. The two conditions (greater than or equal to *and* smaller than or equal to) must be valid at the same time. To check if two (or more) conditions are valid simultaneously, we join them using the **logical operator and**.

We use the logical operator **and** when we want to check whether **all conditions** are **valid**

Let's look at the syntax. For each condition *both before and after* the logical operator `and`, we have to write: (1) a variable (e.g., `numbers[i]`), (2) a comparison operator (e.g., `>=`), and (3) a term of comparison (e.g., 5). At the end of the code, we print the numbers that satisfy both conditions (line 7).

2. or

- Given the following string:

```
[3]: 1 message = "Have a nice day!!!"
```

message is assigned Have a nice day!!!

- And given all punctuation:

```
[4]: 1 punctuation = "\\"\\'()[]{}<.,;:?!^@~#$%&*_-
```

punctuation is assigned
\\"\\'()[]{}<.,;:?!^@~#\$%&*_-

The string punctuation contains all punctuation on a Latin alphabet keyboard. Compare the symbols with the ones on your keyboard and note whether there are additional ones! If so, add them to punctuation in Jupyter Notebook 19! The symbols at the beginning of the string punctuation "\\"\\ might be a bit confusing, so let's disentangle them. The first quote "\\"\\ is the symbol that introduces the string. The following two symbols "\\"\\ are special characters—you might remember the special character "\n", which is used to go to a new line (Chapter 12). The backslash \\ tells Python that the following quote " is an actual backslash character and not the symbol that we use to close a string. The last backslash "\\"\\ is an actual backslash because the following forward slash / is not a special character.

- Print and count the number of characters that are punctuation **or** vowels:

```
[5]: 1 # string of vowels
2 vowels = "aeiou"
3
4 # initialize counter
5 counter = 0
6
7 # for each position in the message
8 for i in range(len(message)):
9
10    # if the current element is punctuation
11    # or vowel
12    if message[i] in punctuation or
13        message[i] in vowels:
14
15        # print a message
16        print(message [i] + " is a vowel
17            or a punctuation")
18
19    # increase the counter
20    counter += 1
21
22 # print the final amount
23 print("The total amount of punctuation or
24 vowels is " + counter)
```

string of vowels
vowels is assigned aeiou

initialize counter
counter is assigned zero

for each position in the message
for i in range len of message

if the current element is
punctuation or vowel
if message in position i in
punctuation or message in position
i in vowels

print a message
print message in position i
concatenated with is a vowel or a
punctuation

increase the counter
counter is increased by one

print the final amount
print(The total amount of punctuation
or vowels is concatenated with
counter

a is a vowel or a punctuation
e is a vowel or a punctuation
a is a vowel or a punctuation

```
i is a vowel or a punctuation
e is a vowel or a punctuation
a is a vowel or a punctuation
! is a vowel or a punctuation
! is a vowel or a punctuation
! is a vowel or a punctuation
The total amount of punctuation or vowels is 9
```

Similarly to what we did for punctuation, we create a string containing vowels (line 2). We also create a counter, which we will use to calculate the number of characters that are punctuation or vowels, and we initialize it to zero (line 5). Then, we get to the core of the solution! We use a for loop to browse all the characters in the string `message` (line 8). **For loops for strings work exactly the same way as for loops for lists.** In the loop body, we check if each character is a punctuation or a vowel by using the membership operator `in` (line 11), which we learned in Chapter 3. More specifically, we check if `message[i]` is in the string `punctuation` or in the string `vowels`. Note that as for the for loop, the membership operator `in` works for strings the same way as it works for lists. Since only one of the conditions can be valid (a character cannot be both a punctuation and a vowel at the same time!), we merge the two conditions—that is, `message[i] in punctuation or message[i] in vowels`—using the **logical operator `or`**.

We use the logical operator `or` when we want to check whether **at least one condition is valid**

The syntax is the same as for the logical operator `and`: we need to write (1) a variable, (2) a comparison operator, and (3) a term of comparison *both before and after* `or`. To conclude the loop body, we print a message for the characters that satisfy at least one condition (line 14), and we increment the counter by one unit (line 17). At the end of the loop, we print the final number of characters that are vowels or punctuation (line 20).

3. not

- Given the following list of integers:

```
[7]: 1 numbers = [4, 6, 7, 9] numbers is assigned four, six, seven, nine
```

- Print out the numbers that are **not** divisible by 2:

<pre>[8]: 1 # for each position in the list 2 for i in range(len(numbers)): 3 4 # if the current number is not even 5 if not numbers[i] % 2 == 0: 6 7 # print the current number 8 print(numbers[i])</pre>	<pre>for each position in the list for i in range len of numbers # if the current number is not even if not numbers in position i modulo two equals zero print the current number print numbers in position i</pre>
--	---

For each position in the list (line 2), we have to check whether the number is *not* even. For a moment, let's think about the opposite: what condition would we write if we had to check whether the number is even? `if numbers[i] % 2 == 0`. To negate a condition, we just add the **logical operator not before** the condition—more specifically, before the variable at the beginning of the condition (line 5).

We use the logical operator **not** when we want to check
whether **the opposite of a condition is valid**

If the condition is satisfied, then we print the number (line 8).

Is this the only way to solve this task? Maybe the first idea you had in mind was more similar to this one:

[8]:	<pre>1 # for each position in the list 2 for i in range(len(numbers)): 3 4 # if the current number is odd 5 if numbers[i] % 2 != 0: 6 7 # print the current number 8 print(numbers[i]) 9</pre>	<pre>for each position in the list for i in range len of numbers # if the current number is odd if numbers in position i modulo two is not equal to zero: print the current number print numbers in position i</pre>
------	--	--

For each position in the list (line 2), we check whether the remainder of `numbers[i]` divided by 2 is not equal to 0 (line 5). If so, then we print the number (line 8).

What solution is better? It's a matter of preference! If you are undecided, pick the solution that looks like the simplest to you, both in term of syntax and reasoning. In coding, there are often various ways of solving a task. Keeping the solution **simple** favors **readability** and **understanding**.

Last note about conditions: when combining conditions, we need to follow a precise order, similarly to what we do with arithmetic operators (see *Solving arithmetic expressions* in Chapter 13). The order from highest to lowest precedence is: not, and, or (easy-to-memorize acronym: **NAO**). When you are uncertain, write the condition to prioritize within round brackets () .

4. not in

- Generate 5 random numbers between 0 and 10. If the random numbers are **not** already **in** the following list, then add them:

[9]:	<pre>1 numbers = [1, 4, 7]</pre>	<pre>numbers is assigned one, four, seven</pre>
------	----------------------------------	---

[10]:	<pre>1 import random</pre>	<pre>import random</pre>
-------	----------------------------	--------------------------

```
for five times
for underscore in range five

generate a random number between zero
and ten
number is assigned random dot randint
zero ten
print the number as a check
print number

if the new number is not in numbers
if number not in numbers:
add the number to numbers
numbers dot append number

print the final list
print numbers
```

We start by importing the package `random` (line 1). Then, we create a `for` loop that runs for five times (line 4)—note the underscore instead of the variable `i` because we will not need any index in the `for` loop body (see *What if I don't use the index in a for loop?* in Chapter 15). Then, we create a random variable (line 7) and print it as a check (line 9). To **evaluate if the variable number is not already in the list numbers** (line 12), we use the **membership operator not in**, which is the opposite of the membership operator `in` (Chapter 3). If the condition is met, then we append the randomly generated number to the list of numbers (line 14). Finally, we print the completed list (line 17).



Insert into the right column

You now know all membership, comparison, and logical operators. Insert each symbol in the right column:

<, or, in, !=, not, >, ==, not in, >=, and, <=

Recap

- The logical operators are and, or, and not.
- When combining conditions, the order of execution is not, and, or (NAO).
- The membership operators are in and not in.

What is GitHub?

You might have heard about GitHub, or you might have browsed some pages on its site (github.com). Surely, you have checked the solutions of the exercises of this book on GitHub! But what is GitHub exactly? In a simplified manner, we can think of GitHub as a cloud service or a huge server for code. Instead of using Dropbox, Google Drive, etc., coders prefer to synchronize their code with GitHub. GitHub has its own language: folders are called *repositories*, sending files to the server is called a *push*, and getting files from the server is called a *pull*. Each repository contains files—they can store any files, either containing code or not—and elements that are specific to coding, such as *issues*, where anybody can indicate bugs to be solved or suggest new features. Why do coders use GitHub instead of other cloud services? Because GitHub supports **version control**, that is, it **keeps track of code changes over time**. Every time we push a code update, we can compare it with previous version(s), and if the new code does not work, then we can go back to an earlier version. Furthermore, GitHub is useful for collaborative projects: programmers can work on different sections of a task individually and then integrate the code without accidentally influencing each other's code, all while keeping track of each programmer's contribution. These tasks are actually executed by **Git**, which is a distributed version control system, that is, a software that manages changes to code. Other platforms that employ Git include GitLab (gitlab.com) and Bitbucket (bitbucket.org), with GitHub being the most popular.



Let's code!

1. The Zen of Python. Solve the following 4 steps, and you will discover the Zen of Python!

- a. Given the following list of strings:

```
strings_to_slice = ["reisk", "kpan", "xfsimpleg", "bosolutionb", "pobetterx",
"weorb", "ofworsep", "aathanx", "hoau", "hfcomplexx", "poors", "opcomplicatedx",
"rwsolutions", "re?o"]
```

Create a new list called `sliced_strings` containing the same strings but without the first two letters and the last letter (example: "gfhio" will become "hi").

- b. Given the following list of strings:

```
strings_to_invert= ["emos", "elpoep", "kniht", "taht", "xelpmoc", "ro",
"detacilpmoc", "si", "retteb", "naht", "elpmis"]
```

Create a new list called `inverted_strings` containing the same strings but inverted (example: "ih" will become "hi").

- c. Given the following list of strings:

```
strings_to_pick = ["this", "sounds", "simple", "but", "is", "it?", "some",
"things", "look", "better", "than", "when", "complex", "but", "complex",
```

"again", "is", "worse", "better", "than", "complicated", "I'm", "confused"]

Find the words that are present both in `sliced_strings` and `inverted_strings`, change them to uppercase, and add them to a new list. What sentence do you get?

- d. Where does the obtained sentence come from? Run the following Python command: `import this`.
2. *Playing with numbers.* Given the following list of numbers:
- ```
numbers = [7, 9, 15, 19, 24, 30, 37, 45, 50]
```
- a. Print the numbers that are divisible by 3 and 5.
  - b. Print the numbers that are divisible by 3 or 5.
  - c. Print the numbers that are divisible by 3 but not 5. Perform this task in two different ways, once using `not`, and once without using `not`.
3. *Upgrading Rock, paper, scissors.* In Chapter 16, we implemented rock, paper, scissors. In that version, there were many repetitions. In coding, we usually do not want repetitions because they can invite errors. How can we make the code less repetitive? By combining conditions! What conditions can you combine in this game? Rewrite rock, paper, scissors in a more succinct way using logical operators. After you have optimized the code, make it a real game by adding a `while` loop that allows players to play as long as they want. Hint: Instead of thinking in terms of computer and player choices, think in terms of outcomes, i.e., tie and the player's (or the computer's) win.

# 20. Behind the scenes of comparisons and conditions

## Booleans

It's finally time to unveil what's behind comparisons and conditions! What does Python "see" when we write a comparison or a condition? Let's find it out with the code below! Follow along with Notebook 20.

### 1. Single comparison or condition

- Given the following assignment:

```
[1]: 1 number = 5 number is assigned five
```

- What is the outcome of the following comparison operation?

```
[2]: 1 print(number > 3) print number is greater than three
 True
```

The printed value is `True`. In fact, it is true that 5 is greater than 3! But what is `True`? A string? A variable? Let's figure it out in the next cell!

- Assign the above operation to a variable and print it. What type is it?

```
[3]: 1 result = number > 3 result is assigned number is greater than three
 2 print(result)
 3 type(result) print result
 type result
 True
 bool
```

We assign the result of the comparison operation `number > 3` to the variable `result` (line 1). Then, we print `result` (line 2) and we get `True`—like in cell 2. Finally, we print the outcome of `type(result)` to determine the type of the variable `result` (line 3)—we mentioned the built-in function `type()` in Chapter 13. We say that the variable `result` is of **type Boolean** and its value is `True`. Booleans are a data type exactly like strings, lists, integers, etc.

Let's continue our exploration of what lies behind comparisons and conditions. Let's look at this example:

- What is the outcome of the following comparison operation?

```
[4]: 1 print(number < 3) print number is less than three
 False
```

This time, the print is `False`. Obviously, 3 is not smaller than 5. Let's continue, similarly to what we did in cell 3.

- Assign the above operation to a variable and print it. What type is it?

|      |                                                            |                                                                             |
|------|------------------------------------------------------------|-----------------------------------------------------------------------------|
| [5]: | 1 result = number < 3<br>2 print(result)<br>3 type(result) | result is assigned number is less than three<br>print result<br>type result |
|      |                                                            | False                                                                       |
|      |                                                            | bool                                                                        |

We assign the output of the comparison operation `number < 3` to the variable `result` (line 1), and we print it (line 2), obtaining `False`, like in cell 4. Then, we print the type of the variable `result` (line 3) and we get `'bool'`, like we did for `True`.

Booleans are a variable **type**. They can have only two values: **True** or **False**

When we write conditions in an `if/else` construct or in a `while` loop header, Python “reads” the result behind the conditions: that is, **True** or **False**. For example, when we write:

|                                              |                                                  |
|----------------------------------------------|--------------------------------------------------|
| 1 if numbers > 3:<br>2     print("Correct!") | if number is greater than three<br>print Correct |
|----------------------------------------------|--------------------------------------------------|

Python “sees”:

|                                       |                          |
|---------------------------------------|--------------------------|
| 1 if True:<br>2     print("Correct!") | if True<br>print Correct |
|---------------------------------------|--------------------------|

## 2. Combining comparisons or conditions

Let’s take the operation a step further and see what happens when we combine conditions.

- What is the outcome of the following comparison operations?

|      |                                                                                                  |                                                                                                                                                             |
|------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [6]: | 1 number = 3<br>2 print(number > 1)<br>3 print(number < 5)<br>4 print(number > 1 and number < 5) | number is assigned 3<br>print number is greater than one<br>print number is less than five<br>print number is greater than one and number is less than five |
|      |                                                                                                  | True                                                                                                                                                        |
|      |                                                                                                  | True                                                                                                                                                        |
|      |                                                                                                  | True                                                                                                                                                        |

We assign 3 to the variable `number` (line 1). Then, we print the outcome of three comparison operations. For all operations—`number > 1` (line 2), `number < 5` (line 3), and `number > 1 and number < 5` (line 4)—the outcome is `True`. Let’s focus on line 4, where we combine two comparison operations with the logical operator `and`. For these combined operations, Python “sees”:

|                         |                     |
|-------------------------|---------------------|
| 4 print(True and True): | print True and True |
|                         | True                |

As we can see, the output of two `True` conditions combined by the logical operator `and` is `True`.

- What happens if we change the first condition to be false?

```
[7]: 1 number = 3
 2 print(number > 4)
 3 print(number < 5)
 4 print(number > 4 and number < 5)
```

|                                                                |
|----------------------------------------------------------------|
| number is assigned 3                                           |
| print number is greater than four                              |
| print number is less than five                                 |
| print number is greater than four and number is less than five |
| False                                                          |
| True                                                           |
| False                                                          |

The first condition is now `False` because 3 is not larger than 4 (line 2), whereas the second condition is still `True` (line 3). The combination of the `False` condition from line 2 with the `True` condition from line 3 returns `False` (line 4). In this last case, Python “sees”:

```
4 print(False and True): print False and True
False
```

Thus, the output of one `True` and one `False` conditions merged by the logical operator `and` is `False`. Let's continue analyzing the remaining combinations!

- What happens if we change the second condition to be false?

```
[8]: 1 number = 3
 2 print(number > 1)
 3 print(number < 2)
 4 print(number > 1 and number < 2)
```

|                                                              |
|--------------------------------------------------------------|
| number is assigned 3                                         |
| print number is greater than one                             |
| print number is less than two                                |
| print number is greater than one and number is less than two |
| True                                                         |
| False                                                        |
| False                                                        |

The first condition is `True` (line 2)—like it was in cell 6—whereas the second condition is now `False` because 3 is not smaller than 2 (line 3). Similarly to cell 7, the combination of one `True` condition and one `False` condition (line 4) returns `False`. In this case, Python “reads”:

```
4 print(True and False): print True and False
False
```

We can deduce that the output of one `False` and one `True` conditions merged by the logical operator `and` is always `False`, regardless of the order of the conditions.

- Finally, what happens if we change both conditions to be false?

```
[9]: 1 number = 3
 2 print(number > 4)
 3 print(number < 2)
 4 print(number > 4 and number < 2)
```

|                                                               |
|---------------------------------------------------------------|
| number is assigned 3                                          |
| print number is greater than four                             |
| print number is less than two                                 |
| print number is greater than four and number is less than two |
| False                                                         |
| False                                                         |
| False                                                         |

Both conditions are `False` because 4 is neither larger than 4 (line 2) nor smaller than 2 (line 3). The combination of the two conditions is `False` too (line 4). This is what Python “sees”:

```
4 print(False and False):
False
print False and False
```

We can summarize the outcome of combinations of conditions using the logical operators `and` in a **truth table**:

|     | First condition | Second condition | First condition <b>and</b> Second condition |
|-----|-----------------|------------------|---------------------------------------------|
| (1) | True            | True             | True                                        |
| (2) | False           | True             | False                                       |
| (3) | True            | False            | False                                       |
| (4) | False           | False            | False                                       |

Row 1 corresponds to the example we saw in cell 6, where both conditions were `True`, and their combination was also `True`. We can pronounce the first row as `True and True gives True`. Row 2, where `True and False gives False`, corresponds to the example in cell 7. Row 3—`False and True gives False`—corresponds to the example at cell 8. Finally, row 4 corresponds to the example in cell 9, where `False and False gives False`. When you write code that combines conditions using `and`, you can use this table as a reference to determine the outcome!

What happens when we combine conditions using the logical operator `or`? Here is the **truth table for or**:

|     | First condition | Second condition | First condition <b>or</b> Second condition |
|-----|-----------------|------------------|--------------------------------------------|
| (1) | True            | True             | True                                       |
| (2) | False           | True             | True                                       |
| (3) | True            | False            | True                                       |
| (4) | False           | False            | False                                      |

For the logical operator `or`, `True and True gives True` (row 1), `False and True gives True` (row 2), `True and False gives True` (row 3), and `False and False gives False` (row 4).

What are the similarities and differences between the `and` and `or` truth tables? The columns for the first and second conditions are the same for both tables, but the results change. For `and`, the result is `True` only when both conditions are `True`, and it is `False` in all other cases. Conversely, for `or`, the result is `False` only when both conditions are `False`, and it is `True` for all other cases. A side note: In other textbooks or on the Internet, you might find that the columns of the first and second condition are inverted. But the results remain the same!

Let's conclude with the **truth table for the logical operator `not`**. Here it is:

|     | Condition | <b>not</b> condition |
|-----|-----------|----------------------|
| (1) | True      | False                |
| (2) | False     | True                 |

`not` inverts conditions. When we write `not` in front of `True` condition, it becomes `False` (row 1). Conversely, when we write `not` in front of a `False` condition, it becomes `True` (row 2).

 Create your examples

In a notebook, write an example for each row of the or truth table and of the not truth table, similar to what we did above for and.

### 3. Where else do we use Booleans?

Booleans are often used as **flags** in while loops. What does this mean?

- Look at this modified version of the example Do you want more candies? from Chapter 17:

|       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [13]: | 1 # initialize variable<br>2 number_of_candies = 0<br>3<br>4 # use a Boolean as a flag<br>5 flag = True<br>6<br>7 # print the initial number of candies<br>8 print("You have " + str(number_of_candies) +<br>" candies")<br>9<br>10 # as long as the flag is True<br>11 while flag == True:<br>12<br>13     # ask if they want a candy<br>14     answer = input("Do you want a candy?<br>(yes/no)")<br>15<br>16     # if the answer is yes<br>17     if answer == "yes":<br>18<br>19         # add a candy<br>20         number_of_candies += 1<br>21<br>22         # print the total number of candies<br>23         print("You have " +<br>24             str(number_of_candies) + " candies")<br>25<br>26     # if the answer is not yes<br>27     else:<br>28<br>29         # print the final number of candies<br>30         print("You have a total of " +<br>31             str(number_of_candies) + " candies")<br>32<br>33         # stop the loop by assigning False to<br>the flag<br>34         flag = False | initialize variable<br>number_of_candies is assigned zero<br><br>use a Boolean as a flag<br>flag is assigned True<br><br>print the initial number of candies<br>print You have concatenated with str<br>number of candies concatenated with<br>candies<br><br>as long as the flag is True<br>while flag equals True<br><br>ask if they want a candy<br>answer is assigned input Do you want a<br>candy? (yes/no)<br><br>if the answer is yes<br>if answer equals yes<br><br>add a candy<br>number_of_candies is incremented by one<br><br>print the total number of candies<br>print You have concatenated with str<br>number of candies concatenated with<br>candies<br><br>if the answer is not yes<br>else<br><br>print the final number of candies<br>print You have a total of concatenated<br>with str number of candies concatenated<br>with candies<br><br>stop the loop by assigning False to the<br>flag<br>flag is assigned False |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

 **Find the differences**

Can you identify some differences between the `while` loop in the example above and the one in Chapter 17?

---

---

---

As you might remember from Chapter 17, for a `while` loop, we have to create a variable that is: (1) initialized *before the header*, (2) included in a condition *within the header*, and (3) allowed to change *in the body* to avoid infinite iterations. In the example in Chapter 17, the variable following these three rules was `answer`. In this example, it is `flag`. We initialize `flag` as a Boolean of value `True` (line 5), then we check if its value is equal to `True` in the `while` loop header (line 11), and finally we allow it to change to `False` (line 32) to avoid infinite loops. `flag` is a common variable name for a Boolean variable that behaves this way—`counter` is another typical variable name for a variable that keeps count of the number of iterations. We can think of a `flag` variable like a traffic light that makes the loop continue or stop. As long as the traffic light is green (i.e., `flag` is `True`), the loop will continue. When the traffic light changes to red (i.e., `flag` is assigned `False`), the loop ends. Using a Boolean flag in the `while` loop is somewhat like providing the answer to a condition instead of asking the header to test the condition.

When using a flag, the construction of a `while` loop might change. What about the variable `answer` in this new code version? We initialize `answer` at the beginning of the `while` loop body, where we use the built-in function `input` to ask a question to the player (line 14). Then we create an `if/else` condition to decide what to do based on the value of `answer` (lines 17–32). If the `answer` is "yes", then we increment the counter `number_of_candies` by 1 (line 20) and we print a feedback to the player (line 23). Otherwise (i.e., `else`), we print a final feedback to the player (line 29) and we allow the flag to change (line 32).

These are several ways to write a `while` loop. Which one should we use? All have pros and cons. Choose the one that appears simpler and easier to understand!

## Recap

- When we write a comparison or a condition, the outcome is a Boolean variable.
- Booleans are a Python type, like lists, strings, integers, etc.
- There are only 2 Boolean values: `True` and `False`.
- Combinations of conditions using `and`, `or`, `not` follow the truth tables.
- Booleans can be used as *flags* in `while` loops (they act like traffic lights).

### What is the difference between GeeksforGeeks and Stack Overflow?

There are several online resources for coding. What are the differences among them? How do we choose which to use? In a simple manner, we can categorize websites into two groups: tutorial websites and question and answer (Q&A) websites. In **tutorial websites**, each page contains clear and extensive explanations about a specific topic. Common website tutorials are GeeksforGeeks ([www.geeksforgeeks.org](http://www.geeksforgeeks.org)), W3Schools ([www.w3schools.com](http://www.w3schools.com)), or learnpython.org ([www.learnpython.org](http://www.learnpython.org)). The last two also offer the possibility of typing code directly in their webpages so that you can immediately test what you learn. On the other hand, in **Q&A website**, each page starts with a question by a user, followed by answers by other users. Usually, questions are about solving bugs or looking for better code implementations. Examples include Stack Overflow ([www.stackoverflow.com](http://www.stackoverflow.com)) or Reddit ([www.reddit.com](http://www.reddit.com)). Q&A websites are extremely useful for coders. We all encounter issues that we don't know how to solve. The great news is that there is always somebody else who had the same issue before us and whose solutions we can find online!



### Let's code!

1. Do you want less exercises? Rewrite the while loop from the exercise *Do you want less exercises?* in Chapter 17 using a Boolean as a flag in the header.
2. Flipping coins! When flipping a coin, we have two outcomes: heads and tails. In this exercise, we will use `True` for heads and `False` for tails. Flip a coin 8 times and save the outcomes in a list whose elements are of type Boolean. How many outcomes of heads and tails did you get? What is the ratio between the number of heads and tails? Now flip a coin 1000 times. What is the new ratio? How do the two ratios differ?
3. Comparator. A comparator is an algorithm that compares two numbers. It is similar to a calculator, but instead of using arithmetic operators, it uses comparison operators. Create a comparator that asks a user for two integers and prints all the possible comparisons between the two integers.

*Example:* If the user enters 3 and 5, then print out:

`3 > 5 is False`

`3 < 5 is True`

etc.

Make sure to: (1) use all the comparison operators; (2) use Booleans wherever possible; and (3) allow the user to use the comparator for as long as they want. Which numbers did you use to test that the comparator works correctly? When do you get `True` as an output?

## PART 6

# FOCUS ON LISTS AND FOR LOOPS

In this part, you will integrate your existing knowledge of lists and for loops with new concepts and properties. At the end of part 6, you will have fully mastered lists and loops!



# 21. Overview of lists

## *Operations, methods, and tricks*

We are halfway through our journey of learning computational thinking and coding in Python! Thus, this is a good moment to take a break and summarize everything we have learned about lists so far. In this chapter, we will put the “grammar” rules for Python lists to use and highlight some new important properties that are worth knowing. The chapter contains a lot of examples and details that will help you improve your coding skills and understand other people’s code. Let’s start! Follow along with Notebook 21!

### 1. Arithmetic operations on list elements

As you might remember from Chapter 13, in Python there are 7 arithmetic operations: addition (+), subtraction (-), multiplication (\*), exponentiation (\*\*), division (/), floor division (//), and modulo (%). To perform arithmetic operations **element-wise**—that is, on list elements—we use **for** loops. **Element-wise operations can be done (1) between two or more lists of the same length or (2) between a list and a number.** In both cases, we **use a for loop**. Let’s see two examples for addition (but they can be valid for any operation).

- Sum two lists element-wise:

```
[1]: 1 odd_numbers = [1, 3, 5]
 2 even_numbers = [2, 4, 6]
 3 summed = []
 4
 5 for i in range(len(odd_numbers)):
 6 summed.append(odd_numbers[i] +
 even_numbers[i])
 7
 8 print(summed)
[3, 7, 11]
```

odd\_numbers is assigned one, three, five  
even\_numbers is assigned two, four, six  
summed is assigned empty list

for i in range len odd numbers  
summed dot append odd\_numbers in position i  
plus even numbers in position i

print summed

We start with `odd_numbers` and `even_numbers`, which are two lists containing 3 integers each (lines 1 and 2), and `summed`, which we initialize as an empty list (line 3). Then, we create a `for` loop that spans the indices of one of the lists of numbers (line 5), and we append to `summed` the sum of the current element of the list `odd_numbers` to the element in the same position in the list `even_numbers` (line 6). Finally, we print the result for a check (line 8). Note that we save the result in a third list (`summed`) that we initialized as empty before the loop (line 3) and that we fill in during the loop (line 6). If we do not want to create a third list, we can overwrite one of the existing lists (e.g., `odd_numbers[i]=odd_numbers[i] + even_numbers[i]`).

- Sum a number to each element of a list:

```
[2]: 1 numbers = [1, 2, 3]
 2 number = 3
 3
```

odd\_numbers is assigned one, two, three  
number is assigned three

```
4 for i in range(len(numbers)):
5 numbers[i] += number
6
7 print(numbers)
[4, 5, 6]
```

`for i in range len of numbers`  
`numbers in position i incremented by number`  
`print numbers`

We create the list `numbers` containing three integers (line 1) and the variable `number` to which we assign the number 3 (line 2). Then, we use a `for` loop to browse all the positions of the list elements (line 4), and we increase each element by the value of `number` (line 5). Finally, we print the result (line 7). Similar to the previous example, we can either overwrite the existing list (as we do in this example) or we can create an empty list before the `for` loop (e.g., `summed = []`) and fill it in the loop (e.g., `summed.append(numbers[i] + number)`).

## 2. “Arithmetic” operations between lists

The operations between lists are not actually arithmetic, but they use arithmetic symbols with a different meaning. **The two possible operations are concatenation**, which uses the symbol `+` (pronounced as concatenated with) **and replication**, which uses the symbol `*` (pronounced as replicated by [number]). Let’s see the examples:

- Concatenate two lists:

```
[3]: 1 odd_numbers = [1, 3, 5]
2 even_numbers = [2, 4, 6]
3 concatenated = odd_numbers + even_numbers
4 print(concatenated)
[1, 3, 5, 2, 4, 6]
```

`odd_numbers is assigned one, three, five`  
`even_numbers is assigned two, four, six`  
`concatenated is assigned odd numbers`  
`concatenated with even numbers`  
`print concatenated`

We create two lists, one containing odd numbers (`odd_numbers`; line 1) and one containing even numbers (`even_numbers`; line 2). Then we concatenate them using the concatenation symbol `+` (line 3), and we store the result in a new list called `concatenate` (line 3). If we don’t want to create a new variable, we can overwrite one of the two existing lists: `odd_numbers = odd_numbers + even_numbers`. Finally, we print the result (line 4), which is a list containing the elements of `odd_numbers` and `even_numbers` sequentially merged.

- Replicate a list 3 times:

```
[4]: 1 numbers = [1, 2, 3]
2 number = 3
3 replicated = numbers * number
4 print(replicated)
[1, 2, 3, 1, 2, 3, 1, 2, 3]
```

`odd_numbers is assigned one,two,three`  
`number is assigned three`  
`replicated is assigned numbers replicated`  
`by number`  
`print replicated`

We create a list called `numbers` (line 1) and an integer variable called `number` (line 2). Then we replicate the list `numbers` by the number of times indicated by the variable `number` using the symbol `*`, and we save the result in a new list called `replicated` (line 3). Once more, instead of creating a new variable, we can overwrite the existing list: `numbers = numbers * number`. Finally, we print `replicated` (line 4). As you can see in the printout, `replicated` contains the list `numbers` repeated three times. When is replication useful? Let’s see the following example:

We initialize `short_list` as a list containing one zero (line 1) and the variable `short_list` containing the value 50 (line 2). Then, we replicate `short_list` by the number of times indicated by `number` (line 3), and we store the result in the variable `long_list`. Finally, we print `long_list` (line 4). As you can see, we obtained a list containing 50 zeros. If we had created `long_list` manually, it would have been very tedious, and we could have easily miscounted the number of zeros in the list! Finally, note that in alternative to create the variables `short_list` and `number`, we can directly write: `long_list=[0]*50`.

### 3. List assignment

When we assign a list to another list, we have to be very careful! Let's see why.

- Given a list containing a few integers:

```
[6]: 1 given_list = [1, 2, 3]
 2 print(given_list)
 [1, 2, 3] given list is assigned one, two, three
 print given list
```

We create a list called `given_list` containing some integers (line 1) and we print it (line 2).

- Assign `given_list` to `new_list`:

```
[7]: 1 new_list = given_list
 2 print(new_list)
[1, 2, 3] new list is assigned given list
 print new list
```

We assign `given_list` to another list called `new_list` (line 1), and we print it (line 2). As we can see, `new_list` contains the same elements as `given_list`, as expected. Let's go one step further!

- Change the first list element of new\_list:

```
[8]: 1 new_list[0] = 40
 2 print(new_list)
 [40, 2, 3]
 new list in position zero is assigned
 forty
 print new list
```

We change the first element of `new_list` to `40` (line 1) and we print `new_list` after the change (line 2). As expected, the first element is now `40`. What about `given_list`?

- Print given list:

```
[9]: 1 print(given_list)
 [40, 2, 3] print given list
```

The first element of `given_list` is also `40`! This happens because when we assign a list to another, we give two names to the same list. It is a bit like when a person has two names: for example, my brother's name is Flavio Alberto. Whether I call him Flavio or Alberto, he is always the same person!

- How can we create an independent copy of a list?

```
[10]: 1 given_list = [1, 2, 3]
 2 new_list = given_list.copy()
 3 new_list[0] = 40
 4 print(given_list)
 5 print(new_list)
[1, 2, 3]
[40, 2, 3]
```

given list is assigned one, two, three  
new list is assigned given list dot copy  
new list in position zero is assigned  
forty  
print given list  
print new list

As we did in cell 6, we create the list `given_list` that contains a few numbers (line 1). Then, instead of assigning `given_list` to `new_list` (line we did in cell 7), we use the **method `.copy()`**, which **creates an independent copy of a list** (line 2). Continuing the brother analogy, it is like if we created a twin that is similar but independent, so that when we make changes, they happen only in the list we actually change. At the end of the example, we change the first element of `new_list` to 40 like we did in cell 8 (line 3), and we print out both lists (lines 4 and 5).

#### 4. Adding one element or a list to a list

We can add **an element** to a list in two ways: either **at the end using the method `.append()`** (see Chapter 4), or **at a specific position using the method `.insert()`** (see Chapter 5). Let's see two easy examples to refresh how the methods work.

- Add one element at the end of a list:

```
[11]: 1 numbers = [1, 2, 3]
 2 numbers.append(4)
 3 print(numbers)
[1, 2, 3, 4]
```

numbers is assigned one, two, three  
numbers dot append four  
print numbers

We create the list `numbers` containing three integers (line 1), and we add the number 4 using the method `.append()` (line 2). Then, we print `numbers` to check the result (line 3).

- Insert the number 2 in position 1:

```
[12]: 1 numbers = [1, 3, 4]
 2 numbers.insert(1, 2)
 3 print(numbers)
[1, 2, 3, 4]
```

numbers is assigned one, three, four  
numbers dot insert at position one, two  
print numbers

We initialize a list containing the integers 1, 3, and 4 (line 1). At position 1, we insert the number 2 using the method `.insert()`, which takes as arguments **first the position and then the value** of the new element (line 2). Finally, we print out `numbers` (line 3).

There are two ways to add **a list** at the **end** of another list: **concatenation** (see cell 3 and another example below) and the **method `.extend()`**.

- Concatenate two lists:

```
[13]: 1 first_list = [1, 2, 3]
 2 second_list = [4, 5, 6]
 3 third_list = first_list + second_list
 4 print(third_list)
[1, 2, 3, 4, 5, 6]
```

first\_list is assigned one, two, three  
second\_list is assigned four, five, six  
third list is assigned first list  
concatenated with second list  
print third list

We create two lists, called `first_list` and `second_list`, to which we assign some integers (lines 1 and 2). Then, we concatenate the two lists to obtain `third_list` (line 3). Finally, we print `third_list` (line 4).

- Add one list at the end of another list:

|                                                                                                                                               |                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[14]: 1 first_list = [1, 2, 3]        2 second_list = [4, 5, 6]        3 first_list.extend(second_list)        4 print(first_list)</pre> | <pre>first_list is assigned one, two, three second_list is assigned four, five, six first list dot extend second list print first list</pre> |
| <pre>[1, 2, 3, 4, 5, 6]</pre>                                                                                                                 |                                                                                                                                              |

We use the same two lists as in cell 13 (lines 1 and 2), but we use the method `.extend()` to merge them. The syntax for `.extend()` is (1) the list to which we want to add another list (2) dot, and (3) the added list in between round brackets (line 3). Then, we print the merged list (line 4).

What are the differences between concatenation and `.extend()`? When using concatenation, we can either create a new list (e.g., `third_list = first_list + second_list`), or we can add a list to an existing one (e.g., `first_list = first_list + second_list`). Instead, when using `.extend()`, we can only modify the list to which we apply the method (i.e., `first_list` in cell 14). In addition, when using `.extend()`, we can add a list **only at the end** of another list, whereas when using **concatenation—combined with slicing**—we can add a list **at the beginning** (e.g. `first_list = second_list + first_list`) **or in the middle** of another list (e.g. `first_list = first_list[:2] + second_list + first_list[2:]`).

## 5. Removing elements from a list

We can remove list elements either based on their *value*, using `.remove()` (see Chapter 4) or on their position, using `.pop()` (see Chapter 5). We can also remove *all* elements using `.clear()`. Let's see some example to refresh these methods and learn some new tricks.

- From the following list, remove all the elements "ciao":

|                                                                                                                      |                                                                                              |
|----------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| <pre>[15]: 1 greetings = ["ciao", "ciao", "hello"]        2 greetings.remove("ciao")        3 print(greetings)</pre> | <pre>greetings is assigned ciao, ciao, hello greetings dot remove ciao print greetings</pre> |
| <pre>['ciao', 'hello']</pre>                                                                                         |                                                                                              |

We start with a list containing three strings, where the element "ciao" is present twice (line 1). Then, we use the method `.remove()`, to eliminate "ciao" (line 2). Finally, we print `greetings` (line 3). Only one "ciao" (the first one) was removed! In lists containing multiple similar elements, the method **`.remove()` deletes only the first element**. How do we remove both "ciao" from `greetings`? The first instinctive idea might be to use a `for` loop that goes through all element positions and removes the unwanted elements based on a certain condition (in this case, remove the element if it is equal to "ciao"). However, this solution does not work for the reasons explained in the *In more depth* section at the end of this chapter. What we need is a `while` loop:

|                                                                                                                                                              |                                                                                                                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| <pre>[16]: 1 greetings = ["ciao", "ciao", "hello"]        2 while "ciao" in greetings:        3     greetings.remove("ciao")        4 print(greetings)</pre> | <pre>greetings is assigned ciao, ciao, hello while ciao in greetings greetings dot remove ciao print greetings</pre> |
| <pre>['hello']</pre>                                                                                                                                         |                                                                                                                      |

We start with the list `greetings` (line 1), then we create a `while` loop where as long as the string "ciao" is in `greetings` (line 2), we remove it using the method `.remove()` (line 3). Finally, we print the result (line 4).

Let's continue to see how to remove an element based on its position and all elements in a list. In the following two cells (17 and 18), we write the list at line 1, and we print the result at line 3. At line 2, we use a different list method. Let's have a look at the examples:

- Remove the string "hello" based on its position:

|                                                                                                            |                                                                                          |
|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <pre>[17]: 1 greetings = ["ciao", "ciao", "hello"]       2 greetings.pop(2)       3 print(greetings)</pre> | <pre>greetings is assigned ciao, ciao, hello greetings dot pop two print greetings</pre> |
|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|

To remove an element based on its position, we use the method `.pop()`, which we learn in Chapter 5 (line 2). As you might remember, **the argument of the method is the position of the element to delete**.

- Remove all elements in a list:

|                                                                                                             |                                                                                        |
|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <pre>[18]: 1 greetings = ["ciao", "ciao", "hello"]       2 greetings.clear()       3 print(greetings)</pre> | <pre>greetings is assigned ciao, ciao, hello greetings dot clear print greetings</pre> |
|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|

To remove all elements in a list, we use the method `.clear()` (line 2). The list **becomes an empty list**.

Another way to remove elements in a list is by using list comprehension. We will see it in the next chapter.

## 6. Sorting a list

Sorting lists is a very common task in coding. For example, we might want to sort names alphabetically (see the exercise "A further step!" below) or a list of prices increasingly or decreasingly. In the three examples below (cells 19, 20, and 21), we will create a list of integers called `numbers` (line 1), use a new method to execute the task (line 2), and print the outcome (line 3).

- Sort the following list of integers:

|                                                                                      |                                                                                |
|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| <pre>[19]: 1 numbers = [5, 7, 6]       2 numbers.sort()       3 print(numbers)</pre> | <pre>numbers is assigned five, seven, six numbers dot sort print numbers</pre> |
|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|

To sort the list `number`, we use the method `.sort()` (line 2). As you can see from the printout, the numbers are sorted in an **increasing (or ascending)** way, that is from the smallest to the greatest. What if we want to sort the numbers in a **decreasing (or descending)** way? The answer is in the next example:

- Sort the following list of integers in a descending way:

|                                                                                                    |                                                                                                         |
|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <pre>[20]: 1 numbers = [5, 7, 6]       2 numbers.sort(reverse = True)       3 print(numbers)</pre> | <pre>numbers is assigned five, seven, six numbers dot sort reverse is assigned True print numbers</pre> |
|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|

We use `.sort()` as we did in the example above, but we add the argument `reverse`, to which we assign the Boolean `True`—you will learn more about method (or function) parameters starting in Chapter 28. As you can see from the printout, the list is now sorted in a descending way: that is, from the greatest to the smallest number.

- Reverse the following list of integers:

|                                                                                                     |                                                                                   |
|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <pre>[21]: 1 numbers = [5, 7, 6]        2 numbers.reverse()        3 print(numbers) [6, 7, 5]</pre> | <pre>numbers is assigned five, seven, six numbers dot reverse print numbers</pre> |
|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|

We use the method `.reverse()` to **invert the order of the elements in the list**. Thus, the last will become the first, the second to last element will become the second, etc. Note that `.reverse()` sorts the element based on their *position*, whereas `.sort()` (see example above) sorts the elements based on their *value*.

## 7. Searching elements

Let's conclude our long journey through list methods by learning how to search and count elements.

- Create a list and search for a specific element:

|                                                                                                                     |                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| <pre>[22]: 1 letters = ["a", "g", "c", "g"]        2 position = letters.index("g")        3 print(position) 1</pre> | <pre>letters is assigned a, g, c, g position is assigned letters dot index g print position</pre> |
|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|

We create the list `letters` containing strings (line 1), and we **look for the position of the element "g"** by using the method `.index()`, which we learned in Chapter 5. Then, we print the results (line 3). As you can see, `.index()` just gives us the position of the first element, which is 1—because element positions start from `0` in Python.

- How do we find all positions?

|                                                                                                                                                                                                                           |                                                                                                                                                                                        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[23]: 1 letters = ["a", "g", "c", "g"]        2 positions = []        3 for i in range(len(letters)):        4     if letters[i] == "g":        5         positions.append(i)        6 print(positions) [1, 3]</pre> | <pre>letters is assigned a, g, c, g positions is assigned empty list for i in range len of letters if letters in position i is equal to g positions dot append i print positions</pre> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

To find all positions of an element in a list, we can use the `for` loop! We create the list `letters` (line 1) and the empty list `positions` that will contain the indices corresponding to the letter "g" (line 2). Then, we create a `for` loop that browses all the positions of the letters (line 3), and if the current letter is equal to "g" (line 4), then we append its position (that is, "i") to the list `positions` (line 5). Finally, we print the result (line 6).

- Count how many times an element is present in a list:

```
[24]: 1 letters = ["a", "g", "c", "g"]
2 n = letters.count("g")
3 print(n)
2
```

letters is assigned a, g, c, g  
n is assigned letters dot count g  
print n

We start with the same list `letters` as in the example above (line 1), and we use the **method `.count()`** to count how many times the letter "g" is in the list (line 2). Finally, we print the result (line 3).

In this chapter, you have refreshed and learned how to execute all the typical operations that we perform on lists by using list methods and various operators. At this point, you can consider yourself an expert in lists! Congratulations!

### A further step!

Answer the following questions to discover more tricks about lists!

1. How can we efficiently remove the elements of a list in even positions?

---

---

2. What is the difference between the method `.clear()` and the keyword `del`?

---

---

3. What is the output of the method `.sort()` for a list of strings? E.g.: `sweets = ["chocolate", "icecream", "candy", "cake"]`

---

---

4. What is the output of the method `.sort()` for a list of strings and numbers? E.g.: `sweets_numbers = ["chocolate", 43, "icecream", "candy", "cake", 18]`

---

---

### Complete the table

In this chapter, you learned or refreshed the 11 list methods. Fill out the table below with method definitions and alternative ways to implement the same operation. Some alternatives are presented in this chapter or in previous chapters, but for others, you will have to come up with new ideas (feel free to consult the internet!)

| Method     | What it does | Alternative |
|------------|--------------|-------------|
| .append()  |              |             |
| .clear()   |              |             |
| .copy()    |              |             |
| .count()   |              |             |
| .extend()  |              |             |
| .index()   |              |             |
| .insert()  |              |             |
| .pop()     |              |             |
| .remove()  |              |             |
| .reverse() |              |             |
| .sort()    |              |             |

## Recap

- We can perform element-wise operations in lists using the arithmetic operators `+, -, *, /, **, //, %`.
- We can perform “arithmetic” operations on lists using concatenation `+` and replication `*`.
- The 11 methods for lists are: `.append()`, `.clear()`, `.copy()`, `.count()`, `.extend()`, `.index()`, `.insert()`, `.pop()`, `.remove()`, `.reverse()`, `.sort()`.
- Of the 11 methods, the 3 methods that return a new value are `.copy()`, `.count()`, and `.index()`. The other 8 methods modify the lists themselves.

## Why not use a for loop to remove list elements?

A for loop is not the right way to remove elements in a list for at least two reasons. Let's see them in this example:

```
[1]: 1 greetings = ["ciao","ciao","hello"]
 2 for i in range(len(greetings)):
 3 print("-----")
 4 print("i == " + str(i))
 5 print("before the if:")
 6 print("greetings")
 7 if greetings[i] == "ciao":
 8 del greetings[i]
 9 print("after the if:")
 10 print("greetings")
```

-----  
(a) i == 0  
(b) before the if:  
(c) ['ciao', 'ciao', 'hello']  
(d) after the if:  
(e) ['ciao', 'hello']  
(f) -----  
(g) i == 1  
(h) before the if:  
(i) ['ciao', 'hello']  
(j) after the if:  
(k) ['ciao', 'hello']  
(l) -----  
(m) i == 2  
(n) before the if:  
(o) ['ciao', 'hello']

-----  
IndexError Traceback (most recent call last)  
Cell In[16], line 6  
 5 print("before the if:")
 6 print("greetings")
----> 7 if greetings[i] == "ciao":
 8 del greetings[i]
 9 print("after the if:")
IndexError: list index out of range

We start with the list `greetings` that we created in Paragraph 5 (line 1). Then, we create a for loop that browses all the positions in the list (line 2). In the for loop, we use an if condition to check whether the current element is equal to the element to remove (line 7). If that is the case, then we remove the current element using the keyword `del`, which we learned in Chapter 6 (line 8). In between the main commands, we print some messages to check the list changes at each iteration: a graphic separator for each loop (line 3), the number of the current iteration (line 4), and the list before deletion (lines 5 and 6) and after deletion (lines 9 and 10). Note that for clarity of the following explanation, the printed lines are identified with letters, which are not actually printed when running the code.

Let's see what happens at each loop:

- First loop ( $i==0$ ): before the if, the list is complete `["ciao", "ciao", "hello"]` (line (c)). After the if, `greetings` contains only `["ciao", "hello"]` (line (e)). Three changes happened: (1) the string "ciao" in position 0 (in orange in Figure 21.1) is removed; (2) the element indices restarted from 0, changing the positions of the remaining elements (that is, the green "ciao" was in position 1 before the if and moved to position 0 after the if, and the string "hello" was in position 2 before the if and moved to position 1 after the if); and (3) the length of the list changed from 3 to 2. The changes (2) and (3) will have consequences in the second and third loops.

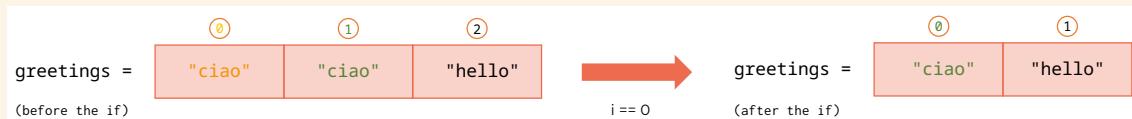


Figure 21.1. Change of list content, element positions, and list length after deletion of a list element.

- Second loop ( $i==1$ ): before the if, the list is the same as it was at the end of the previous loop, that is `["ciao", "hello"]` (line (i)). And after the if, the list remains the same (k) because the current element `greetings[1]`, that is, "hello", does not satisfy the if condition. Why wasn't the string "ciao" in position 0 (green in Figure 21.1) deleted? The change of list index in the previous loop moved "ciao" from position 1 to position 0, so we skip its deletion because we are currently at the second iteration of the for loop!
- Third loop ( $i==2$ ): before the if, the list is still `["ciao", "hello"]` (line (0)). Than, we get an index error at line 6 of the code, where the if conditions is. This is because i is now 2, but `greetings[2]` does not exist because we shortened the list when we deleted the first "ciao" in the first loop. Thus, the error "out of range" is due to a failed attempt to slice the list `greetings` in position 2, which does not exist! Note that the index i is currently 2 because in the header of the for loop (line 2), we stated that i goes from 0 to the length of the list (`len(greetings)`), which is the initial list length and does not adapt to length changes during the loop!

In conclusion, by using a for loop to delete an element in a list, we can cause two errors: (1) we **skip list elements** that we should delete because of the index shift, and (2) we get **out of range errors** related to the index because we shorten the list by removing some elements.

## Let's code!

1. *Selling veggies at the market.* At your stand at the market, you started the day with the following items:

| Item     | N. of items | Price per item |
|----------|-------------|----------------|
| carrots  | 10          | 0.7            |
| zucchini | 12          | 0.5            |
| potatoes | 11          | 0.2            |

- a. Create three lists: one for the items, one for the number of items, and one for their prices.

