Building interactive web apps

with the `R` package `shiny`

Applied Data Analysis and Visualization
Presented by Hanne Oberman
07-06-2022

What we'll discuss

1. The `shiny` framework
2. The user interface (UI)
3. The server
4. Advanced topics
5. Take-aways

The `shiny` framework

The basics

What is `shiny`?

- An `R` package for building web apps.

What is a `shiny` app?

- A fully interactive application, which can be:
    - build as a dashboard;
    - hosted on a webpage;
    - included in `R` Markdown documents.

The aim

Why use `shiny`?

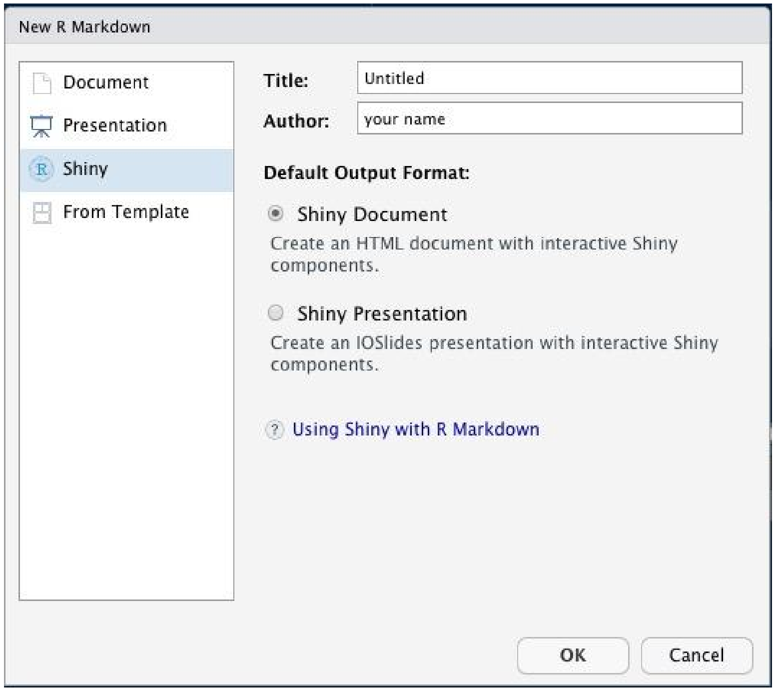
- To create apps!
- Make your `R` workflows:
    - interactive (point-and-click style);
    - reproducible for non-coders;
    - look instantly professional.

The template app

How to build a `shiny` app?

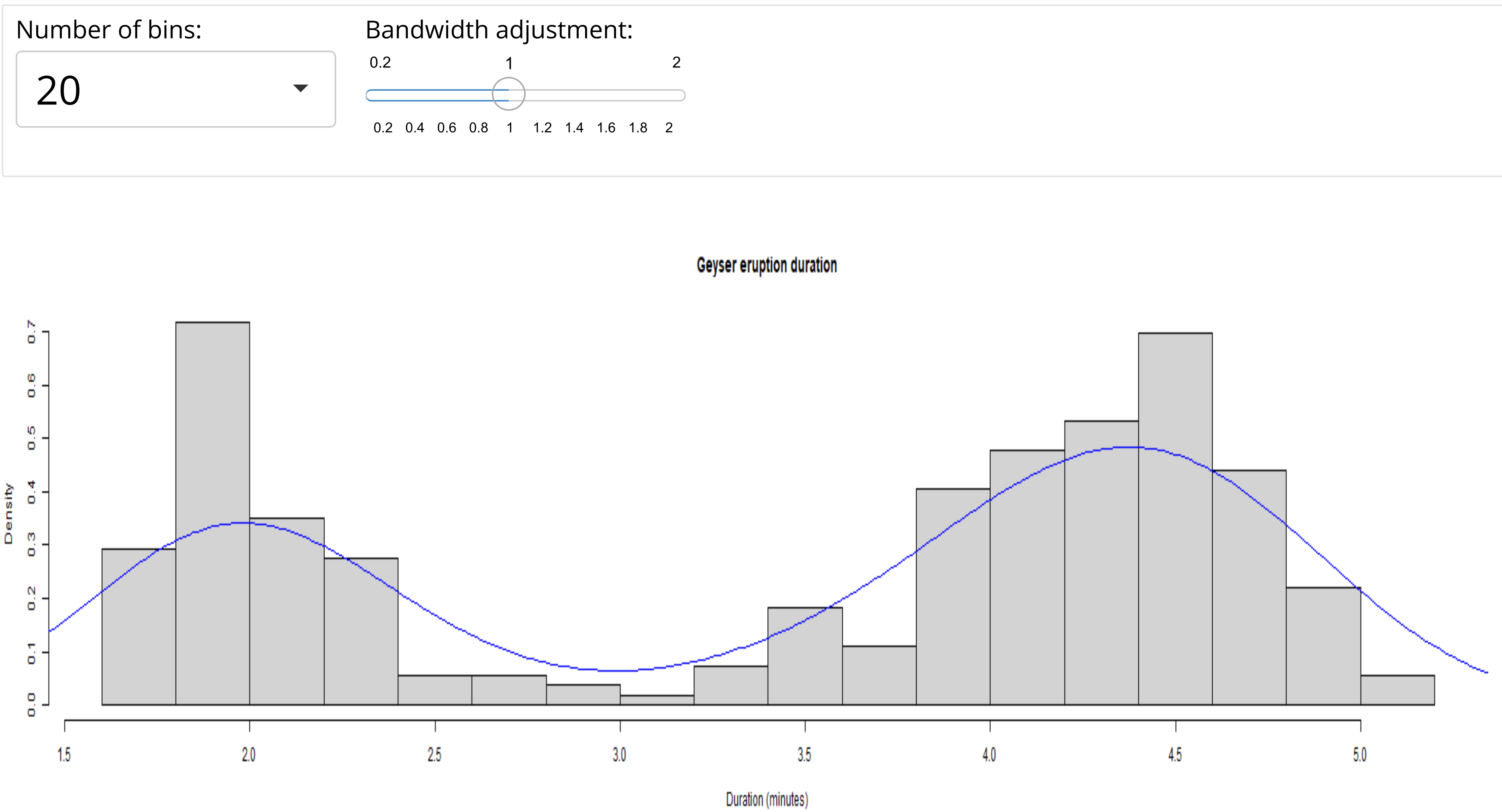
A. Create a file called `app.R` and add `shiny` components*

B. In RStudio: File → New file → R Markdown → Shiny



*file name and components are non-negotiable!

The template app



The components

How does a `shiny` app work?

