

Reproducible research reports

with  quarto®

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Get started

- Install  **quarto**: <https://quarto.org/docs/get-started/>
- Download the [workshop materials](#)
- Open your favorite local editor (VS Code / Jupyter / RStudio) or join online via [RStudio Cloud](#)
- When using R, install the following packages:

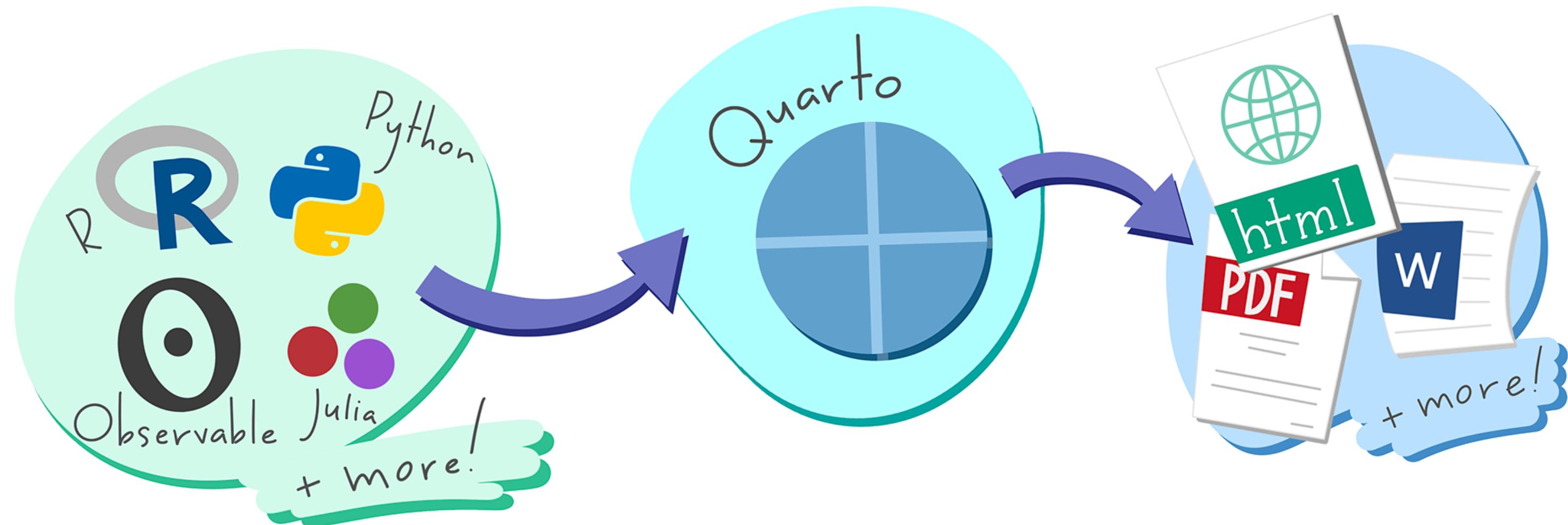
```
1 pkg_list <- c(  
2   "fontawesome", "tidyverse", "quarto", "rmarkdown", "palmerpenguins", "reticulate", "knitr"  
3 )  
4 install.packages(pkg_list)
```

- When using Python, install the following packages using the terminal:

```
1 py -m pip install jupyter numpy matplotlib palmerpenguins tabulate IPython  
2 py -m pip install jupyterlab                      # only when working with Jupyter Lab  
3 py -m jupyter lab test.ipynb                      # only when working with Jupyter Lab
```

What is quarto®?

An open-source publishing system to combine text and code into formatted output documents



Artwork from “Hello, Quarto” keynote by Julia Lowndes and Mine Çetinkaya-Rundel, presented at RStudio Conference 2022.

Illustrated by Allison Horst.

Why quarto®?

“Friends don’t let friends copy-paste” (Aust & Barth, 2023)

Computational non-reproducibility is a widespread problem:

(Artner et al., 2021; Eubank, 2016; Konkol, Kray & Pfeiffer, 2019)

- Typos, copy-paste errors, incorrect rounding, and other reporting errors
- Forgetting to update report after changing data or analysis
- Forgetting to properly save and document data and scripts
- Not indicating software and packages used including their version numbers

Why quarto®?

Quarto can help you make your research more reproducible (same data, same results):

- Avoid errors by combining text, code, and code outputs from the start!
- Also provides an easy way to share and document your code

Quarto can also make you more efficient in the long run:

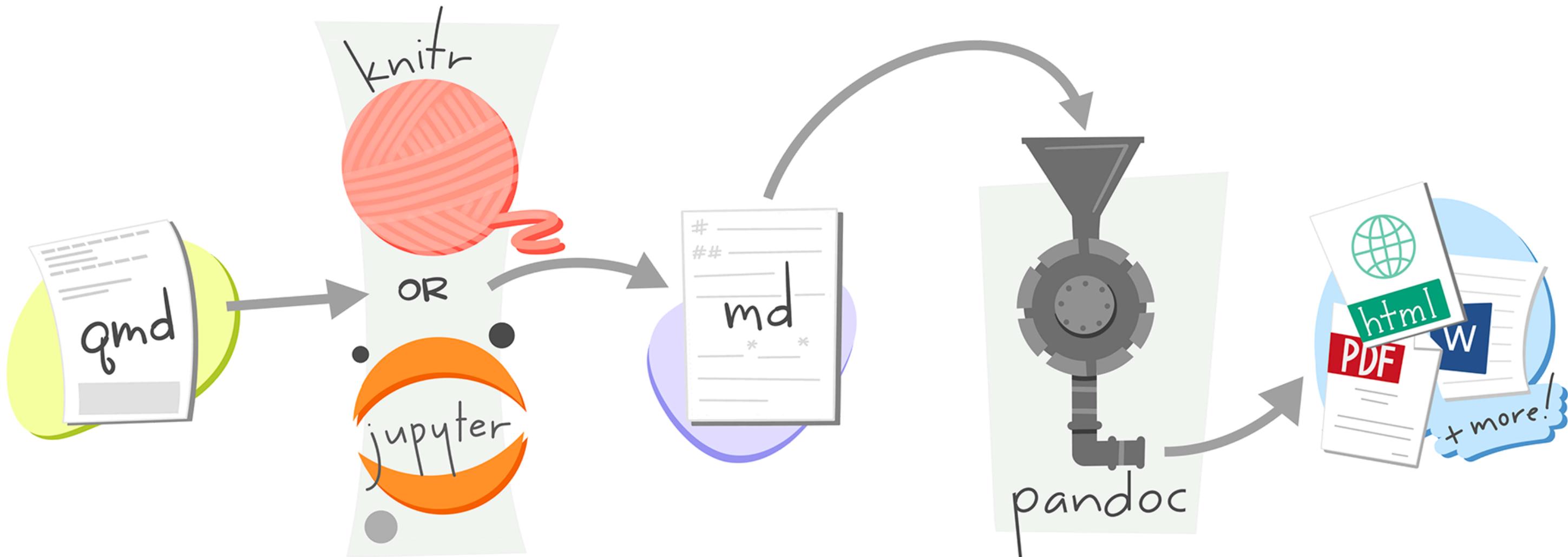
- When data / code are updated, you press one button to rerun your complete analysis and update your report (no more copy-pasting!)

Why quarto®?

Quarto (R/Python/Julia/Observable to ...) is more flexible than alternative solutions:

- [RMarkdown](#) - R to ...
- [Jupyter](#) - Python to ...
- [StatTag](#) - Stata/SAS/R/Python to Word
- [tidystats](#) - R to Word/Google Docs

How does quarto® work?