- b. Today you got 3 customers. You want to keep track of how much money each customer spent and how much produce they bought. Create and initialize a list called `total`, where each element corresponds to the amount spent by a customer (how long is the list? what are its content?).
  - c. The first customer bought 2 carrots, 4 zucchini, and 3 potatoes. Create a list where each element is the number of bought items (i.e., the list will contain 3 elements, corresponding to number of carrots, zucchini, and potatoes, respectively).
  - d. How much did the customer pay? Save the amount in the first position of the list `total` without creating an intermediate variable (*hint*: if you don't know how to do it, first solve the task by using an intermediate variable, and then find a way to remove it).
  - e. The second customer got 3 carrots and 3 potatoes. Create the corresponding item list. How much did the customer pay? Save the amount in the second position of the list `total`.
  - f. The third customer wanted 6 carrots, 4 zucchini, and 1 potatoes. Create the corresponding item list.
  - g. Did you have enough items to sell? Compute it.
  - h. Given that the third customer is going to buy whatever is left (e.g., if they wanted 6 carrots, but only 2 were left, they bought 2), how do you modify their item list? Use `if/elif`.
  - i. How much did the third customer pay? Save the amount in the third position of the list `total`.
  - j. What was the average amount a customer spent at your stand?
  - k. What was your most popular item today? And the one you sold the least? Compute them!
2. New year's countdown! Given the following list: `numbers = [0,1,2,3,4,5,6,7,8,9]`, reverse it using:
    - a. A list method.
    - b. Slicing.
    - c. A `for` loop.

What are the differences among the three methods?

3. App store. You are running a market study on app store data. These are the prices of the apps in the store:

```
app_prices = [
 7.99, 7.99, 2.99, 4.99, 7.99, 9.99, 9.99, 1.99, 1.99, 1.99,
 4.99, 5.99, 3.99, 5.99, 0.99, 3.99, 3.99, 2.99, 1.99, 4.99,
 8.99, 1.99, 3.99, 1.99, 1.99, 8.99, 6.99, 0.99, 6.99, 8.99,
 3.99, 1.99, 0.99, 1.99, 0.99, 8.99, 1.99, 7.99, 3.99, 1.99,
 8.99, 2.99, 4.99, 6.99, 4.99, 7.99, 8.99, 1.99, 2.99, 0.99,
 7.99, 6.99, 7.99, 6.99, 2.99, 0.99, 0.99, 3.99, 2.99, 5.99,
 0.99, 0.99, 7.99, 9.99, 5.99, 5.99, 1.99, 4.99, 5.99, 5.99,
 6.99, 9.99, 5.99, 5.99, 1.99, 8.99, 9.99, 4.99, 9.99, 4.99,
 0.99, 0.99, 2.99, 9.99, 3.99, 6.99, 8.99, 4.99, 1.99, 9.99,
 0.99, 7.99, 1.99, 4.99, 4.99, 0.99, 3.99, 3.99, 1.99, 8.99,
 3.99, 9.99, 5.99, 2.99, 2.99, 2.99, 5.99, 4.99, 3.99, 8.99,
 5.99, 8.99, 8.99, 1.99, 9.99, 7.99, 6.99, 7.99, 4.99, 4.99,
 7.99, 8.99, 7.99, 4.99, 5.99, 5.99, 0.99, 2.99, 8.99, 7.99,
 1.99, 3.99, 3.99, 4.99, 9.99, 0.99, 1.99, 3.99, 9.99, 5.99,
 4.99, 8.99, 6.99, 5.99, 6.99, 7.99, 1.99, 2.99, 9.99, 6.99,
```

9.99, 6.99, 8.99, 8.99, 2.99, 1.99, 9.99, 1.99, 7.99, 9.99,  
4.99, 3.99, 9.99, 9.99, 6.99, 6.99, 7.99, 9.99, 2.99, 4.99]

- a. How many apps are there?
- b. How many apps cost 4.99? Calculate the result in two ways, once using a list method, and once using a `for` loop.
- c. What is the percentage of apps that cost 4.99?
- d. What are the unique prices of the apps in the store? Find them and sort them in ascending order.
- e. How many apps are there for each price?
- f. What is the most popular price for an app?

## 22. More about the for loop

### Various ways of repeating commands on lists and beyond

In the past several chapters, we have learned how to use the `for` loop to browse lists (Chapters 8 and 9), search elements in lists (Chapter 10), change list elements (Chapter 11), and create lists by adding one element at a time (Chapter 12). In addition, we have used the `for` loop to repeat commands independently of lists (see the *In more depth* section in Chapter 15). We will start this chapter by briefly refreshing what we already know for sake of completeness. Then, we will discover new `for` loops that we can use with lists, each of them with their own characteristics and usage. Ready? Follow along with Notebook 22!

#### 1. Repeating commands

As the definition says,

A **for loop** is the repetition of a group of commands for a **determined** number of times.

Let's get a refresher on this concept with the following example:

- Print 3 random numbers between 1 and 10:

|      |                                                                                                            |                                                                                                                    |
|------|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| [1]: | <pre>1 import random 2 3 for _ in range(3): 4     number = random.randint(1, 10) 5     print(number)</pre> | <pre>import random  for underscore in range three number is assigned random dot randint one ten print number</pre> |
| 6    |                                                                                                            |                                                                                                                    |
| 4    |                                                                                                            |                                                                                                                    |
| 3    |                                                                                                            |                                                                                                                    |

We import the package `random` (line 1). Then, we implement the `for` loop (lines 3–5). We start with the header, which contains: (1) the keyword `for`; (2) a variable for the index; (3) the membership operator `in`; and (4) the built-in function `range()` (line 3). In this case, we use an underscore as a variable for the index because we do not need the index in the loop body. We will review the characteristics of the built-in function `range()` in the next paragraph. In the body of the `for` loop—which is always indented with respect to the header—we create a random number between 1 and 10 using the function `.randint()` from the package `random` (line 4), and we print the created number (line 5). The lines of code in the loop body are repeated at each loop or iteration—in this case, three times, as indicated by `range(3)`.

#### 2. For loop with lists

There are at least 4 ways to use the `for` loop with lists. You already know the first one: the `for` loop through indices. In this section, we'll learn the `for` loop through elements, through indices and elements, and list comprehension. Note that *through indices*, *through elements*, and *through indices and*

elements are not technical terms; however, we will use them to distinguish between the different types of for loops. On the contrary, *list comprehension* is a technical term that you can find in any Python book or coding website. In all the examples in this section, we will start with the following list, which contains three strings:

```
[]: 1 last_names = ["garcia", "smith", "zhang"] last names is assigned garcia, smith,
zhang
```

Our task will be to change the first letter of each string to upper case. For that, we will apply the method `.title()` to each list element, and we will overwrite the existing list whenever possible.

## 2.1 For loop through indices

You already know this for loop type. Let's refresh our memories with the following example.

- Capitalize each string using a for loop through indices:

|                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[2]: 1 last_names = ["garcia", "smith", "zhang"] 2 3 for i in range(len(last_names)): 4     print("The element in position " + str(i) +       " is: " + last_names[i]) 6 7 print(last_names)</pre> | <pre>last names is assigned garcia, smith, zhang  for i in range len last names print The element in position concatenated with str of i concatenated with is concatenated with last names in position i last names in position i is assigned last names in position i dot title  print last names</pre> |
| <pre>The element in position 0 is: garcia The element in position 1 is: smith The element in position 2 is: zhang ['Garcia', 'Smith', 'Zhang']</pre>                                                    |                                                                                                                                                                                                                                                                                                          |

We start with the list to modify (line 1). Then, we write the for loop header, which is composed of: (1) the keyword `for`; (2) the index variable `i`; (3) the membership operator `in`; and (4) the built-in function `range` (line 3). `range()` can have three parameters: `start`, which we omit when it is 0-like in this case; `stop`, which usually coincides with the length of the list; and `step`, which we omit when it is 1-like in this example. If we need to browse only the first half of the list, we can write `range(0, len(last_names) // 2)`, or if we want to browse only every second position of the list, we can write `range(0, len(last_names), 2)`. Also, let's not forget that `range()` is a built-in function that can be used independently from a for loop **to creates a range of integers**: for example, `list(range(0, 4))` returns the list `[0, 1, 2, 3]` and `list(range(0, 4, 2))` returns `[0, 2]`. Why do we use `list()` combined with `range()` when creating a list? Because the **built-in function `list()` converts** the output of `range()`—which is its own data type—**to a list**. In the for loop body, we print the current value of the index `i` and the corresponding element `last_names[i]`, extracted by slicing (line 4). Then, we change the current element `last_names[i]` by applying the string method `.title()` and reassigning the result to `last_names[i]` itself (line 5). Finally, we print `last_names` to check the modified list (line 7).

## 2.2 For loop through elements

Let's learn the first new way of implementing the for loop: the for loop through *elements*. Read the example below and try to understand what it does:

- Capitalize each string using a for loop through *elements*:

```
[3]: 1 last_names = ["garcia", "smith", "zhang"]
 2 last_names_upper = []
 3
 4 for last_name in last_names:
 5 print("The current element is " + last_name)
 6 last_names_upper.append(last_name.title())
 7
 8 print(last_names_upper)
The current element is: garcia
The current element is: smith
The current element is: zhang
['Garcia', 'Smith', 'Zhang']

last names is assigned garcia,
smith, zhang
last names upper is assigned
empty list

for last_name in last names
print The current element is
concatenated with last name
last names upper dot append last
name dot title

print last names upper
```

As in the previous example, we start with the list to modify (line 1). We continue with a new empty list called `last_names_upper` that we will fill within the loop (line 2). Then, we create the for loop through elements (lines 4–6). The syntax of the header is: (1) the keyword `for`; (2) a variable; (3) the membership operator `in`; and (4) the list to browse. There are two differences with respect to the for loop through indices. First, the **variable in position (2)** is not named `index` or `i`, but it is usually **called with the singular version of the list name**—that is, if the list name is `last_names`, then the variable name is `last_name`; if the list name is `numbers`, then the variable name is `number`; and so on. This is not a rule but a useful convention among Python coders. The second difference is that we directly use the **list itself**—that is, `last_names—in position (4)`, instead of `range(len(last_names))`. Let's now focus on the loop body. First, we print the current element `last_name` (line 5). As you may notice, there is no slicing (that is, no `[i]`). This is because in a for loop through elements, **the variable in position (2)**—that is, `last_name`—**automatically browses list elements one after the other, without knowing their position**. This is the opposite of what happens in a for loop through *indices*, where the variable in position (2)—that is, `i`—browses list positions without knowing the corresponding elements; to get an element, we must use slicing (e.g., `last_name[i]`). See a schematic of the difference between the two loops in Figure 22.1.

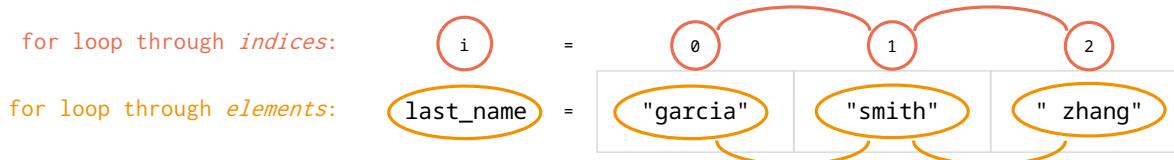


Figure 22.1. Schematics of a for loop through *indices*, where an index browses positions (orange), and a for loop through *elements*, where a variable browses elements (yellow).

In the first iteration of the example, `last_name` is `"garcia"`; in the second iteration, it is `"smith"`; and in

the third iteration, it is "zhang". We conclude by applying the method `.title()` to the string `last_name` and appending the output to `last_names_upper` (line 6). Finally, we print `last_names_upper` (line 8). Why don't we directly modify `last_names`? Because in a for loop through elements, **we cannot modify the list** we are browsing. We can only create a new list (that is, `last_name_upper`) to which we append the modified elements (that is, `last_name.title()`). Let's see what happens if we try to use a for loop through elements to change elements:

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                 |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[1]: 1 for last_name in last_names:         2     print("last_name before change: " + last_name)         3         4     last_name = last_name.title()         5         6     print("last_name after change: " + last_name)         7         8 print(last_names)</pre> <p>last_name before change: garcia<br/>     last_name after change: Garcia<br/>     last_name before change: smith<br/>     last_name after change: Smith<br/>     last_name before change: zhang<br/>     last_name after change: Zhang<br/>     ['garcia', 'smith', 'zhang']</p> | <pre><b>for</b> last_name <b>in</b> last names <b>print</b> last_name before change: <b>concatenated with</b> last name last names <b>is assigned</b> last name dot title <b>print</b> last_name after change: <b>concatenated with</b> last name <b>print</b> last names</pre> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

In the first iteration, the variable `last_name` is "garcia" (line 2), we change it to "Garcia" (line 3), and we print it (line 4). In the second iteration, `last_name` is "smith" (line 2), we change it to "Smith" (line 3), and we print it (line 4). The procedure follows in the third iteration for "zhang". However, when we print the final list, all strings are still lower case (line 6). This is **because the for loop through elements does not keep track of element positions, so it is impossible to know where to overwrite a list element**. Finally, note that because there is no index, in a for loop through elements we **cannot keep track of the iteration number**. If we need to know the iteration number, we can either use a for loop through indices (Section 2.1) or a for loop through indices and elements (Section 2.3).

## 2.3 For loop through indices and elements

As the name implies, the for loop through indices and elements combines a for loop through indices with a for loop through elements. Its implementation is straightforward. Try to understand the example below before reading the subsequent explanation.

- Capitalize each string using a for loop through indices and elements:

|                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[4]: 1 last_names = ["garcia", "smith", "zhang"]         2         3 for i, last_name in enumerate(last_names):         4     print("The element in position " +         5           str(i) + " is: " + last_name)         6         7     last_names[i] = last_name.title()         8         9 print(last_names)</pre> | <pre>last names <b>is assigned</b> garcia, smith, zhang  <b>for</b> i last_name <b>in</b> enumerate last_names <b>print</b> The element in position <b>concatenated with</b> str of i <b>concatenated</b> <b>with</b> is <b>concatenated with</b> last name last names in position i <b>is assigned</b> last name dot title</pre> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

```
7 print(last_names)
The element in position 0 is: garcia
The element in position 1 is: smith
The element in position 2 is: zhang
['Garcia', 'Smith', 'Zhang']
```

```
print last names
```

The for loop header consists of (1) the keyword `for`; (2) two variables separated by comma, called `i` and `last_name`; (3) the membership operator `in`; and (4) the built-in function `enumerate()` with the list `last_names` as an argument (line 3). The differences with the other for loop headers is again in the components (2) and (4). The role of `i` and `last_name` is quite intuitive: `i` is the index that browses all the positions in the list—like in a for loop through *indices*—and `last_name` is the variable that browses all the elements in the list—like in a for loop through *elements*. The values to browse are provided by `enumerate()`, as we can see from the following command (where we use `list()` to convert `enumerate()`'s output data type into a list to be printed):

```
[]: print(list(enumerate(last_names)))
[(0, 'garcia'), (1, 'smith'), (2, 'zhang')]
```

```
print list enumerate last names
```

The **built-in function `enumerate()` provides a list of coupled indices and elements**—that is, `(0, 'garcia')`, `(1, 'smith')`, and `(2, 'zhang')`. Each pair is between round brackets, which indicate a tuple. **Tuples are sequences of elements separated by comma and in between round brackets**. We will talk about tuple characteristics in Chapter 29. During the for loop in this example, the variable `i` is assigned the first element of each pair—that is, `0`, `1`, and `2`—and the variable `last_name` is assigned the second element of each pair—that is, `'garcia'`, `'smith'`, and `'zhang'`. In the remaining part of the example, first we print the position of each element `i` and its value `last_name` (line 4). Then, we apply the method `.title()` to `last_name`, and we assign the result to the element in the same position `last_names[i]` (line 5). Finally, we print the resulting list (line 6). The **for loop through indices and positions** is useful when we need to **extract both positions and elements of a whole list**.

## 2.4 List comprehension

The fourth and last method to use a for loop in combination with lists is called *list comprehension*. It might look complex at first glance, but we are going to untangle it right away!

- Capitalize each string using list comprehension containing a for loop through indices:

```
[5]: 1 last_names = ["garcia", "smith", "zhang"]
 2 last_names = [last_name.title() for
 i in range(len(last_names))]
 3 print(last_names)
['Garcia', 'Smith', 'Zhang']
```

```
last names is assigned gacia, smith,
zhang
last names is assigned last name dot
title for i in range len last names
print last names
```

At line 2, we see: (1) the list name; (2) the assignment symbol; and (3) the list comprehension. In the list comprehension, there are two components embedded within a pair of square brackets: (1) the **value of the list element** that we are going to insert into the list—that is, `last_name.title()`; and (2) a **for loop header**—that is, `for i in range(len(last_names))`. To better understand the syntax, let's have a look at Figure 22.2 comparing the for loop through *indices* from cell 2 and the list comprehension from the cell above.

```
(a) for i in range(len(last_names)):
(b) last_names[i] = last_names[i].title()
(c) last_names = [last_names[i].title() for i in range(len(last_names))]
```

Figure 22.2. Comparison between a for loop through indices (lines a–b) and list comprehension (line c).

As you can see, the components of a list comprehension are the same as the components of a for loop, just in a somewhat inverted position. In a for loop, first we write the header (line (a); orange rectangle), and then we assign the modified element (yellow rectangle) to the element itself (line (b)). In a list comprehension (line (c)), we write first the modified element (yellow rectangle) and then the for loop header (orange rectangle). As you can see, **list comprehension is a one-line command to create or modify a list in a fast and compact way**. We conclude the previous example by printing the new list (line 3).

Can we write a list comprehension containing the header of a for loop through *elements*? Yes! Let's see how.

- Capitalize each string using list comprehension containing a for loop through elements:

|      |                                                                                                                                                                                       |                                                                                                                                                |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| [6]: | <pre>1 last_names = ["garcia", "smith", "zhang"] 2 last_names = [last_name.title() for                last_name in last_names] 3 print(last_names) ['Garcia', 'Smith', 'Zhang']</pre> | <pre>last names is assigned Garcia, smith, zhang last names is assigned last name dot title for last name in last names print last names</pre> |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|

Similarly to before, in the list comprehension we write first the new element of the list—that is, `last_name.title()`—and then the header of a for loop through *elements*—that is, `for last_name in last_names` (line 2). Let's compare the for loop through *elements* from cell 3 with the list comprehension in the cell above. This time, there is a big difference between the for loop and the corresponding list comprehension. Can you find it?

```
(a) for last_name in last_names:
(b) last_names_upper.append(last_name.title())
(c) last_names = [last_name.title() for last_name in last_names]
```

Figure 22.3. Comparison between for loop through elements (lines a–b) and list comprehension (line c).

The difference is that in a for loop through *elements*, we must create a new list—that is, `last_names_upper` (line (b))—whereas in the list comprehension, we can overwrite the existing list—that is, `last_names` (line (c)). The remaining syntax correspondence is the same. In a for loop, first we write the header (line (a); orange rectangle), and then we modify an element (line (b); yellow rectangle). On the other hand, in a list comprehension (line (c)), we write first a modified element (yellow rectangle) and then a for loop header (orange rectangle).

Another interesting characteristic of list comprehensions is that they **can contain a conditional construct**. Let's have a look at it!

- Keep and capitalize only the elements shorter than 6 characters:

```
[7]: 1 last_names = ["garcia", "smith", "zhang"]
 2 last_names = [last_name.title() for
 last_name in last_names if
 len(last_name) < 6]
 3 print(last_names)
 ['Smith', 'Zhang']
```

last names is assigned `garcia, smith, zhang`  
 last names is assigned last name dot title for last name in last names if len last name less than six  
 print last names

We modify the code from cell 6 by adding an **if condition at the end** of the list comprehension (line 2). Once more, let's compare the construct of a list comprehension with the corresponding for loop.

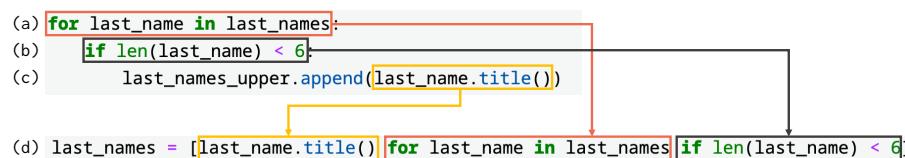


Figure 22.4. Comparison between for loop through elements with condition (lines a, b, and c) and list comprehension (line d).

Similarly to above, in the list comprehension (line (d)) first we write the new element, which is in the last line of the for loop body (yellow rectangle; line (c) in the for loop). Then, we essentially restart from the beginning of the loop and add commands consecutively. Thus, we first write the for loop header (orange rectangle; line (a) in the loop) and then the if condition (black rectangle; line (b) in the loop).

Finally, list comprehensions are extremely useful to **delete list elements based on conditions**. In cell 16 of the previous chapter, we used a while loop containing `.remove()` to delete several elements with similar characteristics. Now, let's learn how to delete elements in a much more compact way with list comprehension.

- Delete elements that are composed of 5 characters:

```
[8]: 1 last_names = ["garcia", "smith", "zhang"]
 2 last_names = [last_name.title()
 for last_name in last_names
 if len(last_name) != 5]
 3 print(last_names)
 ['garcia']
```

last names is assigned `garcia, smith, zhang`  
 last names is assigned last\_name dot title for last name in last names if len last name not equal to five  
 print last names

When deleting elements with list comprehensions, **we have to think about the elements that we are going to keep, not about those that we are going to delete!** This is because in a list comprehension, in the first position we must write the element that we are going to insert into the list. Thus, if we want to delete the elements whose length is 5, we need to reverse our thinking and write the condition that allows us to *keep* the elements whose length is not equal to 5—that is `if len(last_name) != 5` (line 2).

### 📝 Complete the table

In this chapter, you have learned four different ways to write a for loop with lists. Which one

do we use and when? Highlight the differences among the for loops by completing the following table with Yes or No.

| Operation                    | For loop through indices | For loop through elements | For loop through indices and elements | List comprehension |
|------------------------------|--------------------------|---------------------------|---------------------------------------|--------------------|
| Get the current index        |                          |                           |                                       |                    |
| Change list elements         |                          |                           |                                       |                    |
| Delete list elements         |                          |                           |                                       |                    |
| Browse a full list           |                          |                           |                                       |                    |
| Browse only a part of a list |                          |                           |                                       |                    |

### 3. Nested for loops

As the last topic for this chapter, let's learn about nested for loops. A **nested for loop** is a **for loop within another for loop**. How does it work? Read the example below, and try to understand what happens.

- Given the following list of vowels:

```
[9]: 1 vowels = ["A", "E", "I", "O", "U"] vowels is assigned A, E, I, O, U
```

We start with a list of strings (line 1).

- For each vowel, print all the vowels on the right:

|                                                                                                                                                                                                                  |                                                                                                                                                             |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[10]: 1 for i in range(len(vowels)): 2     print("-- " + vowels[i]) 3 4     for j in range(i + 1, len(vowels)): 5         print(vowels[i])</pre><br><pre>-- A E I O U -- E I O U -- I O U -- O U -- U</pre> | <pre>for i in range len vowels print dash dash concatenated with vowels in position i for j in range i plus one len vowels print vowels in position i</pre> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|

The nested for loop in this example is composed of an **outer for loop**, whose header is at line 1, and

an **inner for loop**, whose header is at line 3. In the outer for loop, the index *i* goes from 0 (omitted) to the length of the list (line 1); thus, *i* will browse all list positions. In the inner for loop, the index *j* goes from *i*+1 to the length of the list (line 3); thus, *j* will browse all remaining list positions on the right of the current position *i*. **For each iteration of the outer loop, the inner loop has to be completed before moving to the next iteration of the outer loop.** Here is what happens at each loop:

- In the first outer loop, *i* is 0. We print " - " + `vowels[0]`, which is - A (line 2). Then, we run the whole inner for loop (lines 3–4). The index *j* will start at *i*+1—which is 0+1, and thus 1—and stop at `len(vowels)-1` for the plus one rule—that is, 4. Thus, *j* will go through the positions: [1, 2, 3, 4]. Therefore, in the inner for loop:
  - In the first iteration, *j* is 1. We print `vowels[1]`, which is E.
  - In the second iteration, *j* is 2. Thus, we print `vowels[2]`, which is I.
  - In the third iteration, *j* is 3 and we print `vowels[3]`, which is O.
  - In the fourth iteration, *j* is 4 and we print `vowels[4]`, which is U. The inner loop is completed and we go back to the outer loop.
- In the second outer loop, *i* is 1, thus we print " - " + `vowels[1]`, which is - E (line 2). Then, we run the whole inner for loop again (lines 3–4). The start of the inner loop is *i*+1, which is 1+1—that is, 2. Thus, *j* will go through the positions: [2, 3, 4]. Therefore, in the inner loop:
  - In the first loop, *j* is 2 and we print `vowels[2]`, which is I.
  - In the second loop, *j* is 3 and we print `vowels[3]`, which is O.
  - In the third loop, *j* is 3 and we print `vowels[3]`, which is U. Once again, the inner loop is completed and we go back to the outer loop.
- In the third outer loop, *i* is 2, so we print - I. Then, we run the full inner loop as above, with *j* browsing the positions 3 and 4, corresponding to the elements O and U, respectively.
- In the fourth outer loop, *i* is 3, so we print - O. In the inner loop, *j* is assigned only the position 4, corresponding to the elements U.
- In the last outer loop, *i* is 4, so we print - U. There is no inner loop, because the start, *i*+1, is 5 and coincides with the stop, which is 5 too.

Can we have more loops nested within each other? Yes! As a convention, the index names are *i*, *j*, *k*, etc. However, it is strongly recommended not to use too many for loops because they are computationally very expensive, that is, they use a lot of memory and time. We will talk a bit more about nested for loops in the next chapter, where we will use them to browse lists of lists.

## Recap

- When we use a for loop to repeat commands that do not need the index, we substitute the index with an underscore.
- There are at least 4 types of for loops with lists: through indices (uses `range()`), through elements, through indices and elements (uses `enumerate()`), and list comprehension.
- The built-in functions `list()` can be used to transform the output of `range()` and `enumerate()` into a list.
- The built-in function `enumerate()` simultaneously extracts coupled indices and elements from a list.
- Tuples are sequences of elements separated by commas and in between round brackets.
- Nested for loops are for loops within for loops.

## Basics of Markdown

As you know, in Jupyter Notebooks we can use cells to either write code or to write text. Writing text is fundamental to embed our code into a story (or narrative) that explains the workflow—that is, how we go from the problem formulation to its computational solution. In Jupyter Notebooks, narrative is written in a markup language called Markdown—markup languages are basically coding languages used to write text. Markdown is a simplified version of HTML, the coding language used to program websites. The syntax of Markdown is very simple. The basic syntax rules are:

- Titles start with 1 hash symbol (#), subtitles with 2 hash symbols (##), sub-subtitles with 3 hash symbols (###), etc. to a maximum of 6 hash symbols (#####).

| Command         | Rendering           |
|-----------------|---------------------|
| #Title          | <b>Title</b>        |
| ##Subtitle      | <b>Subtitle</b>     |
| ###Sub-subtitle | <b>Sub-subtitle</b> |

- To italicize text, we add 1 asterisk before and after a word or phrase; to bold text, we add 2 asterisks before and after a word or phrase.

| Command       | Rendering          |
|---------------|--------------------|
| *italic text* | <i>italic text</i> |
| **bold text** | <b>bold text</b>   |

- To display text as code, we add a backtick ` before and after the command.

| Command                                   | Rendering                                 |
|-------------------------------------------|-------------------------------------------|
| <code>print('command in markdown')</code> | <code>print('command in markdown')</code> |

Using Markdown, we can also create tables, add images, write ordered and unordered lists, etc., and integrate HTML code—in case you know it. Find all Markdown rules of syntax at the following website: <https://www.markdownguide.org/>.

## Let's code!

1. All you can eat. These friends are at an all-you-can-eat restaurant:

```
friends = ["Geetha", "Huanxiang", "Megan", "Pedro"]
```

This is the finger food at the buffet: food = ["sushi", "nachos", "samosa", "cheese"]

Each person tries each type of finger food. Print out sentences like:

Geetha eats sushi

Geetha eats nachos

...

for all the friends:

- a. Using nested for loops through *indices*.
- b. Using nested for loops through *elements*.

2. *Playing kids.* At kindergarten, kids are playing a game where they have to pair up with another kid every time the teacher rings a bell. Eventually, every kid will pair up with all the other kids. Given this list of kids:

```
kids = ["Paul", "Juhee", "Luca", "Maria"]
```

- a. Print out all the possible combinations starting from the first kid, that is:

*Paul plays with Juhee*

*Paul plays with Luca*

*Paul plays with Maria*

*Juhee plays with Luca*

*Juhee plays with Maria*

*Luca plays with Maria*

- b. Print all the possible combinations starting from the last kid (Maria).

3. *Cities of the world.* Given the following list cities:

```
cities = ["Bogota", "Riga", "Kinshasa", "Damascus", "New Delhi", "Auckland"]
```

- a. Using a **for** loop through *indices*, create a new list containing city names with more than 7 characters and change them to upper case.
- b. Using a **for** loop through *elements*, create a new list containing initials of cities with a number of characters between 7 and 10.
- c. Using a **for** loop through *indices and elements*, print out each element in lower case and its position.
- d. Using a **list comprehension**, create a new list containing the city names with less than 7 characters and change them to lower case.

4. *Learning to count.* Print consecutive numbers from 10 to 29 using a nested **for** loop. The outer **for** loop will print the first digit, whereas the inner **for** loop will print out the second digit, such as:

10

11

12

...

29

5. *Triangle of numbers.* Ask a user for a number. Then print a triangle of numbers where the maximum row is the queried number. For example:

*Input: 5*

*Output:*

1

2 2

3 3 3

4 4 4 4

5 5 5 5 5

Hint: Consider using the parameter end in the `print()` function. Look for examples on how to use end online.

## 23. Lists of lists

### *Slicing, nested for loops, and flattening*

What is a list of lists?

A **list of lists** is a list whose **elements are lists**.

Lists of lists follow the same rules as lists; they just add an “extra layer” of indices. In this chapter, you will learn how to slice lists of lists, use nested for loops to iterate through them, and explore ways to flatten them. Follow along with Notebook 23. Let’s go!

#### 1. Slicing

To slice a list of lists, we modify the slicing rules that we learned for lists in Chapter 6: by **adding an extra layer of indices**. Let’s see how it works!

- Given the following list of lists:

```
[1]: 1 animals = [["dog", "cat"], ["cow",
 "sheep", "horse", "chicken", "rabbit"],
 ["panda", "elephant", "giraffe",
 "penguin"]]
```

animals is assigned dog, cat, cow, sheep, horse, chicken, rabbit, panda, elephant, giraffe, penguin

The list of lists animals is composed of three elements, which are the lists ["dog", "cat"], ["cow", "sheep", "horse", "chicken", "rabbit"], and ["panda", "elephant", "giraffe", "penguin"] (line 1). We call each of these lists **sub-lists** and their elements ("dog", "cat", "cow", etc.) **sub-element**. Let’s learn how to slice sub-lists and sub-elements!

- Print the sub-lists containing pets, farm animals, and wild animals:

```
[2]: 1 print (animals[0])
2 print (animals[1])
3 print (animals[2])
```

print animals in position zero  
print animals in position one  
print animals in position two

```
['dog', 'cat']
['cow', 'sheep', 'horse', 'chicken', 'rabbit']
['panda', 'elephant', 'giraffe', 'penguin']
```

The sub-list containing pets—["dog", "cat"]—is in position 0; thus, we print animals[0]. Similarly, the list containing farm animals—["cow", "sheep", "horse", "chicken", "rabbit"]—is in position 1, so we print it with the command print(animals[1]) (line 2). Finally, the list containing wild animals—["panda", "elephant", "giraffe", "penguin"]—is in position 2, and thus the command is print(animals[2]) (line 3).

- Print the sub-elements "cat", "rabbit", and from "panda" to "giraffe":

|                                                                                        |                                                                                                                                                                                                                                                                  |
|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[3]: 1 print(animals[0][1]) 2 print(animals[1][-1]) 3 print(animals[2][:3])</pre> | <b>print</b> animals in position <b>zero</b> in position <b>one</b><br><b>print</b> animals in position <b>one</b> in position <b>minus one</b><br><b>print</b> animals in position <b>two</b> in position from the<br>beginning of the sub-list to <b>three</b> |
| <pre>cat rabbit ['panda', 'elephant', 'giraffe']</pre>                                 |                                                                                                                                                                                                                                                                  |

To extract sub-elements, we use **double slicing**, where **the first slicing—indicated by the first pair of square brackets—extracts a sub-list** and the **second slicing—indicated by the second pair of square brackets—extracts one or more sub-elements**. To extract the sub-element "cat", first we extract the sub-list of pets ["dog", "cat"] with the command `animals[0]`—like in cell 2, line 1. Then, from the obtained sub-list, we slice "cat", which is in position 1. Thus, the complete command is `animals[0][1]` (line 1). The string "rabbit" is the last element of the second sub-list containing farm animals. Thus, to slice "rabbit", we write `animals[1][-1]`, where the first slicing [1] extracts the sub-list of farm animals—as we did at cell 2, line 2—and the second slicing [-1] extracts the sub-element "rabbit" (line 2). Finally, the sub-elements from "panda" to "giraffe" are in the sub-list of wild animals, which is `animals[2]`—as we saw in cell 2, line 3. Within this sub-list, "panda" is in position 0, which we omit, and "giraffe" is in position 2, to which we add 1 for the *plus one* rule. Thus, the final command is `print(animals[2][:3])`

## 2. Nested for loops

To browse elements in a list of lists, we can use a nested for loop, where the **outer loop browses the list of lists** and the **inner loop browses the sub-lists**. Try to understand what the following example does and then read the explanation.

- Given the following list of lists:

|                                                                                                               |                                                                                                                                                    |
|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[4]: 1 sports = [["skiing", "skating", "curling"], ["canoeing", "cycling", "swimming", "surfing"]]</pre> | <b>sports</b> is assigned <b>skiing</b> , <b>skating</b> , <b>curling</b> ,<br><b>canoeing</b> , <b>cycling</b> , <b>swimming</b> , <b>surfing</b> |
|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|

We start with a list of lists containing two sub-lists. The first sub-list contains 3 strings, and the second sub-list is composed of 4 strings (line 1).

- Print the sub-list elements one-by-one using a nested for loops through *indices*:

|                                                                                                                    |                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[5]: 1 for i in range(len(sports)): 2     for j in range(len(sports[i])): 3         print(sports[i][j])</pre> | <b>for i in range</b> <b>len</b> <b>sports</b> <b>for j in range</b> <b>len</b> <b>sports</b> in position <b>i</b> <b>print</b> <b>sports</b> in position <b>i</b> in position <b>j</b> |
| <pre>skiing skating curling canoeing cycling swimming surfing</pre>                                                |                                                                                                                                                                                         |

In the outer for loop, the index *i* iterates through the positions 0—corresponding to the sub-list

["skiing", "skating", "curling"]—and 1—corresponding to the sub-list ["canoeing", "cycling", "swimming", "surfing"]—(line 1). During each *outer* for loop, the *inner* for loop browses the current sub-list from 0 (omitted) to the length of the sub-list, which is `len(sports[i])` (line 2). At each iteration of the *inner* for loop, we print the current element `sports[i][j]` (line 3). In practice:

- In the first *outer* loop, *i* is 0, and we execute a full *inner* loop to browse the first sub-list:
  - In the first *inner* loop, *j* is 0, so we print `sports[0][0]`, which is "skiing".
  - In the second *inner* loop, *j* is 1, so we print `sports[0][1]`, which is "skating".
  - In the third *inner* loop, *j* is 2, so we print `sports[0][2]`, which is "curling". The *inner* for loop is over, and we go to the second *outer* for loop.
- In the second *outer* loop, *i* is 1, and we execute another full *inner* loop to browse the second sub-list:
  - In the first *inner* loop, *j* is 0, so we print `sports[1][0]`, which is "canoeing".
  - In the second *inner* loop, *j* is 1, so we print `sports[1][1]`, which is "cycling".
  - In the third *inner* loop, *j* is 2, so we print `sports[1][2]`, which is "swimming".
  - In the fourth *inner* loop, *j* is 3, so we print `sports[1][3]`, which is "surfing". The *inner* for loop is over; also, the *outer* for loop is concluded because there are no more sub-lists.

Can we do the same with a for loop through *elements*? Yes! Think about how we might go about doing this before looking into the following code.

- Print the sub-list elements one-by-one using a nested for loops through *elements*:

|      |                                                                                                                                                                               |                                                                                    |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| [6]: | <pre>1 for seasonal_sports in sports: 2     for sport in seasonal_sports: 3         print(sport)</pre><br><pre>skiing skating curling canoeing cycling swimming surfing</pre> | <pre>for seasonal sports in sports: for sport in seasonal sports print sport</pre> |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|

In the *outer* for loop, the variable `seasonal_sports` is assigned once the first sub-list and once the second sub-list (line 1). In the *inner* for loop, the variable `sport` is assigned each element of the current sub-list (line 2). For each iteration of the *inner* for loop, we print the current value of the variable `sport` (line 3). In other words:

- In the first iteration of the *outer* for loop, `seasonal_sports` is ["skiing", "skating", "curling"] and the *inner* for loop browses all the sub-elements of `seasonal_sports` in the following way:
  - In the first *inner* loop, `sport` is "skiing".
  - In the second *inner* loop, `sport` is "skating".
  - In the third *inner* loop, `sport` is "curling". The *inner* for loop ends, and we go back to the *outer* for loop.
- In the second iteration of the *outer* for loop, `seasonal_sports` is ["canoeing", "cycling", "swimming", "surfing"], and the *inner* for loop browses all the sub-elements of `seasonal_sports` in the following way:
  - In the first *inner* loop, `sport` is "canoeing".
  - In the second *inner* loop, `sport` is "cycling".
  - In the third *inner* loop, `sport` is "swimming".
  - In the fourth *inner* loop, `sport` is "surfing". The *inner* for loop ends—as does the *outer* for loop

because we went thought all the sub-lists.

### 3. Flattening

**Flattening means transforming a list of lists into a list.** In other words, we take the sub-elements out of their sub-lists and we put them in a list. There are many ways of performing this operation. We'll look at four different ways of doing so, but there can be more. For each method of flattening, try to implement it yourself first, and then look into the example and explanation below.

- Given the following list of lists:

```
[7]: 1 instruments = [["contrabass", "cello",
 "clarinet"], ["gong", "guitar"],
 ["tambourine", "trumpet", "trombone",
 "triangle"]]
```

```
instruments is assigned contrabass,
cello, clarinet, gong, guitar,
tambourine, trumpet, trombone, triangle
```

- Flatten the list using a nested for loop through indices:

```
[8]: 1 flat_instruments = []
 2 for i in range(len(instruments)):
 3 for j in range(len(instruments[i])):
 4 flat_instruments.append
 (instruments[i][j])
 5 print(flat_instruments)
```

```
flat instruments is assigned empty list
for i in range len instruments
for j in range len instruments in
position i
flat instruments dot append instruments
in position i in position j
print flat instruments
```

```
['contrabass', 'cello', 'clarinet', 'gong', 'guitar', 'tambourine', 'trumpet',
'trombone', 'triangle']
```

We start with the empty list `flat_instruments`, which we are going to fill out during the subsequent nested for loop (line 1). Then, for each position in the list of lists (line 2) and each position in each sub-list (line 3), we append the current sub-element `instruments[i][j]` to `flat_instruments` (line 4). Finally, we print the final list (line 5). As you can see, we flattened `instruments`, that is, we transform a list of lists into a list whose elements are `instruments`'s sub-elements.

- Flatten the list using a nested for loop through elements:

```
[9]: 1 flat_instruments = []
 2 for group in instruments:
 3 for instrument in group:
 4 flat_instruments.append(instrument)
 5 print(flat_instruments)
```

```
flat instruments is assigned empty list
for group in instruments
for instrument in group
flat instruments dot append instrument
print flat instruments
```

```
['contrabass', 'cello', 'clarinet', 'gong', 'guitar', 'tambourine', 'trumpet',
'trombone', 'triangle']
```

Like the previous example, we start with the empty list `flat_instruments` (line 1). We browse the sub-lists using the outer for loop (line 2), and within each sub-list, we browse the sub-elements using the inner for loop (line 3). We append the current sub-element to `flat_instruments` (line 4). Finally, we print the obtained flattened list (line 5).

- Flatten the list using a for loop and list concatenation:

```
[10]: 1 flat_instruments = []
2 for group in instruments:
3 flat_instruments += group
4 print(flat_instruments)
```

flat instruments is assigned empty list  
for group in instruments  
flat instruments increased by group  
print flat instruments

```
['contrabass', 'cello', 'clarinet', 'gong', 'guitar', 'tambourine', 'trumpet',
'trombone', 'triangle']
```

Once more, we start with the empty list `flat_instruments` (line 1). We write a `for` loop through `elements` to browse the sub-lists (line 2). We concatenate each sub-list to `flat_instruments` (line 3)—the corresponding explicit command is `flat_instruments = flat_instruments + group`. Finally, we print `flat_instruments` (line 4). The advantage of this method is that we use only one `for` loop. As you might remember, `for` loops are computationally expensive—in terms of memory and time—and it is good practice to minimize their use.

- Flatten the list using list comprehension:

```
[11]: 1 instruments = [instrument for group in
instruments for instrument in group]
2 print(instruments)
```

instruments is assigned instrument for  
group in instruments for instrument in  
group  
print instruments

```
['contrabass', 'cello', 'clarinet', 'gong', 'guitar', 'tambourine', 'trumpet',
'trombone', 'triangle']
```

As you might remember from the previous chapter, when using list comprehension, we do not need to create a new list, but we can directly modify the current one—which is `instruments` in this example. In the list comprehension, we write: (1) what we want to add to the list, which is `instrument`; (2) the header of the outer `for` loop, that is, `for group in instruments`; and (3) the header of the inner `for` loop, which is `for instrument in group` (line 1). Note that within the list comprehension we can use a nested `for` loop through `elements` because we do not need element positions. Finally, we print the result (line 2).

## Recap

- Lists of lists are lists with lists as elements.
- When slicing, we use two pairs of square brackets. In the first pair, we write the position of the sub-list to slice; in the second pair, we write the position of the sub-element(s).
- We can use nested `for` loops to browse sub-elements.
- We can flatten a list of lists with a nested `for` loop, a `for` loop combined with concatenation, or a list comprehension.

## Lists of lists and images

You surely know that digital images are composed of pixels, that is, small colorful squares organized in a grid. We can think of the grid as a list of lists where each sub-element corresponds to a pixel of a specific color. Let's consider Figure 23.1.

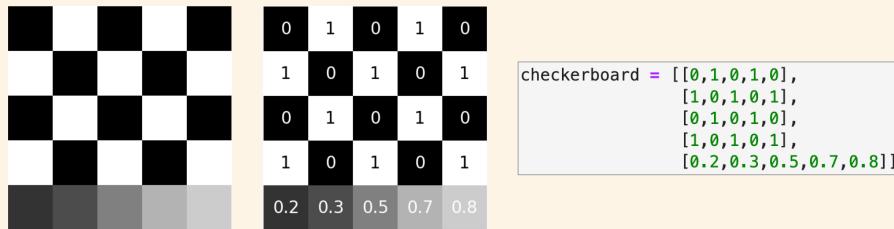


Figure 23.1. Digital representation of a checkerboard. Left: Image rendering. Center: Numerical values corresponding to the checkerboard colors. Right: List of lists encoding the checkerboard colors.

Each black square corresponds to a pixel containing  $0$ , and each white square corresponds to a pixel containing  $1$ . Thus, the first (and the third) row of the checkerboard is represented by the sub-list  $[0,1,0,1,0]$ , and the second (and the fourth) row is represented by the sub-list  $[1,0,1,0,1]$ . The last row of the checkerboard contains pixels colored with various shades of grey. Each pixel corresponds to a decimal (float) number. Darker greys are closer to  $0$  (that is, to black), whereas brighter greys are closer to  $1$  (that is, to white).

What about digital colored images? Each pixel is encoded by an RGB list composed of three numbers, each representing a different color: the first number is for the red (R) component, the second number for the green (G) component, and the third number for the blue (B) component. Let's have a look at Figure 23.2.

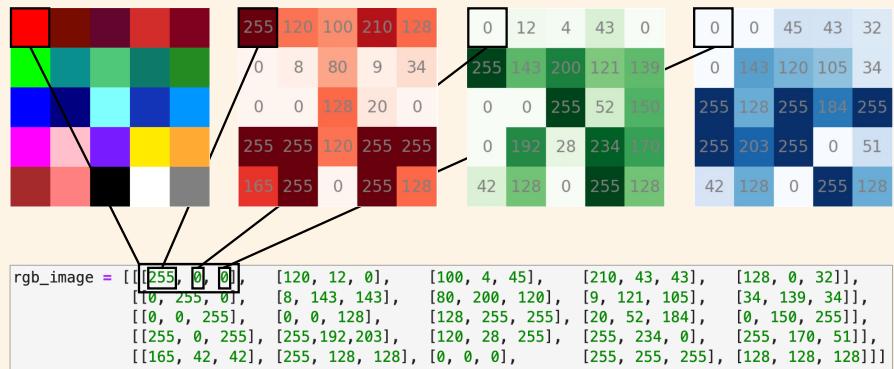


Figure 23.2. Digital representation of a colored image. Top (from left to right): RGB image, red components, green components, and blue components. Bottom: list of lists behind the rendered colored image.

Each pixel is represented by a sub-list composed of three numbers. For example, the top left pixel is red and is represented by the sub-list  $[255, 0, 0]$ , where  $255$  represents the amount of red, the first  $0$  is for the amount of green, and the second zero  $0$  is for the amount of blue. Each row is a list of lists, enclosed in a list of lists of lists! Finally, note that for both greyscale and colored images, the range of the numbers defining the color can go from  $0$  to  $1$  or from  $0$  to  $255$ .

## Let's code!

1. *Playing around.* Given the following list of lists:

```
numbers = [[3,7,1], [7,6,5,4], [8,9,7,4,5]].
```

- How long is each sub-list?
- In the first sub-list, replace the third element with the sum of the previous two elements.
- In the second sub-list, sort the elements in ascending order.
- In the third sub-list, substitute the number 4 with the number 3.
- How many number 7 are there in total? Save their positions in a list of lists (expected result: [[0, 1], [1, 3], [2, 2]]).

2. *Summing up.* Given the following list of lists:

```
numbers = [[1,3,5], [7,2,8], [3,4,9]].
```

- Create a list containing the sum of the numbers in each sub-list (expected result: [9, 17, 16]).
- Sum all the elements of the list of list using (1) a for loop through indices and (2) a for loop through values.

3. *Matrix time!* Give the following matrix:

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

(If you are not familiar with matrices, think of a matrix as a table containing numbers.)

- Print the matrix as a 4x4 table (expected result:  
[4, 1, 3, 9]  
[2, 1, 6, 5]  
[4, 0, 3, 8]  
[7, 2, 6, 2]).
- Multiply all the elements on the main diagonal and print the result (expected result: 24). Note: The main diagonal goes from top-left to bottom-right. In this example, the main diagonal contains: 4,1,3,2.
- Sum the matrix values vertically (expected result: [17, 4, 18, 24]).

## PART 7

# DICTIONARIES AND OVERVIEW OF STRINGS

In the first three chapters of this part, you will learn a new data type called dictionary. In the last chapter, you will integrate your knowledge of strings with new methods and tricks. Let's start!



# 24. Inventory at the English bookstore

## Dictionaries

You already know several data types: strings, lists, integers, floats, and Booleans. In this chapter, you will learn a new data type called *dictionary*. What are dictionaries and what can we do with them? Let's start from this example. Read the code below aloud and follow along with Notebook 24.

- You are the owner of an English bookstore, and these are some classics you sell:

```
[:] 1 classics = {"Austen": "Pride and Prejudice",
 "Shelley": "Frankenstein",
 "Joyce": "Ulysses"}
 2 print(classics) classics is assigned Austen:Pride
 and Prejudice, Shelley:Frankenstein,
 Joyce:Ulysses
 print classics
```

- You are conducting an inventory, and you need to print authors and titles:

```
[:] 1 # as dict_items
 2 print(classics.items())
 3 # as a list of tuples
 4 print(list(classics.items())) as dict_items
 print classics dot items
 as a list of tuples
 print list classics dot items
```

- Then, you need to print authors and titles separately:

```
[:] 1 # authors as dict_items
 2 print(classics.keys())
 3 # authors as a list
 4 print(list(classics.keys()))
 5
 6 # titles as dict_items
 7 print(classics.values())
 8 # titles as a list
 9 print(list(classics.values())) authors as dict_items
 print classics dot keys
 authors as a list
 print list classics dot keys
 titles as dict_items
 print classics dot values
 titles as a list
 print list classics dot values
```

- You notice that the title of the last book is wrong, so you correct it:

```
[:] 1 print("Wrong title: " + classics["Joyce"])
 2 classics["Joyce"] = "Ulysses"
 3 print("Corrected title: " + classics["Joyce"]) print Wrong title: concatenated
 with classics at key Joyce
 classics at key Joyce is assigned
 Ulysses
 print Corrected title: concatenated
 with classics at key Joyce
```

- Then you add two new books that have just arrived: *Gulliver's Travels* by Swift and *Jane Eyre* by Bronte:

```
[1]: 1 # adding the first book (syntax 1)
 2 classics["Swift"] = "Gulliver's travels"
 3 print(classics)
 4
 5 # adding the second book (syntax 2)
 6 classics.update({"Bronte": "Jane Eyre"})
 7 print(classics)
```

adding the first book (syntax 1)  
classics at key Swift is assigned  
Gulliver's travels  
print classics

adding the second book (syntax 2)  
classics dot update Bronte:Jane Eyre  
print classics

- Finally, you remove the books by Austen and Joyce because you have just sold them:

```
[1]: 1 # deleting the first book (syntax 1)
 2 del classics["Austen"]
 3 print(classics)
 4
 5 # deleting the second book (syntax 2)
 6 classics.pop("Joyce")
 7 print(classics)
```

deleting the first book (syntax 1)  
del classics at key Austen  
print classics

deleting the second book (syntax 2)  
classics dot pop Joyce  
print classics

To continue discovering dictionaries, solve the following exercise!