- A user interface (UI):
    - the visible, interactive part;
    - e.g., a web app or dashboard.
- A server:
    - the invisible, processing part;
    - e.g., your own computer or shinyapps.io (shinyapps.io).

```
library(shiny)
ui <- # some code to generate the UI
server <- # some code to generate the server
shinyApp(ui = ui, server = server)
```

The package

What does `shiny` offer?

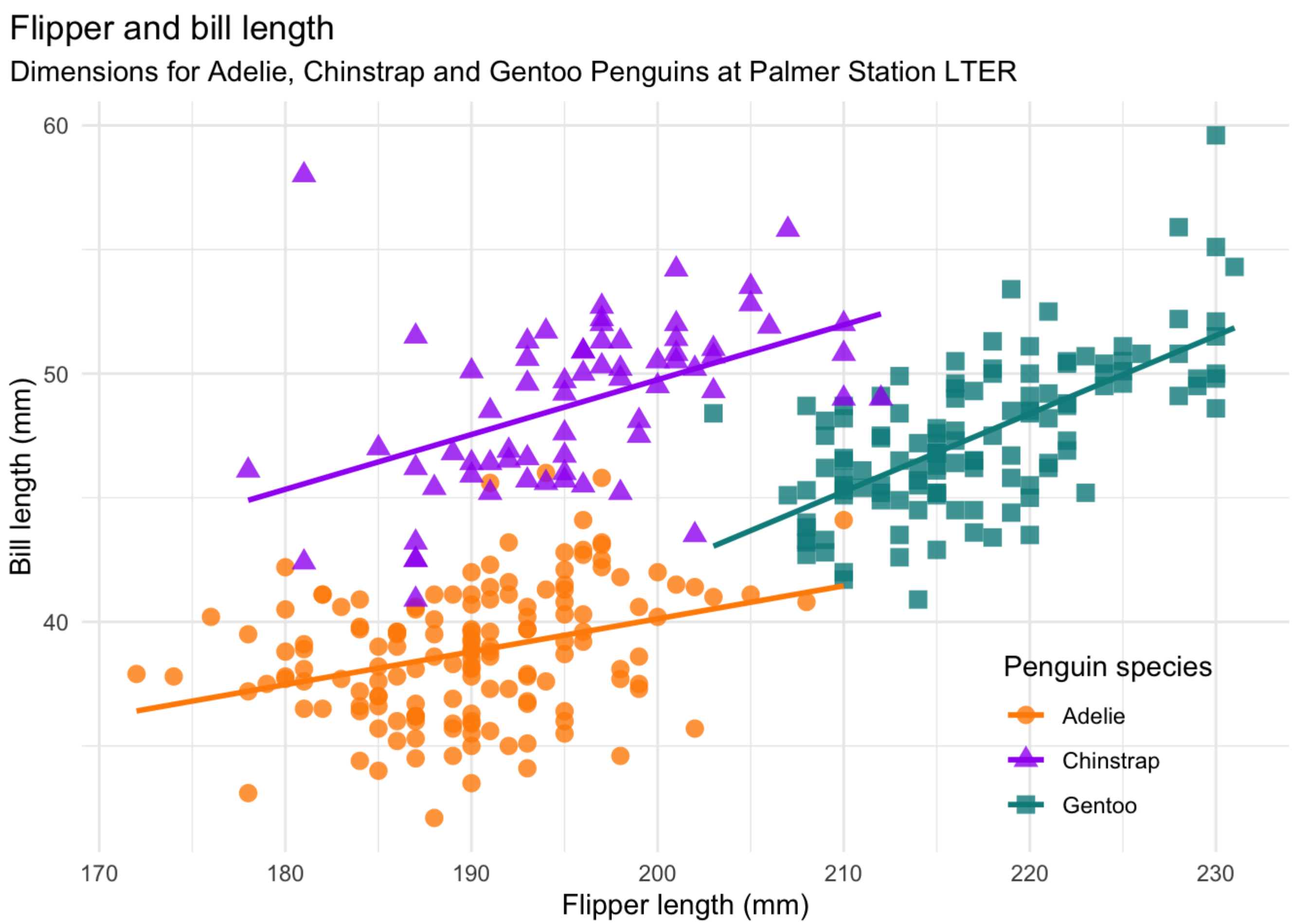
- A collection of wrapper functions to write “app languages”:
  - geared toward `R` users who have zero experience with web development;
  - no knowledge of HTML / CSS / JavaScript required;
  - but you *can* extend it with CSS themes, htmlwidgets, and JavaScript actions.
- Developed by RStudio, so documentation and support are more or less guaranteed.

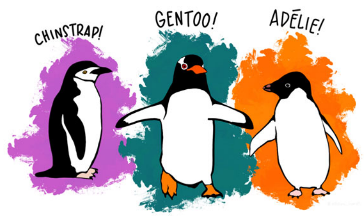
Case study

The palmer penguins (https://allisonhorst.github.io/palmerpenguins/) `penguins` dataset.

```
## # A tibble: 6 x 8
##   species island bill_length_mm bill_depth_mm flipper_length_~ body_mass_g sex
##   <fct>   <fct>           <dbl>         <dbl>            <int>       <int> <fct>
## 1 Adelie  Torge~           39.1          18.7              181        3750 male
## 2 Adelie  Torge~           39.5          17.4              186        3800 fema~
## 3 Adelie  Torge~           40.3          18                195        3250 fema~
## 4 Adelie  Torge~           NA            NA                 NA          NA <NA>
## 5 Adelie  Torge~           36.7          19.3              193        3450 fema~
## 6 Adelie  Torge~           39.3          20.6              190        3650 male
## # ... with 1 more variable: year <int>
```

Case study


Flipper and bill length
Dimensions for Adelie, Chinstrap and Gentoo Penguins at Palmer Station LTER
60
50
40
Bill length (mm)
170
180
190
200
210
220
230
Flipper length (mm)
Penguin species
Adelie
Chinstrap
Gentoo


CHINSTRAP!
GENTOO!
ADÉLIE!

Starting point

```
library(shiny)
ui <- fluidPage()
server <- function(input, output) {}
shinyApp(ui = ui, server = server)
```

Our app

Tips

Don’t rush into coding when you should be thinking.

Before building a `shiny` app, think about:

- What is the app aimed at?
- Who are the end users of your app? Are they tech-literate?
- In what context will the app be used? On what machines (e.g., because of screen size)?

Tips

While building a `shiny` app:

- Keep It Simple, Stupid;
- Use a design/UI first approach;
- Build the front-end and the back-end separately;
- If you copy something just *once*, make it a function;
- Avoid unnecessary complexity and ‘feature creep’.

Tips

After building a `shiny` app:

- Share the app;
- Make it last.

Note. We'll get back to this later!

The UI

Adding a title

```
ui <- fluidPage(
  titlePanel("Palmer penguins")
)
```

The `shiny` function `titlePanel()`

- adds a visible big title-like text to the top of the page;
- sets the “official” title of the web page (i.e., displayed at the name of the tab in the browser).