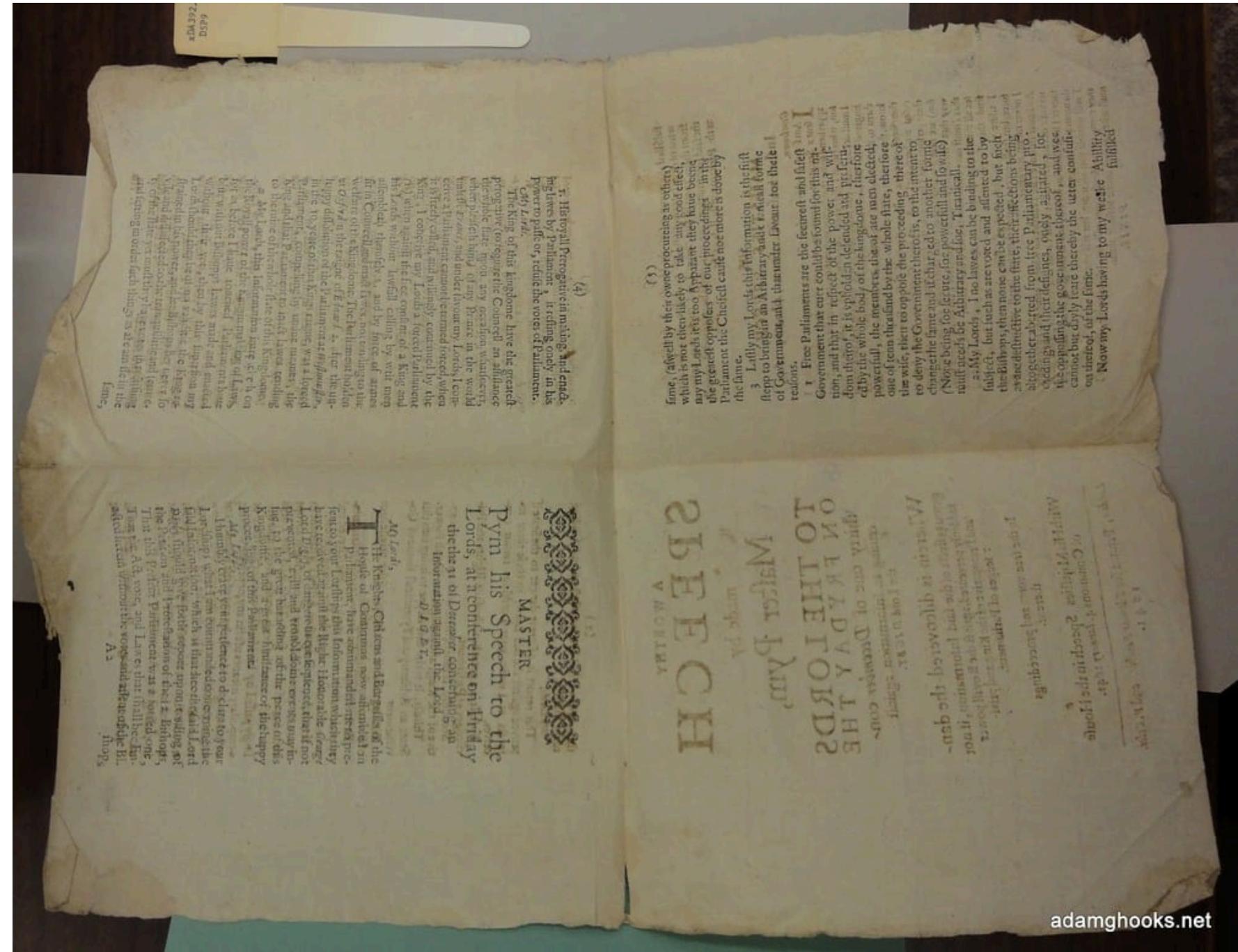


Artwork from “Hello, Quarto” keynote by Julia Lowndes and Mine Çetinkaya-Rundel, presented at RStudio Conference 2022.

Illustrated by Allison Horst.

Why is it called quarto?

The 'quarto' book format



Objectives of this workshop

- Learn what Quarto is and what can you use it for
- Learn how to combine text, code, and code outputs together to create a fully reproducible report
- Learn where to find additional resources and more advanced documentation

Who are we?



Eline Van Geert

🎓 Postdoc researcher

🏡 Brain & Cognition

PPW, KU Leuven

🦋 [elinevg](https://github.com/elinevg)

🌐 evg.ulyssis.be/evg



Lisa Koßmann

🎓 PhD student

🏡 Brain & Cognition

PPW, KU Leuven

🦋 [lisa-kossmann](https://github.com/lisa-kossmann)

linkedin [Lisa Koßmann](https://www.linkedin.com/in/lisa-kossmann/)

Create your first  quarto® document

Create a .qmd file

In your editor, create a .qmd file:

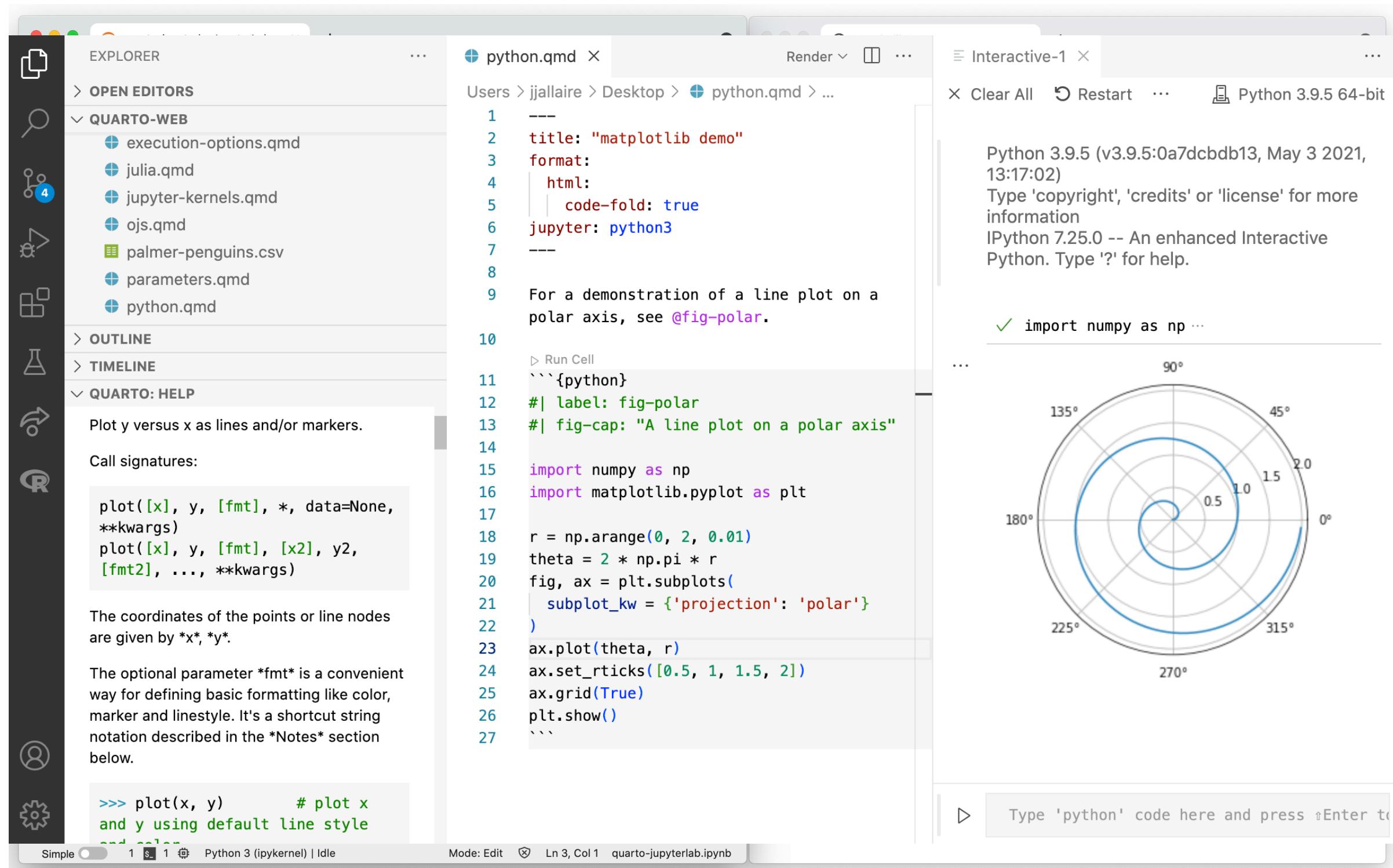
- RStudio: [File](#) -> [New file](#) -> [Quarto document](#)
- VS Code: [File](#) -> [New file](#) -> [Quarto document](#)
- Jupyter: [File](#) -> [New](#) -> [Notebook](#) (creates a .ipynb)