### True or false?

- |                                                                                                                     |   |   |
|---------------------------------------------------------------------------------------------------------------------|---|---|
| 1. A dictionary is a Python type enclosed in squared brackets                                                       | T | F |
| 2. In a dictionary, items are in pairs and are separated by commas                                                  | T | F |
| 3. Items are composed of a key and a value separated by an exclamation mark                                         | T | F |
| 4. .items(), .keys(), .values(), .update(), and .pop() are dictionary elements                                      | T | F |
| 5. To add an item to a dictionary, we can use either the keyword <code>del</code> or the method <code>.pop()</code> | T | F |

## Computational thinking and syntax

Let's discover dictionaries step-by-step. Let's start by running the first cell.

```
[1]: 1 classics = {"Austen": "Pride and Prejudice",
 "Shelley": "Frankenstein",
 "Joyce": "Ulysses"}
 2 print(classics)
```

classics is assigned Austen:Pride and Prejudice, Shelley:Frankenstein, Joyce:Ulysses  
print classics  
{'Austen': 'Pride and Prejudice', 'Shelley': 'Frankenstein', 'Joyce': 'Ulysses'}

At line 1, there is a variable called `classics` to which we assign a sequence of **items** separated by comma and enclosed within **curly brackets {}**. Each item (e.g., "Austen": "Pride and Prejudice") is composed of a **key** ("Austen") and a **value** ("Pride and Prejudice"), which are separated by a colon : . Thus, we can define a dictionary as follows:

A **dictionary** is a sequence of key:value pairs separated by commas , and in between curly brackets {}

At line 2, we print the dictionary.

Let's continue by running the second cell.

```
[2]: 1 # as dict_items
 2 print(classics.items())
 3 # as a list of tuples
 4 print(list(classics.items()))
dict_items([('Austen', 'Pride and Prejudice'), ('Shelley', 'Frankenstein'),
('Joyce', 'Ulysses')])
[('Austen', 'Pride and Prejudice'), ('Shelley', 'Frankenstein'), ('Joyce', 'Ulysses')]
```

To print the dictionary items, we use the method `.items()`, which **extracts items from a dictionary** (line 2). As you can see in the printout, `.items()` returns a specific type called `dict_items`, which contains a list whose elements are the items. We can ignore `dict_items` and print the contained list by enclosing the method output into the built-in function `list()` (line 4).

What if we want to extract all keys and all values separately? Let's look at the following cell.

```
[3]: 1 # authors as dict_items
 2 print(classics.keys())
 3 # authors as a list
 4 print(list(classics.keys()))
 5
 6 # titles as dict_items
 7 print(classics.values())
 8 # titles as a list
 9 print(list(classics.values()))
dict_keys(['Austen', 'Shelley', 'Joyce'])
['Austen', 'Shelley', 'Joyce']
dict_values(['Pride and Prejudice', 'Frankenstein', 'Ulysses'])
['Pride and Prejudice', 'Frankenstein', 'Ulysses']
```

To extract dictionary keys, we use the method `.keys()` (line 2). Like `.items()`, `.keys()` returns its datatype, called `dict_keys` (line 4). To extract the list of keys from the `dict_keys`, we can use the built-in function `list()`. Finally, to extract dictionary `values`, we use the method `.values()` (line 7), which returns the list of values embedded in another datatype called `dict_values`. Once again, to extract the list of values, we use `list()` (line 9).

How do we extract a specific `value` and how do we change it? Let's run cell 4.

```
[4]: 1 print("Wrong title: " + classics["Joyce"])
 2 classics["Joyce"] = "Ulysses"
 3 print("Corrected title: " + classics["Joyce"])
Wrong title: Ulysses
Corrected title: Ulysses
```

```
print Wrong title: concatenated
with classics at key Joyce
classics at key Joyce is assigned
Ulysses
print Corrected title: concatenated
with classics at key Joyce
```

To slice a *value*, the syntax is `dictionary[key]` (pronunciation: dictionary at key), as we can see in `classics["Joyce"]` (line 1). Isn't it similar to the slicing syntax for lists? Let's analyze some similarities and differences between dictionaries and lists with the help of Figure 24.1. In a list, there are *elements* (e.g., "burger", "salad", "coke")—which are the *content* of a list—and corresponding *indices* (e.g., 0, 1, 2)—which define the position of each element. When we want to extract (or slice) an element, we write the name of the list and the index of the element that we want in between squared brackets (`list[index]`). Thus, `todays_menu[0]` gives us "burger". Similarly, in a dictionary, there are *values* (e.g., "Pride and Prejudice", "Frankenstein", "Ulysses")—which are the *content* of a dictionary—and *keys* (e.g., "Austen", "Shelley", "Joyce")—which define the position of each value. When we want to access (or slice) a value, we indicate the name of the dictionary and the key corresponding to the value that we want in between squared brackets. (`dictionary[key]`). Thus, `classics["Austen"]` gives us "Pride and Prejudice". The main difference between lists and dictionaries lies in the way we define the position of an element or value. In lists, indices order elements from position 0 to position `len(list)-1`, in a consecutive and progressive way (we cannot skip a position!). On the other side, in dictionaries, **keys are in no specific order**. Also, note that **numbers cannot be used as keys!**

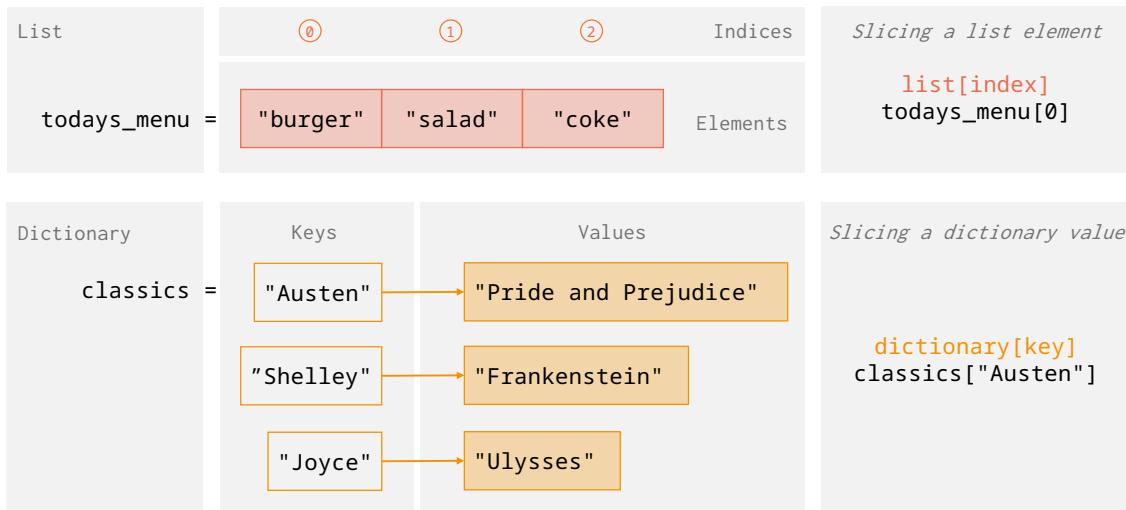


Figure 24.1. Comparing structure and slicing syntax for lists (top) and dictionaries (bottom).

As we cannot change indices but only elements in lists, **we cannot change keys but only values in dictionaries**. As you might have noticed, in the item "Joyce": "Ulyssesssss", we need to correct "Ulyssesssss" to "Ulysses". To do so, we overwrite the value "Ulyssesssss" using the same syntax as that used in slicing: `classics["Joyce"] = "Ulysses"` (line 2). Once more, this is the same syntax as that used in lists (e.g., if we want to change "coke" to "water", we write `todays_menu[2] = "water"`). At the end of cell 4, we check the correction by printing a string ("Corrected title: ") concatenated with the sliced new value (`classics["Joyce"]`), which is "Ulysses"; line 3).

How do we **add a new key:value pair** to an existing dictionary? There are two ways. Let's learn them in cell 5!

```
[5]: 1 # adding the first book (syntax 1)
 2 classics["Swift"] = "Gulliver's travels"
 3 print(classics)
 4
 5 # adding the second book (syntax 2)
 6 classics.update({"Bronte": "Jane Eyre"})
 7 print(classics)

adding the first book (syntax 1)
classics at key Swift is assigned
Gulliver's travels
print classics

adding the second book (syntax 2)
classics dot update Bronte:Jane Eyre
print classics

{'Austen': 'Pride and Prejudice', 'Shelley': 'Frankenstein', 'Joyce': 'Ulysses',
'Swift': 'Gulliver's travels'}
{'Austen': 'Pride and Prejudice', 'Shelley': 'Frankenstein', 'Joyce': 'Ulysses',
'Swift': 'Gulliver's travels', 'Bronte': 'Jane Eyre'}
```

The first way is to use a **slicing-like syntax**, where we write: (1) dictionary name (`classics`); (2) new key in between square brackets (`["Swift"]`); (3) assignment symbol (`=`); and (4) new value ("Gulliver's travels") (line 2). The second way is to use **the method `.update()`**. As an argument, we use a key:value pair in between curly brackets—that is, a dictionary! (line 6). To make sure that we added items correctly, we print the dictionary after every modification (lines 3 and 7).

What about **deleting items**? Let's look into the last cell!

```
[6]: 1 # deleting the first book (syntax 1)
 2 del classics["Austen"]
 3 print(classics)
 4
 5 # deleting the second book (syntax 2)
 6 classics.pop("Joyce")
 7 print(classics)

deleting the first book (syntax 1)
del classics at key Austen
print classics

deleting the second book (syntax 2)
classics dot pop Joyce
print classics

{'Shelley': 'Frankenstein', 'Joyce': 'Ulysses', 'Swift': 'Gulliver's travels',
'Bronte': 'Jane Eyre'}
{'Shelley': 'Frankenstein', 'Swift': 'Gulliver's travels', 'Bronte': 'Jane Eyre'}
```

Also in this case, there are two possibilities. The first way to delete an item is to use the **keyword `del`**, followed by the dictionary name and the key enclosed within square brackets (`classic["Austen"]`; line 2). The second way is to use the method `.pop()`, with the key of the item to delete as an argument (line 6). (Once more, this is similar to lists, where we use the method `.pop()` to delete an element based on its position.) After each deletions, we print the dictionary to check for correctness (lines 3 and 7).

### Complete the table

In this chapter, you have learned five dictionary methods. Summarize what they do by completing the following table.

| Dictionary method | What it does |
|-------------------|--------------|
| .items()          |              |
| .keys()           |              |
| .values()         |              |
| .update()         |              |
| .pop()            |              |

### Recap

- A dictionary is a Python type containing a sequence of key:value items separated by comma, and in between curly brackets {}.
- The dictionary methods .items(), .keys(), and .values() are used to access items, keys, and values, respectively.
- To change a dictionary value, we overwrite the existing value using slicing.
- To add a new item, we use a slicing-like syntax or the method .update().
- To delete an item, we use the keyword del or the method .pop().

### Lists of dictionaries

Can we have lists of dictionaries? Yes! When dealing with them, we just have to remember that they are lists—and not dictionaries! Let's see how they work. Find the code below in Notebook 24.

- Given the following list of dictionaries:

```
[1]: 1 countries = [{"name": "China", "capital": "Beijing"}, {"name": "France", "capital": "Paris"}]
 2 print(countries)
 [{}'name': 'China', 'capital': 'Beijing'}, {}'name': 'France', 'capital': 'Paris']]
```

We create a list called `countries`, composed of two elements that are dictionaries—that is, `{"name": "China", "capital": "Beijing"}` and `{"name": "France", "capital": "Paris"}`. Each dictionary is composed of two items, where the keys are "name" and "capital" (line1). At line 2, we print `countries`.

- Add a list element:

```
[2]: 1 countries.append({"name": "Brazil",
 "capital": "Brasilia"})
2 print(countries)
[{"name": "China", "capital": "Beijing"}, {"name": "France", "capital": "Paris"},
 {"name": "Brazil", "capital": "Brasilia"}]
```

Because country is a list (and not a dictionary!), we use the method `.append()` (and not `.update!`). As an argument, we write the new dictionary that we want to add as the third element of the list (i.e., `{"name": "Brazil", "capital": "Brasilia"}`; line 1). Then, we print to check for correctness (line 2).

- Slice the second element:

```
[3]: 1 print(countries[1]) print countries in position 1
[{"name": "France", "capital": "Paris"}]
```

To slice the second element, we use the usual syntax, `list[index]`, and we obtain the desired element (line 1).

- Print list elements using a `for` loop through elements and a `for` loop through indices:

```
[4]: 1 # for loop though elements
2 print("-> for loop though elements")
3 for country in countries:
4 print(country)
5
6 # for loop though indices
7 print("-> for loop though indices")
8 for i in range(len(countries)):
9 print(countries[i])
-> for loop though elements
{'name': 'China', 'capital': 'Beijing'}
{'name': 'France', 'capital': 'Paris'}
{'name': 'Brazil', 'capital': 'Brasilia'}
-> for loop though indices
{'name': 'China', 'capital': 'Beijing'}
{'name': 'France', 'capital': 'Paris'}
{'name': 'Brazil', 'capital': 'Brasilia'}
```

```
for loop though elements
print -> for loop though elements
for country in countries
print country

for loop though indices
print -> for loop though indices
for i in range len countries
print countries in position i
```

In the `for` loop through elements (lines 3–4), `country` browses the list elements, which are dictionaries. Thus, in the first loop, `country` is `{"name": "China", "capital": "Beijing"}`; in the second loop, `country` is `{"name": "France", "capital": "Paris"}`; and in the third loop, `country` is `{"name": "Brazil", "capital": "Brasilia"}`. In the `for` loop through indices (lines 8–9), `i` iterates over the positions 0, 1, and 2. Thus, `country[i]` browses the corresponding elements—that is, the three dictionaries.

- Print the country names using a for loop through indices and a for loop through values:

|                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <pre>[5]: 1 # for loop though elements 2 print("-&gt; for loop though elements") 3 for country in countries: 4     print(country["name"]) 5 6 # for loop though indices 7 print("-&gt; for loop though indices") 8 for i in range(len(countries)): 9     print(countries[i]["name"]) -&gt; for loop though elements China France Brazil -&gt; for loop though indices China France Brazil</pre> | <pre>for loop though elements print -&gt; for loop though elements for country in countries print country at key name  for loop though indices print -&gt; for loop though indices for i in range len countries print countries in position i at key name</pre> |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

To print the country names, we add a layer of slicing to the for loops that we implemented in cell 4. As we mentioned above, in the first iteration of the for loop through elements (lines 3–4), `country` is the dictionary `{"name": "China", "capital": "Beijing"}`. To extract "China", we need to slice at the key "name"—similarly for the other iterations. Thus, we print `country["name"]`. In the every iteration of the loop through elements (lines 8–9), `country[i]` is one of the dictionaries. To extract the value corresponding to the key "name", we have to write `country[i]["name"]`—in other words: `country[i]` slices the current list element, and `["name"]` slices the dictionary at the key "name".

## Let's code!

- Student's information. For the following scenario, create code similar to that presented in this chapter. You work in a school Registrar's Office, and here are the data of a student:

```
student = {"First name": "Bruce", "Last name": "Zhiang", "Sex": "Male", "Age": 21,
"Course": "Literature", "Hobby": "Swimming"}
```

- Print all the keys and their values.
  - Print all the keys.
  - Print all the values.
  - Bruce has recently changed his study course from Literature to Foreign Languages, so you update his data.
  - There are two pieces of information missing: Address and Phone number, so you add them (use two different syntaxes).
  - Finally, because of new privacy policies, you have to remove Sex and Hobby.
- New T-shirts in the store. You are the owner of a clothing store, and you are getting ready for the summer season. Your supplier has just provided a new set of trendy T-shirts.

- a. You create a dictionary containing characteristics of the new T-shirts: they are red, of size M, and have a round neck.
  - b. Then, you add more information: you received a total of 25 T-shirts and their logo's color is blue (use two different syntaxes).
  - c. Summer is over, and your sales went well. You have sold 20 T-shirts, so you add a new item containing the number of sold T-shirts.
  - d. Finally, you number the amount of T-shirts accordingly (calculate the quantity using the previously created item).
3. Colosseum. You are helping your neighbor's kid with her history assignment. She needs to collect data about the Colosseum. So, you go to the Wikipedia page (<https://en.wikipedia.org/wiki/Colosseum>) and look for some information.
    - a. You start with some information in a table on the right side of Wikipedia's page. Thus, you create a dictionary containing location (Rome), construction years (70–80 AD), and type of structure (amphitheater).
    - b. Then you read the text, and in the first paragraph, you learn that construction began in 72 AD and was completed in 80 AD. So, you remove the previous key about the year of construction. Then, you add two separate keys, one for the starting year and one for the completion year (using two different syntaxes).
    - c. How many years did it take to build the Colosseum?
    - d. How many years have passed since its construction started?

4. At a pet clinic. You are a vet at a pet clinic, and here are some of the pets you are currently taking care of:

```
pets = [{"name": "Toby", "animal type": "dog", "age": 2},
 {"name": "Kitty", "animal type": "cat", "age": 5},
 {"name": "Tiki", "animal type": "parrot", "age": 1}]
```

- a. You have just received a new patient, a 4-year-old horse called Sugar, and you add it to the list.
  - b. Now, you need to print all the animal names. Do it first with a `for` loop through elements and then with a `for` loop through indices.
  - c. Finally, you add an item that states that all the animals are currently in the clinic (what datatype do you use?).
5. Juices! You own a juice stand, and you need to keep track of juices and sales.
    - a. Create a list of dictionaries containing 3 juice flavors (orange, lemon, and pomegranate), their prices, and their colors.
    - b. For each juice, add a new item where the key is 'in shop,' and the value is a Boolean.
    - c. You just received a new order (grape juice), and you add it to your list.
    - d. What is the average price of a juice?

# 25. Trip to Switzerland

## Dictionaries with lists as values

In the previous chapter, you learned about dictionaries and lists of dictionaries. In this chapter, you will learn to code with dictionaries whose values are lists. Follow along with Notebook 25!

- Your friend is planning a trip to Switzerland, and he has asked you for some tips. You start with an empty dictionary to fill out:

```
[]: 1 tips = {} tips is assigned an empty dictionary
```

- He would like to visit some cities and taste typical food. Therefore, you add some recommendations:

```
[]: 1 tips["cities"] = ["Bern", "Lucern"] tips at key cities is assigned Bern,
2 tips["food"] = ["chocolate", "raclette"] Lucern
3 print(tips) tips at key food is assigned chocolate,
raclette
print tips
```

- Because his stay is four days, you add two more cities and two more dishes:

```
[]: 1 tips["cities"].append("Lugano") tips at key cities dot append Lugano
2 print(tips) print tips
```

```
[]: 1 tips["cities"] += ["Geneva"] tips at key cities is incremented by Geneva
2 print(tips) print tips
```

```
[]: 1 tips.get("food").append("onion tarte") tips dot get food dot append onion tarte
2 print(tips) print tips
```

```
[]: 1 tips["food"] = tips.get("food") + ["fondue"] tips at key food is assigned tips dot
get food concatenated with fondue
2 print(tips) print tips
```

- You want to check that the dictionary is correct, so you print all items one by one:

```
[]: 1 for k,v in tips.items(): for k v in tips dot items
2 print(k,v) print k v
```

- Finally, you improve the print for improved readability:

```
[]: 1 for k,v in tips.items(): for k v in tips dot items
2 print("{:>6}: {}".format(k,v)) print symbols dot format k v
```

### 📝 True or false?

1. There are at least 3 ways to add an element to a list that is a dictionary's value. T F
2. `.get()` is a list method, and `.append()` is a dictionary method T F
3. The built-in function `print()` can take comma-separated variables as an argument T F

## Computational thinking and syntax

Let's start analyzing the code above by running the first cell:

```
[1]: 1 tips = {} tips is assigned an empty dictionary
```

We **initialize an empty list** by **assigning curly brackets** to the variable `tips` (line 1).

Let's run the second cell:

```
[2]: 1 tips["cities"] = ["Bern", "Lucern"] tips at key cities is assigned Bern, Lucern
2 tips["food"] = ["chocolate", "raclette"] tips at key food is assigned chocolate, raclette
3 print(tips) print tips
{'cities': ['Bern', 'Lucern'], 'food': ['chocolate', 'raclette']}
```

We fill out the empty dictionary `tips` with two new items. The first item has the string "cities" as a key and the list ["Bern", "Lucern"] as a value (line 1). The second item has the string "food" as a key and the list ["chocolate", "raclette"] as a value (line 2). To check for correctness, we print the dictionary (line 3).

We want to add new elements to the two lists that are `tips`'s values. How do we go about doing so? Let's see four possibilities, one in each of the next four cells. In the first two cells we will add a city, and in the last two cells we will add two types of food. In all cases, the command will be composed of two steps: **(1) extracting the value** (i.e., the list) **corresponding to a certain key**, and **(2) adding the new element to the list**.

Let's add the first city, which is "Lugano":

```
[3]: 1 tips["cities"].append("Lugano") tips at key cities dot append Lugano
2 print(tips) print tips
{'cities': ['Bern', 'Lucern', 'Lugano'], 'food': ['chocolate', 'raclette']}
```

First, we **slice** the list from the dictionary—`tips["cities"]` is ["Bern", "Lucern"]. Then, we add the new elements to the list using `.append()` (line 1). Finally, we print to check for correctness (line 2).

Let's add the second city, that is, "Geneva":

```
[4]: 1 tips["cities"] += ["Geneva"] tips at key cities is incremented by Geneva
2 print(tips) print tips
{'cities': ['Bern', 'Lucern', 'Lugano', 'Geneva'], 'food': ['chocolate', 'raclette']}
```

Like above, we **slice** the list from the dictionary—`tips["cities"]` is now ["Bern", "Lucern", "Lugano"]. Then, we use list **concatenation** as an alternative to the method `.append()`. As you might remember, when using list concatenation we must reassign the changed value to the variable. In this example, we combine assignment and concatenation with the `+=` operator—the extended command is `tips["cities"] = tips["cities"] + ["Geneva"]` (line 1). At line 2, we print `tips` to check the dictionary's content.

Let's now add the first type of food, which is "onion tarte":

```
[5]: 1 tips.get("food").append("onion tarte") tips dot get food dot append onion tarte
2 print(tips) print tips
{'cities': ['Bern', 'Lucern', 'Lugano', 'Geneva'], 'food': ['chocolate', 'raclette', 'onion tarte']}
```

As an alternative to slicing, we can extract a value using the dictionary method `.get()`, which takes the corresponding key as an argument. In our case, `.get("food")` returns the list `["chocolate", "raclette"]`. Then, we add the new element ("onion tarte") using the list method `.append()` (line 1). As you might have noticed, we created a “chain” of methods, combining a dictionary method (`.get()`) that returns a list, with a list method (`.append()`) that modifies the list. At the end of the cell, we print `tips` to check for correctness (line 2).

Finally, let's add the second type of food, that is, "fondue":

```
[6]: 1 tips["food"] = tips.get("food") + ["fondue"] tips at key food is assigned tips dot
 2 print(tips) get food concatenated with fondue
 print tips
{'cities': ['Bern', 'Lucern', 'Lugano', 'Geneva'], 'food': ['chocolate', 'raclette',
'onion tarte', 'fondue']}
```

Like above, we use the method `.get()` to extract the value corresponding to "food", which is the list `["chocolate", "raclette", "onion tarte"]`. Then, we use concatenation to add the last element "fondue". Note that in this case we cannot use the compact operator `+=` because we cannot reassign to `tips.get("food")`. We can only reassign the outcome to `tips["food"]` (line 1). Finally, we print the dictionary to check for correctness (line 2).

In summary, the four ways that we have to add an element to a list that is a value of a dictionary are a combination of **slicing or dictionary method `.get()`** to slice the value from the dictionary, and of **list method `.append()` or concatenation** to add a new element to the list. When coding, you can choose to use only one way or to alternate several ways. But it is important to know all ways to understand code written by somebody else.

In the examples above, you might have noticed that reading the print of a dictionary can be hard when several keys and values are displayed in one long line. Let's learn how to print a key:value pair per line to improve readability:

```
[7]: 1 for k,v in tips.items():
 2 print(k,v)
cities ['Bern', 'Lucern', 'Lugano', 'Geneva']
food ['chocolate', 'raclette', 'onion tarte', 'fondue']
```

We use a `for` loop through *values* with two variables `k`—for the keys—and `v`—for the values. The two names could be different, but conventionally we use the initial of the variable they represent. `k` and `v` simultaneously browse the dictionary items returned by the `.items()` method (line 1). At each iteration, we print the current key `k` with the corresponding value `v` (line 2). Note that `k` and `v` are separated by comma. This is independent from the fact that we are printing the items of a dictionary. The built-in function `print()` can take **variables of different types separated by comma as an argument**. For example, we can use `print("The Swiss cities in the list are", 4)` as an alternative to `print("The Swiss cities in the list are" + str(4))`.

What if we want to print only the keys or only the values? Let's have a look!

```
[]: 1 for k in tips.keys():
 2 print(k)
cities
food
```

In the for loop header, we use only the variable `k` in combination with the method `.keys()` (line 1), and we print `k` only (line 2). Similarly for the values:

```
[]: 1 for v in tips.values():
 2 print(v)
['Bern', 'Lucern', 'Lugano', 'Geneva']
['chocolate', 'raclette', 'onion tarte', 'fondue']
```

In the for loop header, we use only the variable `v` in combination with the method `.values()` (line 1), and we print `v` only (line 2).

Finally, let's have a look at one more elegant way to print dictionaries:

```
[8]: 1 for k,v in tips.items():
 2 print("{:>6}: {}".format(k,v))
cities: ['Bern', 'Lucern', 'Lugano', 'Geneva']
food: ['chocolate', 'raclette', 'onion tarte', 'fondue']
```

The for loop header is the same as in cell 7: `k` and `v` iteratively browse keys and values returned by `.items()` (line 1). The argument of the built-in function `print()` at line 2 looks a bit more complicated. Let's disentangle it! There is a string—constituted by red characters in between quotes—followed by the string method `.format()`, which takes two arguments: `k` and `v`. The symbols in the string contain two pairs of curly brackets, one with the symbols `{:>6}`, and one empty `{}`. These pairs of **curly brackets** have nothing to do with dictionaries. They are **placeholders** for the arguments of the string method `.format()`. The first argument `k` will be printed at the place of `{:>6}` and the second argument `v` at the place of `{}`. What is the meaning of `{:>6}`? It is composed of three parts: (1) the symbol `:` indicates to print the whole text; (2) the symbol `>` specifies that the text is aligned to the right; and (3) the symbol `6` indicates that the printing space is made of 6 characters—because `cities` has 6 characters. What about the colon between the two placeholders? It is simply the colon printed between each key and the corresponding value—e.g., `cities: ['Bern' ...]`. Finally, what is the function of the string method `.format()`? It **formats the arguments and inserts them into the placeholders**.

 Insert into the right column

Insert string, list, and dictionary methods into the right column:

```
.keys(), .upper(), .insert(), .append(), .values(), .copy(), .lower(), .pop(), .count(),
.format(), .capitalize(), .index(), .extend(), .get(), .items(), .title(), .remove(), .clear(),
.update(), .pop(), .reverse(), .sort()
```

## Recap

- To initialize a dictionary, we use a pair of empty curly brackets {}.
  - The dictionary method .get() takes a key as an argument and returns the corresponding value.
  - There are at least 4 different ways to access and modify dictionary values that are lists, by combining:
    - Slicing or .get() to extract a list from a dictionary.
    - List operations (such as concatenation) or methods (e.g., .append()) to modify a list.
  - We can use the for loop through values to browse items, keys, and values of a dictionary.
  - The built-in function print() can take several variables as an argument:
    - Separated by comma, or
    - Using placeholders {} in combination with the string method .format().

## Dealing with KeyError

When coding with dictionaries, key errors can occur. Let's see what it means and how to fix it! Let's consider the same example as in this chapter, and let's slice the value corresponding to the key "cities":

```
[1]: 1 tips ["city"] tips at key city

KeyError Traceback (most recent call last)
Cell In[3], line 1
 ----> 1 tips ["city"]
KeyError: 'city'
```

As you know, to understand an error, we start from the last line. It says `KeyError: 'city'`, which means that we made an error on the key 'city'—it should be 'cities'! To know where the error is, we look for the green arrow, which shows that we need to correct at line 1. To fix it, we just replace "city", with "cities" in the code. Note that we can get the same error message when a key does not exist.



## Let's code!

1. For each of the following scenarios, create code similar to that presented in this chapter.
    - a. *Olympic Games*. You are a sports journalist, and your task is to collect a dictionary of summer and winter sports performed at the Olympic Games.
      - a. Create an empty dictionary that you will fill out with some Olympic Games.
      - b. Add two summer sports and two winter sports.
      - c. The lists in the values look a bit short. Add two more summer sports and two more winter sports. Add each element with a different method.
      - d. Print all items one by one in two different ways.
      - e. Finally, print only the sports lists.
    - b. *Teaching Python*. You are teaching Python to some students, and you want to list their names according to the course they are attending.
      - a. Create an empty dictionary called `students`.
      - b. So far, there are two students for the basic course and three students for the advanced course. Add their names to the dictionary.
      - c. You have just received four new registrations: three for the basic course and one for the advanced course. So, you add the new students' names to the dictionary using four different ways.
      - d. After checking the background of the students attending the basic course, you realize that one of them should be in the advanced course. So you move the student from the basic to the advanced course.
      - e. To check for correctness, you print all items one by one in two different ways.
      - f. Finally, you print the course names and the students' names separately.
  2. *Furniture store*. You are the manager of a furniture store. Here are the pieces of furniture in storage:
- ```
store = {"furniture": ["chair", "table", "sofa"],
```

```
"amount": [24, 7, 6],  
"price" : [200, 500, 1200]}
```

- a. A new customer comes in and buys 4 chairs. Update the dictionary using an arithmetic operation.
 - b. After a few days, you receive new pieces of furniture: 9 carpets worth 150 each and 4 lamps worth 180 each. So, you add them to the dictionary (use different syntaxes).
 - c. The owner of a restaurant comes to your shop and buys all the tables. Update the dictionary (use at least 2 different syntaxes).
 - d. To better visualize what is left, you print the dictionary aligning the keys to the right and the values to the left.
 - e. What is the total price of the furniture in storage?
3. *Shifting list elements!* Given the following dictionary:
- ```
dictionary = {"numbers": [2,3,4,5,6,7,8,9,10]}
```
- a. Add a *key:value* pair where the key is the string even and the value is a list containing True for even numbers and False for odd numbers.  
(Expected result:  

```
{"numbers": [2, 3, 4, 5, 6, 7, 8, 9, 10],
 "even": [True, False, True, False, True, False, True, True]}).
```
  - b. Subtract 1 from each number.
  - c. How do you modify the Boolean list so that it corresponds to the new list of numbers? Hint: Just shift it!
4. *Numbers in a triangle!* Ask a player for an integer. Then, print a triangle where each row contains a consecutive integer between 1 and the number entered by the player. Additionally, each row should include a list containing the number from that row repeated the same number of times as the number itself. To do that, use a dictionary and allow the player to play as long as they want!  
(Example input: 5.  
Expected output:
- ```
1 [1]  
2 [2, 2]  
3 [3, 3, 3]  
4 [4, 4, 4, 4]  
5 [5, 5, 5, 5, 5]).
```

26. Counting, compressing, and sorting

What are dictionaries for?

In this chapter, the final one dedicated to dictionaries, you will learn some typical situations where using dictionaries is very convenient. Try to solve each example by yourself before looking into the solution. You can find the code in Notebook 26!

1. Counting elements

Dictionaries are extremely convenient when we need to save occurrences, that is, the number of times something happens. Let's understand what this means with the following example.

- Given the following string:

```
[1]: 1 greetings = "hello! how are you?" greetings is assigned hello! how are you?
```

- Create a dictionary where the keys are the letters of the alphabet found in the string, and the corresponding values are the number of times each letter is present. Write the code in two ways: (1) using `if/elif`; and (2) using `.get()`.

- Using `if/elif`:

```
[2]: 1 letter_counter = {} letter counter is assigned an empty
2
3 for letter in greetings:
4     if letter not in letter_counter.keys():
5         letter_counter[letter] = 1
6
7     else:
8         letter_counter[letter] += 1
9
10 for k,v in letter_counter.items():
11     print(k,v)
h 2
e 2
l 2
o 3
! 1
3
w 1
a 1
r 1
y 1
u 1
? 1
```

for letter in greetings
if letter not in letter counter dot keys
letter counter at key letter is assigned one
else
letter counter at key letter is incremented by one
for k v in letter counter dot items
print k v

We start with an empty dictionary called `letter_counter` (line 1). We browse each character of the string `greetings` using a `for` loop through elements (line 3)—the `for` loop through elements works the

same way for lists and strings. Then, for each character, we check if it is a key of `letter_counter` and we act accordingly (lines 4–7). More precisely, we first evaluate if the current character is not already a key of `letter_counter` by checking if `letter`, which is a string, is not in the output of `letter_counter.keys()` (line 4). Note that we can directly check the membership of `letter` in `dict_keys` (returned by `.keys()`) without having to transform into a list—in other words, we do not need to write `list(letter_counter.keys())`. If the condition at line 4 is satisfied, then we add a new `key:value` pair, where the key is `letter`, and the value is `1` (line 5). On the other hand, if the current character is already a key in `letter_counter` (else at line 6), then we add `1` to the already existing corresponding value (line 7)—the explicit command is `letter_counter[letter] = letter_counter[letter] + 1`. To better understand this, let's look at what happens at the third and fourth loops. At the third loop, `letter` is `l` (`he_ll_o`). Because `l` is not already a key in `letter_counter` (line 4), we create a new dictionary item, where `l` is the key and `1` is the value (line 5). At the fourth loop, `letter` is `l` again (`he_ll_o`). Because this time `l` is already a key (line 6), we slice the value at `letter_counter[l]`, which is `1`, add `1`, and we reassign it into the dictionary (line 7). We terminate the task by printing each letter and its corresponding amount with a `for` loop through keys and values (lines 9–10).

2. Using `.get()`:

[3]:	<pre>1 letter_counter = {} 2 3 for letter in greetings: 4 letter_counter[letter] = 5 letter_counter.get(letter, 0) + 1 6 for k,v in letter_counter.items(): 7 print(k,v)</pre>	<p>letter counter is assigned an empty dictionary</p> <p>for letter in greetings letter counter at key letter is assigned letter counter dot get letter zero plus one</p> <p>for k v in letter counter dot items print k v</p>
	<pre>h 2 e 2 l 2 o 3 ! 1 _ w 1 a 1 r 1 y 1 u 1 ? 1</pre>	

Similarly to cell 2, we start with the empty dictionary `letter_counter` (line 1), continue with a `for` loop through elements (line 3), and conclude by printing the obtained dictionary to check the correctness of the results (lines 6–7). As opposed to what we saw above, the four lines of code containing the `if/else` construct (lines 4–7, cell 2) are replaced by one single line containing the following: an assignment, the method `.get()`, and a sum (line 4). The method `.get()` contains two arguments, `letter` and `0`, and it acts as follows: **if the key does not exist, `.get()` returns the second argument; if the key already exists, `.get()` returns the corresponding value**. Thus, this is what happens at line 4:

- If the current key `letter` does not exist yet—as in the third loop where `letter` is the first `l` in `he_ll_o`—then `.get(letter, 0)` returns `0`. Then, we add `1` to `0`, and we create a new `key:value` pair in the

dictionary by assigning the result to `letter_counter[letter]`.

- If the current key `letter` already exists—as in the fourth loop where `letter` is the second `l` in `hello`—then `.get(letter, 0)` returns the value corresponding to `letter`—that is, `1`. We add `1` to the returned `1` to increment the count, and we update the existing key:value pair in the dictionary by reassigning.

Why do we use `0` as the second argument? Since in this line of code we need to have `+1` to update the counts of the already existing letters, the only way we have to obtain `1` for a new letter is to sum to `0`.

2. Compressing information

Dictionaries are extremely convenient for compressing redundant information: for example, to store signals acquired by sensors over a long time. Think of a sensor used to detect vibrations in the case of an earthquake. Most of the time, the sensor just records zeros as there is no seismic event. However, when an earthquake occurs, the sensor registers a spike (or a group of spikes) whose magnitude is different from zero. Saving days and days of zeros in a list would require a significant amount of computer memory, and it would be somewhat pointless because the signal information is in the spikes. To reduce the amount of storage memory while keeping the information, we can use a dictionary. How would you do it? And how would you then go back from the dictionary to the original list?

- Given the following list:

```
[4]: 1 sparse_vector = [0, 0, 0, 1, 0, 7, 0, 0,
 4, 0, 0, 0, 8, 0, 0, 0, 6, 0, 0, 0, 0, 0,
 0, 0, 9, 0, 0]
```

sparse vector is assigned a list of numbers

We start with a list called `sparse_vector`, containing many zeros and a few integers spread among the zeros. (Note: in linear algebra, sparse vectors are vectors where the majority of components are zeros.)

- Convert it into a dictionary:

```
[5]: 1 # create the dictionary
2 sparse_dict = {}

3 for i in range(len(sparse_vector)):
4     if sparse_vector[i] != 0:

5         sparse_dict[i] = sparse_vector[i]

6

7 # save the list length
8 sparse_dict["length"] = len(sparse_vector)

9

10 # print
11 for k,v in sparse_dict.items():
12     print(k,v)
3 1
5 7
8 4
12 8
```

create the dictionary
sparse dict is assigned an empty dictionary
for i in range len of sparse vector
if sparse vector in position i is not equal to zero
sparse dict at key i is assigned sparse vector in position i

save the list length
sparse dict at key length is assigned len of sparse_vector

print
for k v in sparse dict dot items
print k v

16 6
24 9
length 27

We start with an empty dictionary called `sparse_dict` (line 2). Then, we browse the list `sparse_vector` with a `for` loop through indices (line 3) to select and save the information—that is, the nonzero integers and their positions in the list. If the current list element `sparse_vector[i]` is not equal to zero (line 4), then we add a new item to the dictionary `sparse_dict`, where the key is the position of the element in the list—that is, `[i]`—and the value is the current nonzero element—that is, `sparse_vector[i]` (line 5). After the loop, we save an item where the key is the string "`length`", and the value is the actual length of the list (`len(sparse_vector)`; line 8). This key:value pair will be useful to convert the dictionary back into a list, like we will see in the next cell. Finally, we print each dictionary item with a `for` loop through elements to check the correctness of our code (lines 11–12).

- How do we get back to the sparse vector?

We start by creating a list of zeros called `sparse_vector_back` of the same length as the original list `sparse_vector`. To create `sparse_vector_back`, we use list replication, where we replicate a list containing a zero ([0]) for a number of times equal to the length of the original list—whose value we saved in correspondence with the key "length". Then, we overwrite the nonzero values into the list. With a for loop, we browse each key:value pair in the dictionary (line 5). If the current key is not equal to "length" (line 6)—we need to make sure that we do not access that item—then we assign the current value `v`, which represents the magnitude of a spike, to the list `sparse_vector_back` in position `k` (line 7). Finally, we print the list to check for correctness (line 10).

3. Sorting dictionaries

In this last example about dictionaries and their applications, we will learn how to sort dictionaries according to their keys or values. Consider a simplified city registry containing citizens' names as keys and their ages as values. Officers might need to sort the registry according to names to send out letters, or according to age to distinguish the kids from the elderly. Let's see how to do it!

- Given the following dictionary:

```
[7]: 1 registry = {"Shaili":4, "Chris":90,  
"Maria":70} registry is assigned Shaili:4, Chris:90,  
Maria:70
```

- Sort the dictionary items according to their keys:

```
[8]: 1 # create a new dictionary
      2 sorted_registry = {}

      3
      4 # sort the keys
      5 sorted_keys = list(registry.keys())
      6 sorted_keys.sort()
      7
      8 # fill out the new dictionary
      9 for k in sorted_keys:
          10     sorted_registry[k] = registry[k]
      11
      12 print(sorted_registry)
      {'Chris': 90, 'Maria': 70, 'Shaili': 4}
```

create a new dictionary
sorted registry is assigned empty dictionary
sort the keys
sorted keys is assigned list registry dot keys
sorted keys dot sort
fill out the new dictionary
for k in sorted keys
sorted registry at key k is assigned registry at key k
print sorted registry

We start with an empty dictionary called `sorted_registry` that will have the same content as `registry`, but the items will be sorted according to the keys (line 2). To sort the keys, we execute two steps. First, we extract the keys using the dictionary method `.keys()` and then transform its output—whose type is `dict_keys`—into a list using the built-in function `list()` (line 5). Then, we sort the obtained keys—`['Shaili', 'Chris', 'Maria']`—in alphabetical order using the list method `.sort()`, obtaining `['Chris', 'Maria', 'Shaili']` (line 6). Finally, we browse the list of sorted keys using a `for` loop through elements (line 9) to fill out `sorted_registry`. For each key `k`, we extract the corresponding value in `registry` (`registry[k]`) and assign it to `sorted_registry` at key `k` (`sorted_registry[k]`), thus creating a new dictionary item. For example, in the first loop, `k` is "Chris", so extract 90 from `registry` (`registry[k]`), and we assign it to "Chris" in `sorted_registry` (`sorted_registry[k]`). Then, we do the same for the keys "Maria" and "Shaili". Finally, we print `sorted_registry[k]` to check for correctness (line 12).

- Sort the dictionary items according to their values:

```
[9]: 1 # create a new dictionary
      2 sorted_registry = {}

      3
      4 # sort keys according to values
      5 sorted_keys = sorted(registry,
                           key = registry.get)
      6
      7 # fill out the new dictionary
      8 for k in sorted_keys:
          9     sorted_registry[k] = registry[k]
      10
      11 print(sorted_registry)
      {'Shaili': 4, 'Maria': 70, 'Chris': 90}
```

create a new dictionary
sorted registry is assigned empty dictionary
sort keys according to values
sorted keys is assigned sorted registry key is assigned registry dot get
fill out the new dictionary
for k in sorted keys
sorted registry at key k is assigned registry at key k
print sorted registry

To sort a dictionary according to values, we use the same procedure as above: we create an empty dictionary (line 2); we sort the keys (line 5); we fill out the empty dictionary using a `for` loop through elements that browses the sorted keys (line 8) and adds sorted key:value pairs to the dictionary (line

9); and we print to check for correctness (line 11). What is different is the way we sort the keys, that is, according to dictionary values. To do that, we use the built-in function `sorted()` (line 5), which takes two arguments: (1) the dictionary whose keys we want to sort and (2) the dictionary combined with the method `.get` (note the absence of round brackets). Note that `sorted()` can be used also with lists and strings—mainly with only one argument—as an alternative to the method `.sort()`. The difference is that `sorted()` returns a variable (e.g., `sorted_list = sorted(original_list)`), whereas `.sort()` directly acts on the list (e.g., `original_list.sort()`).

Recap

- Some typical examples of dictionary use include counting elements, compressing information, and sorting a dictionary according to keys and values.
- The dictionary method `.get(key, initial value)` is used to initialize a key:value pair in a dictionary and fill it up during a `for` loop.
- The built-in function `sorted()` is used to sort a dictionary; note that it creates a new variable.

Remaining dictionary methods

Dictionaries have 11 methods. In the past three chapters, we have learned six dictionary methods: `.items()`, `.keys()`, `.values()`, `.get()`, `.update()`, and `.pop()`. Here are the remaining 5 methods:

- `.clear()`: Deletes all the elements from the dictionary (makes the dictionary empty).
- `.copy()`: Provides a copy of the dictionary and thus allows separate modification.
- `.fromkeys()`: Creates a dictionary with the keys specified in a list and a default value.
- `.popitem()`: Removes the last inserted key:value pair.
- `.setdefault()`: Returns the value of the specified key. If the key does not exist, then it inserts the new key:value pair into the dictionary.

Create your examples

In a notebook, write an example for each of the new dictionary methods introduced in the *In more depth* section above: `.clear()`, `.copy()`, `.fromkeys()`, `.popitem()`, and `.setdefault()`. If you want, you can start from this dictionary:

```
fruit_colors = {"strawberry": "red", "banana": "yellow", "kiwi": "green"}
```

Let's code!

1. From dictionary to list of lists and back! Given the following dictionary:

```
cars = {"sports car": 4, "convertible": 5, "limousine": 2}
```

- a. Transform the dictionary into a list of lists.
(Expected result: [['sports car', 4], ['convertible', 5], ['limousine', 2]]).
 - b. Transform the list of lists back to the original dictionary.
2. *Multiplication table game!* You are a programmer at an educational game company. Your task is to create a game where a kid enters a number, and you display the corresponding multiplication table. To implement the game, create a dictionary where the keys are numbers from 1 to 10 and the values are the results of the multiplications between the key and the value entered by the kid. Use a `for` loop and allow the kid to play as long as they want.

(Example input: 4

Example output:

```
1 x 4 = 4
2 x 4 = 8
3 x 4 = 12
4 x 4 = 16
5 x 4 = 20
6 x 4 = 24
7 x 4 = 28
8 x 4 = 32
9 x 4 = 36
10 x 4 = 40).
```

3. *Spices and herbs.* You work in a grocery store selling spices and herbs. Here are the spices and herbs in the shop:

```
spices_herbs = ["basil", "cinnamon", "licorice", "mint", "rosemary", "thyme",
"cardamom", "turmeric", "cilantro", "oregano", "pepper", "chili", "dill",
"cayenne pepper", "ginger", "garlic", "marjoram", "nutmeg", "sage", "saffron",
"star anise", "bay leaves"]
```

- a. You have to change the labels on the containers and give them a more modern look. The length of the new labels is proportional to the length of the word written on it. Create a dictionary where keys are word lengths and values are lists of words with that length.
- b. You need to know how many labels you have to cut for each length. Create another dictionary where keys are word lengths in an ascending order, and values are the number of labels you have to cut for each length.
- c. What is the most common label? How many letters does it correspond to? Compute it!

27. Overview of strings

Operations, methods, and printing

In this chapter, we will summarize the characteristics of strings, similar to what we did for lists in Chapter 21. You'll notice a lot of commonalities between the two data types, but also some important differences. Follow along with Notebook 27. As usual, try to solve the tasks before looking into the solution. Let's start!

1. String slicing

String slicing works like list slicing (see Chapter 12). Take a look at the two examples below as a refresher.

- Given the following string:

```
[1]: 1 two_ways = "rsecwyadrkd"          two ways is assigned rsecwyadrkd
```

We start with a string of characters (line 1). You might remember that in coding we use the word **characters** instead of **letters**.

- Extract every second character:

```
[2]: 1 print(two_ways[:, :, 2])           print two ways from the beginning to the
                                             end with a step of two
                                             reward
```

The start is the beginning of the string, so we can omit it. Similarly, the stop is the end of the string, so we can omit it too. The step is 2. The outcome is `reward` (line 1).

- Extract every second character and invert the outcome:

```
[3]: 1 print(two_ways[:, :, -2])          print two ways from the beginning to the
                                             end with a step of minus two
                                             drawer
```

Opposite to the above, the start is the end of the string, and the stop is the beginning of the string; therefore, we can omit both. Since we are going backwards, the step is -2 (note the minus symbol). In this case, the outcome is `drawer`. (Did you know that the reverse of `reward` is `drawer`?)

2. “Arithmetic” operations on strings

There are two “arithmetic” operations on strings: concatenation and replication. They follow the same principles as lists do. Let's quickly look at a refresher on how they work.

- Concatenate two strings:

```
[4]: 1 first = "sun"
      2 second = "screen"
      3 combo = first + second
      4 print(combo)
                                             first is assigned sun
                                             second is assigned screen
                                             combo is assigned first concatenated with second
                                             print combo
                                             sunscreen
```

Given two separate strings—"sun" (line 1) and "screen" (line 2)—we can merge them using the concatenation symbol + to obtain "sunscreen" (line 3). We print the result to check for correctness (line 4).

- Replicate a string 5 times:

```
[5]: 1 one_smile = ":)"
      2 five_smiles = one_smile * 5
      3 print(five_smiles)
      :-):-):-):-):-)
```

one smile is assigned smiley face
five smiles is assigned one smile replicated by five
print five smiles

Given a string containing some characters—for example, a smiley face (line 1)—we replicate it by using the replication symbol * and the number of times we want to replicate (5 in this case; line 2). Finally, we print the obtained five smileys (line 3).

3. Replacing or removing substrings

Substrings are parts of strings. In many of the following examples, we will use substrings composed of only one character for simplicity. However, the rules in the examples are also valid so for substrings composed of multiple characters. Let's learn how to replace or remove substrings in a string based on a substring position or content. Let's start by **changing a substring based on its position**.

- Given the following string:

```
[6]: 1 favorites = "I like cooking, my family,
      and my friends"
```

favorites is assigned I like cooking, my
family, and my friends

We start with a string containing a sentence (line 1).

- Replace the character at position 0 with U using slicing and assignment. What happens?

```
[7]: 1 favorites [0] = "U"
```

favorites in position zero is assigned U

```
-----  
TypeError          Traceback (most recent call last)  
Cell In[7], line 1  
----> 1 favorites [0] = "U"  
TypeError: 'str' object does not support item assignment
```

Why do we get the type error 'str' object does not support item assignment? Because in Python **strings are immutable**, that is, **they cannot be changed by assignment**. To change a string—or parts of it—we have to use slicing combined with concatenation or string methods. Let's have a look.

- Redo the same task using slicing and concatenation:

```
[8]: 1 from_position_one = favorites [1:]
      2 favorites = "U" + from_position_one
      3 print(favorites)
      U like cooking, my family, and my friends
```

from position one is assigned favorites
from one to the end of the string
favorites is assigned U concatenated with
from position one
print favorites

The first way to change a substring is to use a combination of **slicing and concatenation**. We slice the part of the string that we want **to keep**, that is, from the character in position 1—the space after

I—to the end, and we save it in the variable `from_position_one` (line 1). Then, we concatenate the desired character in position 0—that is, "U"—to the string `from_position_one` (line 2). Obviously, we can compress the two lines of code into one line: `favorites = "U" + favorites[1:]`—here they are separated for clarity of explanation. Finally, we print out the resulting string (line 3).

