Basic Data Structures in R

HES 505 Fall 2022: Session 2

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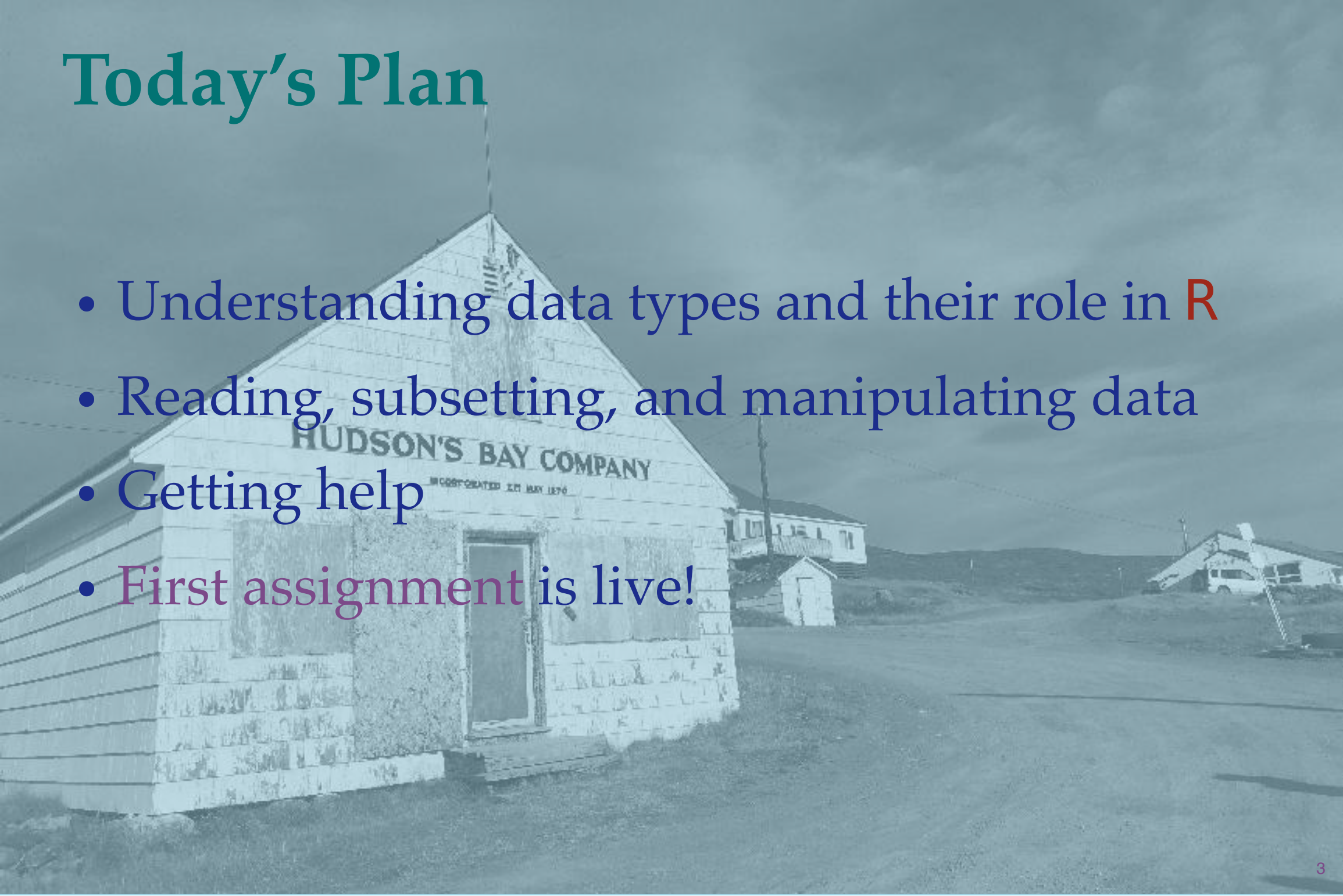
Checking in

1. What are some advantages and disadvantages of using R for spatial analysis
2. What can I clarify about the course?
3. How do you feel about git and github classroom? How can I make that easier for you?