Anatomy of a Quarto document

- Metadata (YAML)
- Code (R / Python)
- Text (Markdown)

Use your preferred editor



The screenshot shows a Quarto JupyterLab interface with the following components:

- EXPLORER** sidebar: Shows open editors, including a Quarto file named `python.qmd` and a CSV file `palmer-penguins.csv`.
- Code Editor**: The `python.qmd` file contains a Quarto document with a code block and a Python script for a polar plot.
- Terminal**: The `Interactive-1` terminal shows the Python environment and a polar plot.
- Plot Viewer**: A polar plot of concentric circles centered at (0.5, 0) in a 2D coordinate system.

```

1  ---
2  title: "matplotlib demo"
3  format:
4  html:
5  | code-fold: true
6  jupyter: python3
7  ---
8
9  For a demonstration of a line plot on a
10 polar axis, see @fig-polar.
11
12  Run Cell
13  ````{python}
14  #| label: fig-polar
15  #| fig-cap: "A line plot on a polar axis"
16
17  import numpy as np
18  import matplotlib.pyplot as plt
19
20  r = np.arange(0, 2, 0.01)
21  theta = 2 * np.pi * r
22  fig, ax = plt.subplots(
23      subplot_kw = {'projection': 'polar'}
24  )
25  ax.plot(theta, r)
26  ax.set_rticks([0.5, 1, 1.5, 2])
27  ax.grid(True)
28  plt.show()
29  ````
```

Add a YAML header

```
1  ---
2  key: value
3  ---
```



Add a YAML header

```
1  ---
2  title: "Your Document"
3  author: "Your name"
4  date: today
5  format:
6    html:
7      code-fold: show
8      embed-resources: true
9  execute:
10    warning: false
11  ---
```

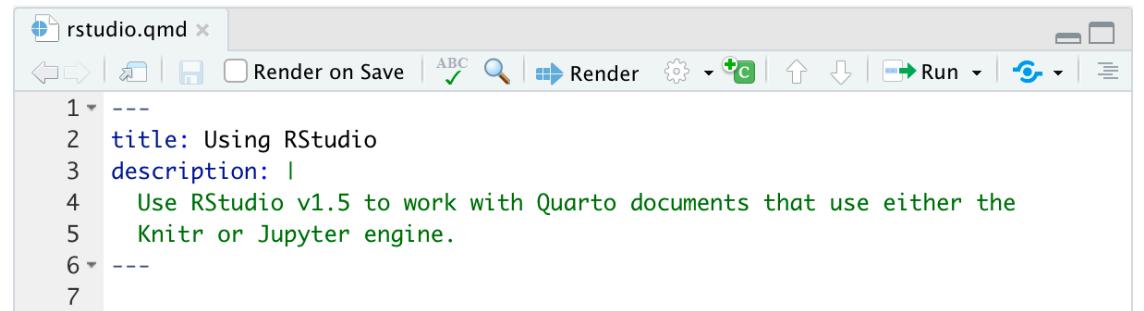
💡 Tip for efficiency

RStudio + VSCode provide rich tab-completion - start a word and tab to complete, or Ctrl + space to see all available options.

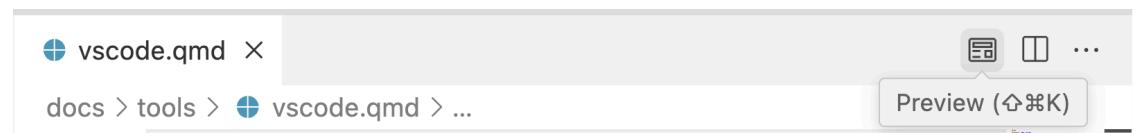
Render your document to HTML/PDF/DOCX



1. Render button in RStudio / Preview button in VS Code



```
1 ---  
2 title: Using RStudio  
3 description: |  
4 Use RStudio v1.5 to work with Quarto documents that use either the  
5 Knitr or Jupyter engine.  
6 ---  
7
```



```
docs > tools > + vscode.qmd > ...
```

Preview (⇧⌘K)



Render your document to HTML/PDF/DOCX

2. System shell via `quarto render`

terminal

```
1 quarto render document.qmd # defaults to html
2 quarto render document.qmd --to pdf
3 quarto render document.qmd --to docx
```

3. R console via `quarto` R package

```
1 library(quarto)
2 quarto_render("document.qmd") # defaults to html
3 quarto_render("document.qmd", output_format = "pdf")
```

⚠ Warning

In order to create PDFs you will need to install a recent distribution of TeX. We recommend the use of TinyTeX (which is based on TeXLive), which you can install with the following command (in the Terminal):

```
quarto install tinytex
```



Add plain text with Markdown formatting

```
1  ### Add a heading in your document  
2  
3  This is a sentence with some **bold text**, *italic text*,  
4  `code`, and a [link] (https://quarto.org/).
```

Add a heading in your document

This is a sentence with some **bold text**, *italic text*, `code`, and a [link](#).