- Redo the same task using the string method `.split()`:

```
[9]: 1 favorites = "I like cooking, my family, and  
     my friends"  
2  
3 parts = favorites.split("I")  
4  
5 print(parts)  
6  
7 favorites = "U" + parts[1]  
8  
9 print(favorites)  
[', ' like cooking, my family, and my friends']  
[U like cooking, my family, and my friends]
```

favorites is assigned I like cooking,
my family, and my friends

parts is assigned favorites dot split
I
print parts

favorites is assigned U concatenated
with parts in position one
print favorites

The second way to change a substring is to combine the **method `.split()` and concatenation**. We start with the string to modify (line 1)—we need to rewrite the original string because we changed it in the previous cell. Then, we apply the method `.split()`, whose argument is **the substring around which we want to split the original string**—in our case, the character "I"—and we assign the output to the variable `parts` (line 3). As we can see from the print of `parts` (line 4), `.split()` returns a list with two elements. The first element contains the characters that are before the argument "I"—that is, an empty string because "I" is in position 0. The second element represents the characters that are after the argument "I"—that is, ' like cooking, my family, and my friends' (notice the space in the first position). As another example, if we want to split the string at the word "cooking", we can write: `parts = favorites.split("cooking")`, and we obtain ['I like ', ', my family, and my friends']. We conclude the string modification by concatenating "U" with the second element in `parts` (line 6), and we print the final result (line 7).

What if we want to **modify a substring based on its content** instead of position? Let's have a look!

- Replace the commas with semicolons using the string method: `.replace()`:

```
[10]: 1 favorites = "I like cooking, my family,  
     and my friends"  
2 favorites = favorites.replace(",", ";")  
3  
4 print(favorites)  
[I like cooking; my family; and my friends]
```

favorites is assigned I like cooking, my
family, and my friends
favorites is assigned favorites dot
replace comma semicolon
print favorites

We start by rewriting the original string (line 1). Then, we use the **method `.replace()`**, which takes two arguments: **the substring that we want to remove**, and **the substring that we want to add**. Note that we reassign the outcome to the original string `favorites` to make the change effective (line 2). Finally, we print to check for correctness (line 3).

What about **removing substrings**? If we want to remove based on **position**, we can just use a **combination of slicing (or `.split()`) and concatenation**. For example: if we want to remove `cooking` from the string `favorites`, we can write: `favorites[:6] + favorites[15:]`, and we get: `I like my family, and my friends`. On the other side, to remove a substring based on its **content**, we need to use a trick.

Let's have a look at it!

- Remove the commas:

<pre>[11]: 1 favorites = "I like cooking, my family, and my friends" 2 favorites = favorites.replace(",", "") 3 print(favorites) [1] I like cooking my family and my friends</pre>	<p><code>favorites</code> is assigned <code>I like cooking, my family, and my friends</code> <code>favorites</code> is assigned <code>favorites</code> dot <code>replace</code> comma empty string <code>print</code> <code>favorites</code></p>
---	--

After rewriting the original string (line 1), we use the method `.replace()`, where the first argument is a comma—the substring we want to remove—and the **second argument is an empty string**. With this trick, **we remove the unwanted substring and we do not substitute it with any new substring** (line 2). Finally, we print `favorites` as a check (line 3). Fun parallel: How does the meaning of the sentence change when you remove the comma?

4. Searching a substring in a string

How do we find a substring in a string? Let's see below!

- Given the following string:

<pre>[12]: 1 us = "we are"</pre>	<p><code>us</code> is assigned <code>"we are"</code></p>
----------------------------------	--

We start with a short string named `us` (line 1).

- Find the positions of the character e using the method `.find()`:

<pre>[13]: 1 positions = us.find("e") 2 print(positions) [1]</pre>	<p><code>positions</code> is assigned <code>us</code> dot <code>find</code> <code>e</code> <code>print</code> <code>positions</code></p>
---	---

We use the **method `.find()` that takes the substring that we want to find as an argument**—in our case, `"e"`. We assign the outcome to the variable `positions` (line 1) and we print it (line 2). Anything unexpected in the outcome? We get only the position 1, whereas in `us`, `"e"` is at positions 1 and 5. This happens because the method `.find()` returns **only the position of the first substring** that it finds. How can we find the position of *all* substrings `"e"`? Try to answer this question before looking into the solution below!

- Find the positions of the character e using an alternative way:

<pre>[14]: 1 # initializing positions 2 positions = [] 3 4 # find all positions of e 5 for i in range(len(us)): 6 if us[i] == "e": 7 positions.append(i) 8 print(positions) [1, 5]</pre>	<p><code>initializing positions</code> <code>positions</code> is assigned empty list</p> <p><code>find all positions of e</code> <code>for i in range len of us</code> <code>if us in position i is equal to e</code> <code>positions</code> dot <code>append</code> <code>i</code> <code>print</code> <code>positions</code></p>
---	--

We initialize the variable `positions`—which will contain the positions of all the substrings `e`—as an empty list (line 2). Then, we create a `for` loop through indices to browse all the positions in `us` (line

5). If the character at the current position *i* is equal to "e" (line 6), then we append *i* to the list *positions* (line 7). Finally, we print *positions* to check for correctness (line 8).

What happens if we look for a substring that is not in the string? Let's have a look!

- Find the positions of the character f using the method `.find()`:

```
[15]: 1 positions = us.find("f")
2 print(positions)
-1
```

positions is assigned us dot find f
print positions

Similarly to cell 13, we use the method `.find()` to look for the substring "f" in the string *us*, and we assign the outcome to the variable *positions* (line 1). Then, we print *positions* (line 2). The outcome is -1. Thus, **when we search for a substring that is not in the string, `.find()` returns -1**. This is a trick that is often used in conditions, such as: `if us.find("f") == -1: print("Character not found!")`.

5. Counting the number of substrings in a string

- Given the following string:

```
[16]: 1 hobbies = "I like going to the movies,
traveling, and singing"
```

hobbies is assigned I like going to the
movies, traveling, and singing

We start with a string containing text about hobbies (line 1).

- Count the numbers of substrings *ing* using the method `.count()`:

```
[17]: 1 n_substrings = string.count("ing")
2 print(n_substrings)
4
```

n substrings is assigned string dot count ing
print n substrings

We use the **method `.count()`** which takes **the substring whose occurrence we want to count**—in our case "ing"—**as an argument**, and we save the outcome in the variable *n_substrings* (line 1). Then we print the result (line 2). The substring is present 4 times: I like going to the movies, traveling, and singing.

6. String to list and back

It can be convenient to separate the words in a string into list elements or to merge strings that are elements of a list into a single string. Let's see how to do both operations.

- Given the following string:

```
[18]: 1 string = "How are you"
```

string is assigned How are you

We start with a string containing three words: *How*, *are*, and *you* (line 1).

- Transform the string into a list of strings where each element is a word:

```
[19]: 1 list_of_strings = string.split()
2 print(list_of_strings)
['How', 'are', 'you']
```

list of strings is assigned string dot
split
print list of strings

Words are separated by spaces. Thus, we can use the method `.split(" ")` with a space as an argument. However, an empty string `" "` is the default argument for `.split()`, thus we can omit it—in other words, writing `.split()` is equivalent to writing `.split(" ")`. We assign the outcome to the variable `list_of_strings` (line 1), and we print it (line 2). As you can see, `list_of_strings` is a list containing three elements, each of them corresponding to one of the words in `string`.

How do we go back to a list? Let's learn it in the next cell!

- Transform the list of strings into a string using the method `.join()`:

```
[20]: 1 string_from_list = " ".join(list_of_strings)      string from list is assigned space dot
       2 print(string_from_list)                         join list of strings
                                                print string from list
How are you
```

The method `.join()` connects the elements of the list in the argument, separating them with the string it refers to. In our case, the list in the argument is `list_of_strings`, which contains the three strings "How", "are", and "you". The string to which `.join()` is applied is a space—that is, `" "` (line 1). The command might look peculiar at first because we apply the method directly to the string value—`" ".join()`. As an alternative, we could assign the space to a variable—`space = " "`—and then apply the method to the variable—`space.join()`. To conclude the task, we print `list_of_strings` to check for correctness (line 2).

7. Changing character cases

There are several options when changing character cases. Let's have a quick look at them with the simple example below.

- Given the following string:

```
[21]: 1 greeting = "Hello! How are you?"      greeting is assigned Hello! How are you?
```

We start with a string where the first character of "Hello" and "How" are uppercase and all the other characters are lowercase.

- Modify the string to uppercase and lowercase; change to uppercase only the first character of the string, and then each word of the string; finally, invert the cases:

```
[22]: 1 # uppercase
       2 print(greeting.upper())
       3 # lowercase
       4 print(greeting.lower())
       5 # change the first character of the
          string to uppercase
       6 print(greeting.capitalize())
       7 # change the first character of each word
          to uppercase
       8 print(greeting.title())
```

<pre>uppercase print greeting dot upper lowercase print greeting dot lower change the first character of the string to uppercase print greeting dot capitalize change the first character of each word to uppercase print greeting dot title</pre>
--

```
9 # invert cases
10 print(greeting.swapcase())
HELLO! HOW ARE YOU?
```

```
invert cases
print greeting dot swapcase
```

To change the string to uppercase, we use the method `.upper()` (line 2) and we get: HELLO! HOW ARE YOU?. Inversely, to change the string to lowercase, we use `.lower()` (line 4) and we obtain: hello! how are you?. To change to uppercase only the first character of the string, we use the method `.capitalize()` (line 6), and the string becomes Hello! how are you?, where only the H of Hello is uppercase. To change to uppercase the first characters of all the words, we use the method `.title()` (line _8). In our example, the outcome is Hello! How Are You? , where H, H, A, and Y are uppercase. Finally, to swap characters from uppercase to lowercase and vice versa, we use the method `.swapcase()` (line _10). We obtain: hELLO! hOW ARE YOU?, where h from hELLO and h from hOW are lowercase, and all the other characters are uppercase.

8. Printing variables

Printing is particularly useful in coding to check for correctness of operations and algorithms. In the previous chapters, we learned that the arguments of the built-in function `print()` can be either concatenated variables (Chapter 2), variables separated by commas (Chapter 25), or a string in combination with the method `.format()` (Chapter 25). Beyond refreshing these printing modalities and pointing out some peculiarities, we will learn f-strings and easier ways to better print numerical variables. Let's start!

- Given the following string:

```
[23]: 1 part_of_day = "morning" part of day is assigned morning
```

We start with the variable `part_of_day` containing the string "morning" as a value (line 1).

- Print Good morning! in 4 different ways, using (1) string concatenation, (2) comma separation, (3) the method `.format()`, and (4) f-strings:

```
[24]: 1 # (1) string concatenation
2 print("Good " + part_of_day + "!")
3 # (2) variable separation by comma
4 print("Good", part_of_day, "!")
5 # (3) the method .format()
6 print("Good {}!".format(part_of_day))
7 # (4) f-strings
8 print(f"""Good {part_of_day}!""")
```

Good morning!
Good morning !
Good morning!
Good morning!

```
(1) string concatenation
print Good concatenated with part of day
concatenated with !
(2) variable separation by comma
print Good part of day !
(3) the method .format()
print Good placeholder ! dot format part
of day
(4) f-strings
print f Good part of day !
```

To print Good morning! using concatenation, we concatenate `part_of_day` to two strings:

"Good " and "!" (line 2). Note that "Good " contains a **space** as the last character; without that space, we would print "Goodmorning!". As an alternative to concatenation, we can use comma separation—that is, we separate the variables by comma (line 4). Note that the printed line contains a space between morning and the exclamation mark (morning !). This happens because **in comma-separated printing, variables are always separated by a space**. Another way is to use the string method `.format()`, which **places its argument in the placeholder {} in the string** (line 6). In our case, the value of `part_of_day`—which is the argument of `.format()`—is positioned in the curly brackets in "Good {}!". A last method is to use **f-strings**, where `f` stands for *formatted*. Within the round brackets of `print()`, we write: (1) `f`, (2) tree opening double quotes "", (3) what we want to print, and (4) tree closing double quotes "". In our case, what we want to print is composed of some characters (e.g., Good and !) and a **variable** that must be **enclosed in a pair of curly brackets**—that is, `{part_of_day}` (line 8).

What if we want to print a string combined with a numerical variable? Let's have a look!

- Given a string and a numerical variable:

<pre>[25]: 1 part_of_day = "morning" 1 time_of_day = 10</pre>	<pre>part of day is assigned morning time of day is assigned ten</pre>
--	--

We consider two variables: `part_of_day`—containing the string "morning" (line 1)—and `time_of_day`—containing the integer 10 (line 2).

- Print

Good morning!

It's 10a.m.

using the same four methods above (note that the sentences are on two separate lines):

<pre>[26]: 1 # (1) string concatenation 2 print("Good " + part_of_day + "!\nIt's " + str(time_of_day) + "a.m.") 3 # (2) variable separation by comma 4 print("Good", part_of_day, "!\nIt's", time_of_day, "a.m.") 5 # (3) the method .format() 6 print("Good {}!\nIt's {}a.m." .format(part_of_day, time_of_day)) 7 # (4) f-strings 8 print(f"""Good {part_of_day}! It's {time_of_day}a.m.""")</pre>	<pre>(1) string concatenation print Good concatenated with part of day concatenated with ! backslash n It's concatenated with str time of day concatenated with a.m. (2) variable separation by comma print Good part of day ! backslash n It's time of day a.m. (3) the method .format() print Good placeholder ! backslash n It's placeholder a.m. dot format part of day time of day (4) f-strings print f Good part of day ! It's time of day a.m. Good morning! It's 10a.m. Good morning ! It's 10 a.m. Good morning! It's 10a.m. Good morning! It's 10a.m.</pre>
---	--

When using string concatenation (line 2), we have to consider a few aspects. First, we embed the escape

character \n—which indicates *newline*—into the string "!\\nIt's", where ! is the last character of the first line, and It's is the beginning of the second line. Second, since time_of_day is an integer, we need to transform it into a string by using the built-in function str() for concatenation. And finally, we have to leave a space after Good and It's to have the correct spaces in the printout. When using comma separation (line 4), the code looks similar to concatenation. However, we do not need to change the numerical variable time_of_day into a string. Also, we do not need to add spaces in the strings "Good" and "!\\nIt's". In the printout, we can notice again that there is a space between morning and !, and between 10 and a.m.. When using .format(), we have to include two placeholders, one for part_of_day and one for time_of_day. Note that both variables are arguments of .format() (line 6). Finally, when using f-strings, we include the two variables directly in between their placeholders—that is,{part_of_day} and {time_of_day}. We also can go to the new line without having to write \n, but just by writing the text on two consecutive lines (lines _8–9).

What about printing numbers with a reduced number of decimals? Let's see the following examples.

- Given the numerical variable:

```
[27]: 1 number = 1.2345
```

```
number is assigned 1.2345
```

We start with a variable containing a float with 4 decimals (line 1).

- Print The number is 1.23—note only the first two decimals—using the four methods above:

```
[28]: 1 # (1) string concatenation
2 print("The number is " + str(round(number, 2)))
3
4 # (2) variable separation by comma
5 print("The number is", round(number, 2))
6
7 # (3) the method .format()
8 print("The number is {:.2f}".format(number))
9
10 # (4) f-strings
11 print(f"""The number is {number:.2f}""")
```

```
The number is 1.23
The number is 1.23
The number is 1.23
The number is 1.23
```

```
(1) string concatenation
print The number is concatenated
with str round number two
(2) variable separation by comma
print The number is round number
two
(3) the method .format()
print The number is colon dot two
dot format number
(4) f-strings
print f The number is number colon
dot two f
```

When using string concatenation (line 2) or comma separation (line 4), we can use the **built-in function round()**, which **takes two arguments: the variable that we want to round** (number) and **the number of decimals that we want to keep** (2). As we have seen previously, when using concatenation, we need to transform the numerical variable into a string, whereas we do not when using comma separation. When using .format(), we add :.2f in the placeholder, where : indicates the start of the formatted part and .2f specifies that we want to keep 2 floating digits after the dot (line 6). A similar formatting is present in f-strings, with the addition that before the colon :, we need to indicate the variable to print—that is, number (line 8).

At this point, you might wonder, **Which of these four ways should I use when printing?** The answer is the one that you prefer! It is just recommended to use one single way thought your code for consistency.

In this chapter, we have summarized or introduced several ways of dealing with strings, using opera-

tions such as concatenation, assignment, or slicing, and methods. Strings have a total of 47 methods, and we have learned 11 of them so far. We will learn 6 more methods in Chapter 30. For the remaining methods, you can consult the many resources that you'll find at the end of this chapter.

Complete the table

In this chapter, you have learned or refreshed 11 string methods. Summarize what they do by completing the following table (continued on the next page).

String method	What it does
.capitalize()	
.count()	
.find()	
.format()	
.join()	
.lower()	
.replace()	
.split()	
.swapcase()	
.title()	
.upper()	

Recap

- In strings, slicing and the “arithmetic” operations (concatenation and replication) work the same way as for lists.
- Strings are immutable and thus assignment is not possible.
- Strings have 47 methods. Of these, the 11 methods learned so far are: `.capitalize()`, `.count()`, `.find()`, `.format()`, `.join()`, `.lower()`, `.replace()`, `.split()`, `.swapcase()`, `.title()`, and `.upper()`.
- There are at least four ways to combine strings and numerical variables when printing: concatenation, comma separation, method `.format()`, and f-strings.
- To round a number to a wanted number of decimals, we can use the built-in function `round()`.

Escape characters

Escape characters are special characters that can be used when creating strings or when printing. Let's see some examples:

- \n (newline): It is used to print a new line. All the characters or variables after \n will be printed on a new line. For example:

```
[1]: 1 print("Shopping list:\napples\noranges")
      Shopping list:
      apples
      oranges
```

- \t (horizontal tab): It is used to create a tab, that is, to indent text towards the right. For example:

```
[2]: 1 print("Dear friend,")
      2 print("\tI hope you are doing fine. I have
            some news...")
      Dear friend,
      I hope you are doing fine. I have some news...
```

- \" (double quote): It is used when you need to print double quotes in string delimited by double quotes. For example:

```
[3]: 1 print("The wise said: \"To live a happy
      life...\"")
      The wise said: "To live a happy life..."
```

- \' (single quote or apostrophe): Similarly to above, it is used to print a single quote when the string is enclosed in between single quotes. For example:

```
[4]: 1 print('It\'s the best time!')
      It's the best time!
```

Let's code!

1. Famous quotes. Given the following string:

```
quote = "The future belongs to those who believe in the beauty of their dreams -
Eleanor Roosevelt"
```

Use string methods to:

- Remove to those who.
- Replace belongs with until.
- Add seems impossible after future.
- Remove The future.
- Replace believe in the beauty of their dreams with it's done.
- Replace Eleanor Roosevelt with Nelson Mandela.

g. Add It always at the beginning of the string.

What quote will you get at the end? Make sure that words are separated by spaces.

2. Commonalities. Given the following strings:

```
dessert = "lemon meringue pie"
```

```
sweet = "honeypot"
```

- a. What characters do the two strings have in common? Save the common characters in a list.
- b. How many times do the common characters appear in dessert? Save the result in a dictionary created in two different ways, that is, using (1) a *dictionary* method, and (2) a *string* method.

3. Palindromes. Palindromes are words that read the same backward as forward, such as *anna* or *madam*. Given the following list of strings:

```
words = ["noon", "dog", "dad", "elephant", "jungle", "otto", "night", "bright",
"kayak", "yeah", "wow"]
```

Save palindrome words in a new list of strings. Hint: Consider using string slicing.

Appendix: String methods

In the following table, you can find all the 47 string methods available in Python. The methods with an asterisk are presented in this book—including the ones that will be introduced in Chapter 30.

String method	What it does
.capitalize()*	Converts the first character to uppercase and all the others to lowercase E.g.: <code>print("hello".capitalize())</code> returns: Hello
.casefold()	Converts a string into lowercase. Differently from .lower(), it can handle more complex cases. E.g.: <code>print("Straße".casefold())</code> returns: "strasse". <code>print("Straße".lower())</code> returns: "straße" (Straße is street in German)
.center()	Returns a string centered within a given number of characters. E.g.: <code>print("hi".center(6))</code> returns: " hi "
.count()*	Returns the number of times a specified value is present in a string E.g.: <code>print("singing".count("ing"))</code> returns: 2
.encode()	Returns an encoded version of the string using the specified encoding—encodings define how characters are rendered on a screen. E.g.: <code>print("hello".encode(encoding='utf-8'))</code> returns: .b'hello'
.endswith()	Returns true if the string ends with the specified value. E.g.: <code>print("hello".endswith('lo'))</code> returns: True
.expandtabs()	Make the tabs in the string of the length defined by the arguments. E.g.: <code>print("h\te\tl\tl\tto".expandtabs(3))</code> returns:h e l l o
.find()*	Return the first position of a substring E.g.: <code>print("singing".find("ing"))</code> returns: 1
.format()*	Formats the string using the specified arguments E.g.: <code>print("Hello, {}".format("how are you?"))</code> returns: Hello, how are you?
.format_map()	Formats specified values—defined in a dictionary—in a string E.g.: <code>print("My dog name is {name} years old".format_map({"name": "Ninja", "age": 7}))</code> returns: My dog Ninja is 7 years old
.index()*	Finds the first substring of a substring E.g.: <code>print("hello".index("l"))</code> returns: 2
.isalnum()*	Checks if all characters in the string are alphanumeric E.g.: <code>print("123hello".isalnum())</code> returns: True
.isalpha()*	Checks if all characters in the string are alphabetic E.g.: <code>print("hello".isalpha())</code> returns: True
.isascii()	Checks if all characters in the string are ASCII. E.g.: <code>print("ë".isascii())</code> returns: False
.isdecimal()	Checks if all characters in the string are decimals E.g.: <code>print("123".isdecimal())</code> returns: True
.isdigit()*	Checks if all characters in the string are digits E.g.: <code>print("123".isdigit())</code> returns: True
.isidentifier()	Checks if the string is a valid identifier, that is, if it only contains alphanumeric letters (a-z and 0-9) or underscores (_), and it does not start with a number nor contain spaces E.g.: <code>print("my string".isidentifier())</code> returns: False
.islower()*	Checks if all characters in the string are lowercase E.g.: <code>print("hello".islower())</code> returns: True
.isnumeric()	Checks if all characters in the string are numeric E.g.: <code>print("123".isnumeric())</code> returns: True
.isprintable()	Checks if all characters in the string are printable E.g.: <code>print("\n".isprintable())</code> returns: False

<code>.isspace()</code>	Checks if all characters in the string are space E.g.: <code>print(" ".isspace())</code> returns: True
<code>.istitle()*</code>	Checks if the string is title-cased E.g.: <code>print("Hello, How Are You?".istitle())</code> returns: True
<code>.isupper()*</code>	Checks if all characters in the string are uppercase E.g.: <code>print("HELLO".isupper())</code> returns: True
<code>.join()*</code>	Joins the strings of a list with the specified separator E.g.: <code>print(", ".join(["hello", "hi"]))</code> returns: hello, hi
<code>.ljust()</code>	Left-justifies the string E.g.: <code>print("hello".ljust(10, '-'))</code> returns: hello-----
<code>.lower()*</code>	Converts the string to lowercase E.g.: <code>print("HELLO".lower())</code> returns: hello
<code>.lstrip()</code>	Removes characters at the beginning of the string (<i>l</i> is for left) E.g.: <code>print("hhello".lstrip("h"))</code> returns: ello
<code>.maketrans()</code>	Transforms the transformation of the characters of the first argument into the characters of the second argument. To print the outcome, we need to use the method <code>.translate()</code> E.g.: <code>transformation = "bake".maketrans("b", "c"); print("bake".translate(transformation))</code> returns: cake
<code>.partition()</code>	Partitions the string into tuple elements E.g.: <code>print("hello, how are you?".partition(" "))</code> returns: ('hello,', ' ', 'how are you?')
<code>.removeprefix()</code>	Removes the specified prefix from the string E.g.: <code>print("hello, how are you?".removeprefix("hello, "))</code> returns: how are you?
<code>.removesuffix()</code>	Removes the specified suffix from the string E.g.: <code>print("hello, hi".removesuffix(", hi"))</code> returns: hello
<code>.replace()*</code>	Replaces substrings in strings E.g.: <code>print("Hello, how is she?".replace("she", "he"))</code> returns: Hello, how is he?
<code>.rfind()</code>	Finds the last substring of a string (<i>r</i> is for right) E.g.: <code>print("hello".rfind('l'))</code> returns: 3
<code>.rindex()</code>	Finds the last substring of a string E.g.: <code>print("hello".rindex('ll'))</code> returns: 2
<code>.rjust()</code>	Right-justifies the string E.g.: <code>print("hello".rjust(10, '-'))</code> returns: -----hello
<code>.rpartition()</code>	Partitions the string into tuple elements starting from the end E.g.: <code>print("hello, how are you?".rpartition(" "))</code> returns: ('hello,', ' ', 'how are you?')
<code>.rsplit()</code>	Splits the string from the end E.g.: <code>print("hello, how are you?".rsplit(","))</code> returns: ['hello', ' how are you?']
<code>.rstrip()</code>	Removes characters from the end of the string E.g.: <code>print("!!!hello!!!".rstrip("!"))</code> returns: !!!hello
<code>.split()*</code>	Splits the string into a list E.g.: <code>print("hello, how are you?".split(","))</code> returns: ['hello', ' how are you?']
<code>.splitlines()</code>	Splits the string at line breaks E.g.: <code>print("hello\nhow are you?".splitlines())</code> returns: ['hello', 'how are you?']

.startswith()	Checks if the string starts with the specified prefix E.g.: <code>print("hello, how are you?".startswith("hello"))</code> returns: True
.strip()	Removes characters on the left and on the right E.g.: <code>print("!!!hello!!!".strip("!"))</code> returns: hello
.swapcase()*	Swaps the case of all characters in the string E.g.: <code>print("Hello, How Are You?".swapcase())</code> returns: hELLO, hOW aRE yOU?
.title()*	Converts the string to title case E.g.: <code>print("hello, how are you?".title())</code> returns: Hello, How Are You?
.translate()	Maps the character of a string through a given translation table (see <code>.maketrans()</code>) E.g.: <code>transformation = "bake".maketrans("b", "c"); print("bake".translate(transformation))</code> returns: cake
.upper()*	Converts the string to uppercase E.g.: <code>print("hello".upper())</code> returns: HELLO
.zfill()	Adds 0 at the beginning of the string until the string reaches the defined length E.g.: <code>print("5".zfill(4))</code> returns: 0005

PART 8

FUNCTIONS

In this part, you'll apply the coding syntax and computational thinking you have learned so far to build reusable units of code called functions. Let's dive in!

28. Printing Thank you cards

Function inputs

To this point, we've learned Python data types—lists, strings, Booleans, dictionaries, integers, and floats. We've also learned how to combine these data types with operators—assignment, membership, arithmetic, comparison, and logical—to create commands—that is, statements, `if/else` conditions, `for` loops, and `while` loops. The next step is to learn how to combine commands into **units of code** called **functions**. We are already somewhat familiar with functions because we have frequently used Python built-in functions, such as `print()`, `len()`, `range()`, etc. In this Part, we will learn what's behind functions and how to write them. Let's begin in this chapter by learning the components of a function and how to provide inputs. Let's start! Follow along in Notebook 28.

1. Basic Thank you cards

- You recently hosted a party, and you want to send *Thank you* cards to those who attended. Create a function that takes a first name as an argument and prints a *Thank you* message containing an attendee's name (e.g., *Thank you Maria*):

```
[:] 1 def print_thank_you (first_name):  
2     """Prints a string containing  
3         "Thank you" and a first name  
4  
5         Parameters  
6         -----  
7         first_name : string  
8             First name of a person  
9         """  
10        print("Thank you", first_name)      def print thank you first name  
                                         Prints a string containing Thank you and  
                                         a first name  
  
                                         Parameters  
  
                                         first name : string  
                                         First name of a person  
  
                                         print Thank you first name
```

- Print two *Thank you* cards:

```
[:] 1 print_thank_you ("Maria")          print thank you Maria  
[:] 1 print_thank_you ("Xiao")           print thank you Xiao
```

What can you deduce about functions from this example? Get some hints by completing the following exercise!

True or false?

- | | | |
|--|---|---|
| 1. <code>def</code> is the keyword that introduces a function definition | T | F |
| 2. <code>first_name</code> is a function input | T | F |
| 3. Function documentation is enclosed in single double quotes | T | F |
| 4. <code>print("Thank you", first_name)</code> (line 10) is executed when we run the first cell | T | F |
| 5. <code>print_thank_you ("Maria")</code> and <code>print_thank_you ("Xiao")</code> are function calls | T | F |

Computational thinking and syntax

Let's start by analyzing how a function works. Let's run the first cell:

[1]:	<pre> 1 def print_thank_you(first_name): 2 """Prints a string containing 3 "Thank you" and a first name 4 5 Parameters 6 ----- 7 first_name : string 8 First name of a person 9 10 print("Thank you", first_name) </pre>	<pre> def print_thank_you(first_name) Prints a string containing "Thank you" and a first name Parameters first_name : string First name of a person print("Thank you", first_name) </pre>
------	---	--

What happens? Apparently nothing! Let's run the two following cells:

[2]:	<pre> 1 print_thank_you("Maria") </pre>	print thank you Maria
	Thank you Maria	

[3]:	<pre> 1 print_thank_you("Xiao") </pre>	print thank you Xiao
	Thank you Xiao	

For each cell, a message is printed that says "Thank you" followed by the name of a person—that is, "Maria" in cell 2 and "Xiao" in cell 3. So, how do functions work?

In cell 1, there is a function **definition**, which specifies **what a function does**. When we run cell 1, we just tell our computer to **"memorize" the function**. To actually **execute the function**—that is, to make it do what we want it to do—we must **call the function**, which is what we do at cells 2 and 3—each of them containing a function **call**. If we do not call a function, then the function will never be executed!

How do we get "Thank you Maria" after running cell 2 and "Thank you Xiao" after running cell 3? Let's understand it with the help of Figure 28.1.



Figure 28.1. Path of a function input.

Let's start with the printed text "Thank you Maria" (left side of Figure 28.1). In cell 2, we provide the string "Maria" to the function call as an **input**—i.e., `print_thank_you("Maria")`. When we run the cell,

"Maria" passes from the call to the variable `first_name` located in the function header in cell 1, line 1 (yellow arrow). The variable `first_name`—which now contains the value "Maria"—is then used in the command at line 10 (black line), which produces the print "Thank you Maria" (orange arrow). Let's now see how we get "Thank you Xiao" (right side of Figure 28.1). Similarly to before, in cell 3, we call the function `print_thank_you()` with the string "Xiao" as an input. When we run the cell, the value "Xiao" is assigned to the variable `first_name` in the function header (yellow line), then used in the function command (black line), and finally printed to screen (orange line). In summary, when we call a function, we **pass** the variables **from a function call** (cell 2 or 3) to a **function definition** (cell 1) as an **input**. Then, the variable will be **used in the function commands**. To be more precise, in Python, we call the input variable **parameter** when it is **in the function definition**—`first_name` in cell 1 is a parameter—and **argument** when it is **in the function call**—"Maria" in cell 2 is an argument, as well as "Xiao" in cell 3. Finally, note that the same mechanism applies when we call any Python built-in function. For example, when we write `len("hello")`, we pass the argument "hello" to the definition of `len()`, which has a syntax similar to the function in cell 1 and contains commands that count the number of characters.

Let's now look into function syntax. In cell 1, we define the function `print_thank_you()`. Any **function definition**—which we usually just call a **function**—is composed of **two parts**: a header (line 1) and a body (lines 2–10). The **header** is made of: (1) keyword `def`; (2) function name; (3) parameters embedded in round brackets; and (4) a colon (line 1). Function names follow the same rules as variable names, that is, they are lowercase and the words that compose them are separated by an underscore.

A function **body** contains two components: (1) documentation (lines 2–8) and (2) code (line 10), and it is always **indented** with respect to the header. In Python, the **documentation** is embedded in between double quotes repeated three times ("""; lines 2 and 8) and is called **docstring**, which is a compact word for "documentation string". A function documentation can follow various styles, and in this book we will use the **NumPy style**, which has the following structure:

- **Short summary** (line 2): A one line summary about what the function does. It is written next to the three opening double quotes.
- **Parameters** (lines 4–7): A description of the parameters—that is, the **inputs**—of the function. It contains: (1) the title **Parameters** (line 4); (2) a sequence of minus signs that act as an underline (line 5); and (3) a list of parameters (lines 6–7)—there is only one parameter in this example; there will be more in the coming examples. Each parameter is described on two consecutive lines. In the first line, we include: (1) a parameter name (`first_name`); (2) a space; (3) a colon; (4) a space; and (5) a parameter type (i.e., `string`) (line 6). In the second line, we write a short description of the parameter. Note that this line is indented.
- Other specifications that we will see in the next chapter.

Finally, the **code** component of a function **body** can contain as many lines of code as needed to execute the desired task—in this initial example, there is only one command (line 10).

Let's conclude this first example by providing a formal definition of function:

A function is a block of code that accomplishes a specific task

What about the inputs? Must a function have inputs? No, there can be functions **without inputs** (see exercise 4 in the Let's code session at the end of this chapter). Can a function contain **more than one input**? Yes! Let's look into the next example—the differences with the function in cell 1 are underlined.

2. Formal Thank you cards

- After a second thought, you decide that it is more appropriate to print formal *Thank you* cards. Modify the previous function to take three arguments—prefix, first name, and last name—and to print a thank you message containing them (e.g., *Thank you Mrs Maria Lopez*):

<pre>[4]: 1 def print_thank_you (prefix, 2 first_name, last_name): 3 """Prints a string containing 4 "Thank you" and the inputs 5 6 Parameters 7 ----- 8 prefix : string 9 Usually Ms, Mrs, Mr 10 first_name : string 11 First name of a person 12 last_name : string 13 Last name of a person 14 15 """ 16 17 print("Thank you", prefix, 18 first_name, last_name)</pre>	<pre>def print_thank_you prefix first name last name Prints a string containing Thank you and the inputs Parameters prefix : string Usually Ms, Mrs, Mr first name : string First name of a person last name : string Last name of a person print Thank you prefix first name last name</pre>
--	---

- Print two formal *Thank you* cards:

<pre>[5]: 1 print_thank_you ("Mrs", "Maria", "Lopez") 2 Thank you Mrs Maria Lopez</pre>	<pre>print thank you Mrs Maria Lopez</pre>
<pre>[6]: 1 print_thank_you ("Mr", "Xiao", "Li") 2 Thank you Mr Xiao Li</pre>	<pre>print thank you Mr Xiao Li</pre>

Computational thinking and syntax

In this function with several inputs (cell 4), we observe three changes with respect to the same function with one single input (cell 1). First, in the function header, there are now three parameters—`prefix`, `first_name`, and `last_name`—which are **separated by comma**. Then, in the docstrings (lines 6–11), we describe each parameter **in the same order** as in the function header—that is, first `prefix`, then `first_name`, and finally `last_name`. Note that for each parameter we use the same syntax that we described above—that is, **parameter name and type in the first line**, and **parameter description in the second line**. Finally, we must **use all parameters** in the function code. In this example, the parameters are used in one single line of code to print the desired message (line 14), but in general, parameters can be used in one or more lines of code.

What about the function calls (cells 5 and 6)? When we **call** the function, we have to make sure that we insert the inputs **in the same order as in the function header**—that is, first `prefix`, then `first_name`, and finally `last_name`. What happens if one of the arguments is **missing** like in the example below?

```
[6]: 1 print_thank_you ("Mr", "Xiao")
-----
TypeError           Traceback (most recent call last)
Cell In[6], line 1
----> 1 print_thank_you("Mr, "Xiao")
TypeError: print_thank_you() missing 1 required positional argument: 'last_name'
```

We get an **error message** saying that the function is missing 1 required positional argument: 'last_name'. This means that we did not write the third argument in the call. How can we modify the function to avoid this error? Let's have a look at cells 7–9! Like before, the function modifications are underlined.

3. Last name missing!

- You are very happy with the *Thank you* cards, but you suddenly realize that some participants did not provide their last names! Adapt the function so that the last name has an empty string as a default value:

<pre>[7]: 1 def print_thank_you (prefix, first_name, last_name = ""): """Prints a string containing "Thank you" and the inputs Parameters ----- prefix : string Usually Ms, Mrs, Mr first_name : string First name of a person last_name : string Last name of a person. <u>The default value is an empty string</u> """ print("Thank you", prefix, first_name, last_name)</pre>	<pre>def print_thank_you prefix first_name last_name is assigned empty string Prints a string containing Thank you and the inputs Parameters prefix : string Usually Ms, Mrs, Mr first_name : string First name of a person last_name : string Last name of a person. The default value is an empty string print Thank you prefix first_name last name</pre>
---	---

- Print two *Thank you* cards, one with a last name and one without a last name:

<pre>[8]: 1 print_thank_you ("Mrs", "Maria", "Lopez") Thank you Mrs Maria Lopez</pre>	<pre>print thank you Mrs Maria Lopez</pre>
<pre>[9]: 1 print_thank_you ("Mr", "Xiao") Thank you Mr Xiao</pre>	<pre>print thank you Mr Xiao</pre>

Computational thinking and syntax

In the function header, we **assign a default value to the input that can be missed** when calling the function. In our case, we assign an empty string to the variable `last_name` (line 1). We call `last_name`

default parameter, and we specify the default value in its description in the docstrings (line 11).

What happens when we call the function? If we provide all three arguments (cell 8), then the function works exactly like its version in cell 4—that is, "Mrs" is passed to `prefix`, "Maria" to `first_name`, and "Lopez" to `last_name`. If we provide only `prefix` and `first_name` but not `last_name` (cell 9), the function prints "Mr" for `prefix` and "Xiao" for `first_name`, and the default empty string for `last_name`—we do not see it printed! What if the missing parameter when calling the function in cell 4 is not the last one but, for example, the first one—i.e., `prefix`? Let's have a look:

```
[6]: 1 print_thank_you ("Xiao", "Li")
-----
TypeError          Traceback (most recent call last)
Cell In[6], line 1
----> 1 print_thank_you("Xiao, "Li")
TypeError: print_thank_you() missing 1 required positional argument: 'last_name'
```

We skipped the `prefix`, but the error tells us that we skipped the last name! This is because the function always **assumes that the missing argument is the last one**. If we want to skip arguments in other positions—that is, `prefix` or `first_name`—then we have to make a final modification to our function, as you can see underlined in the code below.

4. Prefix and/or first name missing!

- Finally, you realize that `prefix` and/or first name are also missing for some guests. Modify the function accordingly:

<pre>[10]: 1 def print_thank_you (prefix = ___, first_name = ___, last_name = ___): """Prints each input and a string con- catenating "Thank you" and the inputs Parameters ----- prefix : string Usually Ms, Mrs, Mr. <u>The default</u> <u>value is an empty string</u> first_name : string First name of a person. <u>The default</u> <u>value is an empty string</u> last_name : string Last name of a person. The default value is an empty string """ print("Prefix:", prefix) print("First name:", first_name) print("Last name:", last_name) print("Thank you", prefix, first_name, last_name)</pre>	<pre>def print_thank_you prefix is assigned empty string first name is assigned empty string last name is assigned empty string Prints a string containing Thank you and the inputs Parameters prefix : string Usually Ms, Mrs, Mr. The default value is an empty string first_name : string First name of a person. The default value is an empty string last_name : string Last name of a person. The default value is an empty string print Prefix: prefix print First name: first name print Last name: last name print Thank you prefix first name last name</pre>
--	--

- Print a Thank you card where the *first name* is missing:

```
[11]: 1 print_thank_you (prefix = "Mrs",
last_name = "Lopez")
Prefix: Mrs
First name:
Last Name: Lopez
Thank you Mrs Lopez
```

print thank you prefix is assigned
Mrs last name is assigned Lopez

- Print a Thank you card where the *prefix* is missing:

```
[12]: 1 print_thank_you (first_name = "Xiao",
last_name = "Li")
Prefix:
First name: Xiao
Last Name: Li
Thank you Xiao Li
```

print thank you first name is
assigned Xiao last name is assigned
Li

Computational thinking and syntax

In the function header, we **assign a default value to each parameter**—in our case, an empty string (line 1)—and we add this information to the docstrings (lines 7 and 11). In this example, we also print each parameter to clarify what happens when we call the function (lines 14–16), as you will see in a bit.

What about the function calls? When we call `print_thank_you` with the arguments `prefix="Mrs"` and `last_name="Lopez"` (cell 11), `first_name` is automatically assigned its default value, that is, an empty string—see the print from line 15. Similarly, when we call the function with the arguments `first_name="Xiao"` and `last_name="Li"` (cell 12), `prefix` is assigned the default empty string—see the print from line 14. In addition, in the print `Thank you Mrs Lopez` (from line 17), there are two spaces between `Mrs` and `Lopez`. This occurs because when we print using comma separation, a space is automatically inserted between variables. Thus, one space separates `Mrs` and the first name—which is missing—and one space separates the first name and `Lopez`. In the same way, in the print `Thank you Xiao Li`, there is an extra space due to the absence of a prefix. What if we want to be precise and ensure that there is one single space between the variables? We could write an `if/elif/else` construct like the following: `if prefix == "": print("Thank you", first_name, last_name) elif first_name == "": print("Thank you", prefix, last_name) else: print("Thank you", prefix, first_name)`. Finally, do we always need to provide default values to the parameters in a function? Not necessarily, especially when there are no appropriate default values or when it's essential that all arguments are specified when calling the function.

Why do we create functions?

At this point, you might wonder, why do we need to create functions? Can we not just write the `print()` command whenever we need it? The functions in cells 1, 4, and 7 contain only a single line of code, so writing a function might seem unnecessary. However, consider the function in cell 10. It has four lines of code, and if we want to reuse them in several cases, we have to keep copying and pasting. As you might remember, minimizing copy-pasting is crucial not only because it is tedious, but

doing so also reduces the risk of errors. Grouping lines of code into a function is a very efficient way to **reuse code** across various parts of a project. In addition, functions help us divide and conquer tasks (see Chapter 16). Each function should contain commands that solve one specific subtask, allowing us to **modularize** our code—that is, breaking it into manageable chunks that are easier to read, modify, and reuse.

Recap

- Functions are blocks of code that accomplish a specific task. They are crucial for code reuse and modularization.
- A function comprises at least three components:
 - A *header*, which starts with the keyword `def`, followed by the name of the function, and round brackets containing the parameters separated by comma. Parameters can have default values.
 - *Docstrings*, which describe what the function does and its parameters.
 - *Code* that solves a task.
- To *call* a function, we write the function name followed by round brackets containing the arguments separated by comma.
- *Parameters* and *arguments* are function *inputs*. Technically, we call *parameters* the variables listed in the function header, and *arguments* the variables in the function call.
- *Docstrings* are fundamental when writing and using functions and can be accessed using the built-in function `help()`—see the *In more depth* session below.

Why is function documentation important?

Writing docstrings is fundamental for both our future selves and for others who may use our code. When we write a function, there is a good chance that we will need to reuse it months or even years later. Without function documentation, it could take us hours to recall what the function does or the types of its inputs—and outputs, as you will see in the next chapter. Investing a few minutes in writing clear documentation can save us countless hours in the future!

Similarly, if somebody else needs to use our functions, they need to understand what the function does and the type and roles of its inputs and outputs. Have you ever tried to use an undocumented function? It can be incredibly frustrating! Moreover, how do we access function documentation? Do we always have to look at the function definition? Fortunately no! We can use the built-in function `help()`! For example, let's have a look at the documentation of the function `print_thank_you()` that we created earlier in this chapter.

```
[1]: 1 help (print_thank_you)           help print thank you
      Help on function print_thank_you in module __main__:

      print_thank_you(prefix='', first_name='', last_name='')
          Prints each input and a string containing "Thank you" and the inputs

      Parameters
      -----
      prefix: string
          Usually Ms, Mrs, Mr. The default is an empty string
      first_name: string
          First name of a person. The default is an empty string
      last_name: string
          Last name of a person. The default is an empty string
```

As you can see, `help()` displays the docstrings we wrote in cell 10. Notice that `help()` requires only the function name as an argument—without round brackets or parameters. Finally, be aware that `help()` can be used for any functions, including Python built-in functions, like you can see in the following example:

```
[2]: 1 help (len)                   help len
      Help on built-in function len in module builtins:

      len(obj, /)
          Return the number of items in a container.
```

The description is a bit technical, but you can think of containers as data types like lists, strings, or dictionaries. So, `Return the number of items in a container` means that `len()` gives us the number of elements in a list, or characters in a string, or key/value pairs in a dictionary, etc. We will learn more about `returning` in the next chapter.



Let's code!

- String cases.** Write a function that prints a given string in lower case, upper case, title case, capitalized, and with swapped cases. Then, call the function twice. Do so once using a string made of one word, and once using a string made of at least two words. Finally, call the function for each element of the following list of strings using a `for` loop: `summer_vacation = ["Hiking trails", "weekEnd campIng", "enjoying nature", "fishing"]`.
- String lengths.** Write a function that takes a list of strings and an integer, and prints only the strings whose length matches the given integer. Call the function using two different word lengths.
- Multiple numbers.** Write a function that takes a list of numbers and an integer, and prints only the numbers divisible by the integer. If the user does not provide a number, then the function divides by 2 by default. Call the function using two different divisors. Finally, call the function without a divisor.
- Doubling numbers.** Write a function that asks a user for a number and prints a dictionary where

the keys are numbers up to the input number, and values are the double of each key. Note that the function does not take any argument. The `input()` function to ask for the number is inside the function.

(Example user input: 5

Expected print: {1: 2, 2: 4, 3: 6, 4: 8, 5: 10})

29. Login database for an online store

Function outputs and modular design

In the previous chapter, we learned about functions and their inputs. In this chapter, we will dive into function outputs. In addition, we'll take a look at designing and organizing multiple functions in a larger project. Let's tackle all this by solving the following task. Follow along with Notebook 29!

- You are the owner of an online store and need to securely store the usernames and passwords of your customers. Create a database where usernames are composed of the initial of the customer's first name followed by their last name (e.g., "jsmith"), and passwords consist of a four-digit code.

First we have to create a database. A **database** is an organized **collection of data** that can be easily accessed and managed. Examples of databases include an inventory at a grocery store, a library catalog, or a phone contact list. In our case, the database will be a collection of customers' usernames and passwords. In general, simple databases can be implemented as **dictionaries**.

How would you create this database, and how would you insert usernames and passwords? What variables would you use and of what types? How many functions would you write, and what would each function do? Take some time to think about your solution before proceeding to the next paragraph!

To solve our task, the first thing to do is to “divide and conquer” by defining what variables and functions we need to create. Let's start with the **variables and their data types**. For each customer, we need two **strings**—one for the username and one for the password. We'll save them in a **dictionary**—that is, a database—where the usernames will be the keys and the passwords will be the values. Let's now think about how to **modularize** the code—that is, how to organize it into functions. We can write three **functions**: one to create a username, one to create a password, and one that calls the previous two functions and adds the created usernames and passwords to a database. Let's take a closer look at how to implement this solution!

1. Creating a username

Read the following text and code and try to deduce what the code does.

- Write a function that creates a username composed of the initial of the first name and the last name:

```
[1]: 1 def create_username (first_name, last_name):  
2     """Creates a lowercase username made of  
3         initial of first name and full last name  
4  
5             Parameters  
6             -----  
7             first_name : string  
8                 First name of a person  
9             last_name : string  
10                Last name of a person  
  
                                         def create_username first name last  
                                         name  
                                         Creates a lowercase username made of  
                                         initial of first name and full last  
                                         name  
  
                                         Parameters  
  
                                         first name : string  
                                         First name of a person  
                                         last name : string  
                                         Last name of a person
```

```

11     Returns
12     -----
13     username : string
14         Created username
15     """
16
17     # concatenate initial of first name
18     # and last name
18     username = first_name[0] + last_name
19
19     # make sure the username is lowercase
20     username = username.lower()
21
22     # return username
23     return username

```

Returns
username : string
Created username
concatenate initial of first name and last name
username is assigned first name in position 0 concatenated with last name
make sure the username is lowercase
username is assigned username dot lower
return username
return username

- Test the function for two customers:

```
[2]: 1 username_1 = create_username("Julia", "Smith")
2 print(username_1)
jsmith
```

username one is assigned create
username Julia Smith
print username one

```
[3]: 1 username_2 = create_username("Mohammed", "Seid")
2 print(username_2)
mseid
```

username two is assigned create
username Mohammed Seid
print username two

What's going on in the three cells above? Get some hints by solving the following exercise!

True or false?

- | | | |
|---|---|---|
| 1. The function has three parameters | T | F |
| 2. In docstrings, we must specify the name, type, and description of the output (also called return), like we do for the parameters | T | F |
| 3. The username is composed of first name and last name | T | F |
| 4. return is the keyword used to return function outputs | T | F |

Computational thinking and syntax

In cell 1, there is a function that creates a username. It takes two parameters—`first_name` and `last_name` (line 1)—which are used to create a username in two consecutive steps. First, we concatenate the initial of the first name—that is, `first_name` in position 0—with the last name, and we assign the result to the variable `username` (line 18). Then, we apply the method `.lower()` to `username` to ensure it is lowercase (line 20). What happens at line 23? We `return username`, meaning that we “push” `username` out of the function. Where does it go? Let’s look into the function calls. In the first line of cell 2, we call the function `create_username()` with the arguments “Julia” and “Smith”. The two arguments are automatically passed to the function header (cell 1, line 1). In the function, the first character of “Julia” and the whole string “Smith” are concatenated into “JSmith” and saved in the

variable `username` (line 18). In the following command, `username` is modified to lowercase and becomes "jsmith" (line 20). At the end of the function, we return `username` (line 23)—that is, "jsmith" is sent out of the function—and we assign it to the variable `username_1` (cell 2, line 1). Finally, we print `username_1` (cell 2, line 2). Similarly, in the second function call (cell 3, line 1), we pass the arguments "Mohammed" and "Seid" to the function `create_username()` (cell 1, line 1), where the username "mseid" is created (lines 18 and 20). The username is *returned* (line 23) to be assigned to the variable `username_2` (cell 3, line 1) and then printed (cell 3, line 2). As above, we use `return` to send a variable from a function body back to the function call. You can see the path of the output variables in Figure 29.1.