Today's Plan

- Understanding data types and their role in R
- Reading, subsetting, and manipulating data
- Getting help
- First assignment is live!



Data types and structures

Data types

- The basic schema that R uses to store data.
- Creates expectations for allowable values
- Sets the "rules" for how your data can be manipulated
- Affects storage and combination with other data types
- Four most common: **Logical**, **Numeric**, **Integer**, **Character**

Logical Data

- Data take on the value of either `TRUE` or `FALSE`.
- Special type of logical called `NA` to represent missing values
- Can be coerced to integers when numeric data is requires (`TRUE` = 1; `FALSE` = 0)

Logical Data (cont'd)

- Can be the outcome of logical test

```
1 x <- runif(10,-10, 10) #generate 10 random numbers between -10 and 10
2 (y <- x > 5) #test whether the values are greater than 5 and assign to obje
```

```
 [1]  TRUE FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE FALSE FALSE
```

```
1 typeof(y) #how is R storing the object?
```

```
[1] "logical"
```

```
1 mean(y) #gives the proportion of y that is greater than 5
```

```
[1] 0.3
```

```
1 x[c(3,6,8)] <- NA #set the 3rd, 6th, and 8th value to NA
2 is.na(x) #check which values are NA
```

```
 [1] FALSE FALSE  TRUE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE
```

Numeric Data

- All of the elements of an object (or variable) are numbers that *could* have decimals
- R can store this as either *double* (at least 2 decimal points) or *integer*

```
1 x <- runif(10,-10, 10) #generate 10 random numbers between -10 and 10
2 typeof(x) #how is R storing the object?
```

```
[1] "double"
```

```
1 class(x) #describes how R will treat the object
```

```
[1] "numeric"
```

Integer Data

- **Integer** data is a special case of numeric data with no decimals

```
mode(x) <- "integer"
x
```

```
 [1] -9 -7  8  0 -2 -8  0  4  5  5
```

```
class(x)
```

```
[1] "integer"
```

```
typeof(x)
```

```
[1] "integer"
```

```
z <- sample.int(100, size=10) #sample 10 integers between 1 and 100
typeof(z)
```

```
[1] "integer"
```

```
class(z)
```

```
[1] "integer"
```

Character Data

- Represent *string* values
- **Strings** tend to be a word or multiple words
- Can be used with logical tests

```
1 char <- c("Sarah", "Tracy", "Jon") #use c() to combine multiple entries
2 typeof(char)
```

```
[1] "character"
```

```
1 char == "Jon"
```

```
[1] FALSE FALSE  TRUE
```

```
1 char[char=="Jon"] <- "Jeff"
2 char
```

```
[1] "Sarah" "Tracy" "Jeff"
```

Factors

- A special case of character data
- Data contains a limited number of possible character strings (categorical variables)
- The `levels` of a factor describe the possible values (all others coerced to `NA`)

```
1 (sex <- factor(c("female", "female", "male", "female", "male")))  #by defau
```

```
[1] female female male   female male
Levels: female male
```

```
1 (sex <- factor(sex, levels = c("male", "female"))) #changing the order of t
```

```
[1] female female male   female male
Levels: male female
```

Coercion

- Sometimes certain functions require a particular `class` of data require conversion (or coercion)
- `mode` - implicitly; `as.xxx` - explicitly

```
text <- c("test1", "test2", "test1", "test1") # create a character vector
class(text)
```

```
[1] "character"
```

```
text_factor <- as.factor(text) # transform to factor
class(text_factor) # recheck the class
```

```
[1] "factor"
```

```
levels(text_factor)
```

```
[1] "test1" "test2"
```

```
as.numeric(text_factor)
```

```
[1] 1 2 1 1
```

Data structures

- Lots of options for how R stores data
- Structure determines which functions work and how they behave
- `length()`, `str()`, `summary()`, `head()`, and `tail()` can help you explore
- Most of the `RSpatial` data structures build on these basic structures

