ISA 401: Business Intelligence & Data Visualization

02: Introduction to R

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Quick Refresher from Last Class

- ✅ Describe course objectives & structure
- ✅ Define data visualization & describe its main goals
- ✅ Describe the BI methodology and major concepts

Quick Refresher from Last Class

Note: Image generated using Midjourney AI v6.1 on Aug 27, 2024. I used the **following prompt:** Taylor Swift holding a sign that says "3D Charts are Awful" with Cincinnati skyline in the background.

Learning Objectives for Today's Class

- Describe why we are using R in this course?
- Understand the syntax, data structures and functions.
- Utilize the project workflow in R and create your first R script.

Pedagogy Behind Using R in this Course

```
crashes =
  # reading the data directly from the source
  readr::read_csv("https://data.cincinnati-oh.gov/api/views/rvmt-pkmq/rows.csv?accessType=DOWNLOAD") |>

  # changing all variable names to snake_case
  janitor::clean_names() |>

  # selecting variables of interest
  dplyr::select(address_x, latitude_x, longitude_x, cpd_neighborhood, datecrashreported, instanceid, typeofperson, v

  # engineering some features from the data
  dplyr::mutate(
    datetime = lubridate::parse_date_time(datecrashreported, orders = "'%m/%d/%Y %I:%M:%S %p", tz =  'America/New_Y
    hour = lubridate::hour(datetime),
    date = lubridate::as_date(datetime)
    )
```

The Beauty of Programming Languages

- Programming languages are **languages**.
- **It's just text** -- which gives you access to **two extremely powerful techniques**!!!

Source: Content in "The Beauty of Programming Languages" is from Hadley Wickham's You Can't Do Data Science in a GUI

Pedagogy Behind Using R in this Course

The Beauty of Programming Languages (Continued)

- `Ctrl` + `C`
- `Ctrl` + `V`
- In addition, programming languages are generally
  - Readable (IMO way easier than trying to figure what someone did in an)
  - Open (so you can G it)
  - Reusable and reproducible (so you can reuse your code for similar problems and other people can get the same results as you easily)
  - Diffable (version control is extremely powerful)

Source: The bullets in "The Beauty of Programming Languages" are based on Hadley Wickham's You Can't Do Data Science in a GUI

Pedagogy Behind Using R in this Course

Why R Specifically?

- It is a general-purpose programming language, which originated for statistical analysis.
- As of Aug 27, 2025, there are 22,578 packages on CRAN (not including those on GitHub).
- The `tidyverse` group of packages have simplified the workflow for data analytics/science.

How to Learn R (Any Programming Language)

- 🗣️ **Get hands dirty ‼️**
- 📖 Documentation! Documentation! Documentation!
- 🔍 (Not surprisingly) Learn to Google/ChatGPT/ChatISA: what that error message means(I do that a lot 😂)

Source: Slide is based on Kia Ora's How I Learn a Technology.

The RStudio Interface, Setup and a Project-Oriented Workflow for your Analysis

RStudio Interface

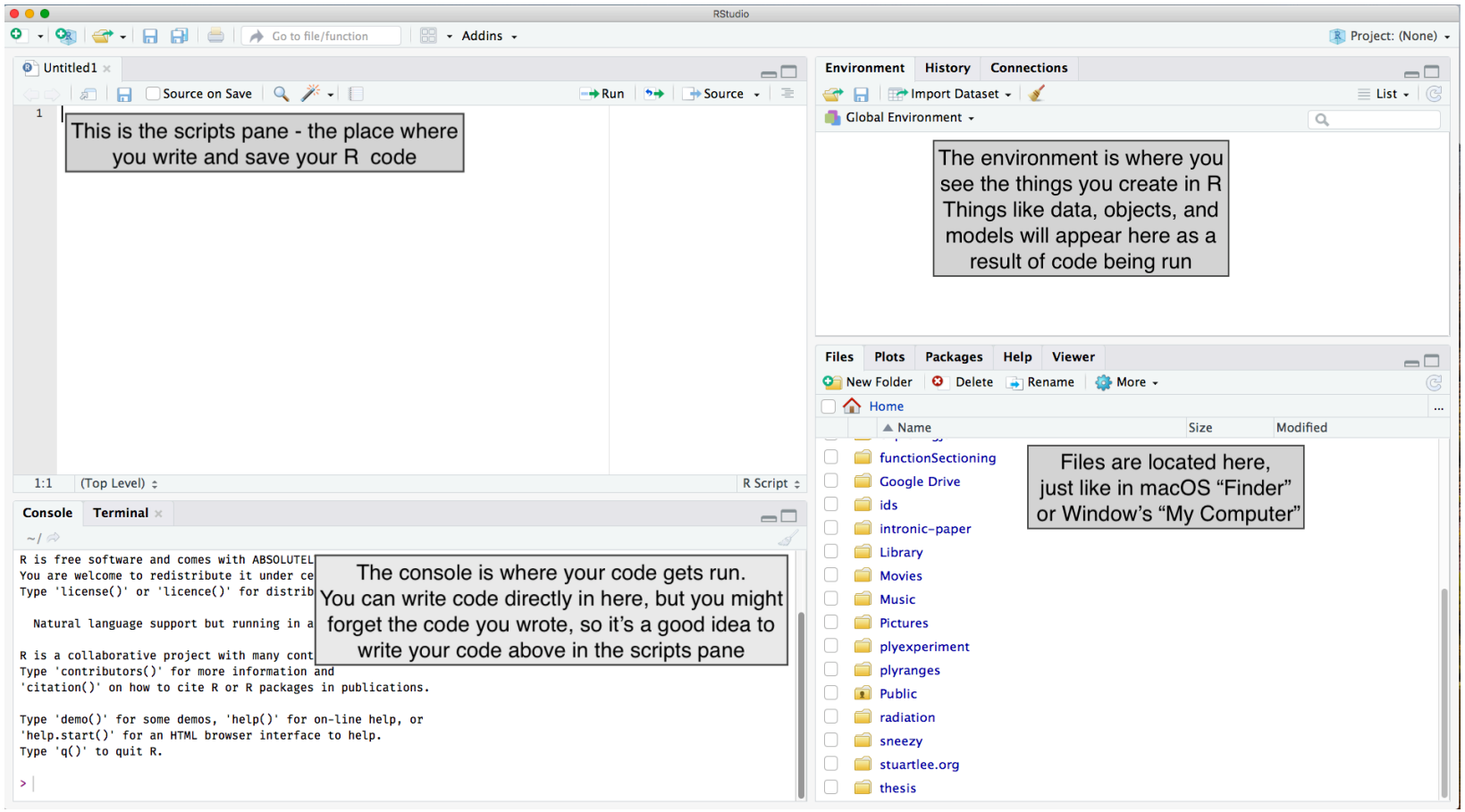
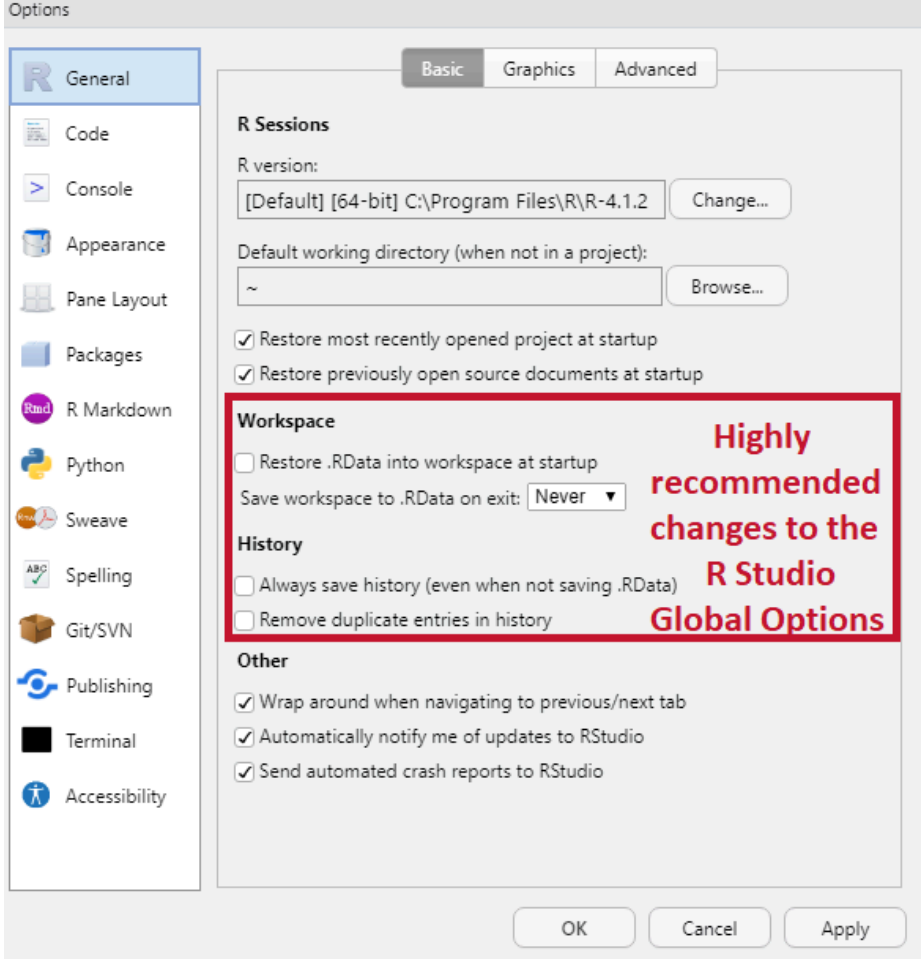