Figure 29.1. Path of a function output.

As is now clear, `return` is the **keyword** we use to **transfer output variables from the function body to the function call**. But it has another important property: it **marks the end of a function**. This means that any line of code written after `return` will never be executed! You might have realized that you have already used numerous returned variables throughout our learning journey. For example, the Python built-in function `int(14.45)` returns 14, which means that in the function `int()`, the last line of code is something similar to `return integer_number`. Similarly, the method `.lower()` applied to the string "JSmith" returns "jsmith" because the last line of code is something similar to `return lower_case_string`.

Finally, let's have a look at the **documentation** of the function in cell 1. As you can see, we specify the **returned variables** (lines 11–14). The syntax is the same as for the **Parameters** (lines 4–9). First, we write **Returns** as a title (line 11), followed by a series of minus signs that act as an underline (line 12). Then, for each returned variable—in this example, there is only one—we write (1) variable name (e.g., `username`), (2) space, (3) colon, (4) space, and (5) type (e.g., `string`) (line 13). On the following line, indented, we write the definition of the returned variable (line 14).

2. Creating a password

We need to implement a function that creates a password composed of four integers. How would you do it? Try to implement it yourself before looking at the solution below.

- Write a function that creates a password composed of four random integers:

[4]:	<pre> 1 import random 2 3 def create_password(): 4 """Create a password composed of 5 four random integers 6 7 Returns 8 ----- 9 password : string 10 Created password 11 12 # create a random number with four digits 13 password = str(random.randint(1000,9999)) 14 15 # return password 16 return password </pre>	<pre> import random def create_password Create a password composed of four random integers Returns password : string Created password create a random number with four digits password is assigned str random dot randint 1000 9999 return password return password </pre>
------	--	--

- Test the function for two customers:

[5]:	<pre> 1 password_1 = create_password() 2 print(password_1) 4883 </pre>	password one is assigned create password print password one
[6]:	<pre> 1 password_2 = create_password() 2 print(password_2) 5005 </pre>	password two is assigned create password print password two

To generate a password with four integers, we'll use a simple trick: we create a random number between 1000 and 9999, which is the range of all the existing numbers with four digits! Then, we transform the obtained number into a string—using the built-in function `str()`—and we assign the result to the variable `password` (cell 4, line 13). Why are we converting the four-digit integer into a string? Because a password does not have any numerical meaning—that is, we do not use it in arithmetic operations such as addition or multiplication. Finally, we return `password` at line 16. Note that this function **does not have any inputs**. Thus, there are no parameters in between the round brackets in the header (line 3), there is no `Parameters` session in the documentation (lines 4–10), and we do not write any arguments in between the round brackets when we call the function (cells 5 and 6, line 1). The returned variable `password` (cell 4, line 16) is saved as `password_1` and `password_2`, at line 1 of cells 5 and 6, respectively. Finally, we print the passwords to check for correctness (cells 5 and 6, line 2).

3. Creating a database

- Write a function that, given a list of lists of customers, creates and returns a database—i.e., a dictionary—of usernames and passwords. The function also returns the number of customers in the database:

```
[7]: 1 def create_database (customers):
2     """Creates a database as a dictionary with
3      usernames as keys and passwords as values
4
5      Parameters
6      -----
7      customers : list of lists
8          Each sublist contains first name and
9          last name of a customer
10
11     Returns
12     -----
13     db : dictionary
14         Created database (shorted as db)
15     n_customers : int
16         Number of customers in the database
17
18     """
19
20     # initialize dictionary (i.e. database)
21     db = {}
22
23     # for each customer
24     for customer in customers:
25
26         # create username
27         username = create_username (
28             customer[0], customer [1])
29
30         # create password
31         password = create_password()
32
33         # add username and password to db
34         db[username] = password
35
36         # compute number of customers
37         n_customers = len(db)
38
39         # return dictionary and its length
40         return db, n_customers
```

<p>def create_database (customers):</p> <p>Creates a database as a dictionary with usernames as keys and passwords as values</p> <p>Parameters</p> <p>-----</p> <p>customers : list of lists</p> <p>Each sublist contains first name and last name of a customer</p> <p>Returns</p> <p>-----</p> <p>db : dictionary</p> <p>Created database (shorted as db)</p> <p>n_customers : int</p> <p>Number of customers in the database</p> <p>"""</p> <p># initialize dictionary (i.e. database)</p> <p>db = {}</p> <p># for each customer</p> <p>for customer in customers:</p> <p># create username</p> <p>username = create_username (customer[0], customer [1])</p> <p># create password</p> <p>password = create_password()</p> <p># add username and password to db</p> <p>db[username] = password</p> <p># compute number of customers</p> <p>n_customers = len(db)</p> <p># return dictionary and its length</p> <p>return db, n_customers</p>	<p>def create database customers</p> <p>Creates a database as a dictionary with usernames as keys and passwords as values</p> <p>Parameters</p> <p>-----</p> <p>customers : list of lists</p> <p>Each sublist contains first name and last name of a customer</p> <p>Returns</p> <p>-----</p> <p>db : dictionary</p> <p>Created database (shorted as db)</p> <p>n_customers : int</p> <p>Number of customers in the database</p> <p>initialize dictionary (i.e. database)</p> <p>db is assigned empty dictionary</p> <p>for each customer</p> <p>for customer in customers</p> <p>create username</p> <p>username is assigned create username</p> <p>customer in position zero customer in position one</p> <p>create password</p> <p>password is assigned create password</p> <p>add username and password to db</p> <p>db at key username is assigned password</p> <p>compute number of customers</p> <p>n customers is assigned len db</p> <p>return dictionary and its length</p> <p>return db n customers</p>
---	--

Let's analyze the function before calling it in the cells below. Let's begin with the input and the outputs. The input is a variable called `customers`, as we can see in the function header (line 1). From the documentation, we learn that `customers` is a list of lists where each sublist contains a first name and a last name (lines 6–7). The outputs are two variables called `db` and `n_customers`, as we can see in the last

line of the function after the keyword `return` (line 36). From the documentation, we learn that `db` is a dictionary that will contain the database (lines 11–12), whereas `n_customers` is an integer that will store the number of customers in the database (lines 13–14). Let's continue with the analysis of the function body. We initialize the variable `db` as an empty dictionary (line 18), which we will fill out within the function and eventually return. Then, for each customer in the list of lists (line 21), we perform three actions. First, we create a username by calling the function `create_username()` that we wrote in cell 1. The inputs are the first name—`customer[0]`—and the last name—`customer[1]`—of the current customer. We save the output in the variable `username` (line 24). Then, we create the password by calling the function `create_password()` from cell 4, and we save the output in the variable `password` (line 27). Finally, we add the username and the password to the database by assigning the variable `password` as a value to the corresponding key `username` in the database `db` (line 30). Once we complete the creation of username and password for each customer and exit the loop, we calculate the number of customers, which corresponds to the length of the dictionary. We use the built-in function `len()`, and we save the output in the variable `n_customers` (line 33). Finally, we return both `db` and `n_customers` (line 36). As you can see, to **return multiple variables**, we write them **after the keyword return and separated by commas**.

It is always very important to **test the correctness of a function by calling it**. So let's call the function and test its behavior!

- Given the following list of customers:

```
[8]: 1 customers = [[ "Maria", "Lopez"], [ "Julia",  
    "Smith"], [ "Mohammed", "Seid"]]
```

customers is assigned Maria Lopez
Julia Smith Mohammed Seid

We create a list of lists called `customers` that contains three sublists (cell 8).

- Create the database using two different syntaxes:

```
[9]: 1 # create the database - separate returns  
  
2 database, number_customers =  
    create_database(customers)  
  
3  
4 # print the outputs  
5 print("Database:", database)  
6 print("Number of customers:", number_customers)
```

create the database - separate
returns
database number customers is
assigned create database customers

print the outputs
print Database: database
print Number of customers: number
customers

```
Database: {'mlopez': '7097', 'jsmith': '6891', 'mseid': '3189'}  
Number of customers: 3
```

When returning multiple outputs, there are two possible syntaxes for a function call. In this first case (cell 9), we create two **output variables separated by a comma** (line 2). The first variable—`database`—contains the returned variable `db` from cell 7, line 36. When we print it at line 5, we see the dictionary containing usernames and passwords for each customer. Similarly, the second variable—`number_customers`—contains the returned variable `n_customers` (cell 7, line 36). When we print `number_customers` at line 6, we see the dictionary length, which is 3. Let's look at the other possible syntax for the outputs.

```
[10]: 1 # create the database - single return
      2 outputs = create_database(customers)
      3 print("Output tuple:", outputs)
      4
      5 # get and print the database
      6 database = outputs [0]
      7 print("Database:", database)
      8
      9 # get and print the number of customers
     10 number_customers = outputs [1]
     11 print("Number of customers:", number_customers)

Output tuple: ({'mlopez': '6350', 'jsmith': '7863', 'mseid': '1953'},3)
Database: {'mlopez': '6350', 'jsmith': '7863', 'mseid': '1953'}
Number of customers: 3
```

In this second case, we assign both returned variables to a single variable called `outputs` (line 2). As we can see from the `print` (line 3), `outputs` is a **tuple** that contains the database and the number of customers. As you might recall from Chapter 22, a tuple is a sequence of elements separated by commas and contained within round brackets. Tuple elements are **immutable**, which means that we cannot overwrite, add, or delete any element. However, we can extract the elements by using the same **slicing** principles that we learned for lists and strings. Thus, to get the dictionary, we slice `outputs` in position `0` (line 6), and we print it as a check (line 7). Similarly, to get the number of customers, we slice `outputs` in position `1` (line 10) and print it as a check (line 11). Obviously, we could have directly printed the sliced variable in both cases—that is, `print("Database:", outputs [0])` and `print("Number of customers:", outputs [1])`.

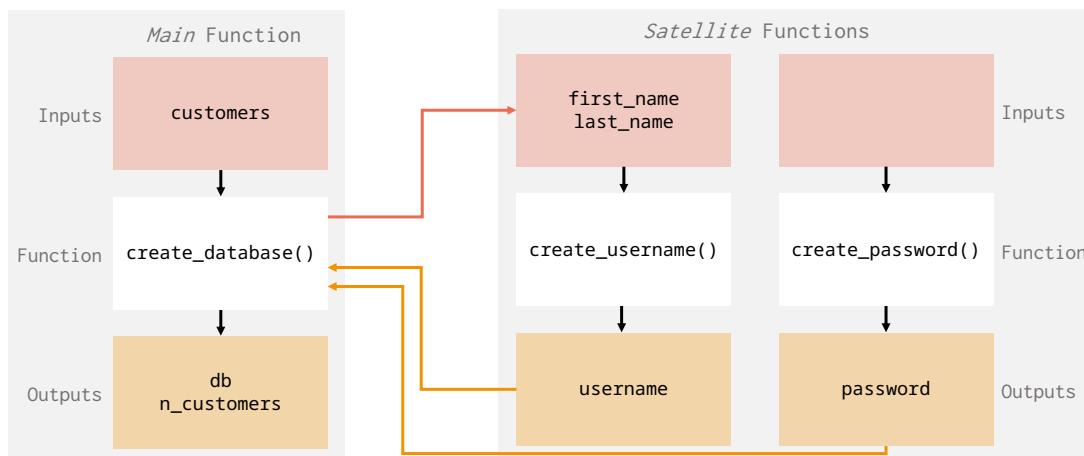


Figure 29.2. Modular organization of code: Main and satellite functions.

Before concluding this chapter, let's briefly analyze how we *modularized* our code with the help of Figure 29.2. We created three functions, each of them with a different role. The function

`create_database()`—on the left side of Figure 29.2—is the **main function**, because it (1) **receives the input** for the task to solve—a list of customer first names and last names; (2) **performs the flow of operations needed to solve the task**—that is, it creates the database of usernames and passwords; and (3) **provides the final output**—that is, it returns the dictionary and the number of customers. In some coding examples outside this book, you may find that the the main function is actually called `main()`. The other two functions—`create_username()` and `create_password()`—are **satellite functions** because each of them **performs one specific task**. How do main function and satellite functions **interact**? Through the flow of **inputs and outputs**! The main function sends inputs to the satellite functions—in our case, `first_name` and `last_name` are sent to `create_username()` (orange line in Figure 29.2)—and receives outputs—`username` from `create_username()` and `password` from `create_password()` (yellow lines). The received outputs can then be used to **create new variables**—such as the dictionary `db` in our example—or **as inputs for subsequent satellite functions**, as you will see in the coding exercise at the end of the chapter.

We'll conclude this chapter with an important note about the **joy and difficulties of coding**. Most likely, when you read the task at the beginning of this chapter and started drafting your own solution, what came to your mind was somewhat different from the solution you found. Maybe your idea was more complicated, maybe less structured, or maybe you got stuck and frustrated. Want to know a secret? The solution that you learned in this chapter did not come out of my mind the way it looks now. The initial idea was messy, redundant, and at times I was uncertain about what to do. In some cases, I started with the lines of code that do the actual job and then wrote a function around them. Other times, when things were very clear to me, I just wrote a function from top to bottom. It required hours of tweaking, corrections, and adjustments to get the code to be structured, clean, and simple-looking. So, don't worry if it takes you quite some time before coming to a final, clean solution when solving a task. That's normal! Do you remember the *In more depth* session in Chapter 17 entitled *Writing code is like writing an email?* We write a draft solution, then we modify it, then we modify it again, and again, and finally we arrive at a satisfactory result. The most important thing in coding is **persistence**!

Recap

- The keyword `return` has two roles:
 - It transfers output variables from the function body to the function call. When multiple variables are returned, they are separated by commas both in the function body and in the function call. In the latter, they can also be collected into a tuple.
 - It marks the end of a function. Commands written after `return` do not get executed.
- Tuples are a data type where elements are immutable, meaning they cannot be changed. Tuple slicing follows the same rules as list (or string) slicing.
- In docstrings, the syntax of returned variables is the same as the syntax of input parameters.
- It is important to test function correctness by calling them with appropriate arguments.
- A project is often composed of a main function and some satellite functions. The main function executes the solution to the whole task, whereas each satellite function executes one specific subtask.

What is None?

Have you ever got `None` as an output when running a function? The keyword `None` indicates that the **function has no return**. In other words, at the end of the function there is no keyword `return` followed by one or more variables. Let's look at the following example, modified from cell 4:

<pre>[4]: 1 import random 2 3 def create_password(): 4 """Create a password composed of 5 four random integers 6 7 Returns 8 ----- 9 password : string 10 Created password 11 12 # create a random number with four digits 13 password = str(random.randint(1000,9999)) 14 15 # print password 16 print(password)</pre>	<pre>import random def create_password Create a password composed of four random integers Returns password : string Created password """ create a random number with four digits password is assigned str random dot randint 1000 9999 print password print password</pre>
--	---

At line 16, we substitute `return password` with `print(password)`. Let's see what changes when calling the function:

<pre>[5]: 1 password_1 = create_password() 2 print(password_1) 4883 None</pre>	<pre>password one is assigned create password print password one</pre>
--	--

The first `print`—4883—comes from the command `print(password)` in cell 4, line 16. The second `print`—`None`—is from the command `print(password_1)` in cell 5, line 2. Because we did not `return password` at the end of the function body (cell 4, line 16), `password_1` will contain the keyword `None`, which is what we see when printing at line 2.



Let's code!

1. What does Bill Gates tweet about? Bill Gates is highly active on Twitter (now known as “X”), with 65.7 million followers as of November 2024. But what does he tweet about? To answer this question, in this exercise, you'll learn how to extract the most common words from some text using basic techniques from natural language processing (NLP), an interesting and challenging computational field focused on analyzing human language. In exercises a, b, and c, you will implement some techniques to preprocess text—that is, to clean text for the main analysis—and in exercise d, you will create the

main function to identify the most common words Bill Gates uses.

- a. *Removing punctuation.* When preprocessing text, a common initial step is to remove punctuation. Write a function that, given a string, returns the same string without any punctuation.

Hint: You can use this punctuation string: ! "#\$%& '+,-./:;=>?@[]^_`{|}~

(Example input: Hello! How are you?. Expected output: Hello How are you).

- b. *Converting to lowercase and segmenting into words.* The next steps are to standardize all words to lowercase and to segment the text, that is, to split the text into individual words. Write a function that, given a string: (1) converts the string to lowercase; (2) segments the text by splitting it into a list of words; and (3) returns the list of words. Hint: You only need two string methods!

(Example input: Hello How are you. Expected output: ['hello', 'how', 'are', 'you']).

- c. *Removing stop words.* Another important step in NLP is removing stop words, which are common words that typically don't add meaningful information to the text (e.g., prepositions). Write a function that, given a list of strings, returns the list without stop words. Hint: Use the following list of stop words: ["all", "how", "to", "what", "are", "the", "a", "of", "in", "it", "from", "and", "for", "about", "my", "on", "can"].

(Example input: ['hello', 'how', 'are', 'you']. Expected output: ['hello', 'you']).

- d. *Counting the most common words.* It's finally time to answer our question: What does Bill Gates tweet about? Create a function that calls the previous functions and returns the most common words in the tweets. More specifically, write a function that, given a list of strings, (1) executes text preprocessing—that is, removes punctuation, converts to lowercase, segments text into words, and removes stop words; (2) creates a dictionary in which the keys are each unique word and the values are their corresponding counts; and (3) returns the 10 most frequent words from the dictionary. Hint: To sort dictionary keys based on their values you can use the following command:

```
sorted_keys = sorted(my_dictionary, key=my_dictionary.get, reverse=True)
```

Use the following list of strings as an input:

```
tweets = ["Meaningful action from business leaders will require the courage to take risks that many companies aren't used to taking.",  
"Thanks to @andersoncooper, @SeaArtsLectures, and everyone who joined our virtual conversation about climate change. Great to have so much support from my hometown for this important work.",  
"Great to see this important step as the United States resumes our global leadership on climate change. Looking forward to working with @POTUS and Congress on a plan to ensure we reach net zero by 2050.",  
"Thanks to @streickercenter for hosting the launch of my virtual book tour. It was great to hear so many thoughtful questions about what we can all do to help avoid a climate disaster.",  
"When I talk to people about climate change, I almost always get asked the same question: What can I do to help? Here are some actions individuals can take to move us closer to a zero-carbon future",  
"Thanks for inviting me on the podcast, @karaswisher.",  
"Thank you, AlokSharma_RDG. We have a lot of work ahead of us to reach net-zero emissions by 2050 and avoid a climate disaster. Your leadership of #COP26 is critical. Thanks also to @howtoacademy, @penguinlive and @Waterstones for hosting the London stop of my virtual book tour!",  
"It was great to talk with @alroker about my new book and the solutions we need to fight climate change."  
"Thanks for another great conversation @Trevornoah!",  
"I wrote How to Avoid a Climate Disaster because I see not just the problem of climate change; I also see an opportunity to solve it. Here's how: http://gatesnot.es/3dh2kQy",  
"I had a great time working with @FortuneMagazine on this special digital issue about climate change. The entire business community has a role to play—and we need to start now.",  
"How to Avoid a Climate Disaster is available now. I hope you'll check out the book, but more importantly, I hope you'll do what you can to help keep the planet livable for generations to come: http://b-gat.es/climatebook"]
```

30. Free ticket at the museum

Input validation and output variations

What happens if we provide wrong inputs to a function? Sometimes the function *breaks*—meaning we get an error—and some other times we get a meaningless result. In both cases, it might be difficult to understand what went wrong. In this chapter, we will learn how to make sure that function inputs are of the right type and *value*. In addition, we will also learn how to return outputs in specific cases, that is, based on conditions or directly as values. Let's tackle all this through the example below. Follow along with Notebook 30!

- You work at a museum and have to update the online system to buy tickets. The update is that people who are 65 and older now qualify for a free ticket. Write a function that asks visitors to enter their prefix, last name, and age; checks the types and *values* of these inputs; and returns a message telling the visitor if they are eligible for a free ticket.

```
[1]: 1 def free_museum_ticket (prefix, last_name, age):  
2     """Returns a message containing inputs  
3         and free ticket eligibility based on age  
4  
5         Parameters  
6         -----  
7         prefix : string  
8             Ms, Mrs, Mr  
9         last_name : string  
10            Last name of a visitor  
11         age : integer  
12            Age of a visitor  
13  
14         Returns  
15         -----  
16         string  
17             Message containing inputs and  
18             eligibility  
19             """  
20  
21         # --- checking parameter types ---  
22  
23         # the type of prefix must be string  
24         if not isinstance(prefix, str):  
25             raise TypeError("prefix must be a  
string")  
  
def free_museum_ticket prefix last  
name age  
Returns a message containing inputs  
and free ticket eligibility based  
on age  
E.g. Mrs. Holmes, you are eligible  
for a free museum ticket because  
you are 66  
  
Parameters  
  
prefix : string  
Ms, Mrs, Mr  
last name : string  
Last name of a visitor  
age : integer  
Age of a visitor  
  
Returns  
  
string  
Message containing inputs and  
eligibility  
  
checking parameter types  
  
the type of prefix must be string  
if not isinstance prefix str  
raise TypeError prefix must be a  
string
```

```

26     # the type of last_name must be string
27
28     if not isinstance(last_name, str):
29         raise TypeError("last_name must be
30             a string")
31
32     # the type of age must be integer
33     if not isinstance(age, int):
34         raise TypeError("age must be an integer")
35
36
37     # --- checking parameter values ---
38
39     # prefix must be Ms, Mrs, or Mr
40     if prefix not in ["Ms", "Mrs", "Mr"]:
41         raise ValueError("prefix must be Ms, Mrs,
42             or Mr")
43
44     # last_name must contain only characters
45
46     if not last_name.isalpha():
47         raise ValueError("last_name must contain
48             only letters")
49
50     # age has to be between 0 and 125
51
52     if age < 0 or age > 125:
53
54         raise ValueError("age must be between
55             0 and 125")
56
57
58     # --- returning output ---
59
60     if age >= 65:
61         return prefix + ". " + last_name +
62             ", you are eligible for a free
63             museum ticket because you are " + str(age)
64
65     else:
66         return prefix + ". " + last_name +
67             ", you are not eligible for a free museum
68             ticket because you are " + str(age)

```

the type of last name must be
string
if not isinstance last name str
raise TypeError last name must be a
string

the type of age must be integer
if not isinstance age int
raise TypeError age must be an
integer

checking parameter values

prefix must be Ms, Mrs, or Mr
if prefix not in "Ms" "Mrs" "Mr":
raise ValueError prefix must be Ms,
Mrs, or Mr

last name must contain only
characters
if not last name dot **isalpha**
raise ValueError last name must
contain only letters

age has to be between 0 and 125
if age less than zero **or** age
greater than 125
raise ValueError age must be
between 0 and 125

returning output

if age greater than 65
return prefix concatenated with dot
space concatenated with last name
concatenated with you are eligible
for a free museum ticket because
you are concatenated with str age
else
return prefix concatenated with
dot space concatenated with last
name concatenated with you are not
eligible for a free museum ticket
because you are concatenated with
str age

 True or false?

- | | | |
|--|---|---|
| 1. In the docstrings, after the description, we can add an example for further clarification | T | F |
| 2. The built-in function <code>isinstance()</code> checks a variable type and returns an integer | T | F |
| 3. <code>raise TypeError()</code> and <code>raise ValueError()</code> stop the function and provide an error message | T | F |
| 4. <code>raise</code> is a function | T | F |
| 5. <code>int</code> and <code>str</code> are the same as <code>int()</code> and <code>str()</code> | T | F |

Computational thinking and syntax

Let's begin to analyze the function by taking a look at what it does. In the docstring description, we see that the aim of `free_museum_ticket()` is to return a message composed of a concatenation of the inputs and the eligibility for a free ticket based on age (line 2). The description is followed by a message **example**, for further clarification (line 3). Adding an example is good practice to make the function **outcome more quickly and easily understood**. Let's continue by looking at the inputs. The function has 3 parameters: `prefix`, `last_name`, and `age` (line 1), whose types and values are described in the documentation (lines 5–12) and further checked in the first 6 blocks of code (lines 20–47). The blocks have a similar structure, composed of an if condition followed by a `raise` statement. Let's have a closer look. The first three blocks check the **parameter types** (lines 20–32). In the first block (lines 22–24), we check if the first parameter `prefix` is a string. To do so, we write an if condition (line 23) composed of (1) the keyword `if`, (2) the logical operator `not`, and (3) the built-in function `isinstance()`, which **checks if a variable is of a specific type**. It takes 2 parameters: the **variable to check**—`prefix`—and the **wanted type**—that is, `str`. Other possibilities for `type` are `int`, `list`, `dict`, etc. Types are not followed by round brackets and should not be confused with the built-in functions `str()`, `int()`, etc. The function `isinstance()` **returns a Boolean**, that is, `True` if the variable is of the desired type—e.g., if `prefix` is a `str`—and `False` otherwise. Why do we use the logical operator `not` in the if condition? To make the condition true when we want it to be executed. In Boolean terms, we can say that if `prefix` is not a string, then the command `if not isinstance()` becomes `if not False`, which is the same as `if True` (see Chapter 19), and thus the following statement gets executed. The statement is composed of (1) the keyword `raise`, which **stops the function**, and (2) the built-in **exception `TypeError()`**, which **specifies the nature of the error**—type—and **provides a message** indicating **what must be done to avoid the error** (line 24). To see the effect of these lines of code, let's call the function using the wrong type for `prefix` and analyze what happens.

```
[2]: 1 # checking prefix type
      2 message = free_museum_ticket(1, "Holmes", 66)
      3 print(message)

-----
TypeError      Traceback (most recent call last)
Cell In[2], line 2
      1 # checking prefix type
----> 2 message = free_museum_ticket(1, "Holmes", 66)
      3 print(message)

Cell In[1], line 24, in free_museum_ticket(prefix, last_name, age)
    20 # --- checking parameter types ---
    21
    22 # the type of prefix must be string
    23 if not isinstance(prefix, str):
----> 24     raise TypeError ("prefix must be a string")
    25
    26 # the type of last_name must be string
    27 if not isinstance(last_name, str):

TypeError: prefix must be a string
```

We use 1 for `prefix`—that is, an integer instead of a string—and correct types for `last_name`—a string—and `age`—an integer—to test one parameter at the time (line 2). We assign the function output to the variable `message`, and we print it (line 3). We get an error message. Let's dig deeper! As usual, we start from the last line. Here, we read the type of exception—`TypeError()`—and the string we wrote as an argument—`prefix must be a string`. Do you remember seeing type errors before? In the *In more depth* sections of Chapter 9, entitled *Dealing with `TypeError`*, and Chapter 14, entitled *Don't name variables with reserved words!*, we learned how to read type error messages and how to fix the code to avoid them. Now, we know what's behind the scenes, that is, how to *create* a `TypeError` message! We've learned quite a lot since then, haven't we? Let's complete the analysis of the error message by looking at the arrows pointing at specific lines of code. The top arrow points at line 2 of cell 2, telling us where the error happens in the *current cell*—that is, where we called the function. The second arrow points at line 24 of cell 1, which is where the error *originated*, that is, where we raised the `TypeError()`. Note that since the error happens at cell 2 and thus the code stops, we do not see any `print` because the command at line 3 is not executed.

Let's continue by checking the type of the second parameter `last_name` (lines 26–28). As for `prefix`, `last_name` must be a string. Thus, we simply reuse the commands at lines 23–24, substituting `prefix` with `last_name` in the `if` statement (line 27) and in the `TypeError()` message (line 28). Let's test whether the type error works, by calling the function with the wrong type for `last_name`—starting from this cell, only the relevant part of the error message is reported from brevity.

```
[3]: 1 # checking last_name type
      2 message = free_museum_ticket ("Mrs", 1.2, 66)
      3 print(message)

-----
Cell In[3], line 2
----> 2 message = free_museum_ticket("Mrs", 1.2, 66)
Cell In[1], line 28, in free_museum_ticket (prefix, last_name, age)
    27 if not isinstance(last_name, str):
----> 28     raise TypeError ("last_name must be a string")
TypeError: last_name must be a string
```

As expected, in the last line of the message, we get `TypeError: last_name must be a string`, which is the error that occurred at line 2 of the current cell, and originated at line 28 of cell 1.

Let's conclude the check of the parameter types with `age` (lines 30–32). In this case, the parameter must be an integer, not a string. Thus, in the built-in function `isinstance()`, the two inputs are the variable `age` and the type `int` (line 31). In `TypeError()`, the message becomes `age must be an integer` (line 32). Let's test the correctness of this code with the following function call.

```
[4]: 1 # checking age type
      2 message = free_museum_ticket ("Mrs", "Holmes", "Hi")
      3 print(message)

-----
Cell In[4], line 2
----> 2 message = free_museum_ticket("Mrs", "Holmes", "Hi")
Cell In[1], line 32, in free_museum_ticket (prefix, last_name, age)
    31 if not isinstance(age, int):
----> 32     raise TypeError ("age must be an integer")
TypeError: age must be an integer
```

We enter the string "`Hi`" as the third parameter. As expected, the error occurs at line 2 of cell 4 and originated at line 32 of cell 1.

The following three blocks of code of `free_museum_ticket()` check the **parameter values** (lines 35–47). Similarly to before, each block contains an if construct composed of an if condition and a statement raising an exception. In the condition, we assess the parameter values by establishing some **criteria specific to the context** of the task. For example, for `prefix`, we establish that the possible values are "`Ms`", "`Mrs`", or "`Mr`". Thus, we enclose the three strings into a list, and we check **if the value of prefix is in that list** (line 38). If not, we raise a `ValueError()` in the following statement (line 39). `ValueError()` is the **exception specific for value errors**, and it works the same way as `TypeError()`. Within the round brackets, we write a message indicating what must be done to avoid the error—in our case, `prefix must be Ms, Mrs, or Mr`. Let's check what happens when raising the value error for `prefix` in the following function call.

```
[5]: 1 # checking prefix value
      2 message = free_museum_ticket ("Dr", "Holmes", 66)
      3 print(message)

      checking prefix value
      message is assigned free
      museum ticket Dr Holmes 66
      print message

Cell In[5], line 2
----> 2 message = free_museum_ticket("Dr", "Holmes", 66)
Cell In[1], line 39, in free_museum_ticket (prefix, last_name, age)
    38 if prefix not in ["Ms", "Mrs", "Mr"]:
----> 39     raise ValueError ("prefix must be Ms, Mrs, or Mr")
ValueError: prefix must be Ms, Mrs, or Mr
```

For `prefix`, we use "Dr", which is not in the list of possible values, ["Ms", "Mrs", "Mr"]. Thus, we get a value error, as the message in the last line specifies. The error happens at line 2 of cell 5 and originated at line 39 of cell 1, as we can see from the two arrows in the pink area.

Let's continue with checking the possible values for `last_name`. What condition should we use? Should we list all the possible last names in the world? What if some are not registered or new? In cases like this, we can look into the **types of characters** composing the string. For last names, we can require that all the characters are letters of the alphabet and, to do so, we can use the string method `.isalpha()`(line 42)—for simplicity, we'll consider only last names composed of characters and not containing punctuation, such as O'Connor, or a space, such as García Lopez. In other contexts, we can perform the check using methods such as `.isalpha()`, `.isdigit()`, `.isalnum()`, `.islower()`, `.isupper()`, `.istitle()`—see Chapter 27—depending on the characteristics that the string must have. If the condition is not met, then we raise a value error saying that the last name must contain only letters (line 43). Let's test the execution of these two lines of code by calling the function with an incorrect value for `last_name`.

```
[6]: 1 # checking last_name value
      2 message = free_museum_ticket ("Mrs", "82", 66)
      3 print(message)

      checking last name type
      message is assigned free
      museum ticket Mrs 82 66
      print message

Cell In[6], line 2
----> 2 message = free_museum_ticket("Mrs", "82", 66)
Cell In[1], line 43, in free_museum_ticket (prefix, last_name, age)
    42 if not last_name.alpha():
----> 43     raise ValueError ("last_name must contain only characters")
ValueError: last_name must contain only letters
```

In the function call (line 2), we use the string "82" for `last_name`. We get the value error with the message that we entered at line 43 in cell 1.

Let's finally check the value of the last parameter `age`. What constraint should we use this time? One reasonable option is to raise a value error if `age` is not within the **range** of a human lifetime. How do we define the range? The minimum is obviously 0 years old. What about the maximum? According to Wikipedia¹, the oldest person ever was Jeanne Calment who died when she was 122 years and 164 days old! So, we can keep a bit of margin and define 125 as the maximum. Therefore, we check if `age` is less than 0 or greater than 125 (line 46). If so, we raise the `ValueError()` with the message suggesting the proper age range to use (line 47). Let's test these commands by calling the function with an age out of range!

¹https://en.wikipedia.org/wiki/List_of_the_verified_oldest_people

```
[7]: 1 # checking age value
      2 message = free_museum_ticket ("Mrs", "Holmes", 130)
      3 print(message)

-----
Cell In[7], line 2
----> 2 message = free_museum_ticket("Mrs", "Holmes", 130)
Cell In[1], line 47, in free_museum_ticket (prefix, last_name, age)
    46 if age < 0 or age > 125:
----> 47     raise ValueError ("age must be between 0 and 125")
ValueError: age must be between 0 and 125
```

In the function call (line 2), we provide the integer `130` for the parameter `age`, and we get the value error that we created at line 47 of the function, as expected.

At this point, you might ask yourself: do I have to implement the input check in *every* function I write? Nope! In Python, we assume that the docstrings clearly indicate expected type and value of the parameters and that a coder passes valid arguments to a function. So, why did we learn it? Because a parameter check is useful in **main functions** or when there are **user-provided inputs**—for example, when using the built-in function `input()`, as you will see in the coding exercise at the end of this chapter.

Let's conclude by analyzing the returns. In `free_museum_ticket()`, we **return different outputs based on conditions** (lines 50–55). To do that, we use an if/else construct where each statement contains the keyword `return`. If the age of the visitor is greater than or equal to 65 (lines 52), then we *return* the string indicating the eligibility to a free ticket (line 53), otherwise (line 54) we *return* a string indicating the ineligibility to a free ticket (line 55). As you might remember from the previous chapter, *return* not only “pushes” the variable out of a function, but it also **stops the function**. Thus, any command following the executed return statement (line 53 or 55) will never be executed. In this function, we also **directly return a value** without creating an intermediate variable—this can be done in any function. In other words, we do not create a variable called `message` to which we assign the concatenation `prefix + " " + last_name + "`, you are eligible for a free museum ticket because you are `" + str(age)`, and then return it as `return message`. We directly return the concatenation. Note that **in the docstrings we only indicate the type**—string—as there is no variable name (line 16).

Let's conclude by calling the functions with the correct input types and values to test the correctness of the two returns.

```
[8]: 1 # person is eligible
      2 message = free_museum_ticket ("Mrs", "Holmes", 66)
      3 print(message)

person is eligible
message is assigned free
museum ticket Mrs Holmes 66
print message

Mrs. Holmes, you are eligible for a free museum ticket because you are 66
```

```
[9]: 1 # person is not eligible
      2 message = free_museum_ticket ("Mrs", "Choi", 38)
      3 print(message)

person is not eligible
message is assigned free
museum ticket Mrs Choi 38
print message

Mrs. Choi, you are not eligible for a free museum ticket because you are 38
```

In both cells, the inputs pass the type and value checks, thus the function executes the code and returns a message according to age. In the first case (cell 8), the age is 66 (line 2)—which is greater than 65—so

the visitor is eligible for a free ticket. In the second case (cell 9), the age is 38 (line 2)—which is less than 65—so the visitor is not eligible for a free ticket.

Match the sentence halves

- | | |
|-------------------------------------|----------------------|
| 1. raise is a | a. built-in function |
| 2. TypeError() and ValueError() are | b. keyword |
| 3. int is a | c. built-in function |
| 4. int() is a | d. exceptions |
| 5. isinstance() is a | e. type |

Recap

- We implement parameter checks in main functions or in presence of external inputs. The check is executed using an if/else construct. In the if condition:
 - When checking a type, we use the logical operator not followed by the built-in function `isinstance()`, whose parameters are the variable to check and the wanted type. Possible types are `str`, `int`, `list`, `dict`, etc.
 - When checking a value, we have to define constraints. We can use membership to a list, variable methods—such as `.isalpha()` for strings—or intervals for numbers.In the statement, we use `raise` followed by the exception `TypeError()` or `ValueError()` with a message indicating how to avoid the error.
- When we want to return different outputs based on conditions, we can use an if/else construct where the statements contain the keyword `return` followed by the wanted output.
- It is possible to return values instead of variables. In this case, in the docstrings we indicate only the type.
- In docstrings, it is possible to write an example after the function definition to enhance clarity.

How can I avoid interrupting the flow?

As you learned in this chapter, `raise TypeError()` and `raise ValueError()` stop the function and provide an error message. But what if we do not want to interrupt the flow of our code? Imagine that `free_museum_ticket()` is a satellite function called by the main function within a larger project. Every time the type or value of an input is not correct, `free_museum_ticket()` stops, displays the “pink” error, and the flow of the whole project is interrupted, creating inconvenience. What can we do to avoid that? One possibility is to make the satellite function provide a Boolean as a return. For example, line 24 of the first block of code of `free_museum_ticket()` could be modified as following:

[1]: 22 # the type of prefix must be string 23 if not isinstance(prefix, str): 24 return prefix, False	the type of prefix must be string if not isinstance prefix str return prefix False
--	--

The main function—which calls `free_museum_ticket()`—would receive both `prefix` and `False`, indicating that there is something wrong about `prefix`. Then, the following code in the main function could handle the situation by asking the user to reenter a correct prefix. The coding exercise at the end of this chapter—especially point c—contains a more complete example of this concept. So, let's start coding!



Let's code!

1. Let's play hangman! Everybody knows hangman! It is a game where the aim is to guess a hidden word by suggesting letters. You have all the knowledge to implement hangman by yourself! Think about the task you have to implement (divide!) and go for it (conquer!). You can then compare your implementation with the one suggested in the following exercises. The first three exercises will invite you to implement satellite functions, each of them representing a sub-task. The last function will suggest how to write the main function.
 - a. Pick a random word. Create a satellite function that given a list of words, returns a randomly selected word in lowercase.
(Example input: `["spoon", "Fork", "KNIFE"]`. Example output: `"fork"`).
 - b. Show the guessed letters. Create a satellite function that given a word and a guessed letter, shows the word with the guessed letter revealed in its correct positions, whereas the remaining, unguessed letters are shown as underscores.
(Example input: `("l", "hello")`. Example output: `_ _ l l _`).
 - c. Check the user input. Create a satellite function that takes a string as an argument and returns the same string in lowercase and a Boolean, which is `True` if the string is a letter, and `False` otherwise. In addition, the function prints specific messages depending on the input string. If the string:
 - Is composed of multiple letters, print: `Please, enter a single letter;`
 - Is composed of one or more numbers, print: `Please, enter a letter not a number;`
 - Is composed of a combination of letters and numbers, print: `Please, enter a letter, not a combination of letters and numbers;`
 - Contains a symbol, print: `Please, enter a letter, not a symbol.`
 (Example input: `e1`. Example output: `e1, False`). Hint: Which strings methods will you use? See the table in the appendix of Chapter 27.
 - d. Assemble the hangman game. Create a main function that given a list of words:
 - Randomly chooses a word from the list;
 - Displays the word with missing letters;
 - Asks the player for a character. If the character is a valid letter, then the game continues; otherwise, the player is prompted until they enter a valid letter;
 - Checks for repeated guesses. If the player had already guessed that letter, print the message `You already guessed this letter. Choose again!`;
 - Checks if the letter is in the word, and updates the word accordingly. Make sure to update also when letters are double (e.g., double "l" in "hello");
 - Keeps asking for a new letter until the word is complete;

- At the end, congratulates the player and asks them if they want to play again. If so, the game restarts with a new word, otherwise the game stops.

(Example input: ["garden", "cave", "quilt", "bubble", "secretary", "light"])

31. Factorials

Recursive functions

In this chapter, you will learn a particular type of function called *recursive functions*. They can be challenging to understand and implement, but they are very useful in certain situations, as you will see. To better understand how recursive functions work, let's compute factorials. Have you ever heard of them? A **factorial** is the **product of all positive integers that are less than or equal to** a given positive integer. For example, the factorial of 4 is 24, calculated as $1 \times 2 \times 3 \times 4$ —or $4 \times 3 \times 2 \times 1$. How would you write a function that calculates the factorial of an integer? Write your own function before looking at the proposed solution below. You will find the code for this chapter in Notebook 31.

- Write a function that calculates the factorial of a given integer using a **for** loop:

```
[1]: 1 def factorial_for (n):
2     """Calculates the factorial of a given
3         integer using a for loop
4
5     Parameters
6     -----
7     n : integer
8         The input integer
9
10    Returns
11    -----
12    factorial : integer
13        The factorial of the input integer
14    """
15
16    # initialize the result to one
17    factorial = 1
18
19    # for each integer between 2 and
20    # the input integer
21    for i in range(2, n+1):
22        # multiply the current result
23        # by the current integer
24        factorial *= i
25
26    # return the result
27    return factorial
28
29
30 # call the function
31 fact = factorial_for(4)
32 print(fact)
```

```
def factorial_for n
Calculates the factorial of a given
integer using a for loop

Parameters
n : integer
The input integer

Returns
factorial : integer
The factorial of the input integer

initialize the result to one
factorial is assigned one

for each integer between two and the
input integer
for i in range two n plus one
multiply the current result by the
current integer
factorial multiply by and reassign i

return the result
return factorial

call the function
fact is assigned factorial for four
print fact
```

Does your implementation look similar to the one above?

- Compare the previous iterative function with the following recursive function:

<pre>[2]: 1 def factorial_rec (n): 2 """Calculates the factorial of a given 3 integer using recursion 4 5 Parameters 6 ----- 7 n : integer 8 The input integer 9 10 Returns 11 ----- 12 integer 13 The factorial of the input integer 14 """ 15 16 # if integer is greater than 1 17 if n > 1: 18 # execute the recursion 19 return factorial_rec(n-1) * n 20 # otherwise 21 else: 22 # return 1 23 return 1 24 25 # call the function 26 fact = factorial_rec(4) 27 print(fact) 28</pre>	<pre>def factorial rec n Calculates the factorial of a given integer using recursion Parameters n : integer The input integer Returns integer The factorial of the input integer if integer is greater than 1 if n is greater than 1 execute the recursion return factorial rec n minus one times n otherwise else return one return one call the function fact is assigned factorial rec four print fact</pre>
--	---

What similarities and differences do you notice between the two functions? Get some hints while solving the following exercise!

✍ True or false?

- | | | |
|---|---|---|
| 1. Both functions have one parameter and one return | T | F |
| 2. Both function contain a for loop | T | F |
| 3. In the recursive function, there is only one return statement in the if/elif construct | T | F |
| 4. We can call a function in the same cell where we write the function | T | F |

Computational thinking and syntax

Let's start by analyzing the function `factorial_for()` in cell 1. In the docstrings, we see that the input is an integer called `n`—as in `number`—(lines 4–7) and the output is another integer called `factorial` (lines 9–12). In the function body, we first initialize the output `factorial` to 1 (line 16). Then, we create a `for` loop where the index `i` will be assigned all the consecutive numbers from 2 to the input number `n` plus 1 (line 19)—do you remember the `plus one` rule for the stop in `range()` from Chapter 8? Within

the loop, we calculate the product between the current value of `factorial` and the current value of `i`, and we reassign the result to `factorial` (line 21). Let's quickly go through the three iterations for more clarity:

- In the first iteration, `factorial` is 1 and `i` is 2, so the result of `factorial*i`—that is, $1*2$ —is 2, which is reassigned to `factorial`.
- In the second iteration, `factorial` is 2 and `i` is 3, so the result of `factorial*i`—that is, $2*3$ —is 6, which is reassigned to `factorial`.
- In the third iteration, `factorial` is 6 and `i` is 4, so the result of `factorial*i`—that is, $6*4$ —is 24, which is reassigned to `factorial`—and is the final value.

We conclude the function by returning `factorial` (line 24). To test the function, we call it with the number 4 as an input, and we assign the returned value to the variable `fact` (line 27), which we print in the following command (line 28). Note that a function **code** and **call** can be **in the same cell** for convenience. In general, we call functions like `factorial_for()` **iterative functions** because they **contain a loop to repeat some parts of their code**.

Let's now move to the recursive function `factorial_rec()` (cell 2) and identify similarities and differences with `factorial_for()` (cell 1). From the docstrings, we see that the function takes an integer `n` as an input (lines 4–7)—similarly to `factorial_for()`—and returns a *value* as an output (lines 9–12)—differently from `factorial_for()`, which returns the *variable* `factorial`. The main difference is in the function body, where `factorial_for()` contains a `for` loop, whereas `factorial_rec()` contains an `if/else` construct (lines 15–22). In this construct, if `n` is greater than 1 (line 16), we return the output of `factorial_rec()` calculated for the consecutive smaller integer—that is, $n-1$ —multiplied by `n` (line 18), otherwise (line 20), we return 1 (line 22). Noticed anything unusual? In the first statement (line 18), we call `factorial_rec()` itself! This is because a **recursive function is a function that calls itself several times, until it reaches a base case**. In other words, recursive functions create a **cascade of function openings and executions** until a certain point where the path is **reversed to return the outputs and close the functions**. Let's understand this mechanism better with the help of Figure 31.1.

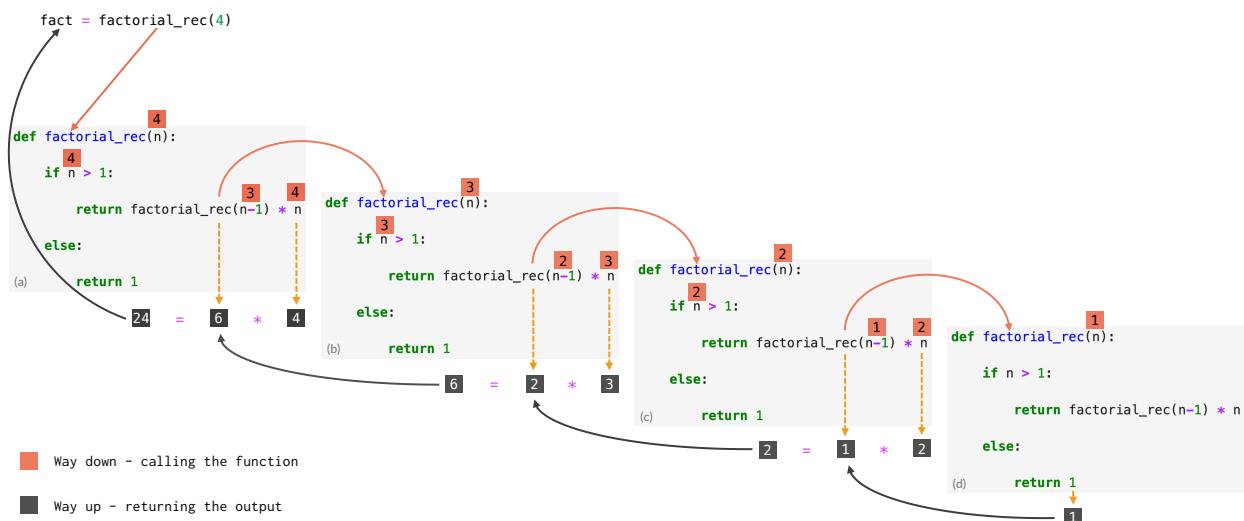


Figure 31.1. The mechanism of a recursive function.

Figure 31.1 contains four major components. First, there is the *initial function call* `fact = factorial_rec(4)` (corresponding to line 25 in cell 2)—see the top left of Figure 31.1. Sec-

ond, there are four simplified representations of `factorial_rec()` in cascade, each of them contained in a gray rectangle and indicated as (a), (b), (c), and (d), respectively. Third, there are orange arrows and numerical squares representing the “way down”, that is, the consecutive openings of several `fact = factorial_rec()` with their current inputs. And fourth, there are black arrows and numerical squares constituting the “way up”, that is, the return of the outputs and the closure of the functions. Now, let’s see how these components interact with each other. When we call `fact = factorial_rec(4)`, we begin the “way down”—as indicated by the first, straight orange arrow—and open a cascade of functions as follows:

- In (a), n is 4—that is, the initial input—thus the header of the function is `def factorial_rec(4)`. The `if` condition is `if 4>1`, which is true, so we move to the following statement containing the call `factorial_rec(3)`— 3 is calculated from $n-1$, that is, $4-1$. From here, we follow the orange arrow and move to (b), leaving the function open in (a) and temporarily disregarding all its remaining code.
- In (b), n is 3, so the header is `def factorial_rec(3)`. The `if` condition is now `if 3>1`, which is True again, so we move to the following statement where we call `factorial_rec(2)`. Thus, we follow the orange arrow and move to (c), leaving the function open in (b) and temporarily disregarding all its remaining code.
- In (c), n is 2, thus the header is `def factorial_rec(2)`. The `if` condition is `if 2>1`, which is True once more, so we move to the following statement where we call `factorial_rec(1)`. Again, we follow the orange arrow and move to (d), leaving the function open in (c) and temporarily disregarding all its remaining code.
- In (d), n is 1, thus the header is `def factorial_rec(1)`. The `if` condition is `if 1>1`, which is false! Therefore, we skip the statement under the `if` and we directly go to the statement under the `else`, which says `return 1`.

We have reached the so-called *base case*. At this point, we start the “way up”. Let’s go through the black numerical squares and arrows to collect the returned values and close the functions:

- In (d), the return is 1 and we pass it to the function call in (c), as indicated by the black arrow. The function in (d) is terminated.
- In (c), we complete the return statement under the `if` conditions—that is, `return factorial_rec(1)*2`. Thus, we multiply the output of `factorial_rec(1)`,—which is 1 from (d)—by 2, obtaining 2, which we pass to the function call in (b), as indicated by the black arrow. The function in (c) is terminated.
- In (b), we complete again the return statement under the `if` conditions. Thus, we multiply the output of `factorial_rec(2)`,—which is 2 from (c)—by 3 and we obtain 6, which we pass to the function call in (a), as indicated by the black arrow. The function in (b) is terminated.
- Finally, in (a), we complete the return statement under the `if` condition for the last time. We multiply the output of `factorial_rec(3)`,—which is 6 from (b)—by 4, obtaining 24, which we pass to the output variable `fact` in the initial call, as indicated by the last black arrow. The function in (a) is terminated, as well as the whole recursion.