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

Tip for Markdown newbies

New to Markdown? Use the visual editor in RStudio or VS Code!

Add plain text with Markdown formatting

Markdown Syntax

italics and **bold**

superscript² / subscript₂

~~strikethrough~~

`verbatim code`

Output

italics and **bold**

superscript² / subscript₂

~~strikethrough~~

verbatim code

Add plain text with Markdown formatting

Markdown Syntax	Output
# Header 1	Header 1
## Header 2	Header 2
### Header 3	Header 3
#### Header 4	Header 4
##### Header 5	Header 5
###### Header 6	Header 6



Add images

```
1  ! [Image caption](figs/quartologo.png) {width='20%' fig-align='left'}
```



Image caption



Add equations

```
1 Formula for population mean:  
2  
3 $$  
4 \mu = \frac{\sum x}{N}  
5 $$
```

Formula for population mean:

$$\mu = \frac{\sum x}{N}$$



Add R code chunks (and code outputs)

```

1  ````{r}
2  #| label: fig-scatterplot
3  #| fig-cap: "Scatterplot of flipper and bill lengths"
4
5  library(palmerpenguins) # for data
6  library(tidyverse)      # for data wrangling and visual
7  library(knitr)          # for tables
8
9  ggplot(data = penguins,
10         aes(x = flipper_length_mm,
11               y = bill_length_mm)) +
12   geom_point(aes(color = species,
13               shape = species))
14  ````
```

- Has 3x backticks on each end ````
- Place engine (**r**) between curly braces **{r}**
- Place options underneath, behind the **#|** (hashpipe): **#| option1: value**

💡 Tip for efficiency

Use a keyboard shortcut to create a new code chunk!

RStudio: Ctrl + Alt + I (OS X: Cmd + Option + I)

VS Code: Ctrl + Shift + I

Options for R code chunks: <https://quarto.org/docs/reference/cells/cells-knitr.html>



Add R code chunks (and code outputs)

```

1  ````{r}
2  #| output-location: column
3  #| label: fig-scatterplot
4  #| fig-cap: "Scatterplot of flipper and bill lengths"
5  #| warning: false
6
7  library(palmerpenguins) # for data
8  library(ggplot2)          # for data visualization
9
10 ggplot(data = penguins,
11         aes(x = flipper_length_mm,
12               y = bill_length_mm)) +
13   geom_point(aes(color = species,
14               shape = species))
15 ````
```