image credit: Stuart Lee

Setting up RStudio (do this once)

Go to **Tools** > **Global Options**:



Uncheck `Workspace` and `History`, which helps to keep R working environment fresh and clean every time you switch between projects.

What is a project?

- Each university course is a project, and get your work organised.
- A self-contained project is a folder that contains all relevant files, for example my `ISA 401/` 📂 includes:
  - `isa401.Rproj`
  - `lectures/`
    - `01_introduction/`
      - `01-introduction.Rmd`, etc.
    - `02_introduction_to_r/`
      - `02_introduction_to_r.Rmd`, etc.
- All working files are **relative** to the **project root** (i.e. `isa401/`).
- The project should just work on a different computer.

101: Operators

Assignment

R has three assignment operators: <-, =, and ->, which can be used as follows.

```
x1 <- 5

x2 = 5

5 -> x3

print(paste0("The values of x1, x2, and x3 are ", x1, ", ", x2, ", and ", x3, " respectively
```

```
## [1] "The values of x1, x2, and x3 are 5, 5, and 5 respectively"
```

The assignment consists of three parts:

- The left-hand side: **variable names** (`x1` or `x2`),
- The assignment operator: `<-` (or alternatively `=`), and
- The right-hand side: **values** (`5`)

Retrieval

We can retrieve/call the object using its name as follows:

```
x1
```

```
## [1] 5
```

```
x3
```

```
## [1] 5
```

Retrieval: Three Common Errors

Case issue: object names in R are **case sensitive**.

```
X1 # should be x1 instead of X1 (see last slide)
```

```
## Error: object 'X1' not found
```

Typo: A spelling error of some sort

```
y3 # should be x3 instead of y3 (see last slide)
```

```
## Error: object 'y3' not found
```

Object not saved: e.g., you clicked **Enter** instead of **Ctrl + Enter** when running your code

```
rm(x2) # removing x2 from the global environment to mimic error
x2 # x2 is not in the global environment (see environment)
```

Arthimetic Operators

While we will not specifically talk about doing math in R, the operators below are good to know.

Operator	Description
+	addition
-	subtraction
*	multiplication
/	division
^ or **	exponentiation
x %% y	modulus (x mod y) 5%%2 is 1
x %/% y	integer division 5%/%2 is 2

Source: The above table is scraped from Quick-R: Operators.

Logical Operators

Logical operators are operators that return `TRUE` and `FALSE` values.

Operator	Description
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
==	exactly equal to
!=	not equal to
!x	Not x
**x	y**
x & y	x AND y
isTRUE(x)	test if X is TRUE

Source: The above table is also scraped from Quick-R: Operators.