Our app

Palmer penguins

Adding some text

To render text in our app, we can just add character/string objects inside `fluidPage()`:

```
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  "An interactive",
  "visualization"
  )
```

Our app

Palmer penguins

An interactive visualization

Adding formatted text

For formatted text, `shiny` has many functions that are wrappers around HTML tags. For example:

- `h1()`: top-level header;
- `h2()`: secondary header;
- `strong()`: bold text;
- `em()`: italicized text;
- `br()`: line break;
- `img()`: image;
- `a()`: hyperlink, etc.

Note. If you already know HTML, you don't need to use these wrapper functions!

Adding formatted text

Let’s replace the UI part of our code with the following:

```
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  "An",
  em("interactive"),
  br(),
  strong("visulalization")
)
```

Our app

Palmer penguins

An *interactive*
visulalization

Adding a layout

The simple sidebar layout:

- provides a two-column layout with a smaller sidebar and a larger main panel;
- visually separates the input and output of the app.

We'll replace the formatted text by a sidebar layout:

```r
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  sidebarLayout(
    sidebarPanel("[inputs]"),
    mainPanel("[outputs]")
  )
)
```

Our app

Palmer penguins

[inputs]

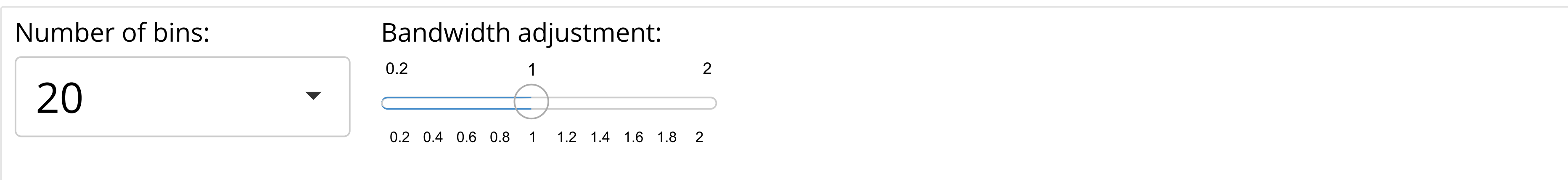
[outputs]

Adding an input element

Inputs allow users to interact with a `shiny` app.

We've seen two types already:

- `selectInput()` creates a dropdown menu (e.g., number of bins in the template app);
- `sliderInput()` creates a numeric scale (e.g., bandwidth adjustment in the template app).

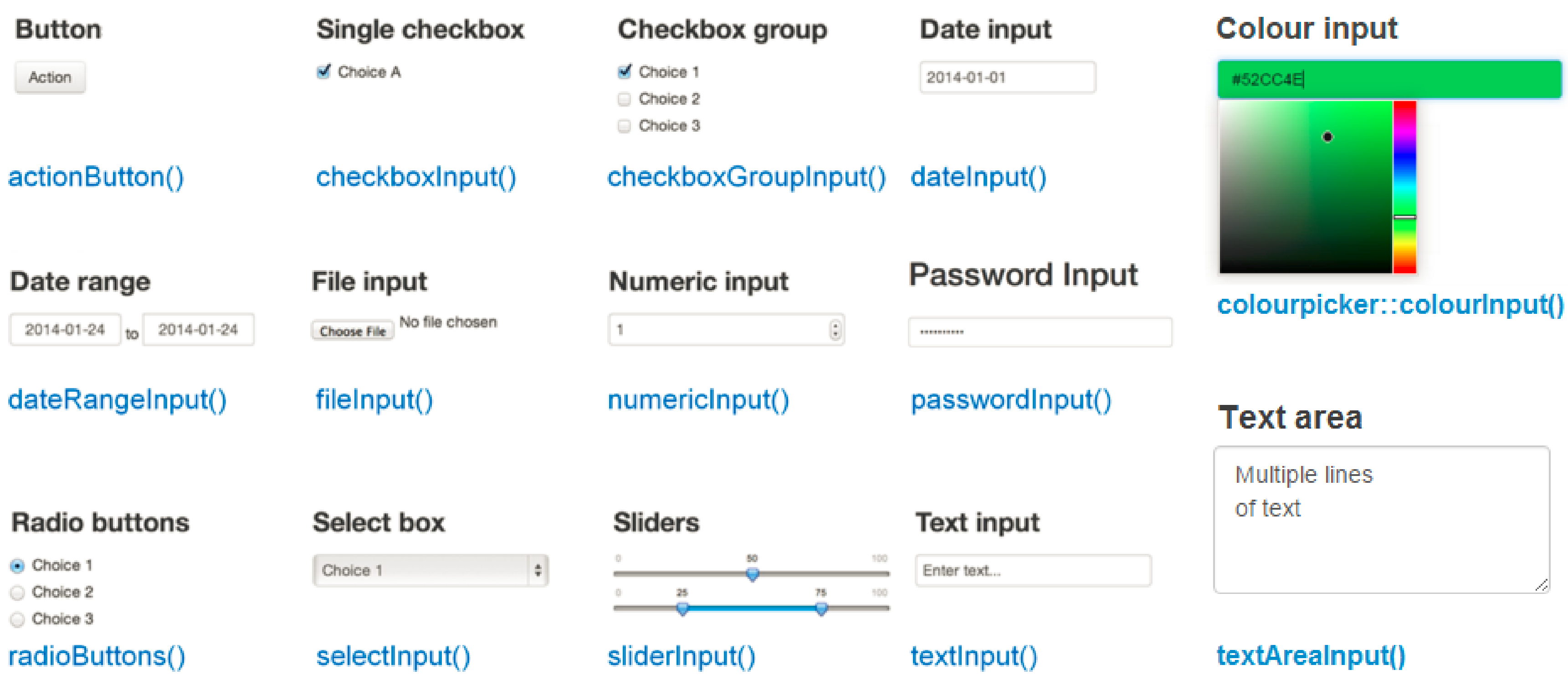


Adding an input element

Can you guess what kind of element these input functions will create?

- `textInput()`;
- `dateInput()`;
- `checkboxInput()`.

Adding input elements



Adding an input element

Which function would suit an input element for the variable `island`?

Location

- Biscoe
- Dream
- Torgersen

```
radioButtons(
  inputId = "location",
  label = "Location",
  choices = c("Biscoe", "Dream", "Torgersen")
  )
```

Adding an input element

All input functions have the same first two arguments:

- `inputId`, the name by which `shiny` will refer to this input when you want to retrieve its current value;
- `label`, which specifies the text displayed right above the input element.

These argument names are typically dropped from the `...Input()` function call:

```
radioButtons("location", "Location", choices = c("Biscoe", "Dream", "Torgersen"))
```

Note. Every input in your app *must* have a unique `inputId`; the app will not work properly otherwise! So keep your `inputIds` simple and sensible.