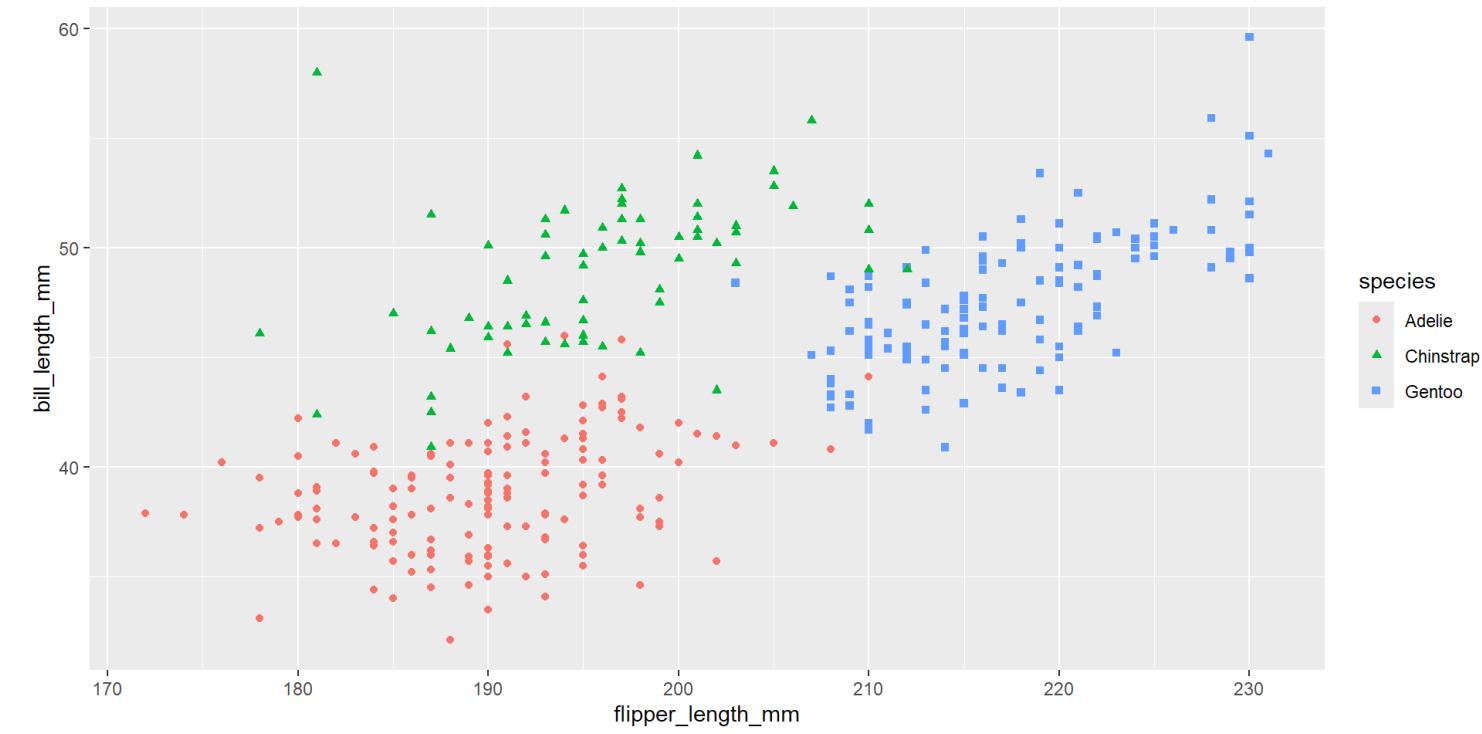


Figure 1: Scatterplot of flipper and bill lengths

Options for R code chunks: <https://quarto.org/docs/reference/cells/cells-knitr.html>

Add Python code chunks (and code outputs)



```

1  ````{python}
2  #| output-location: column
3  #| label: fig-scatterplot-py
4  #| fig-cap: "Scatterplot of flipper and bill lengths in
5
6  import numpy as np
7  import matplotlib.pyplot as plt
8  from palmerpenguins import load_penguins
9
10 penguins = load_penguins()
11
12 penguins['species_color'] = penguins['species']
13 penguins['species_color'].replace(['Adelie', 'Chinstrap',
14                                     ['red', 'green', 'blue'], inplace=True]
15
16 penguins.plot.scatter(x='flipper_length_mm',
17                       y='bill_length_mm',
18                       c='species_color')
19  ````
```

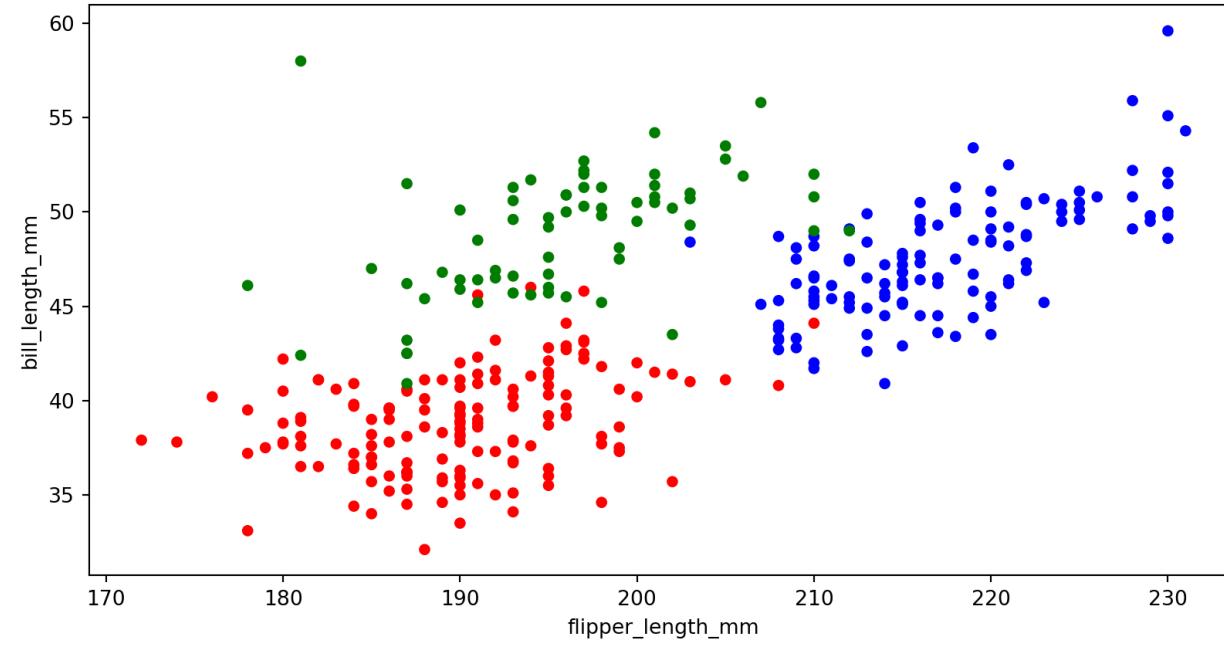


Figure 2: Scatterplot of flipper and bill lengths in Python

Options for Python code chunks: <https://quarto.org/docs/reference/cells/cells-jupyter.html>

Add Markdown table

```
1 | fruit    | price   |
2 | ----- | ----- |
3 | apple    | 2.05   |
4 | pear     | 1.37   |
5 | orange   | 3.09   |
6
7 : Fruit prices {.striped .hover}
```

Fruit prices

fruit	price
apple	2.05
pear	1.37
orange	3.09

More information: <https://quarto.org/docs/authoring/tables.html>

Add R table

```

1  ````{r}
2  #| output-location: column
3  #| label: tbl-stats
4  #| tbl-cap: "Summary statistics for flipper and bill lengths"
5
6  penguins %>%
7  group_by(species) %>%
8  summarise(
9    `Mean bill length` = mean(bill_length_mm, na.rm = TRUE),
10   `Mean flipper length` = mean(flipper_length_mm, na.rm = TRUE),
11   `Correlation, r` = cor(flipper_length_mm, bill_length_mm)
12 ) %>%
13   kable(digits = c(2, 2, 2, 2, 2))
14 ````
```