101: Syntax, Data Types, Data Structures and Functions

Coding Style

> Good coding style is like correct punctuation: you can manage without it, butitsuremakesthingseasiertoread.
> -- The tidyverse style guide

style guide

- ✅ snake_case

Source: Slide is based on Earo Wang's STAT 220 Slides

R is a Vector Language: Sample Output

Learning from a **sample of ten obs. from the standard normal distribution** (i.e., $x \sim \mathcal{N}(0, 1)$)

```
x_vec = rnorm(n=10, mean = 0, sd = 1) # generating std normal dist data
x_vec > 0 # finding which elements in x are larger than 0
```

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

```
sum(x_vec > 0) # summing the number of elements (i.e., how many are > 0)
```

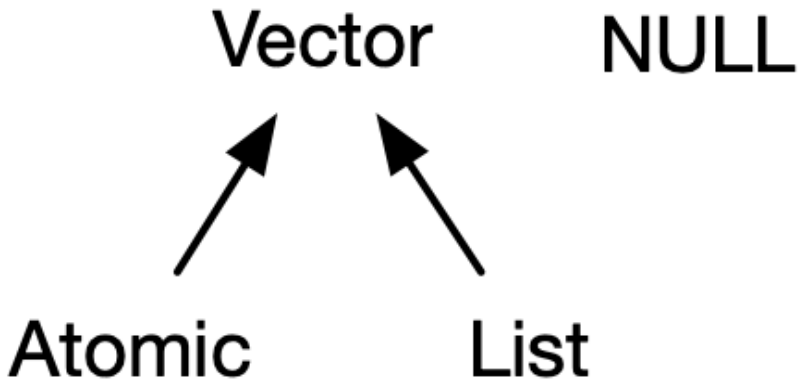
```
## [1] 6
```

If we focus on the obtained outputs, we can see that **both** are vectors:

- `x_vec > 0` returns a vector of size 10 (TRUE/FALSE for each element)
- `sum(x_vec > 0)` returns a vector of size 1

R is a Vector Language: Types and Attributes

- **Vectors** come in **two flavors**, which differ by their **elements' types:**
  - **atomic vectors --** all elements **must have the same type**
  - **lists --** elements **can** be different
- Vector have two important **attributes:**
  - **Dimension** turns vectors into matrices and arrays, checked using `dim(object_name)`.
  - The **class** attribute powers the S3 object system, checked using `class(object_name)`.

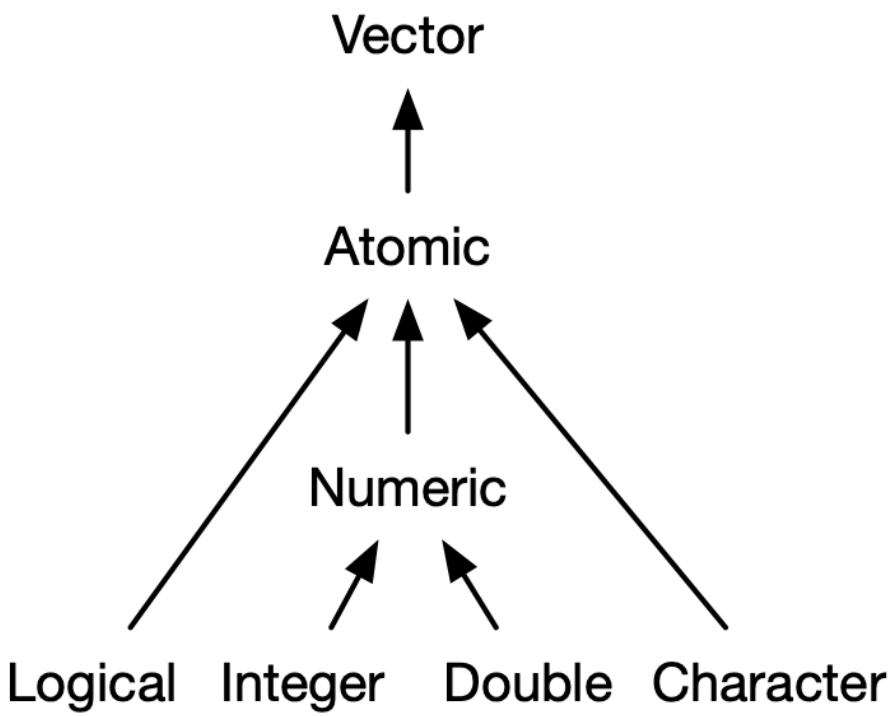



```
class(x_vec)
```

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

Source: The content and image are from Hadley Wickham's Advanced R: Chapter 3 on Vectors

R is a Vector Language: Atomic Vectors



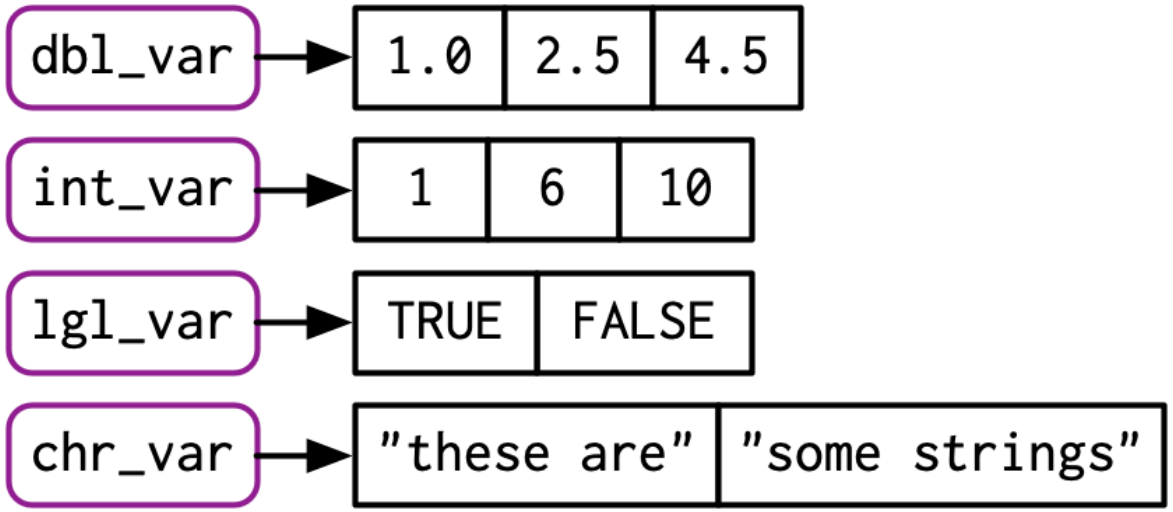

```
dim(x_vec)
```

```
## NULL
```

Atomic vectors have a dim of NULL, which distinguishes it from 1D arrays 🤯!!!