Adding an input element

The resulting UI code looks like:

```
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  sidebarLayout(
    sidebarPanel(
      radioButtons("location", "Location",
                   choices = c("Biscoe", "Dream", "Torgersen"))
    ),
    mainPanel("[outputs]")
  )
)
```

Our app

Palmer penguins

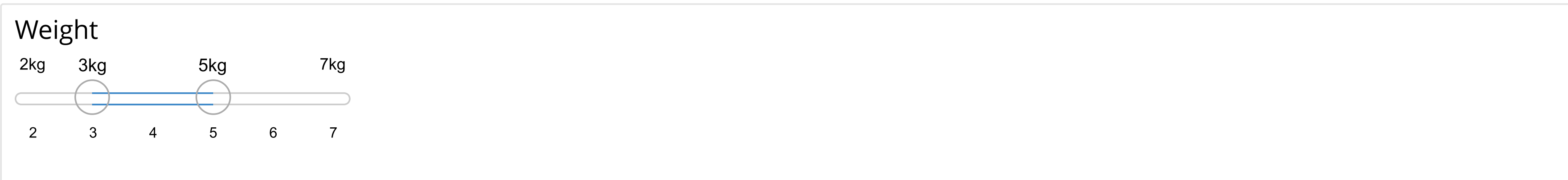
Location

- (•) Biscoe
- ( ) Dream
- ( ) Torgersen

[outputs]

Adding another input element

Let's create an input element for the variable `body_mass_g` as well. Which input function(s) should we use?



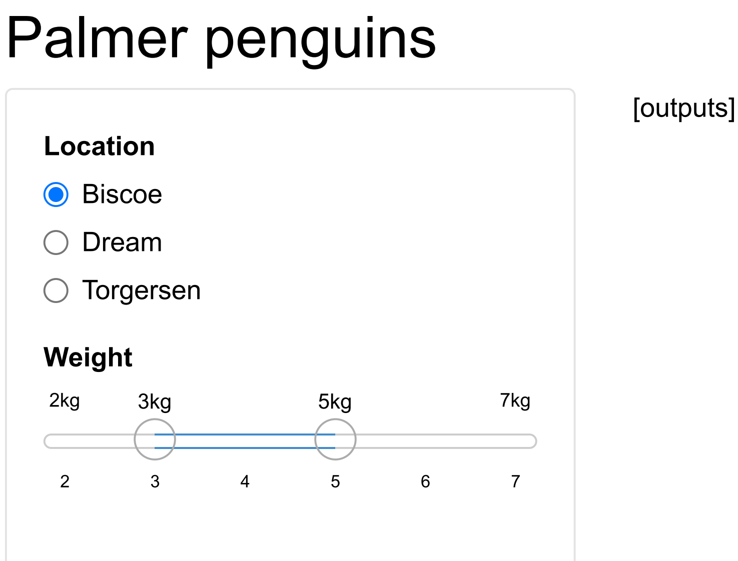

```
sliderInput("weight", "Weight",
            min = 2, max = 7, value = c(3, 5), post = "kg")
```

Adding another input element

The full UI code is now:

```
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  sidebarLayout(
    sidebarPanel(
      radioButtons("location", "Location",
                   choices = c("Biscoe", "Dream", "Torgersen")),
      sliderInput("weight", "Weight",
                  min = 2, max = 7, value = c(3, 5), post = "kg")
    ),
    mainPanel("[outputs]")
  )
)
```

Our app


Palmer penguins
[outputs]
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Adding an output element

Outputs are *shown* in the UI, but *created* on the server side.

That's why we add placeholders for the outputs in the UI.

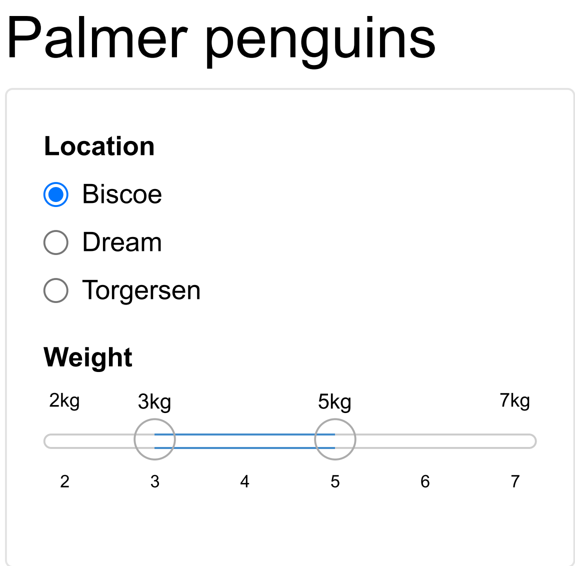
Placeholders:

- Determine where an output will be;
- Give outputs a unique ID to link it to the server;
- Won't actually show anything, yet.

Let's add a figure as output in our app:

```
mainPanel(
  plotOutput("scatterplot")
)
```

Our app


Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Adding another output element

The placeholder doesn’t show anything, because we haven’t created any figure yet on the server side.

But first, let’s add another output element:

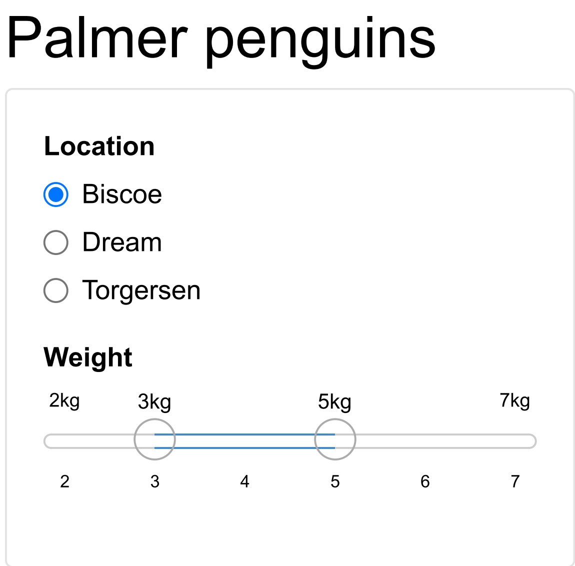
```
mainPanel(
  plotOutput("scatterplot"),
  br(),
  br(),
  tableOutput("descriptives")
)
```

Note. We added a few line breaks `br()` between the two outputs, so that they aren’t crammed on top of each other.