Vectors

- A 1-dimensional collection of elements with the same data type
- Combining two datatypes makes R choose

```
1 series.1 <- seq(10)
2 series.2 <- seq(from = 0.5, to = 5, by = 0.5)
3 series.abc <- letters[1:10]
4 length(series.1)
```

```
[1] 10
```

```
1 length(series.2)
```

```
[1] 10
```

```
1 class(c(series.abc, series.1)) #combine characters with numbers
```

```
[1] "character"
```

Vectors (cont'd)

- Can combine them or perform 'vectorized' operations

```
1 series.comb <- c(series.1, series.2)
2 length(series.comb)
```

```
[1] 20
```

```
1 series.add <- series.1 + series.2
2 length(series.add)
```

```
[1] 10
```

```
1 head(series.add)
```

```
[1] 1.5 3.0 4.5 6.0 7.5 9.0
```

- **What happens if you try to add the character vector to the numeric vector?**

Matrices

- An extension of the numeric or character vectors to include 2-dimensions (rows and columns)
- Arrays extend the idea to multiple dimensions
- Elements of matrix must have the same data type

```
1  (m <- matrix(1:6, nrow = 2, ncol = 3)) #default is to fill by columns
```

```
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
```

```
1  dim(m)
```

```
[1] 2 3
```

```
1  (m <- matrix(1:6, nrow = 2, ncol = 3, byrow = TRUE))
```

```
     [,1] [,2] [,3]
[1,]    1    2    3
[2,]    4    5    6
```

Lists

- Hold a variety of different data types and structures including more lists.
- Use a lot for functional programming (next week).

```
1 (xlist <- list(a = "Waldo", b = 1:10, data = head(mtcars)))
```

```
$a
[1] "Waldo"

$b
 [1]  1  2  3  4  5  6  7  8  9 10

$data
                   mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

Lists (cont'd)

- Lists store information in `slots`
- Adding `names` to a list can help with accessing data

```
1 names(xlist)
```

```
[1] "a"    "b"    "data"
```

```
1 class(xlist$data)
```

```
[1] "data.frame"
```

Data Frames

- Resemble tabular datasets used in spreadsheet programs
- Long vs. wide data
- Special type of list where every element has the same length (but can have different types of data)

```
1  (dat <- data.frame(id = letters[1:5], x = 1:5, y = rep(date(),times=5 )))
```

```
  id x                         y
1  a 1 Tue Aug 15 11:52:58 2023
2  b 2 Tue Aug 15 11:52:58 2023
3  c 3 Tue Aug 15 11:52:58 2023
4  d 4 Tue Aug 15 11:52:58 2023
5  e 5 Tue Aug 15 11:52:58 2023
```

```
1  is.list(dat)
```

```
[1] TRUE
```

```
1  class(dat)
```

Data Frames (cont'd)

- Lots of ways to access and summarize data in data frames
- Useful for making sure your functions are working as intended

```
1  str(dat) #compact summary of the structure of a dataframe
```

```
'data.frame':   5 obs. of  3 variables:
 $ id: chr  "a" "b" "c" "d" ...
 $ x : int  1 2 3 4 5
 $ y : chr  "Tue Aug 15 11:52:58 2023" "Tue Aug 15 11:52:58 2023" "Tue Aug 15
11:52:58 2023" "Tue Aug 15 11:52:58 2023" ...
```

```
1  summary(dat) #estimate summary statistics of data frame
```

```
      id                  x           y
 Length:5           Min.   :1   Length:5
 Class :character   1st Qu.:2   Class :character
 Mode  :character   Median :3   Mode  :character
                    Mean   :3
```

Data Frames (one more time)

- Special cases of `names` (`colnames` and `rownames`)