Source: The image is from Hadley Wickham's Advanced R: Chapter 3 on Vectors

Data Types: A Visual Introduction [1]



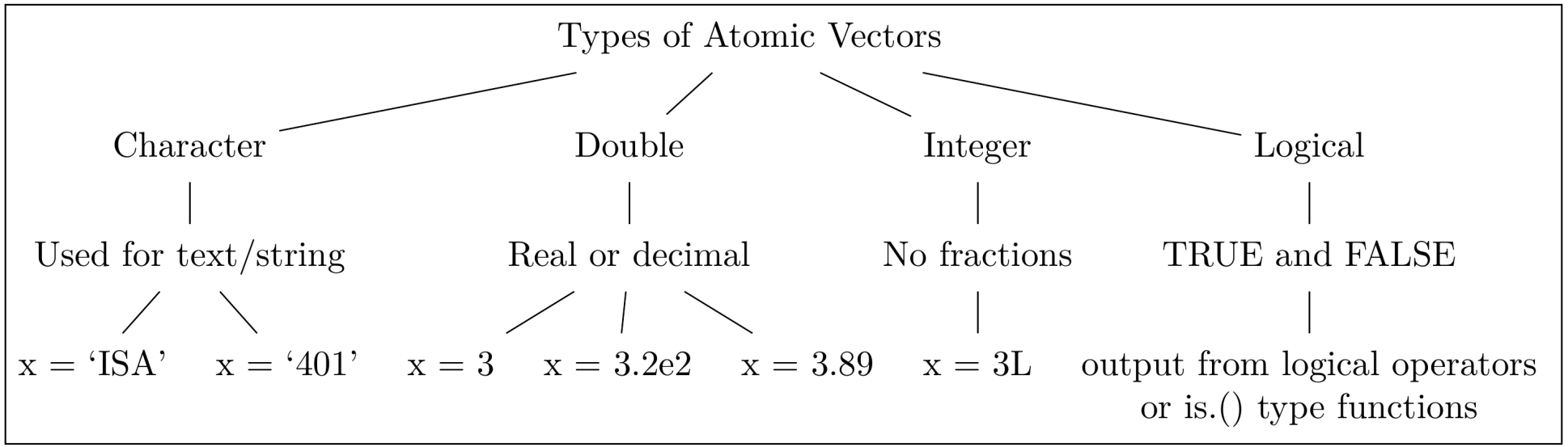
- To check the **type of** an object in R, you can use the function `typeof`:

```
typeof(x_vec)
```

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

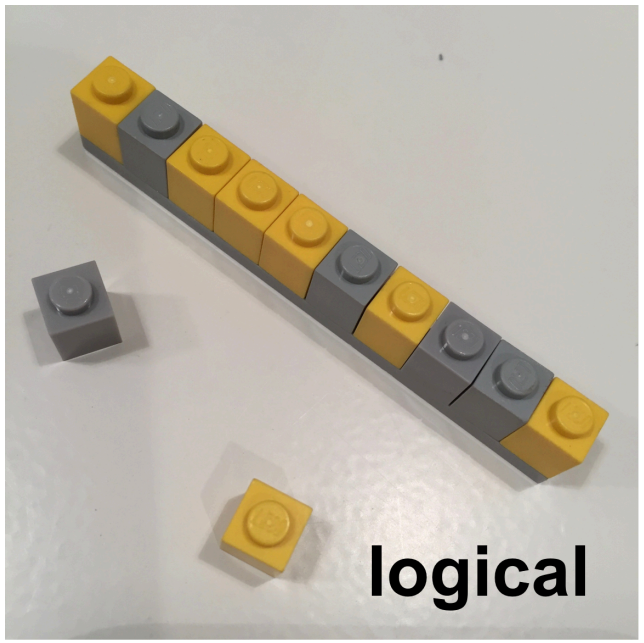
Source: The image is from Hadley Wickham's Advanced R: Chapter 3 on Vectors

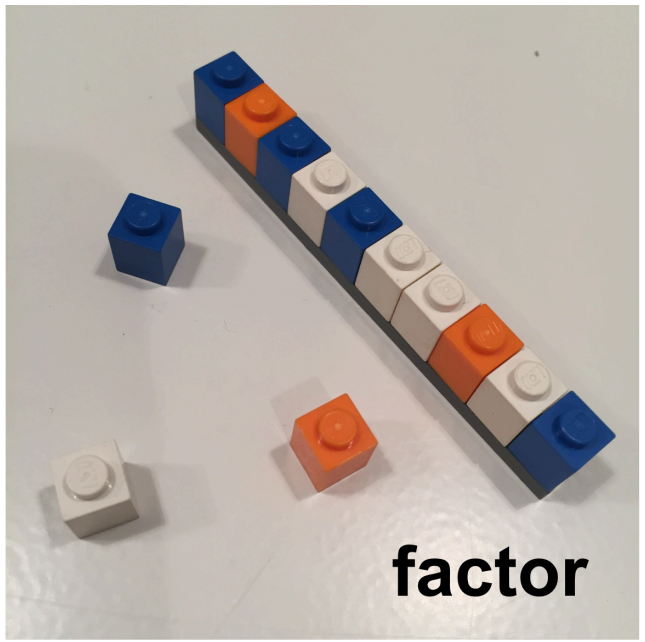
Data Types: A Visual Introduction [2]

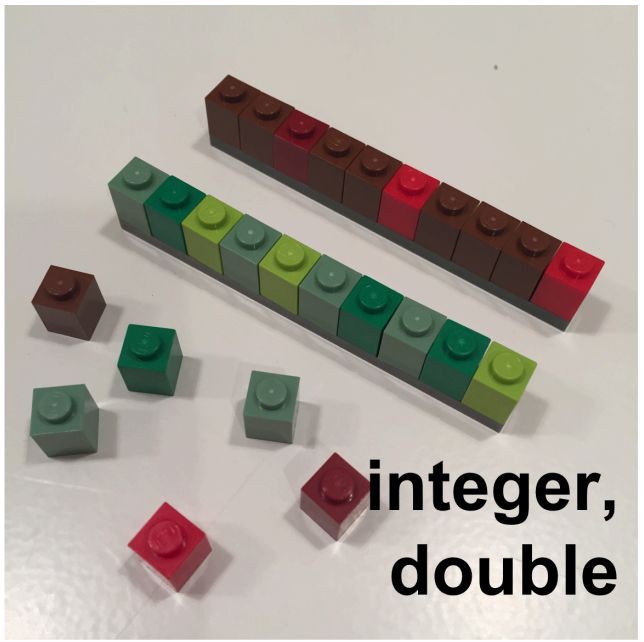


The four data types that we will utilize the most in our course.