The complete UI

```
ui <- fluidPage(
  titlePanel("Palmer penguins"),
  sidebarLayout(
    sidebarPanel(
      radioButtons("location", "Location",
                   choices = c("Biscoe", "Dream", "Torgersen")),
      sliderInput("weight", "Weight",
                  min = 2, max = 7, value = c(3, 5), post = "kg")
    ),
    mainPanel(
      plotOutput("scatterplot"),
      br(),
      br(),
      tableOutput("descriptives")
    )
  )
)
```

Our app


Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Tips

When building the front-end of your app:

- Work on the general appearance first, anything that does not rely on computation (e.g., tabs, inputs, outputs);
- Use mock data and/or text (build an ‘ipsum-app’);
- Make the app self-evident; the main usage of the app should not require reading any manual.

The server

The server function

```
library(shiny)
ui <- fluidPage()
server <- function(input, output) {}
shinyApp(ui = ui, server = server)
```

The server function:

- requires* input and output IDs from the UI;
- builds output objects via `render...()` functions;
- saves the generated output into an output list.

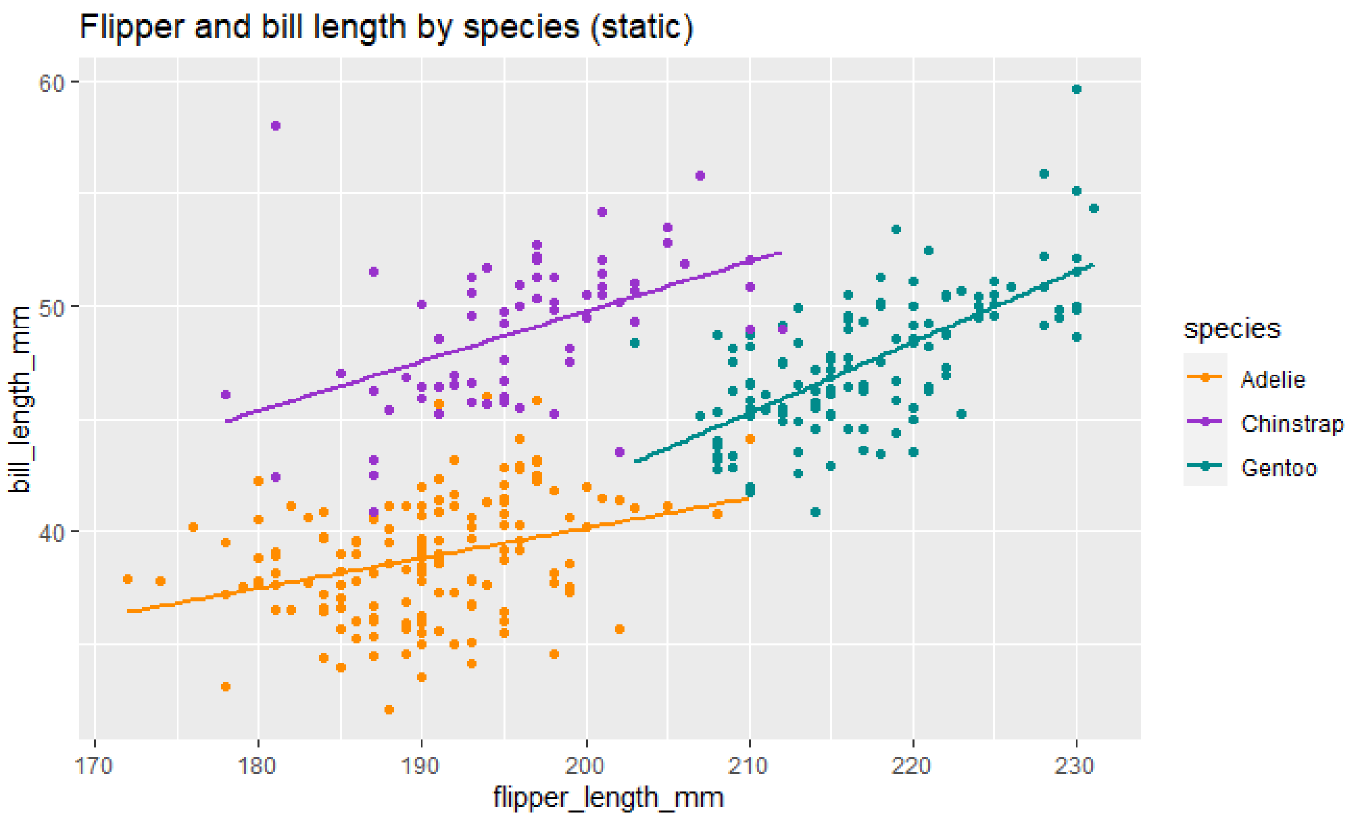
*exceptions apply!

Building static output

Let’s use the exception to the rule to develop our server step-by-step.

```
ggplot(penguins,
  aes(x = flipper_length_mm, y = bill_length_mm, color = species)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE) +
  scale_color_palmer() +
  labs(title = "Flipper and bill length by species (static)")
```