```
1 colnames(dat) #get the names of the variables stored in the data frame
```

```
[1] "id" "x"  "y"
```

```
1 dat$y
```

```
[1] "Tue Aug 15 11:52:58 2023" "Tue Aug 15 11:52:58 2023"
[3] "Tue Aug 15 11:52:58 2023" "Tue Aug 15 11:52:58 2023"
[5] "Tue Aug 15 11:52:58 2023"
```

Tibbles

- Similar to data frames, but allow for *lists within columns*
- Designed for use with the `tidyverse`
- Foundation of `sf` objects

```
1 library(tidyverse) #load the package necessary
2 dat.tib <- tibble(dat)
3 is.list(dat.tib)
```

```
[1] TRUE
```

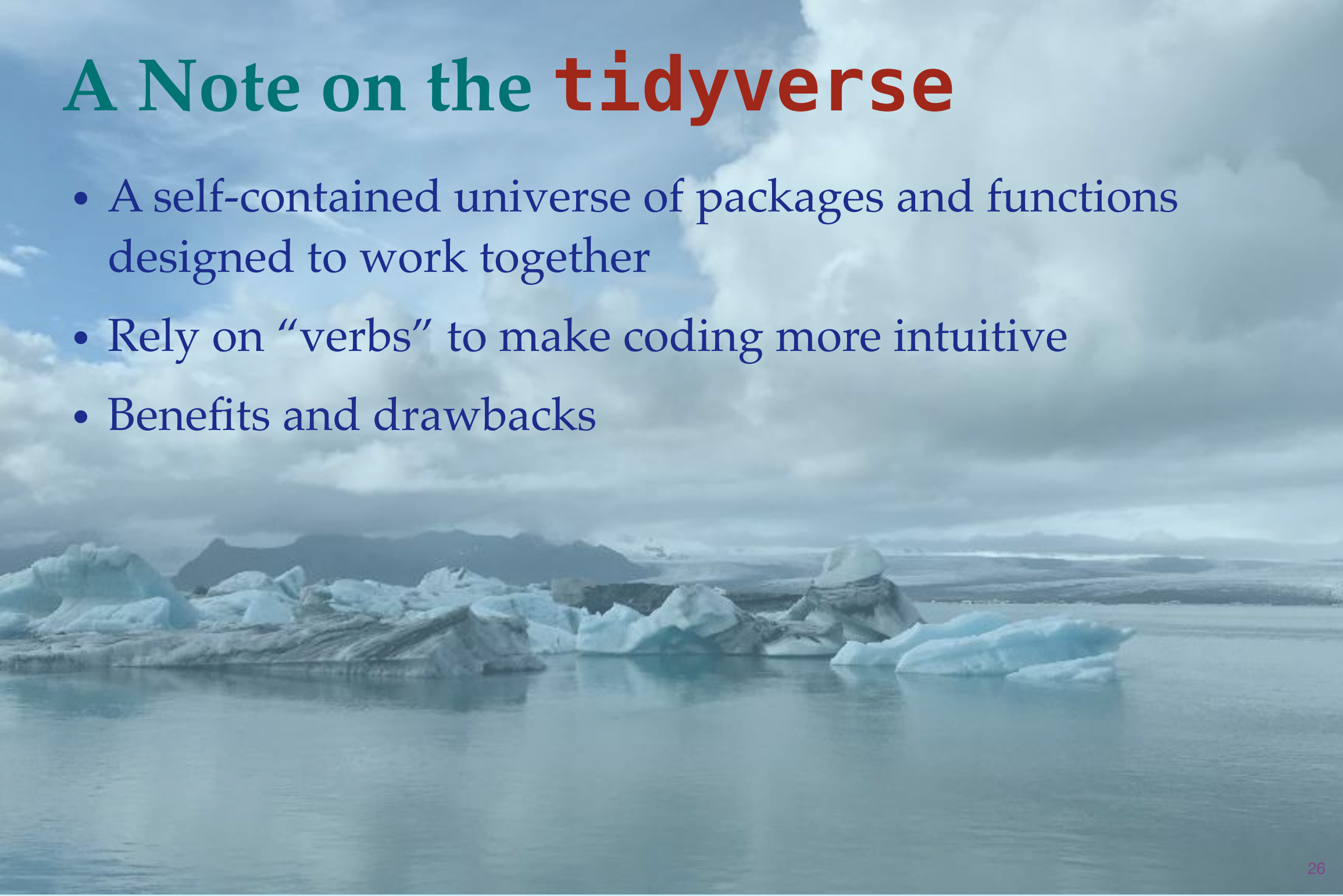
```
1 ## [1] TRUE
2
3 class(dat.tib)
```