Table 1: Summary statistics for flipper and bill lengths

species	Mean bill length	Mean flipper length	Correlation, r
Adelie	38.79	189.95	0.33
Chinstrap	48.83	195.82	0.47
Gentoo	47.50	217.19	0.66

More information: <https://quarto.org/docs/authoring/tables.html>

Add Python table

```

1  ```{python}
2  #| output-location: column
3  #| label: tbl-py
4  #|tbl-cap: "First rows of penguins dataframe"
5
6  from tabulate import tabulate
7  from IPython.display import Markdown
8
9  # Convert to markdown table
10 Markdown(tabulate(penguins[["species", "island", "bill_length_mm"]], 
11 ```)

```

Table 2: First rows of penguins dataframe

	species	island	bill_length_mm	f
0	Adelie	Torgersen	39.1	1
1	Adelie	Torgersen	39.5	1
2	Adelie	Torgersen	40.3	1
3	Adelie	Torgersen	nan	r
4	Adelie	Torgersen	36.7	1

More information: <https://quarto.org/docs/authoring/tables.html>



Add inline R or Python code

- 1 The palmerpenguins package contains data for ` {r} nrow(penguins) ` penguins.
- 2 Remove the space before {r} to make sure the code is evaluated!

The palmerpenguins package contains data for 344 penguins.

- 1 The palmerpenguins package contains data for ` {python} penguins.shape[0] ` penguins.

⚠ Warning

Inline code only works for the chosen engine (knitr: R; jupyter: Python). Specify the engine explicitly in the YAML header.



Add cross-references

```
1 ! [The Quarto logo] (figs/quartologo.png) {#fig-quarto width='20%' fig-align='left'}
```

```
2
```

```
3 See @fig-quarto for the Quarto logo.
```



Figure 3: The Quarto logo

See [Figure 3](#) for the Quarto logo.

- [Figures \(#fig-\)](#)
- [Tables \(#tbl-\)](#)
- [Sections \(#sec-\)](#)
- [Equations \(#eq-\)](#)
- [and more](#)



Add citations

- Add citation in text: @... (manually or using visual editor > Insert citation)

```
1 The palmerpenguins package was developed by @horst2020. We will create a document using Quarto [@quarto] and R [@R] c
```