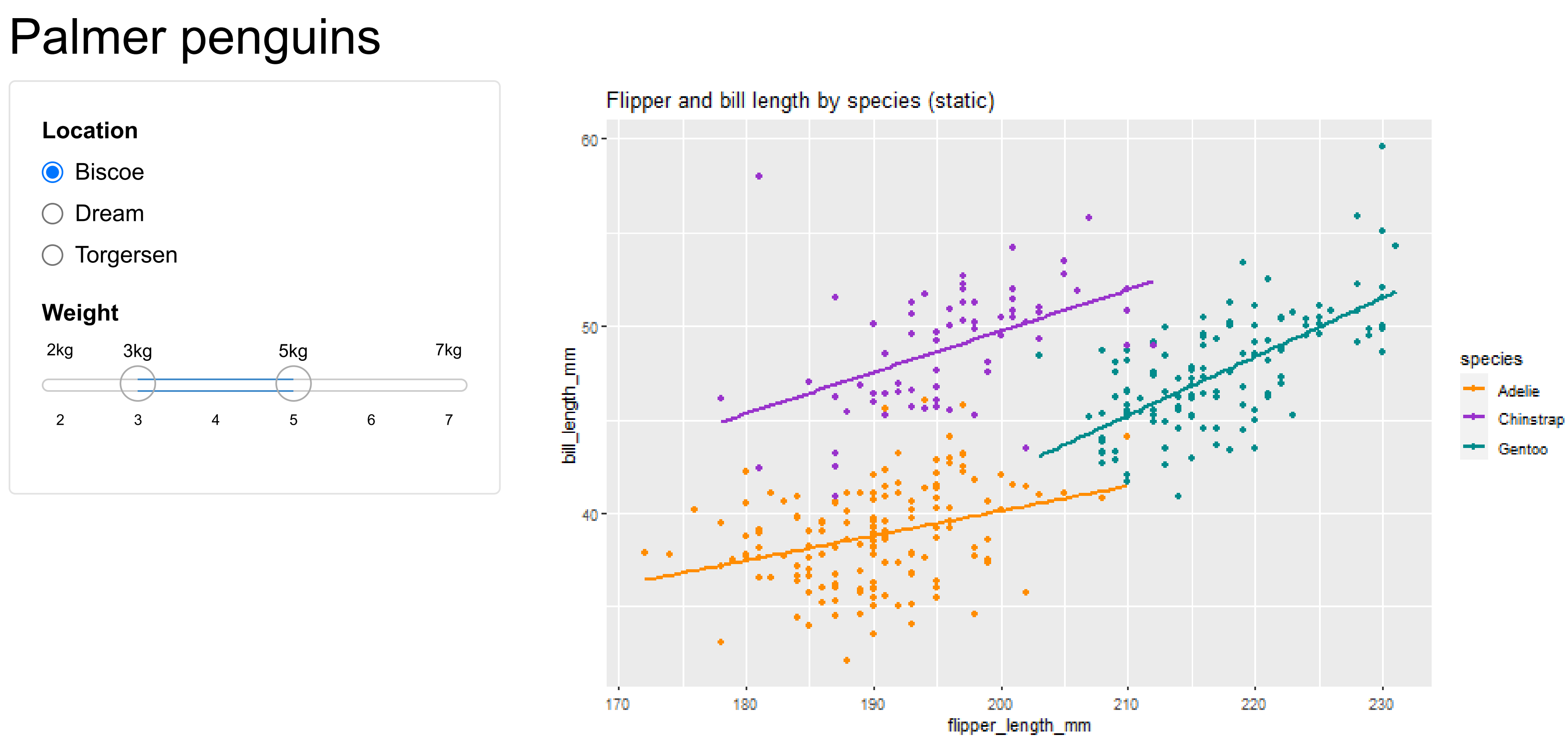
Building static output



Building static output

```
server <- function(input, output) {
  output$scatterplot <- renderPlot({
    ggplot(penguins,
      aes(x = flipper_length_mm, y = bill_length_mm, color = species)) +
      geom_point() +
      geom_smooth(method = "lm", se = FALSE) +
      scale_color_palmer() +
      labs(title = "Flipper and bill length by species (static)")
  })
}
```

Our app


Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7
Flipper and bill length by species (static)
60
50
40
bill_length_mm
170
180
190
200
210
220
230
flipper_length_mm
species
Adelie
Chinstrap
Gentoo

Building interactive output

To make the figure interactive, we have to link the server to the UI inputs.

```
server <- function(input, output) {
  output$scatterplot <- renderPlot({
    ggplot(penguins,
      aes(x = flipper_length_mm, y = bill_length_mm, color = species)) +
      geom_point() +
      geom_smooth(method = "lm", se = FALSE) +
      scale_color_palmer() +
      labs(title = paste("Flipper and bill length at", input$location))
  })
}
```

Whenever the selected location changes, the plot title will update.

Our app

Palmer penguins

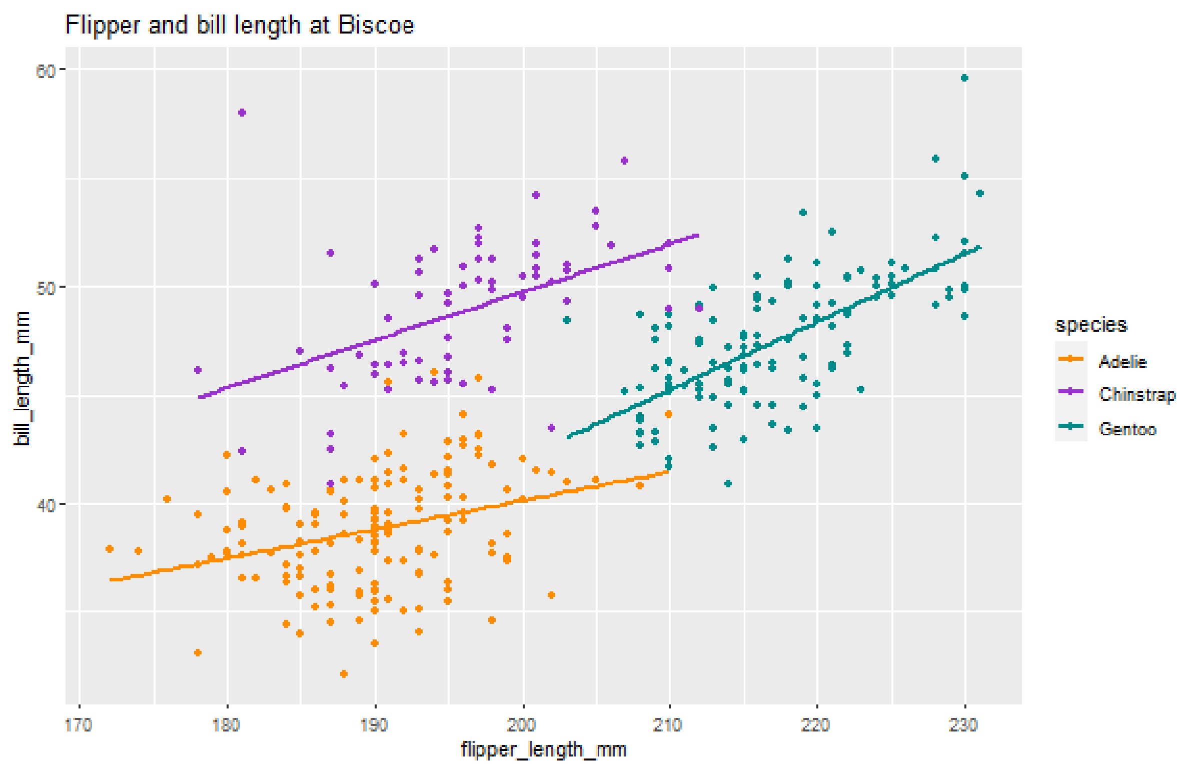
Location

- (selected) Biscoe
- Dream
- Torgersen

Weight

2kg 3kg 5kg 7kg

2 3 4 5 6 7

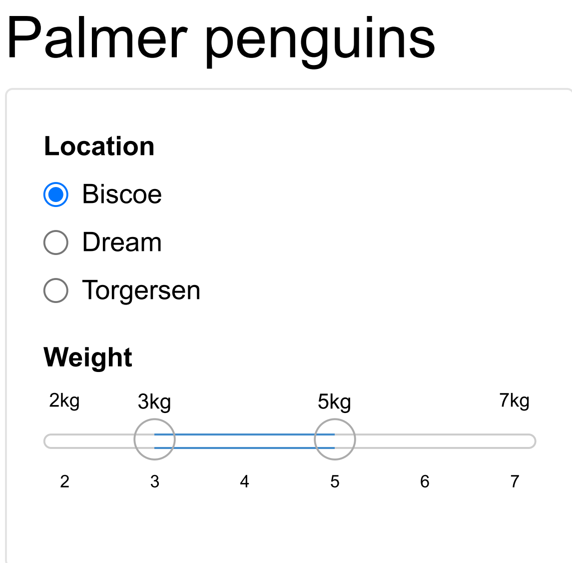


Building an interactive visualization

To incorporate interactivity in the visualization, we have to filter the data based on the input values.

```
server <- function(input, output) {
  output$scatterplot <- renderPlot({
    filtered <- penguins %>%
      filter(island == input$location,
           body_mass_g >= input$weight[1] * 1000,
           body_mass_g <= input$weight[2] * 1000
      )
    filtered %>%
      ggplot(aes(x = flipper_length_mm, y = bill_length_mm, color = species)) +
        geom_point() +
        geom_smooth(method = "lm", se = FALSE) +
        scale_color_palmer() +
        labs(title = "Flipper and bill length")
  })
}
```