```
[1] "tbl_df"     "tbl"        "data.frame"
```

Manipulating data in R

A Note on the `tidyverse`

- A self-contained universe of packages and functions designed to work together
- Rely on "verbs" to make coding more intuitive
- Benefits and drawbacks



Reading Data

- The first step in any data analysis
- Depends on the file type (`.csv`, `.txt`, `.shp`)
- CHECK YOURSELF

```
1  cars <- read.table('file/cars.txt')
2  str(cars)
```

```
'data.frame':   50 obs. of  2 variables:
 $ speed: int  4 4 7 7 8 9 10 10 10 11 ...
 $ dist : int  2 10 4 22 16 10 18 26 34 17 ...
```

```
1  summary(cars)
```

```
     speed           dist       
 Min.   : 4.0   Min.   :  2.00  
 1st Qu.:12.0   1st Qu.: 26.00  
 Median :15.0   Median : 36.00  
 Mean   :15.4   Mean   : 42.98  
 3rd Qu.:19.0   3rd Qu.: 56.00  
 Max.   :25.0   Max.   :120.00  
```

Reading Data (cont'd)

- `tidyverse` convention is to use "verb_object"
- For reading data that means `read_` instead of `read.`
- Different default behaviors!!

```
1 cars_tv <- read_table('file/cars.txt')
2 str(cars_tv)
```

```
spc_tbl_ [50 × 2] (S3: spec_tbl_df/tbl_df/tbl/data.frame)
 $ "speed": chr [1:50] "\"1\"" "\"2\"" "\"3\"" "\"4\"" ...
 $ "dist" : num [1:50] 4 4 7 7 8 9 10 10 10 11 ...
 - attr(*, "problems")= tibble [50 × 5] (S3: tbl_df/tbl/data.frame)
  ..$ row     : int [1:50] 1 2 3 4 5 6 7 8 9 10 ...
  ..$ col     : chr [1:50] NA NA NA NA ...
  ..$ expected: chr [1:50] "2 columns" "2 columns" "2 columns" "2 columns" ...
  ..$ actual  : chr [1:50] "3 columns" "3 columns" "3 columns" "3 columns" ...
  ..$ file    : chr [1:50] "'file/cars.txt'" "'file/cars.txt'"
"'file/cars.txt'" "'file/cars.txt'" ...
 - attr(*, "spec")=
  .. cols(
```

```
..   `"speed"` = col_character(),
..   `"dist"` = col_double()
.. )
```

Reading Data (cont'd)

```
summary(cars_tv)
```

```
   "speed"             "dist"       
 Length:50          Min.   : 4.0  
 Class :character   1st Qu.:12.0  
 Mode  :character   Median :15.0  
                    Mean   :15.4  
                    3rd Qu.:19.0  
                    Max.   :25.0  
```

```
head(cars_tv)
```

```
# A tibble: 6 × 2
  `"speed"` `"dist"`
  <chr>         <dbl>
1 "\"1\""           4
2 "\"2\""           4
3 "\"3\""           7
4 "\"4\""           7
5 "\"5\""           8
6 "\"6\""           9
```

What do you notice??

Selecting Data

- We often want to access subsets of our data
- For named objects we can use $

```
1  speed <- cars$speed #assign the whole speed column to an object
2  head(speed)
```

```
[1] 4 4 7 7 8 9
```

Selecting Data (cont'd)

- More generally we can use [ ] (can use index and logicals)

```
1 (speed2 <- cars$speed[2]) # get the vector named speed and take the 2nd ele
```

```
[1] 4
```

```
1 (speed3 <- cars[4,2]) #get the vector located in the 2nd column and take th
```