Data Types: A Visual Introduction [3]







A visual representation of different types of atomic vectors

Source: The images are from the excellent lego-rstats GitHub Repository by Jenny Bryan

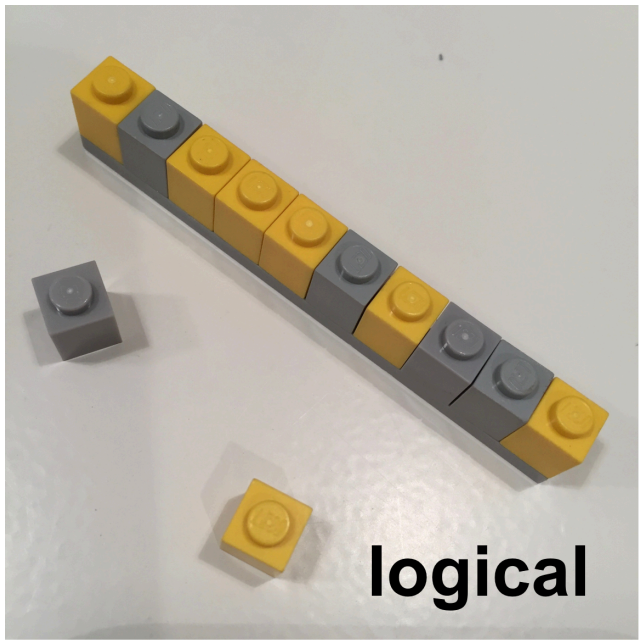
Data Types: Formal Definitions

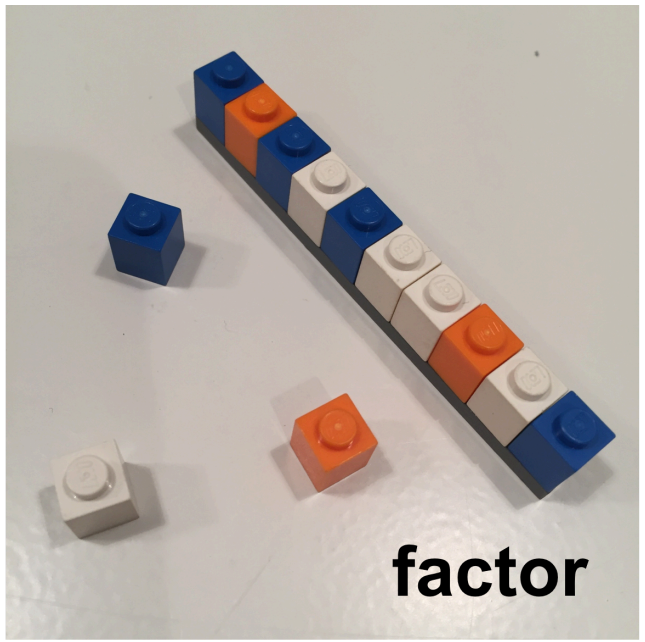
Each of the four primary types has a special syntax to create an individual value:

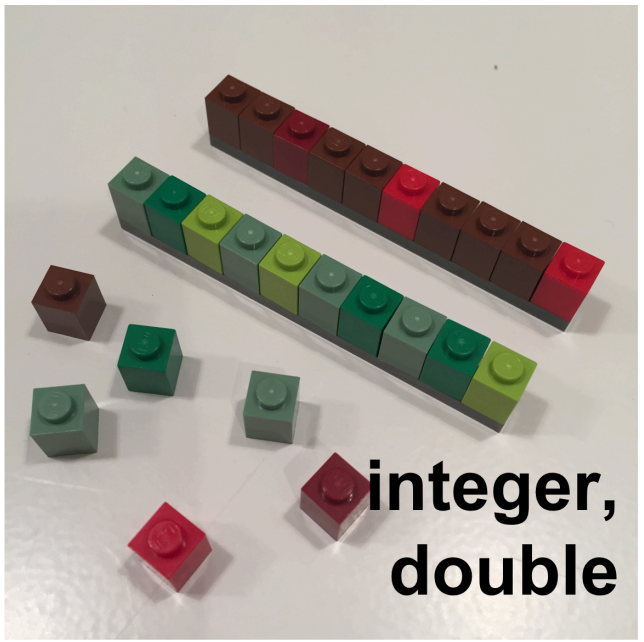
- Logicals can be written in full (`TRUE` or `FALSE`), or abbreviated (`T` or `F`).
- Doubles can be specified in decimal (`0.1234`), scientific (`1.23e4`), or hexadecimal (`0xcafe`) form.
  - There are three special values unique to doubles: `Inf`, `-Inf`, and `NaN` (not a number).
  - These are special values defined by the floating point standard.
- Integers are written similarly to doubles but must be followed by `L`(`1234L`, `1e4L`, or `0xcafeL`), and can not contain fractional values.
- Strings are surrounded by `"` (e.g., `"hi"`) or `'` (e.g., `'bye'`). Special characters are escaped with `\` see `?Quotes` for full details.

Source: The content of this slide is verbatim from Hadley Wickham's Advanced R: Chapter 3 on Vectors

Data Structures: Atomic Vector (1D)