Now that the functioning mechanism is clear, let’s briefly formalize the **syntax** of recursive functions. They typically contain an **if/else construct** where statements return or print a value. One of the two statements is called **base case** because it ensures that the recursion will stop—in our example, `return 1` (line 22). The other statement is called **recursive case** because it contains a call to the function itself—in our example, `return factorial_rec(n-1)*n` (line 18).

Let’s conclude with some advantages and disadvantages of recursive functions. On the one hand, recursive functions contain **compact code** and are appropriate when solving **intrinsically recursive**

problems—see the *In more depth* session at the end of this chapter. On the other hand, they are **computationally expensive** because each call occupies space in memory, which is released only when closing the functions during the “way up”. Finally, recursive functions can be **challenging to debug**.

Recap

- Iterative functions contain a loop to repeat some code.
- Recursive functions call themselves to repeat some code.
- Recursive functions typically contain an `if/else` construct, where one statement is the base case, and the other is the recursive case.
- Recursive functions contain compact code and are appropriate for intrinsically recursive problems. However, they use a large amount of computational memory and can be harder to debug.

When do we use recursive functions?

Recursive functions are helpful to solve **intrinsically recursive** problems, that is, when **repeated patterns** are present. Examples include the calculation of factorials—as you learned in this chapter; computations of Fibonacci numbers—see the coding exercise below; and algorithms to search characters in a string—behind methods like `.find()` there are usually recursive functions. Another common recursive problem is traversing **decision trees**, which are sort of flowcharts used to make consecutive decisions among defined alternatives. Nowadays, they are very popular as they are one of the most valid algorithms in machine learning. As an example, let's have a look at Figure 31.2. In this decision tree (top left), we have to decide where to go this weekend, and we must choose among three options: Park, Movie Theater, or Stay Home. After this

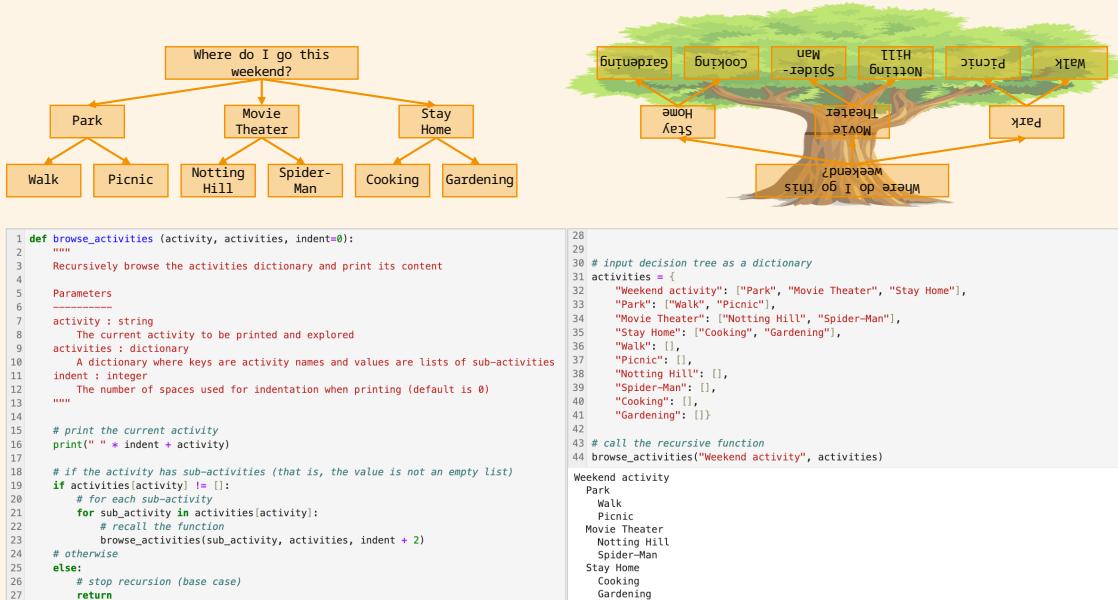


Figure 31.2. Example of decision tree (top left); upside-down version of the decision tree to illustrate the similarity to a natural tree (top right); and simplified code to traverse the decision tree (bottom).

first choice—for example, Park—we must make another more detailed choice—that is, between Walk and Picnic. At each step of the tree, we repeat the same recursive action—that is, taking a choice—that can be conveniently represented by a recursive function—see a simplified example in Figure 31.2 (bottom). Why are decision trees called as such? Because if we turn them upside down, the starting point is like the roots of a tree, the paths through intermediate options are like branches, and the final options are like leaves—see Figure 31.2 (top right).

 Let's code!

1. Fibonacci numbers. You might remember that the Fibonacci sequence is an infinite sequence of numbers where each number is the sum of the two previous numbers.
 - a. Modify the code you implemented in Exercise 6 of Chapter 14 into an iterative function that, given a positive integer, returns the Fibonacci number in that position—and not the whole sequence! Make sure to check the input type.
(Example input: 15. Example output: 610).
 - b. Re-implement the function above into a *recursive* function. Hint: this implementation has 2 base cases!

32. How can I reuse functions?

Working with Jupyter Notebooks and Python Modules

In Part 8, we have learned how to write functions, organize them in projects, handle their inputs and outputs, and implement recursion. We also mentioned that functions are a useful way to reuse code because by calling them we avoid copy/pasting long sequences of commands multiple times. But what if we need the same function in more than one notebook? We obviously don't want to copy/paste it across notebooks! The solution is to use Python modules. In this chapter, you will learn how to create a module, how to import it into a notebook and use its functions, and how to modify it. In other words, you will learn **a new way of working!** As an example, we will reuse the functions to create username, password, and a database that we implemented in Chapter 29. Follow along with Notebook 32! On the website, you will also find the whole module that we will build in this chapter.

1. Creating a module

Do you remember what a module is? In Chapter 15, while learning about `random`, we defined a module as a **unit** containing **functions** for a **specific task**. Let's now refine this definition to be more precise, as follows:

A **module** is a **file** containing **functions** for a **specific task** and whose extension is **.py**

Let's jump right in and create a module! The first thing to do is to open an integrated development environment (IDE)¹. As we mentioned in the Introduction of this book, there are several IDEs, all equally valid. Out of convenience, we will use Spyder because it is part of the suite of tools offered by Anaconda. Open Anaconda and double click on the *Launch* button in the Spyder tile—box 1 in Figure 32.1. Spyder will open, and you should see something very similar to the graphical user interface (GUI) represented in Figure 32.1 (right). On the left side of the GUI, there is a panel to browse and edit modules (box 2). In this case, there's only one open module, named the default `untitled0.py` (box 3). When using modules, we can perform standard file actions using mouse clicks or keyboard shortcuts, such as:

- **Close a module:** Click on the x on the left side of the file name (box 3); or click on *File* (box 4), and then *Close*.
- **Create a new module:** Click on the *New file* icon (box 5); or click on *File* (box 4), and then *New file*; or press *command* if you are on Mac—*control* if you are on Windows—and the letter N simultaneously on the keyboard.
- **Save a module:** Click on the *Save file* icon (box 6); or click on *File* (box 4), and then *Save*; or press *command* if you are on Mac—*control* if you are on Windows—and the letter S simultaneously on the keyboard.

Try to open, create, and save one or more modules to get familiar with them.

¹Modules can also be opened in JupyterLab by clicking on *File*, *New*, and *Python File*. However, IDEs are usually preferred when working with modules

Part 8. Functions

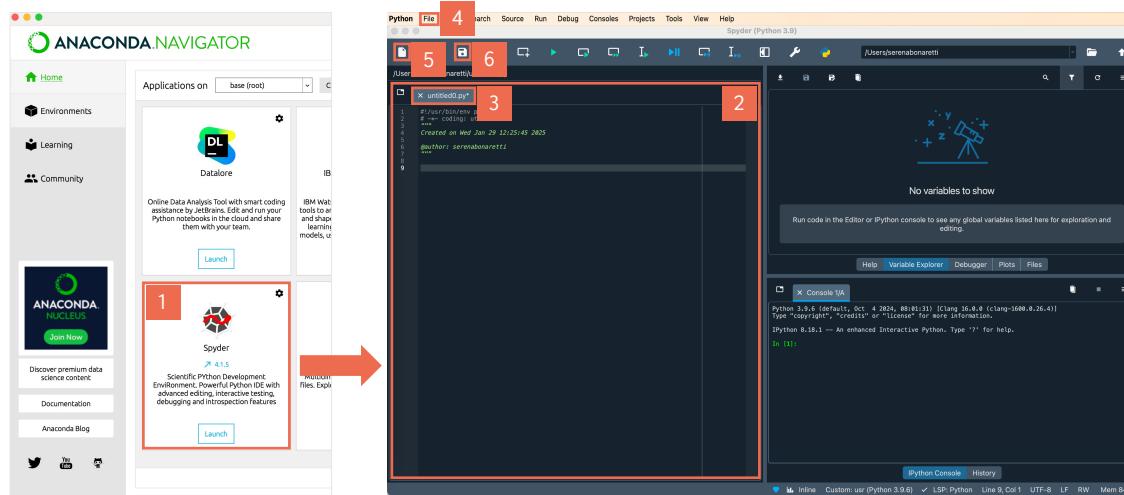


Figure 32.1. Spyder launcher in Anaconda (left) and Spyder graphical user interface (right).

Now, let's create a module for the setup of a database of usernames and passwords. Create a new module file—using mouse clicks or keyboard presses, as you have just learned. Save the module as `setup_database.py` in the *same* folder as Notebook 32. **The rules for module naming are the same as for variable naming**—lowercase and word separation by underscore. You should get something similar to what is shown in box 1 in Figure 32.2.

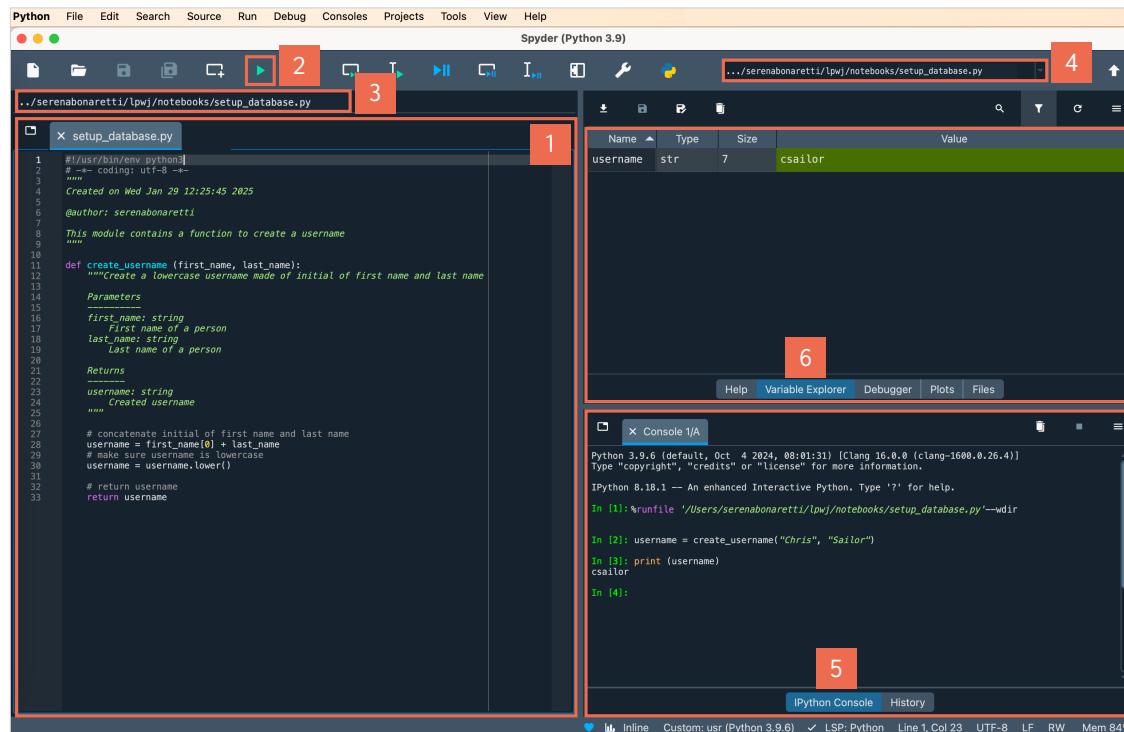


Figure 32.2. Function call from a module in Spyder.

The module starts with two default comments containing information for our computer (lines 1 and 2)—you can keep or delete them, as you wish. Then, there are the **docstrings containing the module's information**:

ule documentation (lines 3–9). Like for functions, module docstrings are enclosed in double quotes repeated three times. Spyder automatically creates docstrings, and you can edit them as you wish. In their default version, they contain the date of the file creation (line 4) and the name of the author (line 6). We add a simple description of the module content for completeness (line 8). Paste the function `create_username()` from Chapter 29 below the docstrings (lines 11–33). Congratulations, you have just created your first module!

Can we execute `create_username()` directly in Spyder? Yes! First, we need to click the **Run file** button (box 2)—this is one of several convenient methods. By doing so, the folder where the file is saved (box 3) and the **working folder**—that is, where the code is executed—(box 4) become the same, making the content of the module available. Then, we move to the **IPython console** (box 5)—or simply console. There, we **call the function** by typing `username = create_username("Chris", "Sailor")` and we press *enter* on the keyboard to execute the code—differently from Jupyter Notebook where we press *shift enter*. In the following line, we type `print(username)`, press enter, and see the `username` `csailor` printed to screen. As you might have noticed, each coding line starts with `In []:`, where `In` stands for *input* and the square brackets `[]` contain the order of execution of the current command, as if it was a Jupyter Notebook cell. This is because **IPython is a precursor of Jupyter Notebook**—and is still its basic engine. Obviously, in the console you can write **any Python command** as you would in a Jupyter Notebook! Finally, in Spyder, we can keep **control of the created variables** in the **Variable Explorer** (box 6). In our case, we have only one variable whose name is `username`, type is `str`, size is 7—that is, it is composed of seven characters—and value is `csailor`. Try creating new variables in the console and then take a look at how they are represented in the Variable Explorer!

2. Importing a module and running a function

Let's go back to our notebook and call `create_username()` from there! We need to (1) **import the module** and (2) **call the function**. There are four ways to do it. Let's go through them!

- Import the module as is, then call the function:

<pre>[1]: 1 import setup_database 2 3 username = setup_database.create_username (4 "John", "Gelb") 5 print(username) jgelb</pre>	<pre>import setup database username is assigned setup database dot create username John Gelb print username</pre>
---	---

We import the module using (1) the **keyword `import`** followed by (2) the **module name without the extension `.py`** (line 1). By doing this, we essentially instruct Python to locate the file `setup_database.py` and make its content available in the current notebook. Now, we can call the function. The syntax is (1) **module name**, (2) **dot**, and (3) **function name**—as in `setup_database.create_username()` (line 3). We complete the function call by adding its arguments—"John" and "Gelb"—and we assign the output to the variable `username`, which we print to check for correctness (line 4). Does this syntax remind you of anything? These are the rules that we learned for the module `random` (Chapter 15), which—now, you know!—is simply a file called `random.py` hosted in a folder somewhere on your computer. To import the `random` module, we write `import random`, and to call its functions we type `random.randint()` or `random.choice()`, as we do for any other module. As you can see, we are unveiling more and more secrets of Python!

- Import a module and create an alias, then call the function:

```
[2]: 1 import setup_database as sdb
2
3 username = sdb.create_username ("John", "Gelb")
4 print(username)
jgelb
```

import setup database as sdb
username is assigned sdb dot create
username John Gelb
print username

When the module name is long, it can be tedious to retype it every time we call a function. To overcome this, we can use **an alias**—usually an **abbreviation**. In our example, we import the module `setup_database` and we rename it as `sdb` (line 1). The syntax is (1) keyword `import`, (2) module name, (3) keyword `as`, and (4) `alias`. Then, we call the function (line 3) using (1) `alias`—instead of the full name—(2) dot, and (3) function name—that is, `sdb.create_username()`. Like before, we add the arguments—`"John"` and `"Gelb"`—and we assign the output to `username`, which we print to check for correctness (line 4). Note that the use of aliases is especially common when using **Python packages**—you might have seen `import pandas as pd` or `import numpy as np`. Packages are just **collections of modules**—that is, of files ending in `.py`—and whose imports and function calls work the same way as for modules.

- Import one single function from a module, then call the function:

```
[3]: 1 from setup_database import create_username
2
3 username = create_username ("John", "Gelb")
4 print(username)
jgelb
```

from setup database import create
username
username is assigned create username
John Gelb
print username

We consider the case where we need **only one function from a module** that contains several functions—we will see how to create such modules in a bit. Importing the entire module could occupy excessive space in memory that instead we want to use for computations. Thus, we import only one single function by writing (1) keyword `from`, (2) module name, (3) keyword `import`, and (4) function name without round brackets (line 1). To call the function, we **directly use the function name** without the module name (line 3). Finally, we print to check the function output (line 4).

- Import the function from a module and create an alias, then call the function:

```
[4]: 1 from setup_database import create_username as cu
2
3 username = cu ("John", "Gelb")
4 print(username)
jgelb
```

from setup database import create
username as cu
username is assigned cu John Gelb
print username

In this last case, we import one single function whose name is very long, and thus, we want to rename it with an alias. To import the function, the syntax is (1) keyword `from`, (2) module name, (3) keyword `import`, (4) function name, (5) keyword `as`, and (6) alias (line 1). To call the function, we directly use the alias—that is, `cu`—(line 3). Finally, we print the output (line 4). Note that this solution is rarely ideal because it can compromise code readability.

Let's conclude this section with two important remarks about imports. First, in a notebook, **imports should be grouped in the very first cell**, before any computation—here, they are spread across different

cells for sake of explanation. Second, we can **import modules into other modules**. For example, we can import the module `random` in `setup_database`, if needed. Like in notebooks, all the imports should be grouped **at the very beginning of the file** to favor code readability.

3. Importing a module from a different folder

What if we want to use a module that is in a different folder than the notebook? As you can guess, we do not want to have multiple copies of the same module! As an example, the module `setup_database` is in the folder `"/Users/serenabonaretti/lpwj/notebooks"` on my computer (box 3 in Figure 32.2.). Let's say that I need to move it to `"/Users/serenabonaretti/lpwj/code"`. How can Python know where the module is now? We tell Python **where to find a module** using the following commands.

- Restart the kernel, then add the module folder and import the module:

<pre>[1]: 1 import sys 2 sys.path.append("/Users/serenabonaretti/lpwj/code") 3 import setup_database</pre>	<pre>import sys sys dot path dot append Users serenabonaretti lpwj code import setup database</pre>
--	---

We restart the kernel to clear the previous imports and make sure that we are correctly testing the code in this section. Then, we import a **built-in module** called `sys` (line 1), which manages file locations—among other things. From `sys`, we call the command `sys.path.append()` (line 2), which takes a string containing the module `path`—that is, its location—as an argument—in this example, `"/Users/serenabonaretti/lpwj/code"`. Note that we have to insert the *whole* module path, which starts with `/Users` in MacOs, and with `C:\`—or another letter of the alphabet—in Windows. Now that Python knows where `setup_database` is, we can import it (line 3). Let's call the function `create_username()` using the same commands as in cell 1 of section 2.

- Call the function:

<pre>[2]: 1 username = setup_database.create_username ("John", "Gelb") 2 print(username)</pre>	<pre>username is assigned setup database dot create username John Gelb print username jgelb</pre>
--	---

Why don't you test these commands? Move your module `setup_database` to another folder, then add the new file location to `sys.path.append("")`. Go back to your notebook, import the module, and call the function!

For the next section, let's bring the module back to the same folder as the notebook for convenience.

4. Changing a function in a module and calling it in a notebook

What if we need to make a change to the function that we call in the notebook? Let's call `create_username()` before and after a change and see what happens!

- Restart the kernel, then call the function *before* the change:

```
[1]: import setup_database
      username = setup_database.create_username ("John",
      "Gelb")
      print(username)
jgelb
```

import setup database
username is assigned setup
database dot create username
John Gelb
print username

We restart the kernel to clear all previous imports and variables from memory. Then, we use the same code as we used in cell 1 to import the module (line 1), call the function (line 3), and print the output (line 4).

Now, let's go to the module in Spyder and make a simple change to the function. For example, let's add `print(first_name, last_name)` at the beginning of the function body (line 28 in Figure 32.3). After a change, **always remember to save the file!** Tip: when the module is not saved, you will see an **asterisk** in the name tab in the module panel. The asterisk will disappear after you save the file (see Figure 32.4).

```
1  def create_username (first_name, last_name):
2      """Create a lowercase username made of initial of first name and last name
3
4      Parameters
5          -----
6          first_name: string
7              First name of a person
8          last_name: string
9              Last name of a person
10
11     Returns
12
13         username: string
14             Created username
15
16         """
17
18     # print inputs
19     print (first_name, last_name)
20
21     # concatenate initial of first name and last name
22     username = first_name[0] + last_name
23
24     # make sure username is lowercase
25     username = username.lower()
26
27     # return username
28     return username
```

Figure 32.3. Module function modified at line 28.

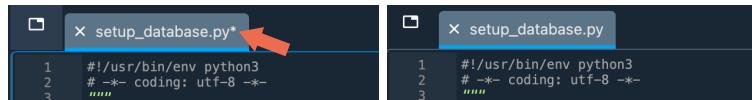


Figure 32.4. Module tab before saving (left) and after saving (right).

Time to call the function again!

- Call the function *after* the change:

```
[2]: 1  username = setup_database.create_username ("John",
      "Gelb")
      print(username)
jgelb
```

username is assigned setup
database dot create username
John Gelb
print username

We call `create_username()` (line 1) and print the output (line 2). We get only one print, that is, the username from line 2, although we expected to see also first name and last name from line 28 of the module. Why does this happen? Because the module and the notebook are not automatically synchronized! When we import a module, the notebook memorizes it as is and does not automatically detect any change that we make afterwards. To **synchronize notebook and module**, we need to use `autoreload`, an IPython extension that **automatically re-imports all modules every time we execute a cell**—as you will see in a bit. What is an **IPython extension**? It is a **module that adds extra functionalities to IPython**—the core of Jupyter Notebook. Extension commands often **start with a percentage**

symbol—they are called **magic commands!**—and can be used only in Jupyter Notebooks—not in Python. Let's see autoreload in action!

- Restart the kernel, then run autoreload:

[1]:	<pre>1 %load_ext autoreload 2 %autoreload 2</pre>	percentage load ext autoreload percentage autoreload 2
------	---	---

Similarly to above, we restart the kernel to have a clear memory. Then, we load autoreload (line 1), and we run autoreload with the **parameter 2**, which indicates that we will **reload all the imported modules** every time we run a cell (line 2). Note that these two lines of code must always be located **in the very first cell of the notebook**—that is, even before the imports—to be effective. Now, let's call the function before—comment out line 28 in the module!—and after the change to test autoreload.

- Call the function *before* the change:

[2]:	<pre>1 import setup_database 2 3 username = setup_database.create_username("John", "Gelb") 4 print(username) jgelb</pre>	import setup database username is assigned setup database dot create username John Gelb print username
------	---	--

As expected, we get the print `jgelb` from line 4. Now, let's make the change in the module again by re-adding `print(first_name, last_name)` at line 28 of the module. **Don't forget to save the file!** It is a **common mistake** not to see the changes reflected in the output because we forgot to save the file! Let's call the function once more, and finally see the effect of autoreload.

- Call the function *after* the change:

[3]:	<pre>1 username = setup_database.create_username("John", "Gelb") 2 print(username) John Gelb jgelb</pre>	username is assigned setup database dot create username John Gelb print username
------	---	--

Finally, we get the print from line 28 of the module—`John Gelb`. This is because autoreload automatically—and secretly!—imported the latest version of `setup_database` before executing the Python commands.

5. Adding functions to a module

As you can imagine, we can add as many functions as we want to a module. However, we should add only the **functions that jointly solve a specific problem or serve a specific task**. For example, in the module `setup_database`, it's meaningful to add `create_password()` and the main function `create_database()` from Chapter 29—see Figure 32.5. It would be inappropriate to add a function that implements—let's say—a calculator because it would be off topic—for that, we would create a separate module. When adding a new function, it is always important to remember three aspects: first, to **update the description** of the module content—see line 8 in Figure 32.5; second, add all **the imports at the very beginning** of the module—see `import random` at line 11 in Figure 32.5; and third, **position the functions in a logically meaningful place** within the file—in our example, first the satellite functions

`create_username()` (lines 13–35) and `create_password()` (lines 38–51), and then the main function `create_database()` (lines 55–90).

```
1  #!/usr/bin/env python3
2  # -*- coding: utf-8 -*-
3  """
4  Created on Wed Jan 29 12:25:45 2025
5
6  @author: serenabonaretti
7
8  This module contains functions to create usernames and passwords, and add them to a database
9  """
10
11 import random
12
13
14 def create_username(first_name, last_name):
15     """Create a lowercase username made of initial of first name and last name
16
17     Parameters
18     -----
19     first_name: string
20         First name of a person
21     last_name: string
22         Last name of a person
23
24     Returns
25     -----
26     username: string
27         Created username
28     """
29
30     # concatenate initial of first name and last name
31     username = first_name[0] + last_name
32     # make sure username is lowercase
33     username = username.lower()
34
35     # return username
36     return username
37
38
39 def create_password():
40     """Create a password composed of four random integers
41
42     Returns
43     -----
44     password: string
45         Created password
46     """
47
48     # create a random number with four digits
49     password = str(random.randint(1000,9999))
50
51     # return password
52     return password
53
54
55 def create_database(customers):
56     """Creates a database as a dictionary with usernames as keys and passwords as values
57
58     Parameters
59     -----
60     customers : list of lists
61         Each sublist contains first name and last name of a customer
62
63     Returns
64     -----
65     db : dictionary
66         Created database (shorted as db)
67     n_customers : int
68         Number of customers in the database
69     """
70
71     # initialize dictionary (i.e. database)
72     db = {}
73
74     # for each customer
75     for customer in customers:
76
77         # create username
78         username = create_username(customer[0], customer[1])
79
80         # create password
81         password = create_password()
82
83         # add username and password to db
84         db[username] = password
85
86         # compute number of customers
87     n_customers = len(db)
88
89     # return dictionary and its length
90     return db, n_customers
```

Figure 32.5. The module `setup_database`.

Copy `create_password()` and `create_database()` from Chapter 29 to the module `setup_database`. Then, let's move to the notebook and call each function to check that they correctly work.

- Call `create_password()`:

```
[4]: 1 password = setup_database.create_password()
      2 print(password)
      4056
```

password is assigned setup database
dot create password
print password

- Call `create_database()`:

```
[5]: 1 customers = [["Maria", "Lopez"], ["Julia",
      "Smith"], ["Mohammed", "Seid"]]
      2 db, n = setup_database.create_database(customers)
      3 print("Database", db)
      4 print("Number of customers:", n)
```

customers is assigned Maria Lopez
Julia Smith Mohammed Seid
db n is assigned setup database
dot create database customers
print Database db
print Number of customers n

Database: 'mlopez': '4476', 'jsmith': '5092', 'mseid': '3543'
Number of customers: 3

As you might have guessed, the call of `any` function from a module follows the syntax that we learned—that is, (1) module name, (2) dot, and (3) function name (line 1 in cell 4, and line 2 in cell 5). Note that we did not need to restart the kernel because we previously ran autoreload, and thus the addition of `create_password()` and `create_database()` are automatically detected.

In this chapter, we learned a **new way of working** that allows us to reuse functions across various projects. In general, we use **Jupyter Notebooks** to **draft code, test it quickly, and integrate narrative** for context—and to learn Python! On the other side, we use **Python modules** to **store functions** that can be called in various **execution environments**, including Spyder, Jupyter Notebook, and the terminal—as you will see in the *In more depth* session at the end of this chapter. Play around with these tools and find your most comfortable way of coding!

Insert into the right column

Group the new syntax and concepts from this chapter in the following table for a structured overview.

```
from, Spyder, random, autoreload, Terminal, import, as, Jupyter Notebook, sys
```

Python keywords	Python built-in modules	Jupyter Notebook extension	Execution environments

Recap

- A module is a file containing functions for a specific task and whose extension is .py.
- In Spyder, we can create and manage modules, and call their functions.
- To import a module we can use four different syntaxes resulting from the combinations of the keywords `import`, `from`, and `as`.
- A package is a collection of modules whose imports and function calls works the same way as for modules.
- To import a module from a separate folder, we use the module `sys` and its command `sys.path.append()`.
- An IPython extension is a module that adds extra functionalities to IPython, which is the core of Jupyter Notebook. Extension commands often start with a percentage symbol and are called magic commands.
- To synchronize a module and a notebook, we use the IPython extension `autoreload`.
- A module can contain as many functions as needed to solve a task. It is good practice to structure a module with (1) documentation, (2) imports, and (3) functions in a logically meaningful order.
- Jupyter Notebook, Spyder, and the terminal are complementary tools to write code.

What is: `if __name__ == "__main__":`

In this chapter, we learned to call functions from a module. However, modules can also be **executed directly**, that is, without manually running cells or calling specific functions. Have you ever seen the command: `if __name__ == "__main__":`? That's what we need! Let's go back to the module `setup_database` that we created in this chapter and add some extra lines of code at the *end* of the file (Figure 32.6 (top)). First, we write the predefined condition `if __name__ == "__main__"`, which tells the computer something like "if you run this file as a module, execute the following commands" (line 93). Then, we write the code to execute. In our case, we create the variable `customers` containing a list of strings with customer names (line 96), call `create_database()` (line 99), and print its outputs (lines 102–103).

```

93  if __name__ == "__main__":
94
95      # input to the main function
96      customers = [["Maria", "Lopez"], ["Julia", "Smith"], ["Mohammed", "Seid"]]
97
98      # create the database
99      database, number_customers = create_database(customers)
100
101     # print the outputs
102     print ("Database:", database)
103     print ("Number of customers:", number_customers)

```

```

Terminal 1
-> serenabonaretti@MacBookAir : cd /Users/serenabonaretti/lpwj/notebooks
-> serenabonaretti@MacBookAir : python3 setup_database.py
Database: {'mlopez': '4098', 'jsmith': '6918', 'mseid': '6770'}
Number of customers: 3
-> serenabonaretti@MacBookAir :

```

Figure 32.6. Code to execute a module (top) and to call it in a terminal (bottom).

Modules can be run in Spyder by simply pressing the *Run* command (box 2 in Figure 32.2). However, the most common way is to use a **terminal**, which is usually preferred **for larger projects** because it runs code in a **fast and automated** way (Figure 32.6 (bottom)). To open a terminal, go to JupyterLab, and click on *File*, *New*, and *Terminal*. Note that in a terminal, we can use only **specific command lines**—not Python! To execute a module, we need two commands. First, we tell the terminal where the module is. To do so, we type **cd**—abbreviation of *change directory*—followed by the **whole path** of the folder containing the module—in this example, `/Users/serenabonaretti/lpwj/notebooks`. We press enter to execute the command. Then, we execute the module by typing (1) the command `python3` (or simply `python` in some terminals), and (2) module name with the extension `.py`. We press enter to execute the command. When the functions are executed, the prints from lines 102 and 103 of the module appear on the terminal, as indicated by the orange arrows in Figure 32.6. Go back to `setup_database`, add the `if __name__ == "__main__"` construct, and run it from Spyder and from terminal. Which way do you prefer?



Let's code!

1. A *module for Bill Gates!* Create a module containing the main and satellite functions you wrote for the coding exercise 1 in Chapter 29 *What does Bill Gates tweet about?* Import the module in a notebook and call the main function. Then, execute the module in a terminal.
2. A *module for hangman!* Do the same as in the previous exercise for the functions of the coding exercise 1 in Chapter 30 *Let's play hangman!*

PART 9

LAST BITS OF BASIC PYTHON

In this part, you will learn how to read and write files and some final types, keywords, built-in functions, and modules. Enjoy it!

33. Birthday presents

Reading and writing .txt files

One important aspect in coding is to know how to read and write files. Let's learn the basics in this chapter! Below is the task we want to solve—follow along with Notebook 33!

- Three of your friends celebrated their birthday this month, and you bought them presents online. Now, it's time to perform a purchase analysis and save it in your records. The purchase amounts are in the file 33_purchases.txt.

How are we going to solve this task? Outline the steps you would take before jumping into the solution below.

To solve the task, we will divide (and conquer!) the problem in three steps. First, we will read the .txt file and store its content into a list. Second, we will analyze the purchases by calculating the minimum, maximum, and total of the amounts in the list. And third, we will save the analysis into a new .txt file. Let's start!

1. Reading a .txt file

Before we start writing the code, it's important to see **what the input file looks like**. Download and save 33_purchases.txt in the same folder as the notebook and open it by double clicking on it either in the File Browser—i.e., the left panel—in Jupyter Lab or in the folder where it is located. You will see something similar to Figure 33.1.

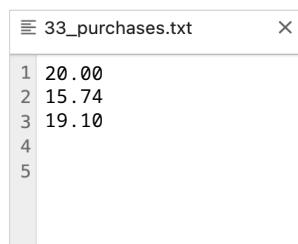


Figure 33.1. Input file.

The file contains three numbers, each on a separate row, representing purchase amounts. Let's read the file and store the three numbers into a list.

- Write a function that reads a .txt file containing one number per row and stores the numbers into a list:

```
[1]: 1 def read_txt (file_name_in):
2     """Reads a .txt file with one number
3         per row and returns them as a list
4
5     Parameters
6     -----
7     file_name_in : string
        Name of the file to read
```

```
def read txt file name in
Reads a .txt file with one number
per row and returns them as a list

Parameters

file name in : string
Name of the file to read
```

```
8      Returns
9      -----
10     numbers : list
11         File content in a list of numbers
12     """
13
14
15     # initialize output
16     numbers = []
17
18     # open the file to read
19     with open(file_name_in, "r") as file:
20
21         # read the file
22         for line in file:
23             print("line as read:", line)
24
25         # remove "\n" from line
26         line = line.rstrip("\n")
27
28         print("line after stripping:", line)
29         print("----")
30
31         # get only the non-empty lines
32         if line != "":
33
34             # transform the number to float
35             number = float(line)
36
37             # add to the output list
38             numbers.append(number)
39
40     # return the output
41     return numbers
42
43 # call the function and print the output
44
45 purchases = read_txt ("33_purchases.txt")
46
47 print("purchases:", purchases)
```

(a) line as read: 20.00
(b)
(c) line after stripping: 20.00
(d)
(e) line as read: 15.74
(f)
(g) line after stripping: 15.74
(h)
(i) line as read: 19.10
(j)
(k) line after stripping: 19.10

Returns

numbers : list
File content in a list of numbers
"
initialize output
numbers is assigned empty list

open the file to read
with open file name in r as file

read the file
for line in file
print line as read line

remove "\n" from line
line is assigned line dot rstrip
backslash n
print line after stripping line
print ----

get only the non-empty lines
if line is not equal to empty
string

transform the number to float
number is assigned float line

add to the output list
numbers dot append number

return the output
return numbers

call the function and print the
output
purchases is assigned read txt 33
purchases dot txt
print purchases purchases

```
(l) -----
(m) line as read:
(n)
(o) line after stripping:
(p) -----
(q) purchases: [20.0, 15.74, 9.1]
```

What happens in the function? Get some hints by completing the following exercise!

True or false?

- | | |
|--|----------|
| 1. The variable <code>file_name_in</code> is a string | T F |
| 2. <code>with</code> and <code>open()</code> are a built-in function and a keyword, respectively | T F |
| 3. In the <code>for</code> loop, we read the file content one line at the time | T F |
| 4. A file cannot contain empty rows | T F |

Computational thinking and syntax

The function `read_txt()` reads a text file containing one number per row and returns the numbers as a list (line 2). The input is the string `file_name_in`—that is, the name of the file to read (lines 4–7)—and the output is the list `numbers` (lines 9–12). In the function body, first we initialize the output `numbers` to an empty list (line 16). Then, we open the file and store its content into a variable by using a standard command composed of four elements (line 19): (1) the keyword `with`, which supports proper **file opening and automatic closing**; (2) the built-in function `open()`, which **opens and reads the file** by taking two arguments—the file name and the string "r" for `reading`—and returns the file content; (3) the keyword `as` to rename the file with its content; and (4) a variable commonly named `file`—or `file_object`, or its abbreviation `fo`—representing the file with its content—if we print `file`, we get something like `<_io.TextIOWrapper name='33_purchases.txt' mode='r' encoding='UTF-8'>`. To extract the content, we write an *indented* `for` loop through values that, at each iteration, stores the current file row into the variable `line` (line 22). When we print `line` for a check (line 23), we get paired prints: (a) and (b), (e) and (f), (i) and (j), and (m), and (n). Why does this happen?

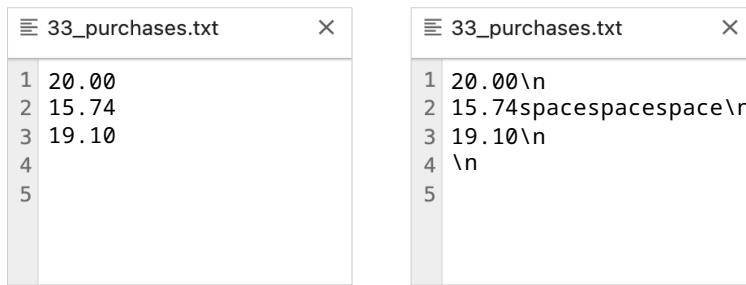


Figure 33.2. How we see a file content (left) vs. how a computer sees a file content (right).

When we **humans** read the file `33_purchases.txt`, we **see three numbers**, each of them in a separate row (Figure 33.2, left). When a **computer** reads the file, it **sees four strings**, each containing some digits and some hidden characters, such as `\n` or space (Figure 33.2, right). Thus, at the first iteration of the `for` loop, the variable `line` contains the string `20.00\n` (line 22). As a consequence, the

print is 20.00 (print (a)) followed by the empty line due to \n (print (b)). At the second iteration, line contains the string 15.74spacespacespace\n, and thus the prints are 15.74 followed by three spaces (print (e))—which we humans do not see!—and an empty line (print (f)). Similarly, at the third iteration, line contains the string 19.10\n, and thus the prints are 19.10 (print (i)) followed by empty line (print (j)). Why is there a fourth iteration? Most likely, who created the file accidentally added a new line before saving the file! Thus, we see no content (print (m)) followed by an empty line (print (n)). Now that we know how a computer reads the file, we have to do some cleaning to obtain the list of numbers! First, we **remove the empty lines** by using the string method .rstrip(), which removes its argument—"\\n"—on the right side of each string line (line 26). To test for correctness, we print line after stripping (line 27), followed by five dashes to ease visualization (line 28). This time, we obtain the line content—prints (c), (g), (k), (o)—without subsequent empty lines. Then, to **remove the empty line at the end of the file**—whose presence was revealed by the print (n)—we create an if condition that excludes empty lines from further processing (line 31). Finally, we **transform the number in line into a float** using the built-in function float(), which **automatically ignores spaces** while converting a string into a number (line 34)—like in the case of 15.74spacespacespace\n. As the last step, we assign the obtained number to the list numbers (line 37) and we return it (line 40). Finally, to execute the function, we call it with the file name "33_purchases.txt" as an input (line 43)—if the file is not in the same folder as the notebook, enter the whole file path! The output is assigned to the variable purchases (line 43), which we print to check for correctness (line 44).

Now that we are aware of the details to consider when reading a file, can we write a more compact code? Yes! The whole function body (lines 15–40) can be shortened in the following three lines!

<pre>15 # open the file 16 with open(file_name_in, "r") as file: 17 18 # read the numbers and transform them 19 # into floats 20 numbers = [float(number) for number 21 in file.read().split()] 22 23 # return the output 24 return numbers</pre>	<pre>open the file with open file_name_in r as file read the numbers and transform them into floats numbers is assigned float number for number in file dot read dot split return the output return numbers</pre>
---	---

We open the file (line 16) using the same command that we learned above (cell 1, line 19). Then, we read the file, clean its content, and create the output list in one single command containing a list comprehension (line 19). To untangle it, let's read the command starting from the for loop: for numbers in file.read().split() assign float(number) to numbers. The method .read() of the variable file **transforms the file content into a long string**—that is, '20.00\n15.74 \n19.10\n\n'. Then, the string method .split() divides the obtained string at white spaces or new lines and transform it into a list of strings—that is, ['20.00', '15.74', '19.10']. Finally, at each loop iteration, each list element is transformed into a float using float(number) and automatically added to the list numbers. Note that since we are using list comprehension, we do not need to initialize the outcome variable numbers. At the end of the function, we return the output numbers (line 22)—as we did in cell 1, line 40.

Now that the three numbers are in the numerical list, let's do some simple analysis on them!

2. Analyzing the numbers

- Write a function that takes a list of numbers as an input and returns the minimum, maximum, and sum as separate variables.

```
[2]: 1 def calculate_stats (numbers):
2     """Returning minimum, maximum, and sum
3         of a list of numbers
4
5         Parameters
6         -----
7         numbers : list
8             Contains numbers
9
10        Returns
11        -----
12        minimum : float
13            Minimum of the list
14        maximum : float
15            Maximum of the list
16        total : float
17            Sum of the list numbers
18
19        # calculate the minimum
20        minimum = min(numbers)
21
22        # calculate the maximum
23        maximum = max(numbers)
24
25        # calculate the sum
26        total = sum(numbers)
27
28        # return the stats
29        return minimum, maximum, total
30
31    # call the function
32    mn, mx, tot = calculate_stats(purchases)
33
34    print("minimum:", mn)
35    print("maximum:", mx)
36    print("total:", tot)
```

<pre>def calculate_stats numbers Returning minimum, maximum, and sum of a list of numbers Parameters numbers : list Contains numbers Returns minimum : float Minimum of the list maximum : float Maximum of the list total : float Sum of the list numbers """ # calculate the minimum minimum = min(numbers) # calculate the maximum maximum = max(numbers) # calculate the sum total = sum(numbers) # return the stats return minimum, maximum, total</pre>	<pre>def calculate stats numbers Returning minimum, maximum, and sum of a list of numbers Parameters numbers : list Contains numbers Returns minimum : float Minimum of the list maximum : float Maximum of the list total : float Sum of the list numbers calculate the minimum minimum is assigned min numbers calculate the maximum maximum is assigned max numbers calculate the sum total is assigned sum numbers return the stats return minimum maximum total call the function mn mx tot is assigned calculate stats purchases print minimum mn print maximum mx print total tot</pre>
--	--

```
minimum: 15.74
maximum: 20.0
total: 54.84
```

Computational thinking and syntax

The function `calculate_stats()` takes a list of numbers as an input (lines 4–7) and returns three variables containing minimum, maximum, and total sum of the list numbers, respectively (lines 9–16). To

calculate the minimum, we use the built-in function `min()`, which takes a list as an input and **returns the minimum number of the list** (line 20). Similarly, to calculate the maximum, we use the built-in function `max()`, which given a list as an input, **returns the maximum number of the list** (line 23). Finally, to calculate the total amount, we use the built-in function `sum()` that, given a list as an input, **returns the sum of the numbers in the list** (line 26). We store the three outputs into the variables `minimum`, `maximum`, and `total` making sure that **we do not use the function names**—see the *In more depth* section *Don't name variables with reserved words!* in Chapter 14. At the end of the function, we return the three variables separately (line 29). Finally, we call the function (line 32) and print the three variables `mn`, `mx`, and `tot` to test for correctness (lines 33–35).

As the last step of our task, let's save the results of the analysis into a new text file!

3. Saving the analysis

- Create a function that given the minimum, maximum, and total, writes them to a file on three consecutive lines, specifying what they represent:

```
[3]: 1 def write_txt(file_name_out, minimum,
               maximum, total):
2     """Writing minimum, maximum, and sum
       to a file
3
4     Parameters
5     -----
6     file_name_out : string
7         Name of the file to write
8     minimum : float
9         Minimum of the list
10    maximum : float
11        Maximum of the list
12    total : float
13        Sum of the numbers in the list
14    """
15
16    # open the file to write
17    with open(file_name_out, "w") as file:
18
19        # write the file content
20        file.write("minimum: " + str(minimum)
21                  + "\n")
22
23        file.write("maximum: " + str(maximum)
24                  + "\n")
25
26        file.write("total: " + str(total))
27
28    # call the function
29    write_txt("33_purchases_stats.txt", mn, mx,
30              tot)
```

```
def write txt file name out minimum
maximum total
Writing minimum, maximum, and sum to a
file

Parameters

file name out : string
Name of the file to write
minimum : float
Minimum of the list
maximum : float
Maximum of the list
total : float
Sum of the numbers in the list

open the file to write
with open file name out w as file

write the file content
file dot write minimum: concatenated
with str minimum concatenated with
backslash n
file dot write maximum: concatenated
with str maximum concatenated with
backslash n
file dot write total: concatenated with
str total

call the function
write txt 33 purchase stats dot txt mn
mx tot
```

What's new in this function? Discover it by completing the following exercise.

True or false?

- | | |
|--|----------|
| 1. The argument "w" in open() defines that we want to close a file | T F |
| 2. .write() is a method of the variable file | T F |
| 3. When writing a file content, we use string concatenation | T F |

Computational thinking and syntax

The function `write_txt()` takes four inputs, that is, the name of the file to write and the calculated minimum, maximum, and total (lines 4–13), and it has no return. We begin the function body with a command that **simultaneously creates and opens a new file** (line 17) and has the same components as the command we used to `open` and `read` a file (cell 1, line 22). The difference is the inputs of `open()`, which now are the name of the file to `write` and the string "`w`" for `writing`—instead of "`r`" for `reading`. Then, indented with respect to the previous line of code, we add the commands to write the file content. Each command is composed of the variable `file` followed by its method `.write()`, which takes **the string to be written into the file as an argument**. Thus, to write the minimum, the argument is "`minimum:` " concatenated with the minimum converted into a string—`str(minimum)`—and the special character "`\n`" to send the following content to a new row (line 20). Similarly, to write the maximum, the argument is "`maximum:` " concatenated with `str(maximum)` and the special character "`\n`" (line 21). Finally, to write the total, the argument is "`total:` " concatenated with the string of `total`. In this last case, we do not add "`\n`" because we do not want to add an empty line at the end of the file (line 22). To conclude, we call the function (line 25), and we obtain the new file `33_purchases_stats.txt`. Check the file by opening it in the File Browser in Jupyter Lab or in the folder. You will see something similar to Figure 33.3.

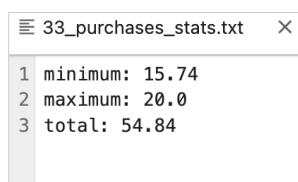


Figure 33.3. Output file.

In this chapter, we learned how to read a file, analyze its content, and write a new file. Did you also notice how the various **functions interact** among each other? We organized `read_txt()`, `calculate_stats()` and `write_txt()` into a **pipeline** where **the output of each function is the input of the following function** (see Figure 33.4). In general, pipelines are a convenient way to solve problems with **linear solutions** and are an alternative to the organization in main and satellite functions—which we learned in Chapter 29. Depending on the nature of the solution, we can use different function configurations to divide and conquer our computational problem!

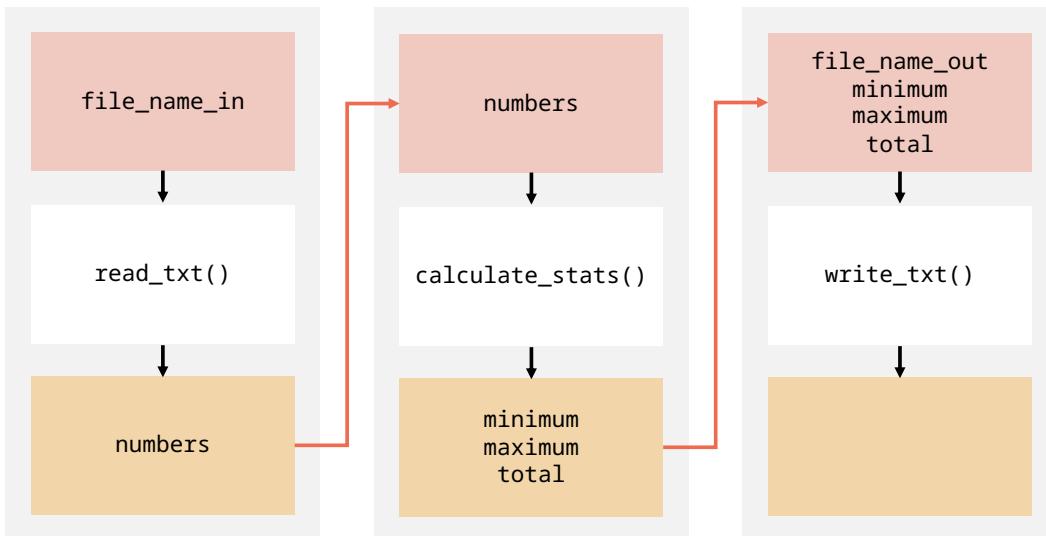


Figure 33.4. Pipeline of functions, where the output of a function (yellow rectangle) is the input of the following function (orange rectangle).

Recap

- To open-and-read or create-and-save a file, we use the command `with open() as file`, where:
 - `with` is a keyword that supports opening and closing a file;
 - `open()` is a built-in function whose arguments are the name of the file to read or write and the strings "`r`" when reading or "`w`" when writing the file;
 - `as` is a keyword to rename the variable representing the file;
 - `file` (or `file_object` or `fo`) is a conventional file name for the variable representing the file.
- To read a file content, we use either a `for` loop that goes through each line of the file content, or the method `.read()` that returns the file content as a long string. To clean the file content, we use string methods such as `.rstrip()` or `.split()`.
- To write content to a file, we use the method `.write()`, which takes a string (or a concatenation of strings) as an argument.
- To calculate minimum, maximum, and sum of a list, we use the built-in functions `min()`, `max()`, and `sum()`.
- To solve problems with linear solutions, we organize functions in pipelines where the output of the previous function is the input of the following function.