```
[1] 22
```

```
1 (speed20 <- cars[cars$speed > 20,]) #return all columns where speed >20
```

```
   speed dist
44    22   66
45    23   54
46    24   70
47    24   92
48    24   93
49    24  120
50    25   85
```

Selecting Data (cont'd)

- For lists we use `[[]]` to access a particular slot and `[]` to access data in that slot

```
1  xlist <- list(a = "Waldo", b = 1:10, data = head(mtcars))
2  xlist[[3]][1,2] #get the 3rd slot in the list and return the value in the 1
```

```
[1] 6
```

Selecting Data (cont'd)

- In the `tidyverse` we use `select()` to choose columns
- The `%>%` operator allows us to link steps together

```
speed <- read.table('file/cars.txt') %>%
  select(., speed)
head(speed)
```

```
  speed
1     4
2     4
3     7
4     7
5     8
6     9
```

Selecting Data (cont'd)

- Use `slice` to get rows based on position

```
1 (speed2 <- read.table('file/cars.txt') %>%
2   select(., speed) %>%
3    slice(., 2))
```

```
  speed
2     4
```

Selecting Data (cont'd)

- Use `filter` to choose rows that meet a condition

```
1  (speed2 <- read.table('file/cars.txt') %>%
2    filter(., speed > 20))
```

```
   speed dist
44    22   66
45    23   54
46    24   70
47    24   92
48    24   93
49    24  120
50    25   85
```

Changing Data

- Updating data (CAUTION)
- Often using a combination of index and logicals

```
x <- runif(10,-10, 10) #generate 10 random numbers between -10 and 10
x[c(3,6,8)] <- NA #set the 3rd, 6th, and 8th value to NA
is.na(x) #check which values are NA
```

```
 [1] FALSE FALSE  TRUE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE
```

Changing Data

- Creating new variables
- Can use $

```
1 head(mtcars, 3)
```

```
                mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4      21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
Mazda RX4 Wag  21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
Datsun 710     22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
```

```
1 mtcars$hpwt <- mtcars$hp/mtcars$wt
2 head(mtcars[,c(1, 5:12)],3)
```

```
                mpg drat    wt  qsec vs am gear carb     hpwt
Mazda RX4      21.0 3.90 2.620 16.46  0  1    4    4 41.98473
Mazda RX4 Wag  21.0 3.90 2.875 17.02  0  1    4    4 38.26087
Datsun 710     22.8 3.85 2.320 18.61  1  1    4    1 40.08621
```

Changing Data

- Creating new variables
- Using `tidyverse`, `mutate` creates new variables for the entire dataset

```
1 mtcars_update <- mtcars %>%
2   mutate(., hpwt = hp/wt)
3 head(mtcars_update[,c(1, 5:12)], 3)
```

```
                mpg drat    wt  qsec vs am gear carb     hpwt
Mazda RX4      21.0 3.90 2.620 16.46  0  1    4    4 41.98473
Mazda RX4 Wag  21.0 3.90 2.875 17.02  0  1    4    4 38.26087
Datsun 710     22.8 3.85 2.320 18.61  1  1    4    1 40.08621
```

Changing Data

- Creating new variables
- Using `summarise` creates group level summaries

```
1 mtcars_group <- mtcars %>%
2  group_by(., cyl) %>%
3   summarise(., meanmpg = mean(mpg))
4 mtcars_group
```

```
# A tibble: 3 × 2
    cyl meanmpg
  <dbl>   <dbl>
1     4    26.7
2     6    19.7
3     8    15.1
```

Getting help

2 Kinds of Errors

- **Syntax Errors**: Your code won't actually run
- **Semantic Errors**: Your code runs without error, but the result is unexpected

Asking good questions

- What are you trying to do?
- What isn't working?
- What are you expecting?
- Why aren't common solutions working?

Reproducible examples

- Don't require someone to have your data or your computer
- Minimal amount of information and code to reproduce your error
- Includes both code and your operating environment info
- See the `reprex` package.

Wrap-up