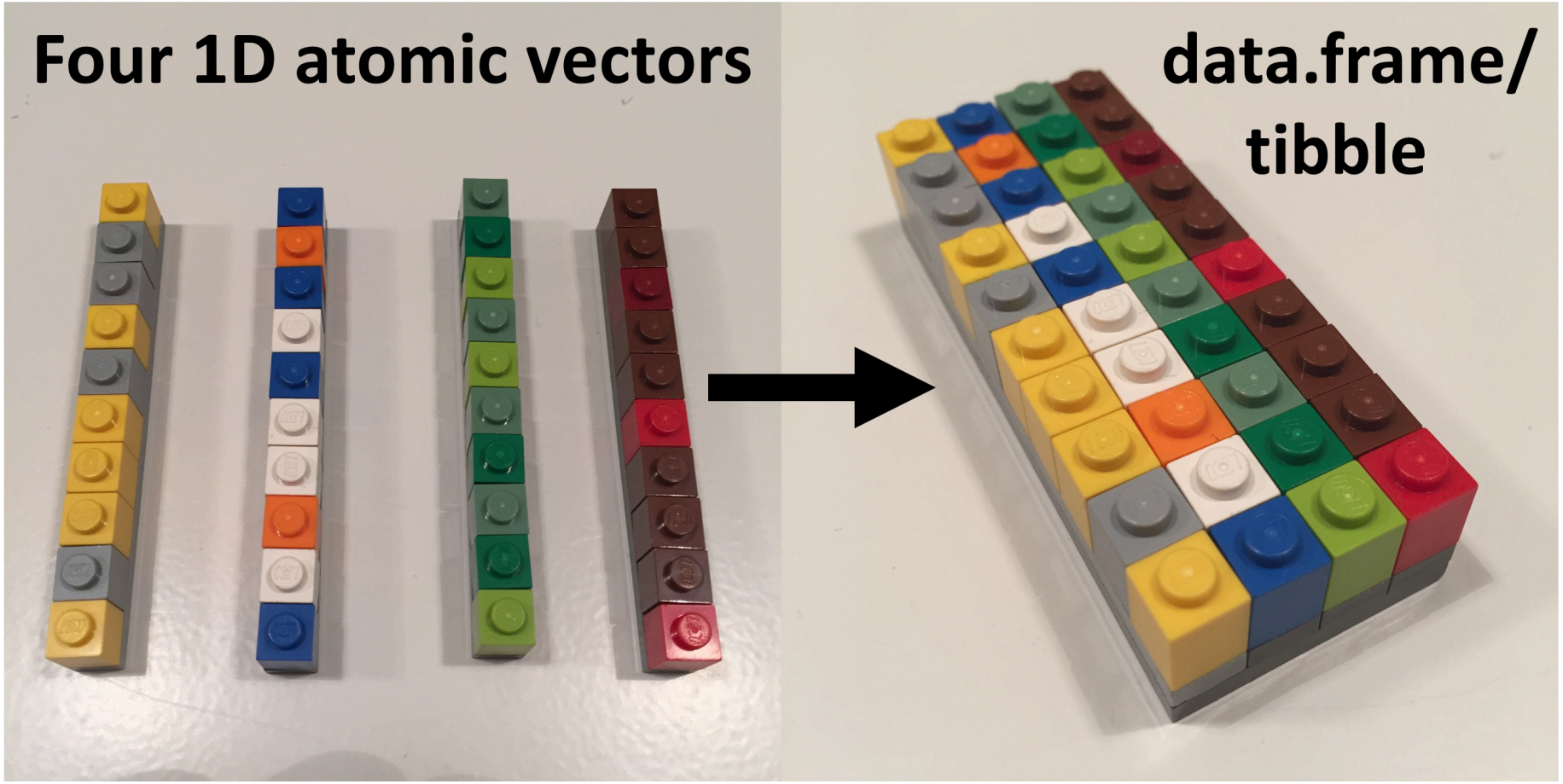


Keeping the visual representation of different types of atomic vectors in your head!!

```
dept = c('ACC', 'ECO', 'FIN', 'ISA', 'MGMT')
nfaculty = c(18L, 19L, 14L, 25L, 22L)
```

Source: The images are from the excellent lego-rstats GitHub Repository by Jenny Bryan

Data Structures: 1D ➡ 2D [Visually]



Source: The images are from the excellent lego-rstats GitHub Repository by Jenny Bryan

Data Structures: 1D ➡️ 2D [In Code]

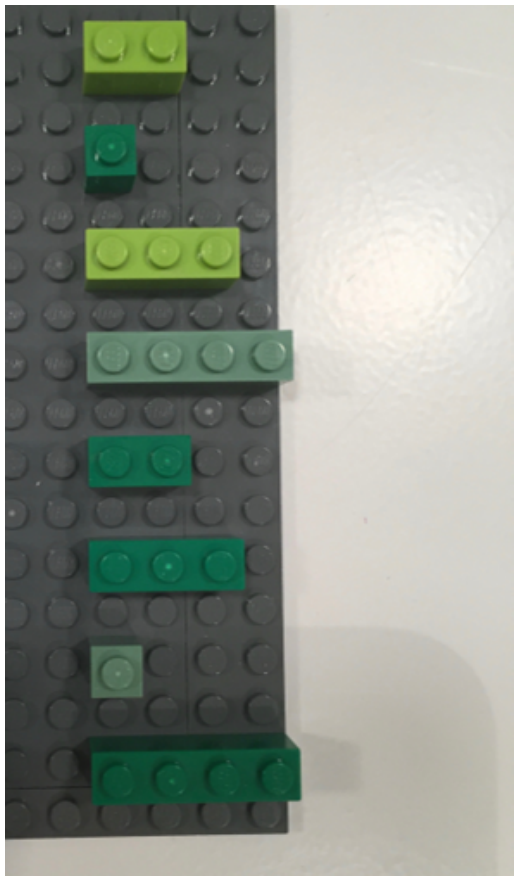
```
library(tibble)

fsb_tbl <- tibble(
  department = dept,
  count = nfaculty,
  percentage = count / sum(count))
fsb_tbl
```

```
## # A tibble: 5 × 3
##   department count percentage
##   <chr>      <int>      <dbl>
## 1 ACC           18      0.184
## 2 ECO           19      0.194
## 3 FIN           14      0.143
## 4 ISA           25      0.255
## 5 MGMT          22      0.224
```

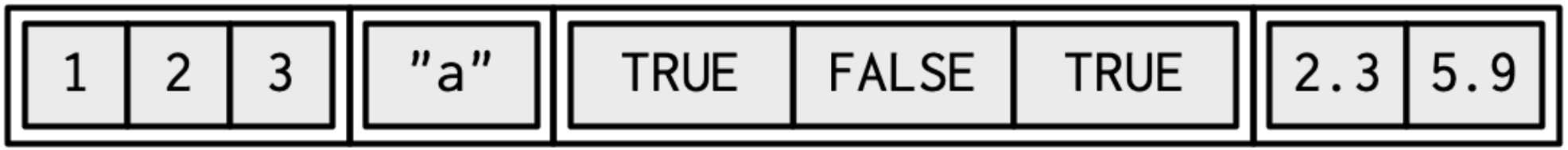
Data Structures: Lists [1]

An object contains elements of **different data types**.



Source: The image is adapted from the excellent lego-rstats GitHub Repository by Jenny Bryan

Data Structures: Lists [2]




```
lst <- list( # list constructor/creator
  1:3, # atomic double/numeric vector  of length = 3
  "a", # atomic character vector of length = 1 (aka scalar)
  c(TRUE, FALSE, TRUE), # atomic logical vector of length = 3
  c(2.3, 5.9) # atomic double/numeric vector of length =3
)
lst # printing the list
```

```
## [1] "1:3"                 "a"                   "c(TRUE, FALSE, TRUE)"
## [4] "c(2.3, 5.9)"
```

Source: Image is from Hadley Wickham's Advanced R: Chapter 3 on Vectors

Data Structures: Lists [3]

data type

```
typeof(lst) # primitive type
```

```
## [1] "list"
```

data class

```
class(lst) # type + attributes
```

```
## [1] "list"
```

data structure

```
str(lst)
# sublists can be of diff lengths and typ
```

```
## List of 4
##  $ : int [1:3] 1 2 3
##  $ : chr "a"
##  $ : logi [1:3] TRUE FALSE TRUE
##  $ : num [1:2] 2.3 5.9
```

Source: Slide is based on Earo Wang's STAT 220 Slides.