How do I organize folders and files?

When coding, we deal with several kinds of files, including modules, notebooks, and data. As projects become larger and more complex, it is important to organize folders and files properly to avoid confusion. A common way is to have a hierarchical structure that starts with a **project folder** enclosing the whole project and containing sub-folders for the sub-projects. Within each sub-folder, it is common to have one folder for **code**—which can contain two sub-folders, one for

notebooks and one for modules—one folder for **data**—with one or more datasets—, and one folder for **documentation**—such as a website, a readme file, or any other document (Figure 33.5, left). This general structure can be adapted to the material of a specific project. For this book, we can create a project folder called *learn_python_with_jupyter*, containing sub-folders named after the book chapters and structured based on their specific material. As an example, the folder *32_modules* contains only the subfolder *code* with the module *setup_database.py* and the notebook *32_modules.ipynb*. The folder *33_read_write_file* contains two folders, that is, *code* with the notebook *33_rw_txt_file.ipynb*, and *data* with the input file *33_purchases.txt* and the output file *33_purchases_stats.txt*. Finally in the project directory, there is the folder *documentation* containing the .pdf of the book (Figure 33.5, right). Every time we approach a new project, let's start by organizing folders and files in a structured way. It is the first step to divide and conquer with clarity!

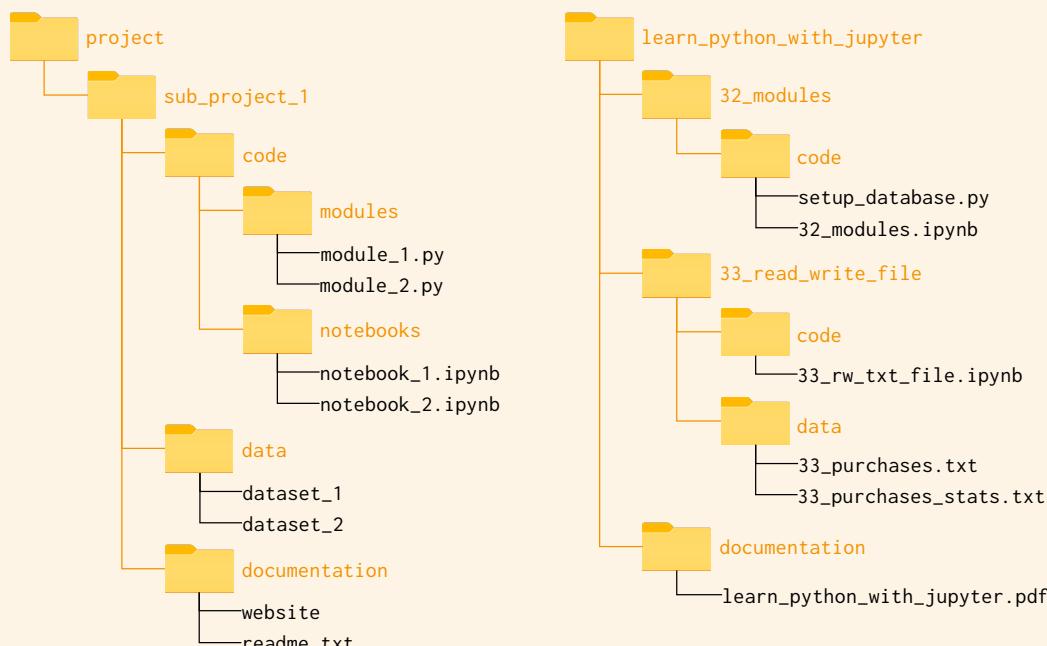


Figure 33.5. Schematics of a common folder and file structure for computational projects (left) and example for the material of Chapters 32 and 33 of this book (right).

Let's code!

1. *Login database for Hollywood actors.* You work at a famous Hollywood agency and need to create usernames and passwords for the actors' accounts.
 - a. *Reading input file.* Create a function that reads the file *actors.txt*—download it from the website—and returns a list of lists where each sub-list contains first name and last name of an actor. Hint: What string method can you use to separate first names and last names?
 - b. *Creating usernames and passwords.* Write a function that reads a list of lists where each sub-list contains first name and last name of an actor, then computes username and password for each actor, and finally returns a list of lists where each sub-list contains a username and a

password. Call the functions from the module `setup_database` (Chapter 32).

- c. *Writing usernames and passwords to file.* Create a function that, given a list of lists where each sub-list contains a username and a password, writes the list to a .txt file where each row contains username and password of an actor. Make sure not to create an empty line at the bottom of the file!

34. What's more in Python?

Additional types, keywords, built-in functions, modules

We are getting to the end of our journey in developing computational thinking while learning Python. Before getting to the last part of this book, where we will learn object oriented programming, let's take a moment to analyze a few more data types, keywords, built-in functions, and modules that are very useful when coding in Python. For the remaining ones, you will be referred to reliable webpages. Follow along with Notebook 34!

1. Data types

We extensively learned about strings, lists, integers and floats, Booleans, and dictionaries. Let's now have a look at the main characteristics of tuples and sets.

1.1 Tuples

We previously learned about tuples as the data type of the output of the built-in function `enumerate()` (Chapter 22), of the dictionary method `.item()` (Chapter 24), and of any function returning more than one variable (Chapter 29). As you might remember, tuples are a sequence of elements enclosed in between **round brackets** and separated by commas. They are **immutable**—that is, their elements cannot be replaced, added, or removed—thus, they are the ideal data type for **variables that do not change throughout the code**. In addition, tuples have only two methods, that is, `.count()`, which returns the **number of times an element is present in a tuple**, and `.index()`, which returns the **position of an element in a tuple**. Let's have a look at a simple example of a tuple and its two methods.

- Given the following tuple:

```
[1]: 1 image_size = (256, 256, 3)           image size is assigned 256 256 3
      2 print(image_size)                   print image size
      (256, 256, 3)
```

The tuple `image_size` contains the dimensions of an RGB image (line 1), where the first element 256 corresponds the number of rows, the second element 256 to the number of columns, and 3 to the color channels—that is, red, green, and blue, as you might remember from the *In more depth* section *Lists of lists and images* in Chapter 23. In the following line, we print the tuple to check for correctness (line 2).

- Calculate how many times 256 is present:

```
[2]: 1 print(image_size.count(256))           print image size dot count 256
      2
```

We use the method `.count()` that takes the number whose presence we want to count—that is, 256—as an argument and returns the number of times that number is present—that is, 2—which we directly print (line 1).

- Compute the position of 3:

```
[3]: 1 print(image_size.index(3))           print image size dot index three
      2
```

We use the method `.index()` that takes the number whose position we want to know—that is, 3—as an input and returns its position—that is, 2—which we directly print (line 1).

1.2 Sets

A **set** is a data type whose elements are enclosed in between **curly brackets** and **separated by comma**. Sets have three main characteristics: (1) they are **immutable**—like tuples; (2) they are **unordered**, that is, their elements do not have a fixed position—thus, sets **cannot be sliced**; and (3) they contain **unique** elements, therefore no duplicates are allowed. Let's have a look at a set.

- Given the following set, print it:

```
[4]: 1 cities = {"Buenos Aires", "Prague", "Delhi", "Delhi"}  
2 print(cities)  
3 print("The number of elements is:", len(cities))  
  
{'Delhi', 'Buenos Aires', 'Prague'}  
The number of elements is: 3
```

```
cities is assigned Buenos  
Aires Prague Delhi Delhi  
print cities  
print The number of elements  
is: len cities
```

We create a set called `cities` containing 4 elements that are strings (line 1) and we print it (line 2). From the print, we can see that the resulting set is different from what we defined at line 1. Because sets are unordered—characteristic (2) above—the elements are internally organized differently than in their definition, and they might be printed in a different order every time. Second, because sets contain only unique elements—characteristic (3) above—"Delhi" is present only once. Thus, `cities` actually contains only 3 elements, as we can see when printing its length (line 3).

Given their characteristics, sets are very convenient **intermediates for list operations**. We can use set properties to remove duplicates from a list and two set methods—`.union()` and `.intersection()`—to respectively merge two lists and find their common elements—sets have 15 more methods, which you can easily explore on the internet¹. Let's look at some examples.

- Given the following list:

```
[5]: 1 cities = ["San Francisco", "Melbourne",  
"San Francisco", "Milan"]
```

```
cities is assigned San Francisco  
Melbourne San Francisco Milan
```

We start with the list `cities` containing four strings, two of which are the same—"San Francisco" is both in positions 0 and 2.

- Remove the duplicates:

```
[6]: 1 cities = list(set(cities))  
2 print(cities)
```

```
cities is assigned list set cities  
print cities
```

```
['Milan', 'Melbourne', 'San Francisco']
```

We use the built-in function `set()` to **transform the list into a set**, and thus automatically **remove duplicate elements**. Then, we use the built-in function `list()` to transform the obtained set **back to a list** (line 1). From the print, we see that "San Francisco" is now present only once. Note that the order of the list elements is now different from the original list (cell 5) because sets are unordered. Thus, this trick is useful only when the element order is not important! Let's look into the next examples.

¹Example: https://www.w3schools.com/python/python_ref_set.asp

- Given the following lists:

```
[7]: 1 cities_1 = ["Santiago", "Bangkok",
    "Cairo", "Santiago"]
1 cities_2 = ["Cairo", "Cape Town"]
```

cities one is assigned Santiago Bangkok
Cairo Santiago
cities two is assigned Cairo Cape Town

We start with two lists called `cities_1` and `cities_2` containing 4 and 2 strings respectively.

- Create a new list that contains unique elements from both lists:

```
[8]: 1 all_cities = list(set(cities_1).union(
    set(cities_2)))
2 print(all_cities)
['Bangkok', 'Cape Town', 'Santiago', 'Cairo']
```

all cities is assigned list set cities
one dot union set cities two
print all cities

Let's understand the nested code at line 1 with the help of Figure 34.1. We transform the two lists `cities_1` and `cities_2`—represented by the orange and yellow rectangles at the top of the figure—to the corresponding sets—orange and yellow ellipses—at the top of the figure—using the built-in function `set()`. Then, we apply the method `.union()` to `set(cities_1)` with `set(cities_2)` as an argument to **merge the elements that are present in both sets**—we could have also applied `.union()` to `set(cities_2)` with `set(cities_1)` as an argument. To the output set, we directly apply the built-in function `list()` and obtain `all_cities`—green rectangle at the bottom of the figure—that is, a list containing the four unique elements of the two initial lists. At line 2 of the code, we print `all_cities` to test for correctness.

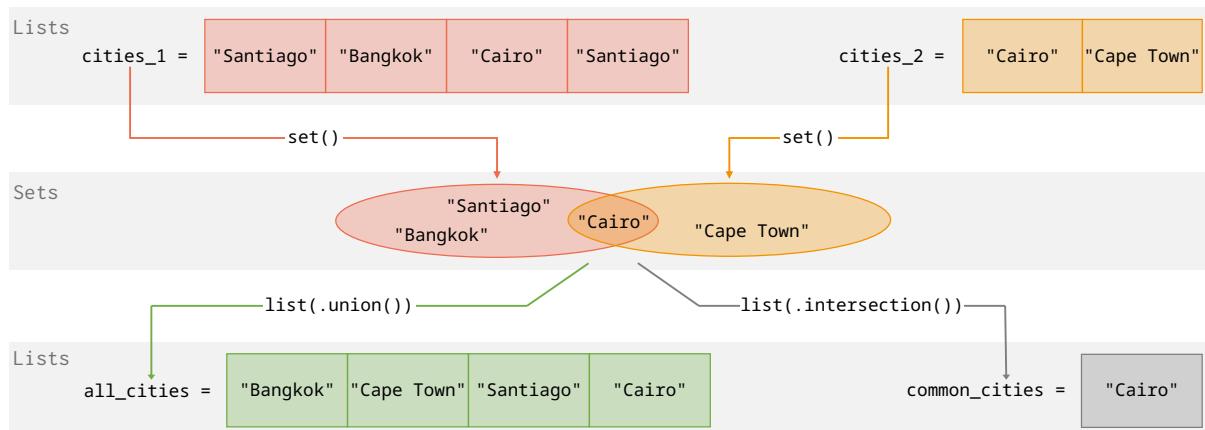


Figure 34.1. Using the sets methods `.union()` and `.intersection()` to merge two lists or find their common elements.

- Create a new list that contains the elements common to both lists:

```
[9]: 1 common_cities = list(set(cities_1).
    intersection(set(cities_2)))
2 print(common_cities)
['Cape Town']
```

common cities is assigned list set cities
one dot intersection set cities two
print common cities

We perform the same steps as above but we use the set method `.intersection()` to **extract the common elements in the sets**. We obtain the list `common_cities`—gray rectangle in Figure 34.1—containing only the common element "Cape Town". Finally, we print to check for correctness (line 2).

2. Keywords

You already know many Python keywords—including `for`, `del`, `def`, `if`, etc. You can find the complete list of keywords on several webpages². In this section, we will focus on `lambda`.

2.1 `lambda`

The keyword `lambda` is used to create **one line functions containing one single operation**. These compact functions are called **anonymous functions**—because they do not have a name!—or **lambda functions**—after the keyword. To understand how they work, let's compare a simple regular function that calculates the double of a number with its corresponding lambda function.

- Here is the regular function:

[10]:	<pre> 1 def double_number (number): 2 """Returns the double of a number 3 4 Parameters 5 ----- 6 number : float 7 The input number 8 9 Returns 10 ----- 11 float 12 The double of the input number 13 """ 14 15 return number * 2 16 17 print(double_number(5)) 10 </pre>	<pre> def double number number Returns the double of a number Parameters number : float The input number Returns float The double of the input number return number times two print double number five </pre>
-------	--	---

In the function `double_number`, the input is a float (lines 1 and 4–7) and the output is the calculated double (lines 9–12 and 15). We call the function for the number 5 and directly print the output (line 17).

- Here is the corresponding lambda function:

[11]:	<pre> 1 double_number = lambda number: number * 2 2 print(double_number(5)) 10 </pre>	<pre> double number is assigned lambda number number times two print double number five </pre>
-------	---	--

The typical syntax of a lambda function is represented at line 1 after the assignment symbol. It includes: (1) the keyword `lambda`; (2) the function `input`—that is, `number`; (3) `colon`; and (4) the **operation that computes the output**—that is, `number * 2`. It is common to **assign a lambda function to a variable**—in our case, `double_number`—to call it. To better understand the syntax of a lambda function, let's compare it with the syntax of the corresponding regular function, with the help of Figure 34.2. The input number (orange rectangle) is in between round brackets in the header of a regular function (line (a)), whereas it is positioned right after the keyword `lambda` in a lambda function (line (c)). The operation that computes the output `number * 2` (yellow rectangle) is after the keyword `return` in a

²Example: https://www.w3schools.com/python/python_ref_keywords.asp

regular function (line (b)), whereas it is after the colon in a lambda function (line (c)). Finally, the regular function has a name—e.g., `double_number` (gray rectangle at line (a))—whereas a lambda function is often **assigned to a variable** (gray rectangle at line (c)).

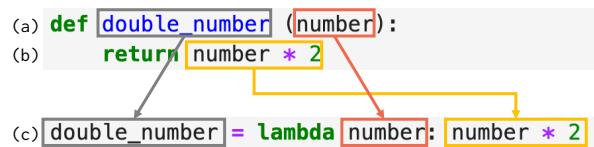


Figure 34.2. Regular function (a-b) and corresponding anonymous function (c).

To **call a lambda function**, we write the **name of the function variable** followed by the **input in round brackets** (cell 11, line 2). For convenience, we directly print the output to check for correctness. Lambda functions are particularly convenient when we want to apply simple operations to list elements. To do so, we use the built-in function `map()`, as you will learn in the coming section.

3. Built-in functions

In the past chapters, you learned several Python built-in functions, including `print()`, `input()`, `len()`, `sum()`, etc. Python has a total of 71 built-in functions, which you can discover in the official Python documentation³. In this chapter, we briefly explore `map()`.

3.1 map()

The built-in function `map()` is commonly used to **apply a lambda function to each element of a list**. It somehow acts like a `for` loop that extracts one list element at the time and applies a wanted function to it. Let's see how `map()` works with the following example.

- Double each list element using a lambda function:

<pre>[12]: 1 numbers = [3, 5, 7] 2 doubles = list(map(double_number, numbers)) 3 print(doubles) 10</pre>	<pre>numbers is assigned three five seven doubles is assigned list map double number numbers print doubles</pre>
--	--

We create a list containing three integers and we name it `numbers` (line 1). Then, we use `map()` with two inputs: the lambda function `double_number`—from cell 11—and the list we want to apply the lambda function to, that is, `numbers` from line 1—note that it's also common to write the lambda function directly into the `map()` command: `map(lambda number: number * 2, numbers)`. Because `map()` returns its own type, we transform the output to a list using the built-in function `list()` (line 2). Finally, we print the output to check for correctness (line 3).

4. Modules

Python provides numerous built-in modules that can be found on the official website⁴. In this section, we will learn one more function of the module `random` and introduce the module `time`.

³docs.python.org/3/library/functions.html

⁴docs.python.org/3/library/

4.1 random

We already know two functions of the module `random`, that is, `.randint()` to generate random numbers within a range and `.choice()` to randomly pick an element from a list. When using these functions, it can be hard to **debug code or verify the correctness of results** because the generated random output is **different at each execution**. For example, when we generate a random number twice, we obtain two different results, as we can see in the example below.

- Generate a random integer between 1 and 10 twice:

```
[13]: 1 import random
      2
      3 n = random.randint(1, 10)
      4 print("n:", n)
      5 n = random.randint(1, 10)
      6 print("n:", n)

n: 7
n: 9
```

import random
n is assigned random dot randint one ten
print n n
n is assigned random dot randint one ten
print n n

We begin by importing the module random (line 1). We use the command `.randint()` to generate a random integer between 1 and 10 (line 3), and we print it (line 4). The generated number is 7. Then, we rewrite the same commands as above (lines 3–4) to generate another random integer between 1 and 10 (lines 5–6). This time, we obtain 9. As expected, the two generated numbers are different. But how are these numbers created? When we call `.randint()`, we execute a process similar to the one shown in Figure 34.3. The core is an **algorithm** consisting of a set of complicated but **deterministic**—that is, well defined—operations that transform an input number into an output number. The input number is called **seed number** and is usually determined from the combination of the current time and date on our computer—and thus it is unique because time always progresses. The output number is a **pseudorandom number**—not completely random!—because it looks random but is actually generated by a deterministic process.

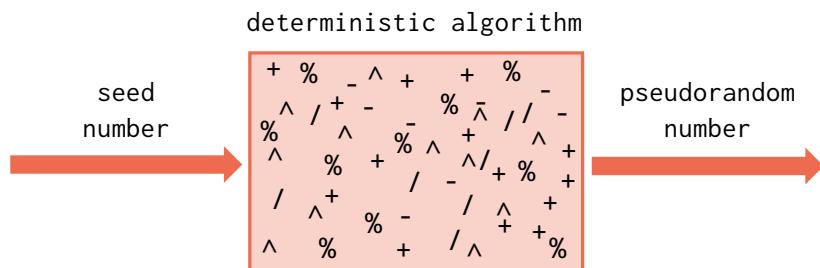


Figure 34.3. Scheme of a pseudorandom number generator.

Can we generate the **same random number**—or better, pseudorandom number—every time we run the code? Yes, when we specify the **seed number**! Let's see how it works in the following example.

- Generate a random integer between 1 and 10 twice, using a seed number:

```
[14]: 1 random.seed(18)
2 n = random.randint(1, 10)
3 print("n:", n)
4
5 random.seed(18)
6 n = random.randint(1, 10)
7 print("n:", n)

n: 3
n: 3
```

```
n is assigned random dot seed 18
n is assigned random dot randint one ten
print n n

n is assigned random dot seed 18
n is assigned random dot randint one ten
print n n
```

From the module `random`, we call the function `.seed()`, which **takes a seed number as an input** (line 1)—in this example, 18. We generate a random number between 1 and 10 using the same commands as above—that is, lines 2–3 are the same as lines 3–4 from cell 13. We obtain the number 3. Then, we reuse the same commands to provide the same seed number and generate a new random number (lines 5–7). As expected, we obtain 3 again. Thus, when using a seed number, the generation of a random number is **reproducible** and we can debug code and verify results much easier. Finally, what number should we pick as a seed number? Any number we want! Our choice of a seed number is the only real random factor when generating random numbers!

4.2 time

Knowing the **computational time**—that is, how long a computation takes—is very important, especially when running large projects. In Python, we can use the module `time`. Let's see how it works with the following example.

- Compare the time it takes to create a list with ten, a hundred, and a thousand zeros, using a `for` loop vs. list replication. What do you think the time difference will be?

```
[15]: 1 import time
2
3 # lists lengths
4 n_of_elements = [10, 100, 1000]
5
6 # for each length
7 for n in n_of_elements:
8
9     print("N. of zeros:", len(numbers))
10
11    # create the list using the for loop
12    start = time.time()
13    numbers = []
14    for _ in range(n):
15        numbers.append(0)
16    end = time.time()
17    print("For loop: {:.6f} sec".format(end-start))
18
```

```
import time

lists lengths
n of elements is assigned 10 100
1000

for each length
for n in n of elements

print N. of zeros: len numbers

create the list using the for loop
start = time dot time
numbers is assigned empty list
for underscore in range n
numbers dot append zero
end is assigned time dot time
print For loop: {:.6f} sec dot format
end minus start
```

```
19      # create the list using list replication
20
21      start = time.time()
22      numbers = [0]*n
23
24      end = time.time()
25      print("List repl: {:.6f sec".format(end-start))

N. of zeros: 10
For loop: 0.004142 sec
List repl 0.000001 sec

N. of zeros: 100
For loop: 0.000024 sec
List repl 0.000002 sec

N. of zeros: 1000
For loop: 0.000147 sec
List repl 0.000004 sec
```

```
create the list using list
replication
start is assigned time dot time
numbers is assigned zero list
replication n
end is assigned time dot time
print List repl: {:.6f sec dot
format end minus start
```

Let's start by analyzing the code to create the lists. We begin with the list `n_of_elements`, which contains the lengths of the lists that we are going to create (line 4). Then, we write a `for` loop that spans the list lengths (line 7). For each length, first, we print the number of zeros that will be contained in the list (line 9). Then, we create a list using a `for` loop (lines 11–17), that is, we initialize the empty list (line 13), create a `for` loop through indices that goes from `0` (omitted) to the current length (line 14), and we append `0` to the list `numbers` at each iteration (line 15). Finally, we create a list using list replication (line 19–23), where we replicate the list `[0]` by the number of zeros `n` (line 21). How do we calculate the time of these computations? First, we import the module `time` (line 1). Then, before each list creation, we call the function `.time()` from the module `time` and we assign the output to the variable `start` (lines 12 and 20). This command corresponds to **pressing start on a stopwatch**. After each list creation, we call again the function `.time()` from `time`, and we assign it to the variable `stop` (lines 16 and 22)—like we pressed **stop on a stopwatch**. Finally, we print the **difference between stop and start** to know the computational time in **seconds** (lines 17 and 23). To obtain a clear print, we use the string method `.format()` with six digits. As you can see, creating a list with a `for` loop is much slower than with list replication, especially for long lists! Finally, the computational time depends on the amount of processes—for example, emails, opened documents, etc.—that are currently running on the computer and the characteristics of the computer, thus, it can be different at different times or across computers.

5. Swapping variables

Let's conclude with a nice trick in Python—not available in many other programming languages!—that is, is the ability to swap variables in a single line. Let's see how it works in the example below:

```
[16]: 1 v_1 = "a"
2 v_2 = "b"
3 print("v_1:", v_1)
4 print("v_2:", v_2, "\n-----")
5
6 v_1, v_2 = v_2, v_1
7
8 print("v_1:", v_1)
9 print("v_2:", v_2)

v_1: a
v_2: b
-----
v_1: b
v_2: a
```

```
v one is assigned a
v two is assigned b
print v one v one
print v two v two backslash n dashes

v one v two is assigned v two v one

print v one v one
print v two v two
```

We create two variables, that is, `v_1` to which we assign the string "`a`" (line 1) and `v_2` to which we assign the string "`b`" (line 2). We print them for a check (lines 3 and 4). Then, we swap the variables by writing: (1) the two variables separated by a comma, (2) the assignment symbol, and (3) the two variables separated by a comma in inverted order (line 6). When we reprint the variables (lines 8 and 9), we can see that the values are swapped because `v_1` now contains "`b`" and `v_2` now contains "`a`"!

Recap

- Tuples are a data type containing immutable elements and have two methods: `.count()` and `.index()`.
- Sets are a data type whose elements are immutable, unordered, and unique. They have 17 methods, including `.union()` and `.intersection()`. Sets can be useful intermediaries for list operations such as duplicate removal, merging two lists, or find the common elements in two lists.
- The keyword `lambda` allows the creation of anonymous functions, which are compact functions composed of (1) `lambda`, (2) input, (3) colon, and (4) operation generating the output.
- The built-in function `map()` is useful when applying a lambda function to each element of a list.
- The function `.seed()` from the module `random` allows us to create reproducible random—or more technically, pseudorandom—numbers.
- To calculate computational time, we use the module `time`. Its function `.time()` acts like the start or stop of a stopwatch.

What is pip install?

Have you ever seen the command `pip install`? It is a terminal command to install Python packages. A **package** is simply a **collection of modules**—that is, .py files containing functions for a specific task, as you might recall from Chapter 32. Some of the most popular packages include NumPy for numerical computing, Pandas for data manipulation and analysis, Matplotlib and Seaborn for data visualization, Scikit-learn for machine learning and Tensorflow and Pytorch for deep learning. To share a package with others, developers upload it to PyPi (Python Package Index; www.pypi.org), a repository hosting hundreds of thousands of Python packages. When we want to use a package in our code (e.g. Pandas), we typically follow 2 simple steps:

1. Install the package. To do that, we open the terminal and we write `pip install` and the name of the package—e.g., `pip install pandas`. This command downloads the package from PyPi and installs it on our computer
2. Import the package in our Python code. We import packages exactly like we import modules, that is by writing the command `import` followed by the name of the package—e.g., `import pandas`

How to create a package is beyond the scope of this book; however, you can find a detailed guide in the official documentation at packaging.python.org.

Let's code!

1. *How long does it take to square numbers?* Create a regular function that given a number returns its square. Then, write the corresponding lambda function. Finally, apply both functions to a list of 10 numbers. How long do all these operations take?
2. *How long does it take to concatenate lists?* Create two lists, one containing integers from 0 to 10000, and another containing integers from 10001 to 20000. Hint: use `range()`—see Chapter 8. Then, merge the two lists once by adding one element at the time from the second list to the first, and once by using list concatenation. Which method is faster? By how much?

PART 10

OBJECT-ORIENTED PROGRAMMING

In this last part, you will learn how to code using classes and objects, with their attributes and methods. Ready to expand your horizon?

35. Let's build an online store!

Classes and objects, attributes and methods

Up to this point, we've learned Python's grammar, including data types, operators, loops, and functions. We've also learned how to code following the principles of **procedural programming**, that is, creating **step-by-step instructions** that are **executed sequentially** to get to the solution of a task. In this last part of the book, we will switch gears and learn the basics of **object-oriented programming**—commonly abbreviated as OOP. It is a different way of thinking about code, based on the **representation of the world in classes and objects, with their attributes and methods**. Let's get familiar with these new concepts while solving the following task. Follow along with Notebook 35!

- You are building a new online store where you will sell various types of products. Each product will have a similar webpage containing characteristics such as name, original price, and discount. In addition, there will also be two possible actions: apply coupon (to add the value of a coupon to the discount) and calculate price (to calculate an item price).
 1. Create a template for the webpage and then customize it for a T-shirt and a lamp with the following characteristics:
 - T-shirt: name: **Feel good**, original price: **30 coins**, launch discount: **4 coins**;
 - Lamp: name: **Lux**, original price: **40 coins**, no launch discount.
 2. Then, execute these actions for each product:
 - Calculate the price after the discount;
 - Calculate the price after adding the coupon **SAVE4** worth **4 coins** to the T-shirt and the coupon **SUMMER10** worth **10 coins** to the lamp.

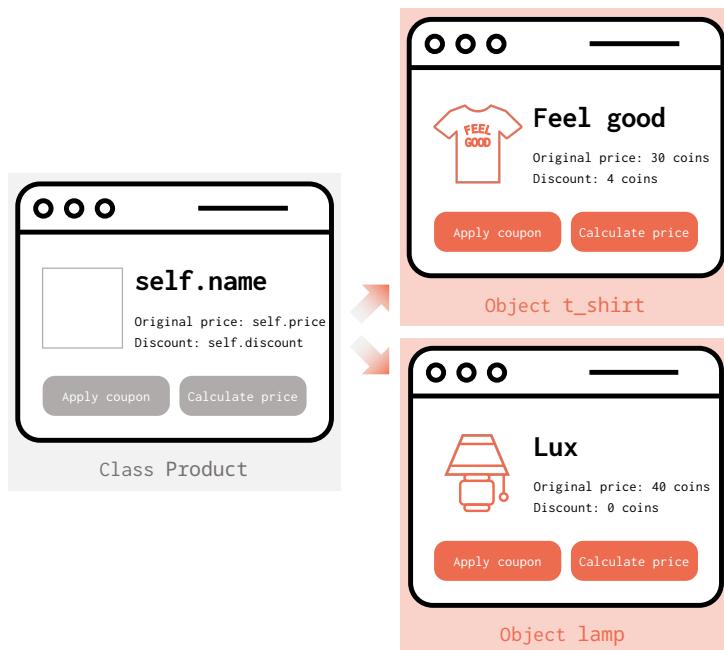


Figure 35.1. Representation of the class **Product** (left) and its objects **t_shirt** and **lamp** (right).

How do we solve this task? We will create a **class** (in grey in Figure 35.1) for the webpage template and two **objects**, one for the T-shirt, and one for the lamp (in orange). For the product **characteristics**—name, price, and discount—we will define **attributes**, whereas for the **actions**—apply coupon and calculate price—we will implement **methods**. For now, just focus on understanding the syntax of the code and its functionality. By the end of the chapter, concepts and definitions will become clear. In the next pages, the code will be presented without pronunciation guides, and functions will have reduced documentation because of the large number of commands. However, it is always recommended to read code carefully and write complete function documentation for better understanding and reuse. Enough talk, let's jump into the code!

1. Class, objects, and attributes

Let's start from the first point of the task. Here we have a class representing the webpage template and an object representing the T-shirt—we will create the object representing the lamp at the end of this first section. Read the code below and try to understand its syntax and functionality.

- Here is the class representing a product and its attributes:

```
[1]: 1 class Product:  
2     """Class representing a product"""  
3  
4     # --- CONSTRUCTOR -----  
5     def __init__(self, name):  
6         """Constructor"""  
7         self.name    = name  
8         self.price   = 0  
9         self.discount = 0
```

- Here is the object `t_shirt` with its attributes at instantiation and after customization:

```
[2]: 1 t_shirt = Product("Feel good")  
2  
3 print("-> Attributes of the object t_shirt at instantiation:")  
4 print("Name:", t_shirt.name)  
5 print("Price:", t_shirt.price, "coins")  
6 print("Discount:", t_shirt.discount, "coins")  
7  
8 print("-> Attributes of the object t_shirt after customization:")  
9 t_shirt.price = 30  
10 print("Price:", t_shirt.price, "coins")  
11 t_shirt.discount = 4  
12 print("Discount:", t_shirt.discount, "coins")
```

- (a) -> Attributes of the object `t_shirt` at instantiation:
- (b) Name: Feel good
- (c) Price: 0 coins
- (d) Discount: 0 coins
- (e) -> Attributes of the object `t_shirt` after customization:
- (f) Price: 30 coins
- (g) Discount: 4 coins

What happens in the code above? Get some hints by solving the following exercise.

 True or false?

- | | | |
|---|---|---|
| 1. To create a class we use the keyword class | T | F |
| 2. Product is an object and t_shirt is a class | T | F |
| 3. A class contains a constructor | T | F |
| 4. We use the variable self both in classes and objects | T | F |
| 5. An attribute is a variable whose value can change | T | F |

Computational thinking and syntax

In cell 1, we create a **class** by writing: (1) the keyword **class**, (2) the **class name**, and (3) **colon** (line 1). Unlike variable names, class names are **capitalized**, and if they consist of multiple words, each word begins with a capital letter—such as in `CustomerOrder`, for example. In our code, the class name is `Product`. All the code that follows this first line is **indented**. We write a **one-line documentation** describing the purpose of the class (line 2). Then, there is the **constructor** (lines 4–9), which is a method—that is, a class function, as we will see in the next section—that is always present in a class and is used to create an object, as we will learn in a bit. The constructor has the predefined name `__init__()` and one or more parameters in between round brackets (line 5). The **first parameter** is a variable commonly called **self**. For now, just consider `self` as part of the syntax. We will clarify its meaning in the `In more depth` section in the next chapter. The second parameter is `name`. Below the header, there is a one-line documentation specifying that this is the constructor (line 6). In the body, there are three variables, which we call **attributes** (lines 7–9). Each is composed of (1) `self`, (2) `dot`, (3) **attribute name**, (4) **assignment symbol**, and (5) **a variable or an initializing value**. In our example, the first attribute is `self.name` (line 7), and it is assigned the variable `name`—that is, the second parameter of the constructor (line 5). The second attribute is `self.price` and is initialized with `0` (line 6). Similarly, the third attribute is `self.discount` and is initialized with `0` (line 7). Note that an input variable and the corresponding attribute often have the **same name**—such as `name` and `self.name`—to improve readability and indicate their connection. Also, it is common to align the assignment symbols vertically for a clearer readability of the attributes. Finally, all the attributes are in blue in Jupyter Notebook. When we run a cell containing a class, the class is saved in memory but no code is executed—similarly to when we run a cell containing a function without its call. To “execute” the code of a class, we need an object.

To **instantiate**—that is, create—an object, we write: (1) **object name**, (2) **assignment symbol**, (3) **class name**, and (4) **arguments**—excluding `self`!—in between round brackets. In our example, we instantiate `t_shirt` as an object of the class `Product` with the argument “Feel good” (cell 2, line 1). What happens behind the scenes when we instantiate an object? We **call the constructor** of the class! In our case, we call `__init__()` in `Product` and we pass the argument “Feel good” to the variable name (orange arrow in Figure 35.2). There, the value in `name`—that is, “Feel good”—is assigned to the attribute `self.name` (line 7 in cell 1, and grey arrow in Figure 35.2, left). At this point, the object `t_shirt` is created and it **has all the attributes specified in the class** (black arrows in Figure 35.2). The syntax for an **attribute** in an **object** is: (1) **object name**, (2) `dot`, and (3) **attribute name**. Thus, the attribute `self.name` in the class `Product` is `t_shirt.name` in the object `t_shirt`. Similarly, the attribute `self.price` in `Product` is `t_shirt.price` in `t_shirt`, and `self.discount` is `t_shirt.discount`.

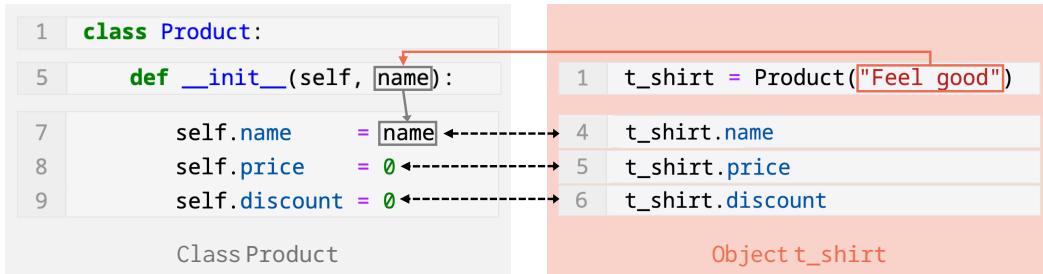


Figure 35.2. Class `Product` (left) and its object `t_shirt` (right). At instantiation, "Feel good" is passed to the parameter `name` and `t_shirt` gets the attributes of `Product`.

What are the **initial values** of an object's attributes? **At instantiation**, the object's attributes have the **values defined in the constructor**—remember, the class is a template! Thus, when we print `t_shirt.name`, we obtain `Feel good` (line 4; print (b)), that is, the value in `name`, as defined in the class (cell 1, line 7). When we print `t_shirt.price`, we obtain `0` (line 5; print (c)), as defined in the class (cell 1, line 8). And similarly, when we print `t_shirt.discount`, we obtain `0` (line 6; print (d)), as defined in the class (cell 1, line 9). How can we **customize the values of an object's attribute**? Simply, by **assignment**. Thus, to set the original price of the T-shirt to 30 coins, we write `t_shirt.price = 30` (line 9), and from the print we see that the attribute `t_shirt.price` now has value 30 (line 10; print (f)). Similarly, to customize the launch discount, we assign the value 4 to `t_shirt.discount` (line 11), and when we print it, we see that the value is now 4 coins (line 12, print (g)).

Let's create the object `lamp`, as requested by the first point of the task. How would you do it? Instantiate `lamp` and play with its attributes before looking at the solution below.

- Here is the object `lamp` with its attributes:

```
[3]: 1 lamp = Product("Lux")
2 lamp.price = 40
3 print("Name:", lamp.name)
4 print("Price:", lamp.price, "coins")
5 print("Discount:", lamp.discount, "coins")
(a) Name: Lux
(b) Price: 40 coins
(c) Discount: 0 coins
```

We instantiate `lamp` as an object of the class `Product` with the value "Lux" as the argument (line 1). Then, we change the lamp price from the default 0—in the class, `self.price` is initialized to 0 (cell 1, line 8)—to 40 with an assignment (line 2). Because the lamp has no discount, `lamp.discount` has the default value 0 (cell 1, line 9), and thus we do not need to write any assignment command. When we print the attributes, we see that `lamp.name` is now "Lux" (line 3, print (a)), `lamp.price` is 40 (line 4; print (b)), and `lamp.discount` is 0 (line 5; print (c)).

2. Methods

Let's tackle the second point of the task! We need to implement two actions, that is, applying a coupon and calculating an item price. To do so, we copy the class `Product` and we add two methods called `apply_coupon()` and `calculate_price()` (cell 4, lines 12–27)—in the code below you will find also the

built-in method `__str__()` (lines 31–33) that we will discuss at the end of the chapter. Because the class is changed, we need to re-instantiate the object `t_shirt` to add the new functionalities (cell 5). Read the following code and try to understand what it does!

- Here is the complete class with its attributes and methods:

```
[4]: 1 class Product:
2     """Class representing a product"""
3
4     # --- CONSTRUCTOR -----
5     def __init__(self, name):
6         """Constructor"""
7         self.name = name
8         self.price = 0
9         self.discount = 0
10
11
12     # --- METHODS -----
13     def apply_coupon(self, coupon):          # added
14         """Updates discount based on a coupon"""
15         if coupon == "SAVE4":
16             self.discount = self.discount + 4
17             print("Coupon SAVE4 applied!")
18         elif coupon == "SUMMER10":
19             self.discount = self.discount + 10
20             print("Coupon SUMMER10 applied!")
21         else:
22             print("Your coupon is not valid")
23
24     def calculate_price(self):           # added
25         """Calculates price after discount"""
26         updated_price = self.price - self.discount
27         return updated_price
28
29
30     # --- BUILT-IN METHOD -----
31     def __str__(self):                  # added
32         """Prints the object characteristics"""
33         return "Name: " + self.name
```

- Instantiate the object `t_shirt` with its attributes. Then, calculate the price after discount, and the price after discount and coupon:

```
[5]: 1 # instantiating the object with its attributes
2 t_shirt = Product("Feel good")
3 t_shirt.price = 30
4 t_shirt.discount = 4
5 print("Name:", t_shirt.name, "| original price:", t_shirt.price,
6      "coins | launch discount:", t_shirt.discount, "coins")
```

```

7 # calculating the price after launch discount
8 print("-> Price after launch discount")
9 t_shirt_price = t_shirt.calculate_price()
10 print("Price:", t_shirt_price, "coins")
11
12 # applying the coupon
13 print("-> Applying the coupon")
14 t_shirt.apply_coupon("SAVE4")
15 print("Discount:", t_shirt.discount, "coins")
16
17 # calculating the price after launch discount and coupon
18 print("-> Price after launch discount and coupon")
19 t_shirt_price = t_shirt.calculate_price()
20 print("Price:", t_shirt_price, "coins")
(a) Name: Feel good | original price: 30 coins | launch discount: 4 coins
(b) -> Price after launch discount
(c) Price: 26 coins
(d) -> Applying the coupon
(e) Coupon SAVE4 applied!
(f) Discount: 8 coins
(g) -> Price after launch discount and coupon
(h) Price: 22 coins

```

What are methods and how do they work? Get some hints by solving the following exercise!

True or false?

- | | | |
|--|---|---|
| 1. Methods are functions in a class | T | F |
| 2. An object cannot call a class method | T | F |
| 3. The method <code>apply_coupon()</code> modifies the attribute <code>t_shirt.discount</code> | T | F |
| 4. The method <code>calculate_price()</code> adds the discount to the original price | T | F |

Computational thinking and syntax

Methods are simply **functions in a class**. Their **first parameter** is usually **self**, as we can see in the headers of `apply_coupon()` (cell 4, line 13) and `calculate_price()` (line 24). In case of additional parameters, they are placed after `self`—such as `coupon`, which is in second position in the `apply_coupon()` header (line 13). Because `self` is a parameter, **attributes can be accessed and modified directly within methods**. We will explain why in the *In more depth* session in the next chapter. Thus, in `apply_coupon()` we can modify `self.discount` without passing it as parameters (lines 16 and 19). Similarly, in `calculate_price()` we can directly use `self.price` and `self.discount` (line 26). What do `apply_coupon()` and `calculate_price()` do? The method `apply_coupon()` contains an `if/elif/else` construct specifying the update of `self.discount` based on a coupon. If `coupon` is "SAVE4" (line 15), we add 4 coins to `self.discount` (line 16) and we print a message accordingly (line 17); otherwise if `coupon` is "SUMMER10" (line 18), we add 10 coins to `self.discount` (line 19) and we print a message accordingly (line 20); otherwise (line 21), we print that the coupon is not valid (line 22). The method `calculate_price()` calculates and returns the updated price as the difference between the value of `self.price` and the value of `self.discount` (lines 24–25). In general, methods can be defined **in any**

order in the class and they can be **called in any order and multiple times by an object**. Let's see how. The syntax to **call a method from an object** is: (1) **object name**, (2) **dot**, (3) **method name**, and (4) **arguments**—if any—in between round brackets, **excluding self**. The method's **output** can be assigned to a **variable**, of course. In our example, first, we re-instantiate the object customizing its attributes, and we print them for a check (cell 5, lines 2–5; print (a)). Then, we calculate the price after launch discount by writing `t_shirt.calculate_price()` (line 9), and we assign the output to `t_shirt_price`, which we print to obtain 26 (line 10; print (c)). What happens exactly when we call the method? As you can see in Figure 35.3, `t_shirt` calls `calculate_price()` in the class (orange arrow), which is **executed using the values of the object's attributes**. Thus, `self.price - self.discount` is $30 - 4$ (line 26). The resulting value 26 is assigned to `updated_price`, which is returned (line 27) and passed to the variable `t_shirt_price` (gray arrow) (cell 5, line 9). Finally, the price is printed for a check (line 10; print (c)).

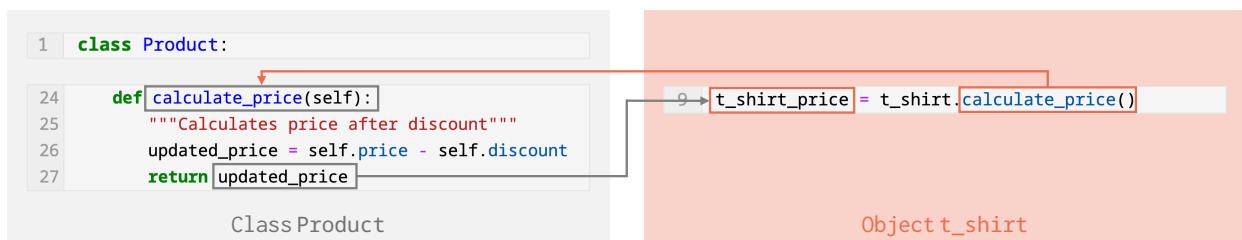


Figure 35.3. Method `calculate_price()` defined in the class `Product` (left) and called by the object `t_shirt` (right).

Let's apply the coupon and calculate the final price. The object `t_shirt` calls the method `apply_coupon()` with the argument "SAVE4" (line 14). Similarly to above, `apply_coupon()` is executed using the values of the object attributes. Because the `if` condition in the method is true (cell 4, line 15), we execute `self.discount + 4`—that is, $4 + 4$ —and we update `self.discount` with the new value 8 (line 16). Then, we print the message that the coupon has been applied (line 17; print (e)). To check for correctness, we print the object's attribute `t_shirt.discount`, and we see the updated value 8 (cell 5, line 15; print (f)). Finally, we calculate the T-shirt price with the updated discount that includes launch discount and coupon. To do so, we simply recall the method `calculate_price()` (line 19). Within the method, we subtract 8—value in `self.discount`—from 30—value in `self.price`—to obtain 22 (cell 4, line 26), which is returned (line 27) to the variable `t_shirt_price` (cell 5, line 19) and eventually printed (line 20; print (h)).

How would you calculate the price of the object `lamp` before and after applying the coupon "SUMMER10"? Give it a try before looking into the solution below.

- Instantiate the object `lamp` with its attributes and calculate its price before and after applying the coupon SUMMER10:

```

[6]: 1  # instantiating the product lamp with its attributes
2  lamp = Product("Lux")
3  lamp.price = 40
4
5  # calculating the original price
6  print("-> Original price")
7  lamp_price = lamp.calculate_price()
8  print("Price:", lamp_price, "coins")

```

```

9
10 # calculating the price after coupon
11 print("-> Price after coupon")
12 lamp.apply_coupon("SUMMER10")
13 lamp_price = lamp.calculate_price()
14 print("Price:", lamp_price, "coins")

```

- (a) -> Original price
- (b) Price: 40 coins
- (c) -> Price after launch discount and coupon
- (d) Coupon SUMMER10 applied!
- (e) Price: 30 coins

Similarly to cell 3, we instantiate `lamp` as an object of the class `Product` with the argument "Lux" (line 2), and we customize its price to 40 coins (line 3). Because the lamp has no launch discount, we do not need to modify its attribute `lamp.discount`, which has the default value of 0 coins. We calculate the original price by calling `lamp.calculate_price()` (line 7). In the method, `self.price - self.discount` is $40 - 0$ (cell 5, line 26), that is 40, which is returned (line 27) to the variable `lamp_price` (cell 6, line 7) and printed (line 8, print (b)). Then, we apply the coupon "SUMMER10" using the method `apply_coupon()` (line 9). This time, the true condition is `elif coupon == "SUMMER10"` (cell 4, line 18). Thus the discount is updated from the original value 0 to the new value 10 (line 19). Moreover, the feedback message stating that the coupon was applied is printed (line 20; print (d)). Finally, we recalculate the price using the method `calculate_price()` (cell 6, line 13). In the corresponding method, `self.price - self.discount` is $40 - 10$ (cell 5, line 26), that is 30, which is returned (line 27) to the variable `lamp_price` (cell 6, line 13), and eventually printed (line 14, print (e)).

As we mentioned at the beginning of this section, classes can also have **built-in methods**—that is, **predefined methods**—whose names start and end with double underscore. Also for built-in methods, the first argument is commonly `self` (cell 5, lines 5 and 31). The most common built-in method is the **constructor** `__init__()` (line 5 in cells 1 and 4), which is mandatory in a class to allow for object instantiation. Another commonly used built-in method is `__str__()`, which defines **the print of an object**. In our example (cell 5, lines 31–33), we *return* the string "Name: " concatenated with the attribute `self.name`. Let's see what happens when we print the two objects we created in this chapter.

- Print the two objects:

```
[10]: 1 print(t_shirt)
2 print(lamp)
Name: Feel good
Name: Lux
```

When we print the object `t_shirt` (line 1), we obtain Name: Feel good. Similarly, when we print `lamp` (line 2), we obtain Name: Lux. With the built-in method `__str__()` we somehow overwrote the built-in function `print()`. Without `__str__()`, we would get something like `<__main__.Product object at 0x102d8cbb0>` when executing `print(t_shirt)` or `print(lamp)`. In the following chapters, we will not focus further on built-in methods; however, you can find a complete list of built-in methods in the official Python documentation¹.

At this point, you might ask: When do I use object-oriented programming instead of procedural programming? Usually object-oriented programming is used in **projects that involve objects with similar**

¹<https://docs.python.org/3/library/operator.html>

characteristics and behaviors. For example, on a social media platform, every person is an object with attributes such as name, posts, number of likes, and is able to perform actions such as follow somebody, like a post, and send a message. Similarly, in a school registry, each student has a name, an age, a curriculum, and can change a course, receive a grade, or participate in a school event. In a customer registry, each customer has a name, an email address, a phone number, and can send an email, schedule a meeting, generate an invoice. As you can see, a lot of software that we use in everyday life is based on object-oriented programming. You will also have the opportunity to explore more examples in the coding exercises at the end of these last few chapters.

Let's conclude this chapter with formal definitions of the concepts we learned:

A **class** is a template containing properties and actions

An **object** is an instance of a class

An **attribute** is a variable that represents a property of an object

A **method** is a function that represents an action that an object can perform

Before moving to the next chapters where we will expand the online store example and discover new interesting properties of object-oriented programming, complete the exercise below to summarize and memorize the concepts we have discussed so far.