Our app

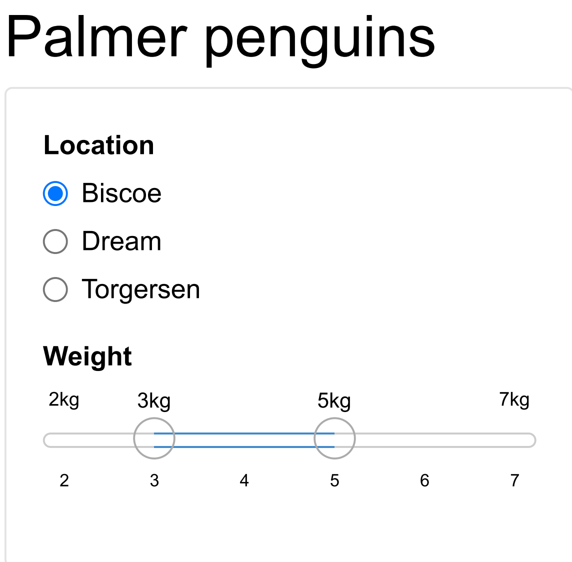

Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Building an interactive summary table

To complete our app we need to build an interactive output for the table placeholder and add it to the server:

```
output$descriptives <- renderTable({
  filtered <- penguins %>%
      filter(island == input$location,
           body_mass_g >= input$weight[1] * 1000,
           body_mass_g <= input$weight[2] * 1000
      )
  filtered %>%
    group_by(species) %>%
    summarise(across(c(bill_length_mm, flipper_length_mm), mean, na.rm = TRUE))
})
```

Our app


Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Intermezzo

Reactivity

Short break from our app to talk about a crucial concept in `shiny`: reactivity.

Reactivity enables your outputs to react to changes in inputs.

On the most basic level, it means that when the value of a variable `x` changes, anything that relies on `x` (i.e. has `x` in it) gets re-evaluated.

Consider the following code

```
x <- 5
y <- x + 1
x <- 10
```

What is the value of `y`?

Reactivity

What is the value of `y`?

```
x <- 5
y <- x + 1
x <- 10
```

In ordinary programming, the value of `y` is still 6.

In reactive programming, however, `x` and `y` are *reactive expressions*. Now, the value of `y` updates reactively, and becomes 11.

Reactivity is the foundation for the responsiveness of `shiny` apps.

Reactivity

In our server, we implicitly use reactivity when we filter the data for our outputs:

```
filtered <- penguins %>%
    filter(island == input$location,
         body_mass_g >= input$weight[1] * 1000,
         body_mass_g <= input$weight[2] * 1000
    )
  )
```

Whenever one of the inputs changes, our outputs change with it. But, this part of code is duplicated, because we didn’t use a reactive variable.

Reactivity

We can avoid code duplication by:

- defining a reactive variable that will hold the filtered dataset;
- using that variable in the `render...()` functions.

```
filtered <- reactive({
 penguins %>%
    filter(island == input$location,
           body_mass_g >= input$weight[1] * 1000,
           body_mass_g <= input$weight[2] * 1000
      )
})
```