Data Structures: Lists [3]

A list can contain other lists, i.e. **recursive**

```
# a named list
str(
  list(first_el = lst, second_el = iris)
  )
```

```
## List of 2
##  $ first_el :List of 4
##   ..$ : int [1:3] 1 2 3
##   ..$ : chr "a"
##   ..$ : logi [1:3] TRUE FALSE TRUE
##   ..$ : num [1:2] 2.3 5.9
##  $ second_el:'data.frame':    150 obs. of  5 variables:
##   ..$ Sepal.Length: num [1:150] 5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
##   ..$ Sepal.Width : num [1:150] 3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
##   ..$ Petal.Length: num [1:150] 1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
##   ..$ Petal.Width : num [1:150] 0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
##   ..$ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1 ...
```

Data Structures: Lists [4]

Subset by `[]`

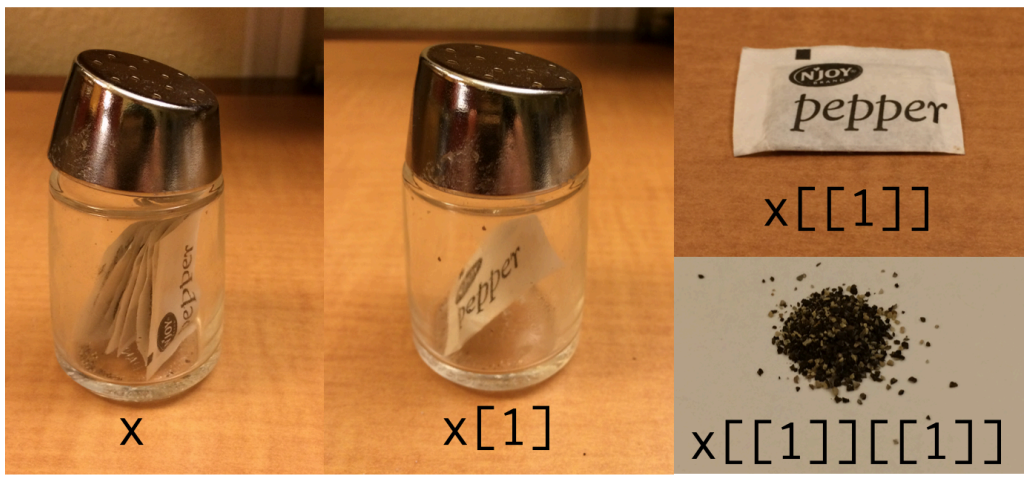
```
lst[1]
```

```
## [[1]]
## [1] 1 2 3
```

Subset by `[[]]`

```
lst[[1]]
```

```
## [1] 1 2 3
```



Sources: The slide is based on Earo Wang's STAT 220 slides and image is from Hadley Wickham's Tweet on Indexing lists in R.

Data Structures: Matrices

A matrix is a **2D data structure** made of **one/homogeneous data type.**

```
x_mat = matrix( sample(1:10, size = 4), n
str(x_mat) # its structure?
```

```
##  int [1:2, 1:2] 5 10 2 4
```

```
x_mat # printing it nicely
print('-----------------')
x_mat[1, 2] # subsetting
```

```
##      [,1] [,2]
## [1,]    5    2
## [2,]   10    4
## [1] "-----------------"
## [1] 2
```

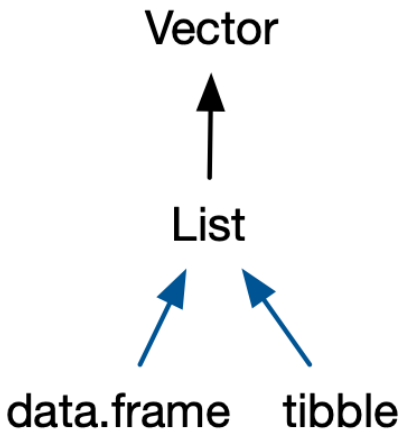
```
x_char = matrix(
  sample(letters, size = 12), nrow = 3, n
x_char
```

```
##      [,1] [,2] [,3] [,4]
## [1,] "u"  "l"  "b"  "k"
## [2,] "o"  "q"  "r"  "f"
## [3,] "w"  "j"  "e"  "g"
```

```
x_char[1:2, 2:3] # subsetting
```

```
##      [,1] [,2]
## [1,] "l"  "b"
## [2,] "q"  "r"
```

Data Structures: Data Frames [1]



> If you do data analysis in R, you're going to be using data frames. A data frame is a named list of vectors with attributes for `(column) names`, `row.names`, and its class, "data.frame". -- Hadley Wickham

Source: Image is from Hadley Wickham's Advanced R: Chapter 3 on Vectors

Data Structures: Data Frames [2]

```
df1 <- data.frame(x = 1:3, y = letters[1:3])
typeof(df1) # showing that its a special case of a list
```

```
## [1] "list"
```

```
attributes(df1) # but also is of class data.frame
```

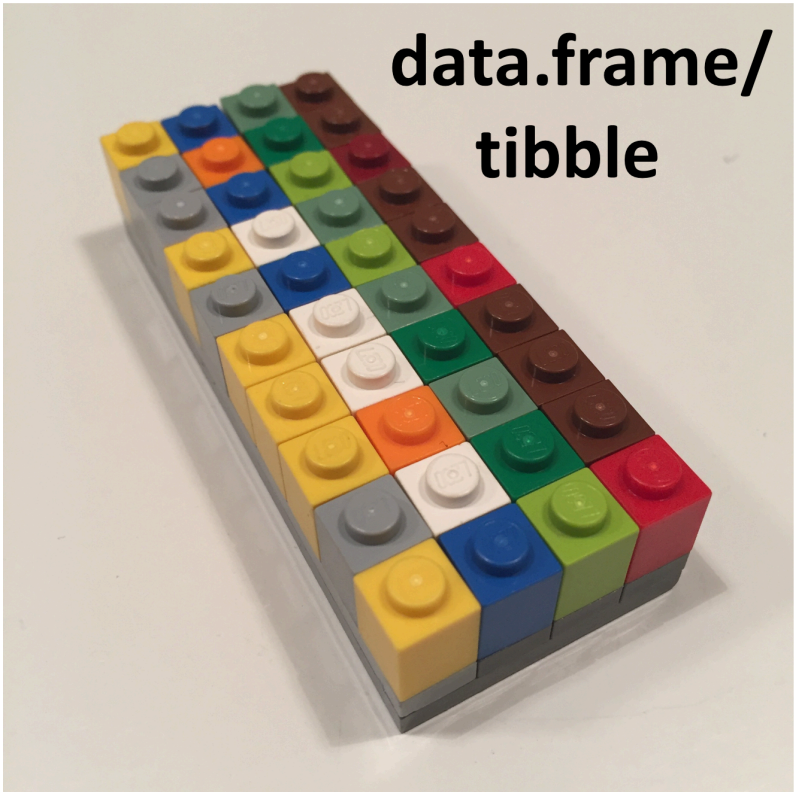
```
## $names
## [1] "x" "y"
##
## $class
## [1] "data.frame"
##
## $row.names
## [1] 1 2 3
```