📝 Insert into the right column

Summarize the difference between classes and objects by completing the table with the following phrases:

`object_name.attribute_name`, present, capitalized with no spaces, `object_name.method_name()`,
a template, absent, `self.attribute_name`, an instantiation of a class,
`lowercase separated by underscore`, `def method_name()`

	Class	Object
What it is		
Name style		
<code>self</code>		
Attribute syntax		
Method syntax (creation in class / call in object)		

Recap

- In **object-oriented programming**, we represent the world in classes and objects with attributes and methods.
- A **class** is a template and is introduced by the keyword `class`.
- An **object** is an instance of a class.

- **Attributes** are variables representing an object's properties.
- **Methods** are functions in a class representing actions that an object can perform. Their first parameter is usually `self`.
- Classes can have **built-in methods**, such as the constructor `__init__()` and `__str__()`, which defines an object's print.

Python data types are classes!

Since the beginning of our journey, we have used **methods** for lists—e.g., `.append()`, `.remove()`—for strings—e.g., `.lower()`, `.upper()`—for dictionaries—e.g. `.keys()`, `.values()`—and for other data types, including tuples and sets. Does this ring any bell? In Python, **data types are classes** and the **variables** we create **are objects!** And we are familiar with many of their methods! Let's look into this simple code:

```
[1]: 1 greeting = "hello"
      2 print(greeting.upper())
      3 print(type(greeting))
HELLO
<class 'str'>
```

greeting is assigned hello
print greeting dot upper
print type greeting

At line 1, we create the object `greeting`. To be consistent with the syntax, we should write `greeting = str("hello")`, but Python provides us a shortcut—that is, the quotes—to simplify the instantiation. Then, we call the method `.upper()` to change its content to uppercase and we print it (line 2). You can imagine the class defining a string as containing 47 methods, including `.upper()`, `.lower()`, etc., exactly like `calculate_price()` or `apply_coupon()` in this chapter. Finally, when we print the type of `greeting` (line 3), we see that it is of class `str`—that is, string. Similarly, let's have a quick look into a list:

```
[2]: 1 numbers = [1, 3, 5]
      2 print(numbers.index(3))
      3 print(type(numbers))
1
<class 'list'>
```

numbers is assigned one three five
print numbers dot index three
print type numbers

We instantiate the object `numbers` from the class `List` using a provided shortcut—that is, the square brackets—(line 1). Then, we call the method `.index()` with argument 3 and we directly print the output 1 (line 2). As for strings, we can imagine the code defining the list class as containing a sequence of 11 methods—the ones we summarized in Chapter 21. Finally, when printing the type, we see that it is of class `list` (line 3).

Let's code!

1. More items in the online store! Create two more objects from the class `Product` with the following characteristics:
 - A beach ball called *Giant ball*, original price: 10 coins, launch discount: 0.50 coins. Calculate its price before and after applying the coupon `SAVE4`.

- b. A diary called *My adventures*, costing 15 coins, launch discount: 3 coins. Calculate its price before and after applying the coupon SPRINGSALES30.

What do you get when you print each object?

2. Sportswear testimonials. You work for a famous sportswear company who hires champions for advertising.

- a. Create a class named *Athlete* that represents sports champions. The class contains 4 attributes: first name and last name (which are also the parameters of the constructor), sports type, and earnings. Then, create an object for each of the following athletes:

- Yannick Sinner, tennis, 10000 coins;
- Christiano Ronaldo, soccer, 20000 coins;
- Serena Williams, tennis, 15000 coins.

Make sure that when you print an object, you print first and last name.

- b. Last year, soccer clothing sales had a small increase, so you give Ronaldo an earning increase. To do so, modify the class by adding a method called `increase_earning()`, which increases the earnings by a given percentage. Then, call the method `increase_earning()` for Ronaldo with a 1% bonus increase. How much is Ronaldo earning now?
- c. Similarly, tennis clothing sales in the past year had a relevant increase, so you decide to give a 5% earning increase to the athletes playing tennis. To do so, create a list called *athletes* whose elements are the created objects. Add a 5% raise to the athletes playing tennis using a `for` loop and an `if` condition. How much are they earning now?

36. Securing the online store

Encapsulation

In this chapter, we will build on the online store example to learn **encapsulation**, that is, how to **define the access to attributes and methods** by making them **public or private**. To learn what it means, have a look at the task and the implementation of its solution below. You already know most of the code. Search for the differences between this implementation and the one in the previous chapter, and try to understand what they imply. Follow along with Notebook 36!

- While filling out the online store, you realize that you want to minimize errors that could compromise revenue. Thus, you make the attributes representing price and discount private and create get and set methods to access them. In addition, you realize that you need to include the tax amount in the calculation of the final price. Therefore, you implement a private method that calculates the tax amount and modify `calculate_price()` accordingly:

```
[1]: 1  class Product:
2      """Class representing a product"""
3
4      # --- CONSTRUCTOR -----
5      def __init__(self, name):
6          """Constructor"""
7          self.name      = name
8          self.__price   = 0           # modified
9          self.__discount = 0         # modified
10         self.__tax_rate = 0.02     # added
11
12
13     # --- GET/SET METHODS -----
14     def get_price(self):          # added
15         """Gets the price value"""
16         return self.__price
17
18     def set_price(self, price):    # added
19         """Sets the price value"""
20         if isinstance(price, (int, float)) and price > 0:
21             self.__price = price
22         else:
23             raise ValueError("Price must be a number greater than 0")
24
25     def get_discount(self):        # added
26         """Gets the discount value"""
27         return self.__discount
28
29     def set_discount(self, discount): # added
30         """Sets the discount value"""
31         if isinstance(discount, (int, float)) and 0 < discount < self.__price:
32             self.__discount = discount
```

```

33     else:
34         raise ValueError("Discount must be a number greater than 0 and less than
35                         the product's price")
36
37     # --- METHODS -----
38     def apply_coupon(self, coupon):
39         """Updates discount based on a coupon"""
40         if coupon == "SAVE4":
41             self.__discount = self.__discount + 4      # modified
42             print("Coupon SAVE4 applied!")
43         elif coupon == "SUMMER10":
44             self.__discount = self.__discount + 10    # modified
45             print("Coupon SUMMER10 applied!")
46         else:
47             print("Your coupon is not valid")
48
49     def __calculate_tax(self, price):           # added
50         """Calculates tax on price"""
51         tax = round(price * self.__tax_rate, 2)
52         print("Tax amount on", price, "coins:", tax, "coins")
53         return tax
54
55     def calculate_price(self):
56         """Calculates price after discount and tax"""
57         # calculate the discounted price
58         discounted_price = self.__price - self.__discount # modified
59         # calculate tax on the discounted price
60         tax = self.__calculate_tax(discounted_price)       # added
61         # add tax to the discounted price
62         taxed_price = discounted_price + tax              # added
63         return taxed_price
64
65
66     # --- BUILT-IN METHODS -----
67     def __str__(self):
68         """Prints the object characteristics"""
69         return "Product: " + self.name

```

- To test the new code, you fill out again the T-shirt with its details, that is, name: Feel good; original price: 30 coins; and launch discount: 4 coins. Then, you calculate the T-shirt price before and after applying the coupon SAVE4:

```

[2]: 1 # creating the object
2 t_shirt = Product("Feel good")
3 print("t_shirt name:", t_shirt.name)
4
5 # providing and retrieving the original price
6 print("-> Original price")
7 t_shirt.set_price(30)
8 print("Price:", t_shirt.get_price(), "coins")
9

```

```

10 # providing and retrieving the discount
11 print("-> Launch discount")
12 t_shirt.set_discount(4)
13 print("Launch discount:", t_shirt.get_discount(), "coins")
14
15 # calculating the price after launch discount and tax
16 print("-> Price after launch discount and tax")
17 t_shirt_price = t_shirt.calculate_price()
18 print("Price:", t_shirt_price, "coins")
19
20 # applying the coupon and calculating the price
21 print("-> Price after launch discount, coupon, and tax")
22 t_shirt.apply_coupon("SAVE4")
23 t_shirt_price = t_shirt.calculate_price()
24 print("Price:", t_shirt_price, "coins")

```

- (a) Name: Feel good
- (b) -> Original price
- (c) Price: 30 coins
- (d) -> Launch discount
- (e) Launch discount: 4 coins
- (f) -> Price after launch discount and tax
- (g) Tax amount on 26 coins: 0.52 coins
- (h) Price: 26.52 coins
- (i) -> Price after launch discount, coupon, and tax
- (j) Coupon SAVE4 applied!
- (k) Total discount: 8 coins
- (l) Tax amount on 22 coins: 0.44 coins
- (m) Price: 22.44 coins

What are the novelties in the code above and what are their effects? Get some hints by solving the following exercise.

True or false?

1. To make an attribute or a method private, we add one underscore at the beginning T F
of its name
2. self.__price, self.__discount, and self.__tax_rate are private attributes T F
3. An object can set the value of a private attribute by a set method and get its T F
value by a get method
4. An object can directly call a private method T F
5. The final price is calculated by subtracting the discount from the original price T F
and adding the tax

Computational thinking and syntax

Let's start by analyzing the **attributes** in the constructor (cell 1, lines 7–10). The attribute `self.name` (line 7) is the same as in Chapter 35 (cell 5, line 7). We call this kind of attributes **public**—you are already familiar with them. On the other side, the attributes `self.__price` and `self.__discount` (lines 8 and 9) are now **private**. To make an attribute private, we add a **double underscore** at the beginning of

their names. Also the new attribute `self.__tax_rate` (line 10) is private because its name starts with a double underscore—we will use `self.__tax_rate` in the method `__calculate_tax()` (line 51). What is the main difference between public and private attributes? It's about the way we **access** them, that is, how we **assign a value** to an attribute or **retrieve the value** from an attribute. Let's first refresh how to access public attributes.

Public attributes can be **directly** accessed both within a **class** and by an **object**.

As you already know, within a **class**, we access a public attribute by using the syntax `self.attribute_name`. For example, within the class `Product`, we directly access the public attribute `self.name` in the built-in method `__str__()` (cell 1, line 69). Similarly, from an **object**, we access a public attribute by using `object_name.attribute_name`. For example, from `t_shirt`—which we instantiate in cell 2, line 2—we directly access the public attribute `t_shirt.name` (line 3) to print it (`print(a)`). What about private attributes?

Private attributes can be **directly** accessed **only** within a **class**; they can be accessed by an **object** **only** through **get/set methods**.

In a **class**, we access a private attribute by using the syntax `self.__attribute_name`, similarly to what we would do for a public attribute. For example, in `calculate_price()` we directly access the private attributes by writing `self.__price` and `self.__discount` (line 58). On the other side, if an **object** tries to directly access a private attribute, we get an **AttributeError** saying that the attribute does not exist:

```
1 print("t_shirt price:", t_shirt.__price, "coins")
-----
AttributeError      Traceback (most recent call last)
Cell In[3], line 1
----> 1 print("t_shirt price:", t_shirt.__price, "coins")

AttributeError: 'Product' object has no attribute '__price'
```

To avoid this error, we use an attribute's get and set methods (lines 14–34), which have a typical structure:

- A **get method**—also called **getter**—**returns a private attribute**. For example, `get_price()` returns `self.__price` (line 16), and `get_discount()` returns `self.__discount` (line 27). The name of a getter is usually composed of `get` followed by underscore and the name of the attribute—without a double underscore—and the input is usually `self`.
- A **set method**—also called **setter**—**assigns the value of a parameter to a private attribute**. For example, in `set_price()`, we assign the input `price` to the private attribute `self.__price` (line 21), and in `set_discount()`, we assign the input `discount` to the private attribute `self.__discount` (line 32). The assignment is often conditional on a **check of the parameter type and value**. We commonly check the type using `isinstance()`—in our case with a tuple as a second parameter containing the possible numerical types—and the value as a numerical range, as we learned in Chapter 30. In our example, the parameters `price` and `discount` must be an integer or a float greater than 0 (lines 20 and 31), and `discount` must also be less than the product `price` (line 31). If the conditions are not met (lines 22 and 33), we raise a `ValueError` (lines 23 and 34), with a message containing the requirements

for both type and value, for convenience—it is also possible to raise `ValueError` and `TypeError` separately. The name of a setter is usually composed of `set` followed by underscore and the name of the attribute—without a double underscore. Similarly, the name of the parameter is usually the same as the name of the attribute—with a double underscore—to show the correspondence. Finally, setters usually take two inputs—that is, `self` and the parameter that will be assigned to the private attribute—and have no returns.

How does an `object` use get and set methods? By calling them with the usual syntax `object_name.method_name`. Let's have a look at `t_shirt` (cell 2). We provide the price of 30 coins by calling the setter with the command `t_shirt.set_price()` (line 7). When executing the code, the argument 30 goes through the `set_price()` method in the class (cell 1, lines 18–23). Because 30 satisfies the type and value checks—it is an integer greater than 0—it will be assigned to the attribute `self.__price` (line 21). We can retrieve the price amount by calling the getter with the command `t_shirt.get_price()`, which returns the value of the attribute `self.__price` (cell 1, line 16), that is, 20 coins, which we print (cell 2, line 8; `print(c)`). Similarly, we provide the discount of 4 coins by calling the setter with the command `t_shirt.set_discount()` (cell 2, line 12). In the setter (cell 1, lines 29–34), the value of `discount` satisfies the type and value conditions—it is an integer between 0 and 30—(line 31) and thus is assigned to the attribute `self.__discount` (line 32). Finally, we can retrieve and print the discount amount by calling the getter with the command `t_shirt.get_discount()` (cell 2, line 13; `print(e)`).

Now that syntax and functionality are clear, you might wonder: **why and when should I make an attribute public or private?** It's a matter of **protection of the integrity code** and the judgment often depends on the context and the coder's interpretation of the whole project. In general, we make an attribute **public** when it can be freely accessed **without risks** of unintended changes or bugs. In our example, the attribute `self.name` is public to allow easy change of the product name, because it would not cause any economic damage to the online store. On the other side, we make an attribute **private** when we want some **control** on how it is used and modified. In our code, `self.__price` and `self.__discount` are private because we want to check their types and values before assignments to avoid compromising revenues. What about `self.__tax_rate` (cell 1, line 10)? Why doesn't it have a getter and a setter? Since the tax rate is constant for all items, we do not want to introduce any possibility for the object to change it, so as to avoid potential damage.

Let's now look into encapsulation for **methods**. It works as follows:

Public methods can be **directly** accessed both within a **class** and by an **object**.

Private methods can be accessed only within a **class—not** by an **object**.

Let's analyze the three methods in the `Product` class (cell 1, lines 38–63). The first method is `apply_coupon()` (lines 38–47), which is public, that is, its accessibility works the same way as in Chapter 35. However, in the method's code the attribute `self.__discount` is now private (lines 41 and 44). The second method is the newly added `__calculate_tax()` (lines 49–53), which is private. Similarly to attributes, we make a method private by adding a **double underscore at the beginning of its name**. Within `__calculate_tax()`, we calculate the tax amount as the product of the input price and the tax rate—defined by the private attribute `self.__tax_rate`—and we round it to the first two decimals for convenience (line 51). Then, we print the tax amount (line 52), and we return it (line 53). Finally, the third method is `calculate_price()` (lines 55–63), which remains public. However,

its code is modified with respect to Chapter 35. We calculate the discounted price by subtracting `self.__discount` from `self.__price`—both of them are now private attributes—and we store the result in `discounted_price` (line 58). Then, we calculate the tax amount by calling the private method `__calculate_tax()` (line 60). To **call a public or private method** within a class, we use the syntax `self.method_name()`. The method `__calculate_tax()` takes `discounted_price` as an input and returns the tax amount as an output. Finally, the tax amount is summed to the discounted price and stored in `taxed_price` (line 62), which is finally returned (line 63).

How are the methods used by an **object**? As defined above, objects can **call only public methods** using the syntax `object_name.method_name()`, as we learned in the previous chapter. They can **not call private methods**. In our example, we call the methods in the same sequence as in the previous chapter, that is, first `calculate_price()` to calculate the price, then `apply_coupon()` to apply a coupon, and finally `calculate_price()` again to recalculate the price (Chapter 35, cell 5, lines 7–20; this chapter, cell 2, lines 15–24). However, the outcome is different because the price calculation now includes a tax. Let's briefly go through the code. First, we calculate the price with launch discount and tax by using the public method `calculate_price()` (cell 2, line 17). Within the method, we subtract the discount of 4 coins from the original price of 30 coins to obtain the discounted price of 26 coins (cell 1, line 58). Then, we calculate the tax by calling the private method `__calculate_tax()` (line 60), which receives the discounted price of 26 coins as an input, multiplies it by the tax rate `0.02` (defined at line 10) and rounds the result to two digits (line 51). The obtained amount of `0.52` coins is printed (line 52; `print(g)`) and returned (line 53) to the variable `tax` in `calculate_price()` (line 60). Finally, the value of `tax` is summed to the value of `discounted_price` to obtain `26.52` coins (line 62). This value is returned (line 63) and assigned to the variable `t_shirt_price` (cell 2, line 17), which is then printed (line 18; `print(h)`). Second, we apply the coupon `SAVE4`. We call the public method `apply_coupon()` (line 22), which adds 4 coins to the private attribute `self.__discount` (cell 1, line 41) and prints a message (line 42; `print(j)`). Finally, we recalculate the T-shirt price after launch discount, coupon, and tax. We call `calculate_price()` (cell 2, line 23), which executes the same steps as above. Because the total discount is now 8 coins, the tax amount is calculated on 22 coins, resulting in `0.44` coins (`print(l)`). The final amount of `22.44` coins is returned and assigned to the variable `t_shirt_price` (line 23), which is finally printed (line 24; `print(m)`).

What happens if an object tries to call a private method? Similarly to attributes, we get an error:

```
1 t_shirt.__calculate_tax(price)
-----
AttributeError      Traceback (most recent call last)
Cell In[4], line 1
----> 1 t_shirt.__calculate_tax(price)

AttributeError: 'Product' object has no attribute 'calculate_tax'
```

Even if we tried to access a private method, we obtain an `AttributeError`, as we can see in the last line of the message. This can be deceiving. However, the presence of the round brackets after the method name in the line indicated by the arrow will help us detect that we are dealing with a method, and not an attribute.

Once more, you might ask: **when do we make a method public or private?** Similarly to attributes, we make a method public when it can be used by an object without compromising the code, whereas we make a method private when we do not want the object to access it or when it supports some other

methods, like `__calculate_tax()`.

To conclude, find a summary of the syntax of accessibility to public and private attributes and methods within the same class and by an object in Table 36.1. It is important to mention that in the majority of programming languages, encapsulation also includes a third category of attributes and methods called **protected**. However, this goes beyond the scope of exploring the basics of object-oriented programming of this book.

Class attributes and methods	Accessibility within the class	Accessibility by an object
Public Attribute <code>.name</code>	Direct <code>self.name</code>	Direct <code>t_shirt.name</code>
Private Attribute <code>.__price</code>	Direct <code>self.__price</code>	Using getters and setters <code>t_shirt.get_price()</code> <code>t_shirt.set_price()</code>
Public Method <code>calculate_price()</code>	Direct <code>self.calculate_price()</code>	Direct <code>t_shirt.calculate_price()</code>
Private Method <code>__calculate_tax()</code>	Direct <code>self.__calculate_tax()</code>	Not possible

Table 36.1. Accessibility to the public and private attributes and methods of a class (left column), within the same class (central column), and by an object instantiated from the class (right column).

Recap

- In **encapsulation**, we define public or private access to attributes and methods.
- The name of a private attribute or a method starts with a **double underscore**.
- A **public attribute or method** can be accessed both **within the class** and **by the object**, whereas a **private attribute or method** can be accessed **only within the class**.
- An **object** can call a **get method**—or getter—to retrieve the value of a private attribute and a **set method**—or setter—to assign a value to a private attribute.

The `self` is a little crab!

In the past two chapters, we used `self` extensively within the class, considering it as a syntax particle for convenience. But what is `self`? A fun way is to think of it like a little crab whose left legs represent the attributes and right legs represent the methods (Figure 36.1, left). Because `self` is the first input parameter of the methods of a class—including the constructor!—every method has access to all the legs of the crab, that is, all the attributes and methods. For example, the getter `get_price()` (cell 1, lines 14–16) receives `self`—the whole crab!—as an input and returns `self.__price`—the second left leg! The method `calculate_price()` (lines 55–63) receives `self` as an input and uses not only the attributes `self.__price` and `self.__discount`—the second and third left legs—(line 58), but also the method `__calculate_tax()`—the second right leg—(line 60) (Figure 36.1, right). The role of `self` is to tie together all the attributes and methods and make them accessible to the other attributes and methods. This accessibility is made possible

using **dot notation**, that is, using the syntax: (1) `self`, (2) dot, and (3) name of attribute or method. When operating with an object, `self` represents that object within the class, because it carries the attribute values of that object. For example, when calling `calculate_price()` for the object `t_shirt`, the operation `self.__price - self.__discount` is `30 - 4`. In summary:

`self` represent the current instance of the class and
is used to access its attributes and methods within the class.

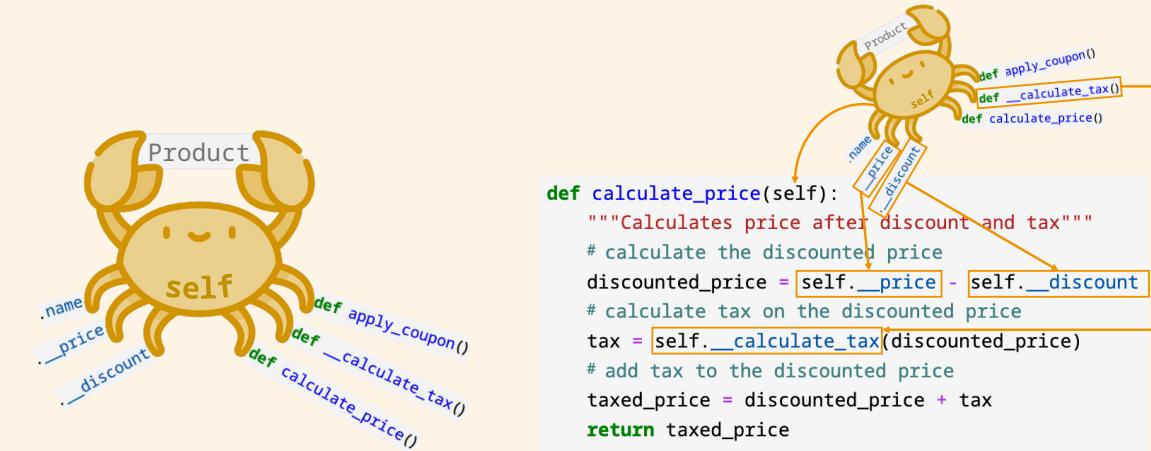


Figure 36.1. Illustration of `self` as a crab, where the left legs represent the attributes and the right legs represent the methods (left) and its role in a class method (right).

Finally, the name `self` is a convention. `self` is not a reserved word in Python, and it is colored black in Jupyter Notebook, like any other variable. However, it is recommended to use the name `self` to ensure code readability.



Let's code!

1. Let's add more items to the online store! From the updated class `Product`, instantiate the following objects from the previous chapter:
 - A lamp called `Lux`, original price: 40 coins, no launch discount. Calculate its price before and after applying the coupon `SUMMER10`.
 - A beach ball called `Giant ball`, original price: 10 coins, launch discount: 0.50 coins. Calculate its price before and after applying the coupon `SAVE4`.
 - A diary called `My adventures`, costing 15 coins, launch discount: 3 coins. Calculate its price before and after applying the coupon `SPRINGSALES30`.
2. Running a used car garage. You run a used car garage and have just received a new vehicle that needs to be added to the garage database. The car is a gray WJ from the LP brand. From the current report, you see that it traveled 30000 km in 2024 and 50000 km in 2025. It also has a dent on the front left door.
 - a. Create a class representing a car similar to the one above. What attributes will you create and of what types? Which attributes will be public and which ones private? For the private

attributes, write getters and setters.

- b. Now you go for the inspection. You notice that the car has another dent on the left back door.
How do you modify the class to add this new information?
- c. Finally, you want to print a report on the car's status. The report must contain all the car characteristics, the amount of km the car traveled each year and their average, and the number of dents and their locations. Add at least two methods to perform this final task. Which methods will be public and which methods will be private?

37. How can I add a book sample?

Inheritance

So far, we have learned the basics of object-oriented programming. That is, we've learned the concepts of classes and objects, with their public and private attributes. In this chapter, we will extend the capabilities of classes and objects by using **inheritance**. Here, you will get familiar with the concepts of **parent and children classes** and their properties. Ready? Let's enhance the online store with some new features! Follow along with Notebook 37.

- It's time to add books to the online store. For their webpages, you need to add a **Read Sample** button so that customers can preview the books before buying. However, you have to make sure that this button does not appear on the pages of other products, such as clothing or furniture. How can you do it?

Have a look at Figure 37.1. Any ideas? Everything will be clearer in a bit!



Figure 37.1. The parent class `Product` (left), the child class `Book` with the additional functionality `Read sample` (middle), and the object `coding_book` (right).

Let's continue with the code!

- You keep the class `Product` as it is—see Chapter 36, cell 1 and Notebook 37, cell 1. That will be the *parent class*.
- You create a child class representing books that inherits all attributes and methods from the `Product` class. Then, you add a private attribute representing the book sample—with its get and set methods—and create a public method that prints the sample:

```
[2]: 1  class Book(Product):
2      """Child class representing a book"""
3
4      # --- CONSTRUCTOR -----
5      def __init__(self, name):
6          """Constructor"""
7          super().__init__(name)
8          self.__book_sample = ""
9
10
```

```

11     # --- GET/SET METHODS -----
12     def get_book_sample(self):
13         """Gets the book sample"""
14         return self.__book_sample
15
16     def set_book_sample(self, book_sample):
17         """Sets the book sample"""
18         if isinstance(book_sample, str):
19             self.__book_sample = book_sample
20         else:
21             raise TypeError("book_sample must be a string")
22
23
24     # --- METHODS -----
25     def read_sample(self):
26         """Prints the book sample"""
27         if self.__book_sample != "":
28             print(self.__book_sample, "[...] - Enjoying the book? Buy it!")
29         else:
30             print("Book sample not available")

```

- To test the new code, you instantiate an object representing a coding book called `Let's code`, original price 20 coins, and launch discount 2 coins. Then, you print the book's characteristics, its price after applying the coupon `SUMMER10`, and its sample:

```

[3]: 1 # creating the object and setting the attributes
2 coding_book = Book("Let's code!")
3 coding_book.set_price(20)
4 coding_book.set_discount(2)
5
6 # printing the characteristics
7 print("Book name:", coding_book.name,
8      "| original price:", coding_book.get_price(),
9      "coins | launch discount:", coding_book.get_discount(), "coins")
10
11 # printing the price
12 print("-> Price after launch discount, coupon, and tax")
13 coding_book.apply_coupon("SUMMER10")
14 print("Price: ", coding_book.calculate_price(), "coins")
15
16 # reading the book sample
17 print("-> Reading book sample")
18 coding_book.set_book_sample("Coding is a lot about telling a computer what to do")
19 coding_book.read_sample()

```

(a) Book name: Let's code! | original price: 20 coins | launch discount: 2 coins
(b) -> Price after launch discount, coupon, and tax
(c) Coupon SUMMER10 applied!
(d) Tax amount on 8 coins: 0.16 coins
(e) Price: 8.16 coins
(f) -> Reading book sample
(g) Coding is a lot about telling a computer what to do [...] - Enjoying the book? Buy it!

Get a few more hints about inheritance by solving the following exercise before reading the next section!

True or false?

- | | | |
|--|---|---|
| 1. Product is the child class and Book is the parent class | T | F |
| 2. A child class can use attributes and methods of the parent class | T | F |
| 3. A child class cannot add its own attributes and methods | T | F |
| 4. The method <code>read_sample()</code> prints the value of <code>self.__book_sample</code> | T | F |

Computational thinking and syntax

Did you get an idea of what inheritance is in object-oriented programming? Consider the facial features of a child. Let's say a boy *inherited* many characteristics from his parents, such as his eye and hair color. But he has also some features that are unique to him, such as his smile. In object-oriented programming, inheritance is similar. A **child class**—or **subclass**—inherits its attributes and methods from its **parent class**—or **superclass**—and can add new ones that are unique to itself. In other words:

Inheritance is a mechanism that enables a **child class** to derive and extend the attributes and methods of a **parent class**.

Let's see how inheritance works by analyzing the code of the online store. Let's start with the syntax, and then we will look into the functionality. The class `Book` (cell 2) is the child class of the parent class `Product` (Chapter 36, cell 1). To create a child class, we write: (1) keyword `class`, (2) class name, and (3) **name of the parent class in between round brackets** (cell 2, line 1). With this line, **we pass all the attributes and methods of the parent class to the child class**—as if they were the eyes and hair color from the parents to their child. Right below, we write a one-line documentation describing the class (line 2). Then, we write the **constructor** (lines 5–8), which is needed **only when new attributes are added** with respect to the parent class—you will see an example of a child class without a constructor in the next chapter. In our example, the constructor takes `self` and `name` as parameters (line 5), like in the parent class (Chapter 36, cell 1, line 5). Within the constructor, we must call the parent class's constructor by using a typical command composed of: (1) built-in function `super()`, which further gives the child class access to all the parent class's attributes and methods, (2) a dot, and (3) call to the constructor of the parent class. Then, we add a new private attribute called `self.__book_sample`, which we initialize as an empty string (line 8). This **addition** and the ones below are **unique to the child class**—as if they were the child's smile in the example above. The **parent class will not have access to the new attribute**—as parents cannot inherit their child's smile. Because `self.__book_sample` is private, we write a getter (lines 12–14) to return its value, and a setter (lines 16–21) to assign a value. In the setter, the assignment is conditional on the input being a string (line 18). Finally, we add a new method that prints the book sample (lines 25–30). Within the method, if the book sample is not an empty string (line 27), we print the value of `self.__book_sample` (line 28). Otherwise (line 29), we print that the book sample is not available (line 30).

What happens on the **object** side? Let's look into cell 3. We instantiate the object `coding_book` from the child class `Book` (line 2). Then, we set the price by using the setter `set_price()` inherited from the par-

ent class `Product` (line 3). Similarly, we set the discount by using `set_discount()` from `Product` (line 4). Then, we print the book characteristics by directly accessing the attribute `coding_book.name` and using the getters `get_price()` and `get_discount()`, which are once more inherited from the parent class `Product` (line 7, print (a)). Similarly, we calculate the price after the initial discount, coupon, and tax by using the methods `apply_coupon()` (line 11; print (c)) and `calculate_price()` (line 12, prints (d) and (e)), inherited from `Product`. Finally, we use the new methods added in the child class `Book`. First, we set the book sample by using the setter `set_book_sample()` (line 16). Because the argument is a string, it gets assigned to `self.sample` within the class (cell 1, lines 18–19). Finally, we call the method `read_sample()` to print the sample (cell 2, line 17; print (g)).

In this chapter, we learned the concepts of parent class and child class and their properties. Can we create **more than one child class** from the same parent class? Yes! You will see an example in the next chapter. And can we still instantiate objects from the parent class? Yes, as you will see in the first coding exercise below. Before moving to the next sessions, take some time to refresh the accessibility to public and private attributes and methods of the parent class by a child class and a child object with the help of Table 37.1.

Parent class attributes and methods	Accessibility by a child class	Accessibility by a child object
Public Attribute <code>.name</code>	Direct <code>self.name</code>	Direct <code>coding_book.name</code>
Private Attribute <code>__price</code>	Using getters and setters <code>self.get_price()</code> <code>self.set_price()</code>	Using getters and setters <code>coding_book.get_price()</code> <code>coding_book.set_price()</code>
Public Method <code>calculate_price()</code>	Direct <code>self.calculate_price()</code>	Direct <code>coding_book.calculate_price()</code>
Private Method <code>__calculate_tax()</code>	Not possible	Not possible

Table 37.1. Accessibility to the public and private attributes of a parent class (left column) by the child class (central column) and an object instantiated from the child class (right column).

Recap

- **Inheritance** consists in creating one or more **child classes** (or subclasses) from a **parent class** (or superclass).
- The child class **inherits attributes and methods** from the parent class and **can add new ones**.
- To create a child class, we use the keyword `class` followed by the child class name and the parent class name in between round brackets.
- A child class needs a **constructor only when it adds new attributes**. In this case, the first line of the constructor is composed of the built-in function `super()` followed by dot and the constructor of the parent class.

Attributes and methods and round brackets

When using an attribute or calling a method, it can happen to mistakenly add or remove the round brackets at the end of their name. Here is how to recognize these errors and correct them. When we mistakenly add round brackets after an attribute, we obtain the following error:

```
[4]: 1 print(coding_book.name())
      ^
      -----
IndexError          Traceback (most recent call last)
Cell In[4], line 1
----> 1 print(coding_book.name())
      ^
      TypeError: 'str' object is not callable
```

It is a `TypeError` saying that a string is not callable, which—as you might remember—means that we cannot call a string as if it were a function. To correct the error, we simply remove the round brackets. On the other side, when we forget the round brackets after a method—this might happen especially if the method does not have any inputs—we do not obtain an error message, but a print similar to the following:

```
[5]: 1 print(coding_book.calculate_price)    print coding book dot calculate price
      <bound method Product.calculate_price of <__main__.Book object at 0x10783d850>>
```

It says that we are looking at—and not calling!—the method `calculate_price()` of the class `Product`—`Product.calculate_price`—called by the object `Book`—`Book` object. To avoid this print, we call the method by adding round brackets—along with any arguments—after its name.



Let's code!

1. Testing the parent class. Instantiate an object `t_shirt` from the parent class `Product` having the same characteristics as in the previous chapter, that is, name: `Feel good`, initial price: 30 coins, launch discount: 4 coins, coupon `SAVE4`. Try to set a book sample and call the method `read_sample()`. What happens and why?

2. Buying an electric car. You want to buy a new electric car, and these are the cars you like:

- Model E-Nature, energy consumption: 15 kWh per 100 km, battery capacity: 75 kWh;
- Model E-Green, energy consumption: 18 kWh per 100 km, battery capacity: 40 kWh.

You want to calculate whether the battery capacity of these cars is sufficient for a trip of 300 km. To do so, you create:

- A parent class called `Vehicle`. Its constructor contains the attributes representing model and energy consumption. The method calculates the energy needed as the energy consumption divided by 100 and multiplied by the distance to drive.
- A child class called `ElectricCar`. It adds an attribute representing the battery capacity and a method that prints whether the trip can be completed with the calculated energy.

Which car will you buy?

3. School management system. You have to develop a software program for a school that calculates the total number of hours each teacher works per week and the average grade of each student. The

characteristics that teachers and students have in common are first name and last name. In addition to these, each teacher has a number of working hours per day and a number of working days per week, whereas each student has grades in math, history, and music. How would you represent this situation using object-oriented programming? Test your solution for the following two teachers: Tom Kind who works 5 hours a day, 4 days a week; and Ani Heart who works 3 hours a day, 5 days a week. Then, for the following three students: Amber Brown has 8 in math, 9 in history, and 5 in music; Mark Fox has 5 in math, 8 in history, and 7 in music; and Sophia Baker has 9 in math, 7 in history, and 8 in music

38. Customizing the coupon for electronics

Polymorphism

In this final chapter, you will learn about **polymorphism**, which literally means *many forms* in Ancient Greek. It is the property of a child class that allows us to **overwrite one or more methods** of the parent class. As a result, objects from the parent class and its child classes can use a **method with the same name but perform different actions**. Let's see what this means in practice by performing the last addition to the online store. Follow along with Notebook 38!

- To complete the online store, you add electronic products. When purchasing them, customers can only use the coupon TECH100, worth 100 coins, instead of the SAVE4 and SUMMER10 coupons, which can be used for other products. How would you change the apply_coupon functionality to satisfy this new requirement?

The solution to our task is depicted in Figure 38.1. We will create a child class called `Electronics` that appears similar to its parent class `Products`. However, the method `apply_coupon()` will contain different code to allow the use of the `TECH100` coupon. We will test our code with a new object called `laptop`.

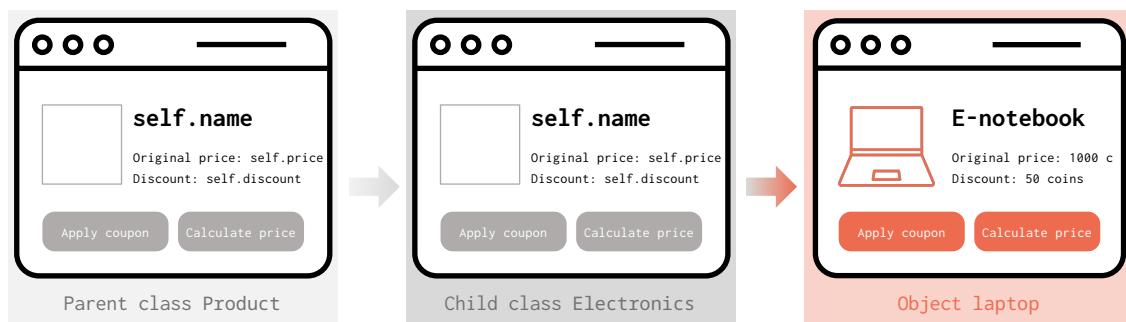


Figure 38.1. The parent class `Product` (left), the child class `Electronics` (middle), and the object `laptop` (right). Despite the similarity between parent and child class, the method `apply_coupon()` performs different functionalities.

Let's have a look at the code!

- You keep the same parent class `Product` as in Chapter 36, cell 1—find it also in Notebook 38, cell 1.

- You create the new child class `Electronics` that inherits from `Product` and overwrites its method `apply_coupon()`:

```
[2]: 1 class Electronics(Product):
2     """Child class representing an electronic product"""
3
4     # --- METHODS -----
5     def apply_coupon(self, coupon):
6         """Updates discount based on a coupon - overwrites parent method"""
7         if coupon == "TECH100":
8             self.set_discount(self.get_discount() + 100)
9             print("Coupon TECH100 applied!")
10        else:
11            print("Your coupon is not valid")
```

- To check the correctness of the code, you create a new object `laptop` named `E-notebook`, with the original price of 1000 coins, and launch discount of 50 coins. Then, you calculate the price before and after applying the coupon `TECH100`:

```
[3]: 1 # instantiating the object
2 laptop = Electronics("E-notebook")
3 laptop.set_price(1000)
4 laptop.set_discount(50)
5
6 # calculating price after launch discount
7 print("-> Price after launch discount")
8 laptop_price = laptop.calculate_price()
9 print("Price:", laptop_price, "coins")
10
11 # calculating price after coupon
12 print("-> Price after coupon")
13 laptop_price.apply_coupon("TECH100")
14 laptop_price = laptop.calculate_price()
15 print("Price:", laptop_price, "coins")
```

(a) -> Price after launch discount
 (b) Tax amount on 950 coins: 19.0 coins
 (c) Price: 969.0 coins
 (d) -> Price after coupon
 (e) Coupon TECH100 applied!
 (f) Tax amount on 850 coins: 17.0 coins
 (g) Price: 867.0 coins

True or false?

1. The child class `Electronics` inherits attributes and methods from the parent class `Product` T F
2. The child class `Electronics` does not overwrite the method `apply_coupon()` of the parent class `Product` T F
3. The objects of the child class `Electronics` can use only the coupon `TECH100` T F

Computational thinking and syntax

Let's start by analyzing the class (cell 2). We create `Electronics`, a child class that inherits attributes and methods from the parent class `Product` (line 1). Because `Electronics` does not add new attributes beyond those of the parent class, we omit the constructor (see Chapter 37). The only change we make is to overwrite the method `apply_coupon()` (lines 5–11) from the parent class (Chapter 36, cell 1, lines 38–47). Overwriting methods is the core of polymorphism. Let's recall what we learned at the beginning of the chapter:

Polymorphism is a mechanism that enables a **child class** to **overwrite a method** of the parent class while **keeping the same method name**.

In other words, in the child class we write a method with the same name as in the parent class but containing different commands. In our example, we want to allow customers to exclusively use the `TECH100` coupon when buying electronics. Thus, in the method `apply_coupon()` of `Electronics` we implement an `if/else` construct, where if the coupon is `TECH100` (line 7), we add `100` coins to the discount (line 8) and we print that the coupon was successfully applied (line 9). Otherwise (line 10), we print that the coupon is not valid (line 11). As you might remember from the previous chapter, because `self.__discount` is a private variable in the parent class, we cannot access it directly from the child class, thus we use the get and set methods (see Table 37.1).

Let's now look at the object (cell 3). We instantiate `laptop` with the name `E-notebook` (line 2), and we call the setters `set_price()` with argument `1000` coins (line 3) and `set_discount()` with argument `50` coins (line 4). Then, we calculate the price by calling the method `calculate_price()` (line 8)—which includes the calculation of the tax amount (print (b))—and we print the price after tax (line 9; print (c)). Afterwards, we call the newly implemented `apply_coupon()` (line 13), and we get the message that the coupon was successfully applied (print (e)). Finally, we recalculate the price by calling `calculate_price()` once more (line 14)—obtaining the print of the tax amount (print (f))—and we print the final price (line 15; print (g)). As you can see, `laptop` called `apply_coupon()` from `Electronics`—not from `Product`!—and `calculate_price()` from `Product` because in `Electronics` we do not overwrite `calculate_price()`.

What happens if we apply a coupon that is valid for the parent class? Let's try with `SAVE4`:

```
1 laptop.apply_coupon("SAVE4")
Your coupon is not valid
```

The output message tells us that the coupon is not valid. This is because `laptop` is an instantiation of the child class `Electronics`, and thus it uses the method `apply_coupon()` in `Electronics`, not in `Product`, as we mentioned previously.

What if we use the coupons `SAVE4` and `TECH100` for the objects `t_shirt` of class `Product`?

```
1 t_shirt = Product("Feel good")
2 t_shirt.apply_coupon("SAVE4")
3 t_shirt.apply_coupon("TECH100")
(a) Coupon SAVE4 applied!
(b) Your coupon is not valid
```

Because it is of the class `Product`, `t_shirt` calls the implementation of `apply_coupon()` from the parent class (Chapter 36, cell 1, lines 38–47). There, the coupon `SAVE4` satisfies the `if` conditions (line 40), thus

it can be applied (line 2 above; print (a)). On the other side, the coupon TECH100 does not satisfy either the if (line 40) or the elif (line 43) conditions; therefore, it is not considered valid (line 3 above; print (b)).

Similarly, what happens when we use the coupons SAVE4 and TECH100 for coding_book of class Book?

```
1 coding_book = Book("Let's code!")
2 coding_book.apply_coupon("SAVE4")
3 coding_book.apply_coupon("TECH100")
```

- (a) Coupon SAVE4 applied!
- (b) Your coupon is not valid

Because the child class Book does not overwrite the method apply_coupon() of Product, the object coding_book uses the method apply_coupon() from Product. Therefore, similarly to the outcomes for t_shirt, the coupon SAVE4 is applicable (line 2 above; print (a)), whereas the coupon TECH100 is not (line 3 above; print (b)).

In summary, for laptop, t_shirt, and coding_book, we called the function apply_coupon() using the same syntax object_name.method_name() but we obtained different results—TECH100 is valid for laptop but not for t_shirt and coding_book, whereas SAVE4 is valid for t_shirt and coding_book but not for laptop. This is the strength of polymorphism: **when we instantiate an object from a class, the appropriate method is automatically selected based on the object's class, without requiring specific intervention.**

In the last four chapters, we learned the basics of object-oriented programming, a way to code based on the representation of the world with classes and objects, characterized by attributes—representing their properties—and methods—representing their actions. As an example, we implemented a simplified version of an online store (see Figure 38.2). From the parent class Product, we instantiated the object t_shirt—and the object lamp, not represented here for simplicity—(Chapter 35)

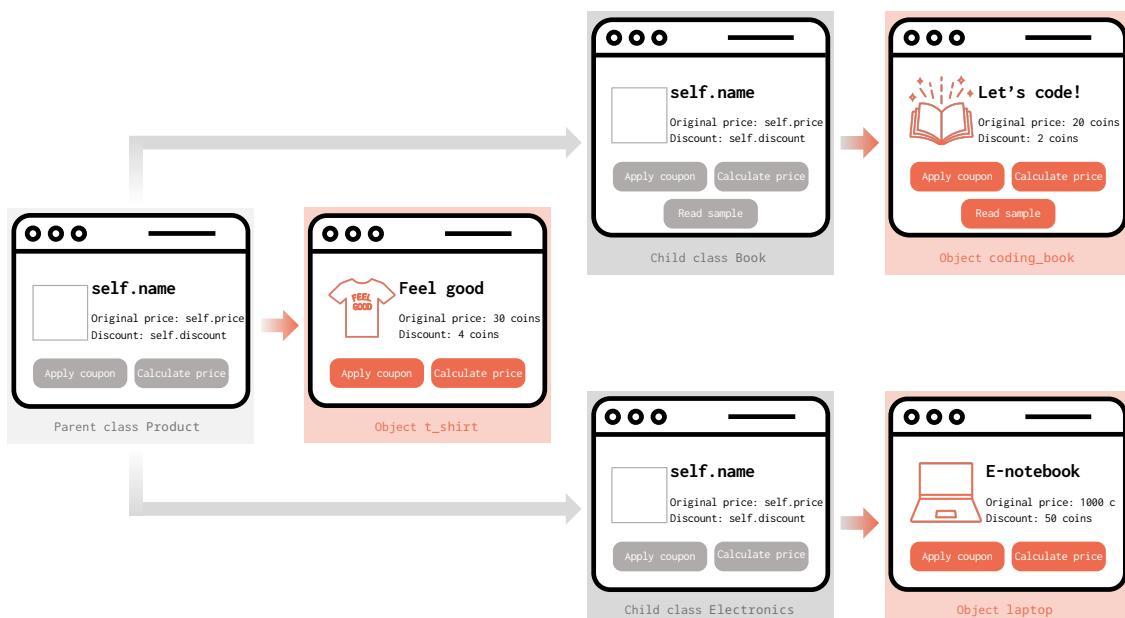


Figure 38.2. Graphical summary of the representation of an online store in object-oriented programming.

and we created two child classes, Book and Electronics. Book inherits all attributes and methods from Product and adds the private attribute `self.__book_sample`—with its getter `get_book_sample()` and setter `set_book_sample()`—and the public method `read_sample()` (Chapter 37). Electronics inherits all attributes and methods without adding any of its own, but overwrites the method `apply_coupon()`, leveraging on polymorphism (Chapter 38). We can imagine the online store expanding with other child classes to represent beauty products, food, or games. In addition, child classes can have their own child classes too. Electronics can have child classes representing smartphones—with their specific features, such as screen size and camera quality—and speakers—with features such as maximum output power and connectivity technology. Thanks to object-oriented programming, we can represent the real world through a **hierarchy of parent and child classes**, with code that is modular, reusable, and easily extensible.

Recap

- **Polymorphism** enables child classes to **overwrite parent class methods** while **keeping the same method name**.
- When it is called, the **correct method** is **automatically selected** based on the object's class.

How do I use ChatGPT when coding?

In the last year, large language models have emerged as a support in coding. Among the most common are ChatGPT by OpenAI, Copilot by Microsoft, and Claude by Anthropic. How do we use them when coding? These models are a fantastic resource when creating functions, writing code documentation, and brainstorming when encountering obstacles. However, we have to be aware of a few limitations. First, these models are mainly created from data from the internet, and they often provide **outputs that are average**, rather than original. Thus, whenever we need to code something common, their support is useful; but when we need to code something specific, we might still have to do the hard work. Second, the outputs that these models give are **not reproducible**, which means that if we prompt the same requirements at different times, we obtain different answers. Therefore, we always have to check and validate the model outputs because they might vary. Last, these models tend to be **verbose**, proposing code that is over-complicated or adding commands that are not needed to solve the task. Therefore, we always need to read the code carefully and select the commands that do what we require. The **human judgment** of the output of a language models is still fundamental, and my hope is that with this book I could provide you the tools to better **understand the elements of coding** and **develop computational thinking** to reason out how to solve a given task. Thank you for learning with me!

Let's code!

1. **Polygons.** Create a parent class representing a regular polygon. The class has two attributes, the number of sides and side length; and two methods, one to calculate the perimeter and one to calcu-

late the area. Then, create a child class representing an equilateral triangle. The area of a triangle is calculated as $\frac{\sqrt{3}}{4} \cdot s^2$, where s is the side. In addition, implement a child class representing a square whose area is calculated as the square of the side. Finally, instantiate two objects, a triangle and a square of side 4, and calculate their perimeter and area

2. *Online food ordering.* You have to create a new software program for online food ordering. The client requested a basic ordering system with two customized options, one for pizza and one for burgers. The base order has an initial price of 10 coins. For pizza, the price increases by 20% if the size is medium, and by 50% if the size is large. For burgers, the price increases by 1.5 coins if the customer adds cheese and by 1 coin if they add onions. To test your code, create four orders: a small pizza, a medium pizza, and a large pizza, as well as a burger with both extra cheese and onions. What is the total cost?

References and sources

- The cover is inspired by the cover of the book “Working in Public: The Making and Maintenance of Open Source Software” by Nadia Eghbal. Stripe Press. 2020
- A few examples and exercises in the book were inspired from online material, ChatGPT, and the book “Coding for Kids: Python: Learn to Code with 50 Awesome Games and Activities” by Adrienne Tacke. Rockridge Press. 2019
- Figure 1.1 is modified from the original by Cy21 and downloaded from <https://commons.wikimedia.org/wiki/File:QWERTY-home-keys-position.svg>
- Figure 16.1 is by the U.S. Naval Historical Center Online Library Photograph and downloaded from https://en.wikipedia.org/wiki/Debugging#/media/File:First_Computer_Bug,_1945.jpg
- The tree in Figure 31.2 is by OpenClipart-Vectors and downloaded from <https://pixabay.com/vectors/tree-nature-drawing-plant-branches-2027899>
- The icons in Figures 33.5, 35.1, 36.1, 37.1, 38.1, and 38.2 are downloaded from www.freepik.com