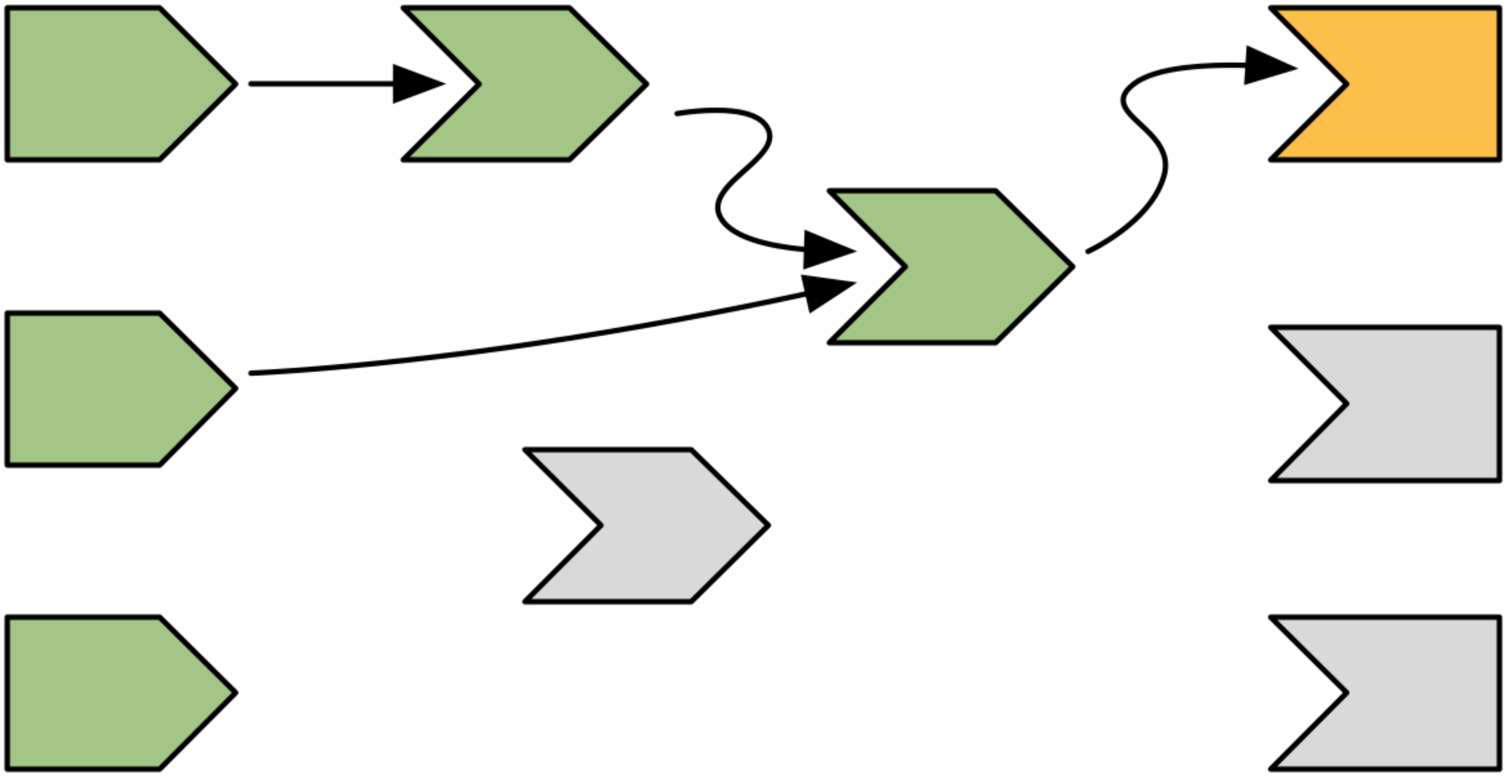
Reactivity

What is going on behind the scenes?

- The price input changes →
- `shiny` 'looks' at the reactive(s) that depend on price →
- `filtered()` is re-evaluated →
- `shiny` 'looks' at the reactive(s) that depend on `filtered()` →
- The two `render...()` functions are re-executed →
- The plot and the table output are updated.

This can be visualized in a dependency tree, to show what value depends on what other value.

Reactivity



The server (continued)

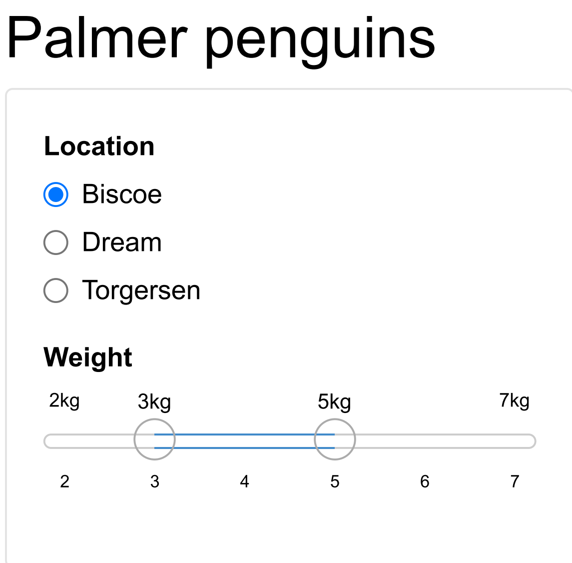
The final app

```
server <- function(input, output) {
  filtered <- reactive({
    penguins %>%
      filter(island == input$location,
             body_mass_g >= input$weight[1] * 1000,
             body_mass_g <= input$weight[2] * 1000
             )
  })

  output$scatterplot <- renderPlot({
    filtered() %>%
      ggplot(aes(x = flipper_length_mm, y = bill_length_mm, color = species)) +
        geom_point() +
        geom_smooth(method = "lm", se = FALSE) +
        scale_color_palmer() +
        labs(title = "Flipper and bill length")
  })

  output$descriptives <- renderTable({
    filtered() %>%
      group_by(species) %>%
      summarise(across(c(bill_length_mm, flipper_length_mm), mean, na.rm = TRUE))
  })
}
```

Our app


Palmer penguins
Location
Biscoe
Dream
Torgersen
Weight
2kg
3kg
5kg
7kg
2
3
4
5
6
7

Tips

When building the back-end of your app:

- Use sensible non-reactive defaults while developing (e.g., `data <- mtcars` instead of `data <- reactive(...).`);
- Think about what could to be 'hard coded' in the final app too, because of the reactivity vs. speed trade-off;
- Extract the complex (but non-reactive) processing functions and put them in separate files;
- Add user feedback to make server-side requirements explicit (e.g., input validation, pop-up messages, loading icons).

Advanced topics

Design

- Use more complex layouts, such as tabs or dashboards;
- Make the output elements ‘clickable’ with `plotly` and `datatable`;
- Change input element options from the server side with `update...()` functions.

Robustness

- Run the app in the viewer panel, a separate window, and your browser;
- Monkey test it (i.e., click EVERYTHING);
- Provide the wrong inputs (e.g., a corrupt data file, a file with the ‘wrong’ extension, an ‘impossible’ numeric input, etc.);
- Modularize your app;
- Use the `golem` framework for production-grade `shiny` apps (but decide up-front!).

Deployment

Deploy your app on shinyapps.io (https://www.shinyapps.io/):

- You'll have a link to use/share the app online;
- Non-R-users will be able to interact with your app;
- You can tweak your app to cache certain outputs, or have several users in one session (like Google Drive documents);
- But, with a free account, your app will be public;
- And if your app is too popular, you will eventually need to pay server costs.

Note. You could also host your app on your own website. Or don't deploy it at all (e.g., for privacy reasons).

Take-aways

Summary

- `shiny` allows you to build interactive (web) apps from `R`;
- `shiny` apps consist of two parts, the user interface (UI) and the server:
  - In the UI, you design what is shown to the user,
  - In the server, you do all the modeling and building of the outputs,
  - You link the UI and the server to make the app interactive,
  - To optimize these interactions, you can use reactive expressions;
- This is only the tip of the iceberg, there are many more things you can do with `shiny`.

Inspiration

Check out these amazing resources:

- RStudio's introduction to shiny webinar (https://www.rstudio.com/resources/webinars/introduction-to-shiny/);
- Hadley Wickham's book Mastering Shiny (https://mastering-shiny.org/);
- The official cheatsheet (https://rstudio.com/resources/cheatsheets/);
- The more advanced Engineering Shiny (https://engineering-shiny.org/);
- This webinar on Modularizing Shiny (https://www.youtube.com/watch?v=ylLLVo2VL50).

And look for examples here:

- The Shiny Gallery (https://shiny.rstudio.com/gallery/);
- The annual `shiny` contest (https://www.rstudio.com/blog/winners-of-the-2nd-shiny-contest/).

Check out my app!

hanneoberman.shinyapps.io/shinymice-demo/
(https://hanneoberman.shinyapps.io/shinymice-demo/)

Your own `shiny` app

For assignment 2 you will build your own `shiny` app in groups.

The assignment is due Thursday June 23rd *before* the start of your lab.

The assignment is posted on the course website and group composition will be announced by your lab teacher on Thursday.

Planning

Practical on Thursday

- Materials for the lab can be found online now. Please read and complete **Part 1. A simple example** of the lab *before* the lab. This will make sure you can build your own app successfully during the lab.

Lecture next week

- A new (supervised) machine learning method: **decision trees** and **random forests**.

Assignment 2

- Build your own `shiny` app before June 23rd.

Thank you!