In contrast to a regular list, a data frame has **an additional constraint: the length of each of its vectors must be the same.** This gives data frames their **rectangular structure.**

Source: Content is from Hadley Wickham's Advanced R: Chapter 3 on Vectors

Data Structures: Data Frames [3]

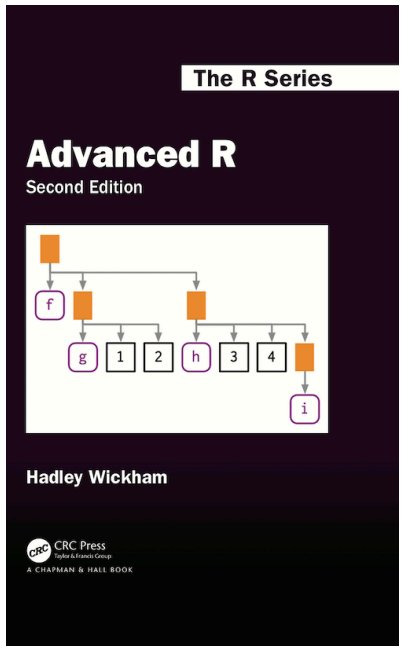
As noted in the creation of `df1`, columns in a data frame can be of different types. Hence, it is more widely used in data analysis than matrices.



Source: The image is adapted from the excellent lego-rstats GitHub Repository by Jenny Bryan

Data Structures: So What is a Tibble Anyway?

> Tibble is a **modern reimagining of the data frame**. Tibbles are designed to be (as much as possible) **drop-in replacements for data frames** that fix those frustrations. A concise, and fun, way to summarise the main differences is that tibbles are **lazy and surly: they do less and complain more**. -- Hadley Wickham



To learn more about the basics of tibble, please consult the reference below:

- Data frames and tibbles (Click and read from 3.6 up to and including 3.6.5)

Functions

A function call consists of the **function name** followed by one or more **argument** within parentheses.

```
temp_high_forecast = c(86, 84, 85, 89, 89, 84, 81)
mean(x = temp_high_forecast)
```

```
## [1] 85.42857
```

- function name: `mean()`, a built-in R function to compute mean of a vector
- argument: the first argument (LHS `x`) to specify the data (RHS `temp_high_forecast`)

Source: Slide is based on Earo Wang's STAT 220 Slides

Function Help Page

02:00

Check the function's help page with `?mean`

Class Activity

> *Please take 2 minutes to investigate the help page for `mean` in R Studio.*

```
mean(x = temp_high_forecast, trim = 0, na.rm = FALSE, ...)
```

- Read **Usage** section
  - What arguments have default values?
- Read **Arguments** section
  - What does `trim` do?
- Run **Example** code

Source: Slide is based on Earo Wang's STAT 220 Slides

Function Arguments

Match by **positions**

```
mean(temp_high_forecast, 0.1, TRUE)
```

```
## [1] 85.42857
```

Match by **names**

```
mean(x = temp_high_forecast, trim = 0.1,
```

```
## [1] 85.42857
```

Source: Slide is based on Earo Wang's STAT 220 Slides

Use Functions from Packages

```
dplyr::cummean(temp_high_forecast)
```

```
## [1] 86.00000 85.00000 85.00000 86.0000
```

```
dplyr::first(temp_high_forecast)
```

```
## [1] 86
```

```
dplyr::last(temp_high_forecast)
```

```
## [1] 81
```

Images sourced from https://www.wikihow.com/Change-a-Light-Bulb

Write Your Own Functions

```
# function_name <- function(arguments) {
#   function_body
# }
my_mean <- function(x, na.rm = FALSE) {
  summation <- sum(x, na.rm = na.rm)
  summation / length(x)
}

my_mean(temp_high_forecast)
```

```
## [1] 85.42857
```

Demo

Your First R Script File

Refer to our in class code.

Recap

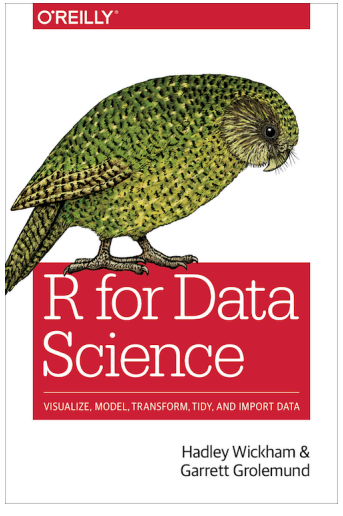
Summary of Main Points

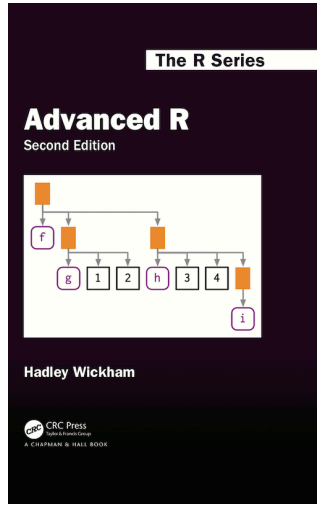
By now, you should be able to do the following:

- Describe why we are using R in this course?
- Understand the syntax, data structures and functions.
- Utilize the project workflow in R and create your first R script.

Things to Do to Prepare for Our Next Class

- Go over your notes, read the **references below**, and **complete** the self-paced R tutorial.
- Complete Assignment 02 on Canvas.





- Workflow: basics
- Workflow: scripts
- Workflow: project

- Names and values
- Vectors
- Subsetting