- Specify .bib file in YAML

```
1 bibliography: references.bib
```



Add tabssets

```
::: {.panel-tabset}
```

```
## Element 1
```

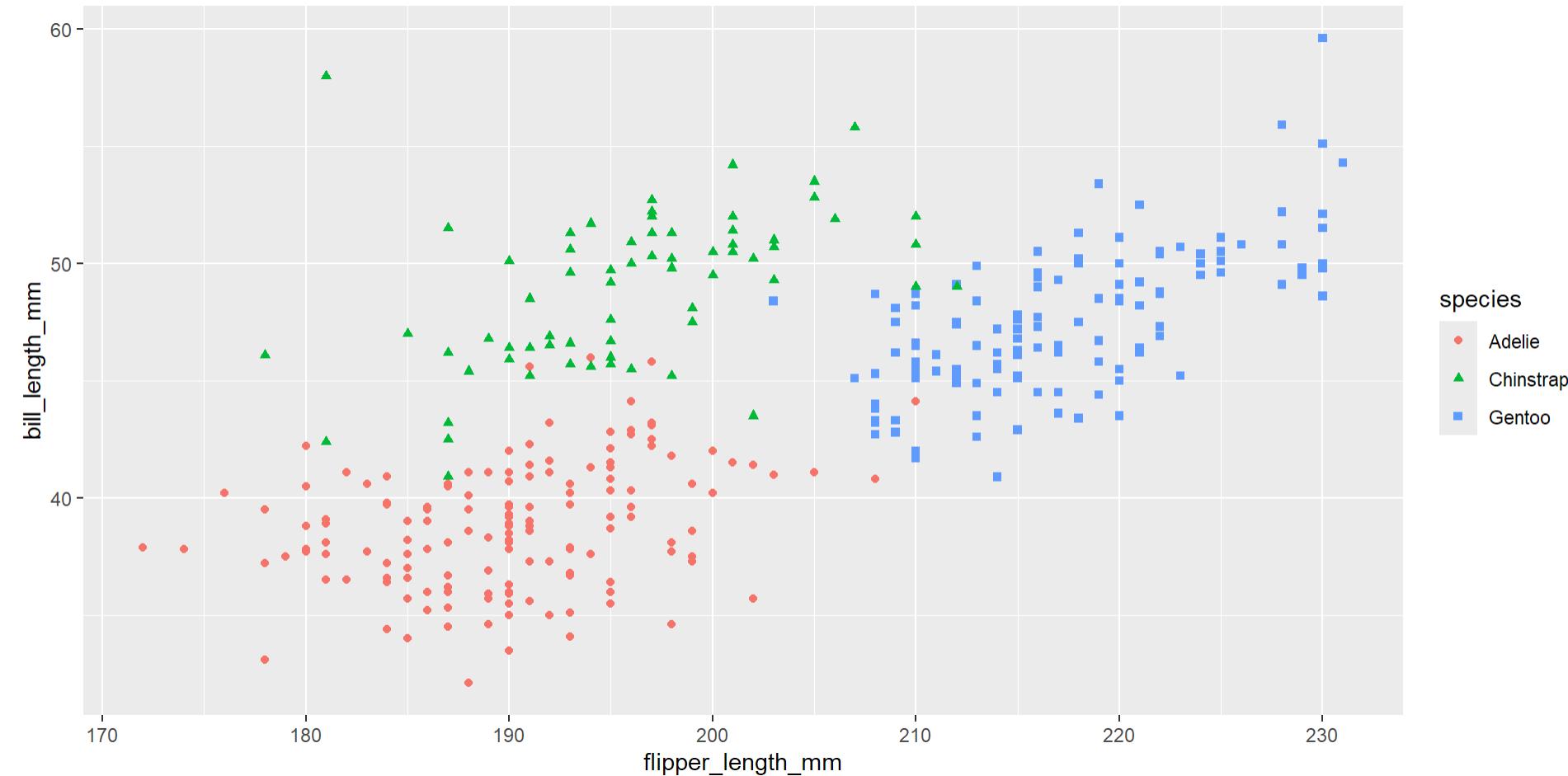
```
## Element 2
```

```
:::
```

Add tabs

R figure

Python figure



Scatterplot of flipper and bill lengths in R



Add footnotes

1 This sentence ends with a footnote.^[^1]

2

3 ^[^1]: This is an example footnote.

This sentence ends with a footnote.¹

Bonus features

- [interactive outputs](#) (only for HTML outputs):
 - [htmlwidgets](#) for R
 - [Jupyter widgets](#) for Python/Julia
 - [Observable JS](#)
 - [Shiny](#) for R and Python
- [callouts](#)
- [videos](#)
- [diagrams](#)

Bonus features

- code annotation
- article layout
- Extensions:
 - shortcodes and filters (e.g., fontawesome icons )
 - journal article formats
 - custom formats
- and much more! <https://quarto.org/docs/guide/>

Observable JS

```
viewof temp = Inputs.range([0, 100], {step: 1, value: 34, label: htl.html`Temp ºC`})
```

Temp °C

34

Converting temperature from °C to °F

Celsius = 34°C and Fahrenheit = 93.2°F.

Generated using this code chunk, text, and inline code:

```
1  ````{ojs}
2  viewof temp = Inputs.range([0, 100], {step: 1, value: 34, label: htl.html`Temp ºC`})
3  ```
4
5  Converting temperature from ºC to °F <br>
6  Celsius = ${d3.format(".0f")(temp)} and Fahrenheit = ${d3.format(".1f")(temp * 9/5 + 32)}.
```

Other output formats

- Presentations (Revealjs / Beamer / PowerPoint)
- Dashboards
- Websites
- Books
- Manuscripts
- ...

Examples of advanced use cases

- Your poster using Quarto: [posterdown](#), [typst-poster](#), [quarto_poster](#), or [docposter](#)
- Your PhD thesis using Quarto: [PhD thesis Eline](#); [other Quarto books](#)
- Your journal articles using Quarto
(e.g. using [apaquarto](#), [other formats](#), or [Quarto Manuscripts](#))
- Parametrized reports using Quarto: [blog on parametrized reports](#); [Quarto documentation on parameters](#)
- Your website using Quarto: [personal website](#); [documentation website](#); [other website projects](#)
- Your [dashboards](#) or [interactive documents](#) using Quarto

Awesome Quarto resources (only a selection!)

- [Quarto cheatsheet](#)
- [Awesome Quarto list](#)
- [Quarto for Scientists](#)
- [Quarto FAQ](#)
- [Quarto questions](#)

Bonus: What to do with my existing .Rmd or .ipynb?

For some of you - nothing changes! Keep using RMarkdown and Jupyter.

However, most existing `.rmd` or `.ipynb` can be rendered as-is via Quarto

terminal

```
1 quarto render my-favorite.rmd --to html
```

Since Jupyter notebooks can either be treated as a linear document to be re-executed or an already evaluated document there are additional options like: `--execute`

terminal

```
1 quarto render my-favorite.ipynb --to html --execute
```

Bonus: Why Quarto, instead of RMarkdown

- Batteries included, shared syntax
- Choose your own editor and your preferred data science language
- Better accessibility and richer features out of the box
- More enhancements overtime - RMarkdown still maintained, but majority of new features built into Quarto

Collaboration with other colleagues in other languages - shared format, choose your editor and your native language

Quarto, crafted with love and care

Development of Quarto is sponsored by RStudio, PBC. The same core team works on both Quarto and R Markdown:

- Carlos Scheidegger ([@cscheid](https://twitter.com/cscheid))
- Charles Teague ([@dragonstyle](https://twitter.com/dragonstyle))
- Christophe Dervieux ([@cderv](https://twitter.com/cderv))
- J.J. Allaire ([@jjallaire](https://twitter.com/jjallaire))
- Yihui Xie ([@yihui](https://twitter.com/yihui))

Here is the [full contributors list](#). Quarto is open source and they welcome contributions in their github repository as well! <https://github.com/quarto-dev/quarto-cli>.

Attributions

The slides and materials for this workshop were heavily based on other existing guides and workshops:

- [Quarto official documentation](#)
- [Getting Started with Quarto](#) by Tom Mock (CC BY 4.0)
- [Quarto workshop](#) by Julien Barnier and Aurélie Siberchicot

Icon attributions:

- to do by Michael Appleford from Noun Project (CC BY 3.0)

Thank you very much for providing these open resources!

Feedback, further questions or want to connect?



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