# Documenting and Data Analysis in R

## R Basics

Maxwel Coura Oliveira, PhD

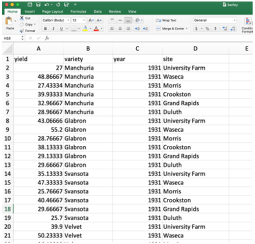
University of Wisconsin-Madison

# Outline

- How to install R and Rstudio
- Intro to R, RStudio and Markdown
- Data types
- Importing datasets

+ - * / ^ <- [ ] $ > <

== ! %in% & |



| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | yield | variety | year | site | |
| 2 | 27 | Manchuria | 1931 | University Farm | |
| 3 | 48.86667 | Manchuria | 1931 | Waseca | |
| 4 | 27.43334 | Manchuria | 1931 | Morris | |
| 5 | 39.93333 | Manchuria | 1931 | Crookston | |
| 6 | 32.96667 | Manchuria | 1931 | Grand Rapids | |
| 7 | 28.96667 | Manchuria | 1931 | Duluth | |
| 8 | 43.06666 | Glabron | 1931 | University Farm | |
| 9 | 55.2 | Glabron | 1931 | Waseca | |
| 10 | 28.76667 | Glabron | 1931 | Morris | |
| 11 | 38.13333 | Glabron | 1931 | Crookston | |
| 12 | 29.13333 | Glabron | 1931 | Grand Rapids | |
| 13 | 29.66667 | Glabron | 1931 | Duluth | |
| 14 | 35.13333 | Svansota | 1931 | University Farm | |
| 15 | 47.33333 | Svansota | 1931 | Waseca | |
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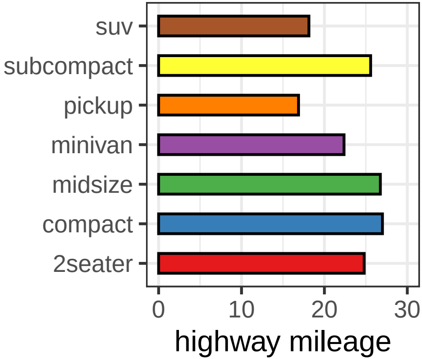
| 19 | 25.7 | Svansota | 1931 | Duluth | |
| 20 | 39.9 | Velvet | 1931 | University Farm | |
| 21 | 50.23333 | Velvet | 1931 | Waseca | |

# Whats is R? RStudio?

- R – a programming language + software that interprets it
- RStudio – popular software to write R scripts and interact with the R software

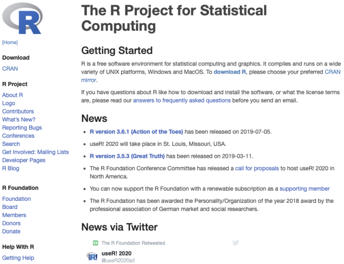
# Why learn R?

- Free, open source, cross platform
    - 10,000+ "packages"
    - Works on many data types
- Statistical data analysis
- Produced high-quality graphics
- Reproducibility and repeatability
- Write documents and manuscripts



# How to download R? RStudio?

- R



## The R Project for Statistical Computing

### Getting Started

R is a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS. To **download R**, please choose your preferred CRAN mirror.

If you have questions about R like how to download and install the software, or what the license terms are, please read our answers to frequently asked questions before you send an email.

### News

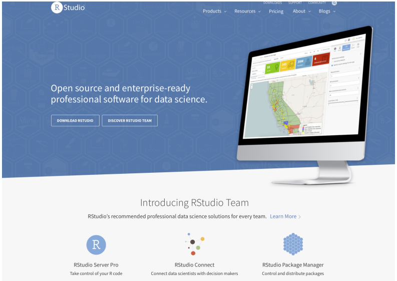
- **R version 3.6.1 (Action of the Toes)** has been released on 2019-07-05.
- useR! 2020 will take place in St. Louis, Missouri, USA.
- **R version 3.5.3 (Great Truth)** has been released on 2019-03-11.
- The R Foundation Conference Committee has released a call for proposals to host useR! 2020 in North America.
- You can now support the R Foundation with a renewable subscription as a supporting member
- The R Foundation has been awarded the Personality/Organization of the year 2018 award by the professional association of German market and social researchers.

### News via Twitter

The R Foundation Retweeted

**useR! 2020**
@useR2020stl

- Rstudio



Open source and enterprise-ready professional software for data science.

Introducing RStudio Team

RStudio's recommended professional data science solutions for every team. Learn More >

RStudio Server Pro
Take control of your R code

RStudio Connect
Connect data scientists with decision makers

RStudio Package Manager
Control and distribute packages

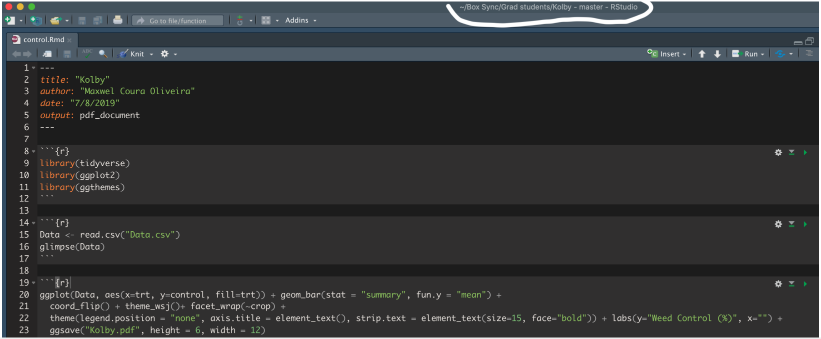
- Video tutorial

# Setup a working directory

- Open RStudio
- *File* > *New project* > *New directory* > Empty project
- Enter a name for this new folder: r-basics
- Choose a convenient location:
- ~/ is the Documents folder on the computer
- Click "*Create project*"

# Create a new R script

- File > New File > R script (.R or .Rmd)
- Save it in your project directory
- Look on the top left of the R Studio window to see where it's saved



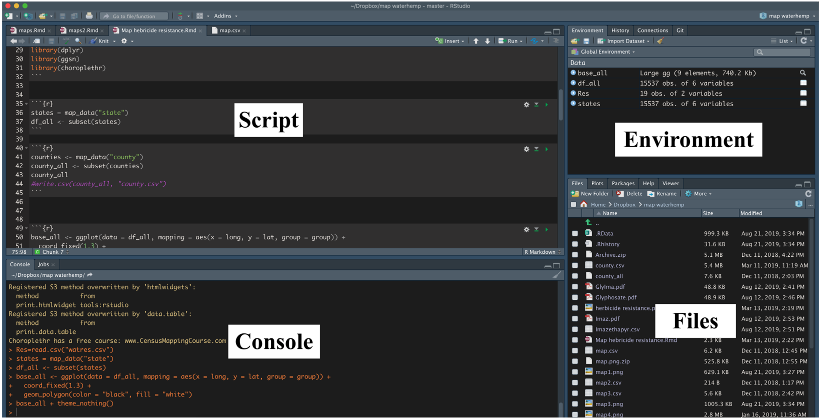
~~~
---
title: "Kolby"
author: "Maxwel Coura Oliveira"
date: "7/8/2019"
output: pdf_document
---

```{r}
library(tidyverse)
library(ggplot2)
library(ggthemes)
~~~

```{r}
Data <- read.csv("Data.csv")
glimpse(Data)
```

```{r}
ggplot(Data, aes(x=trt, y=control, fill=trt)) + geom_bar(stat = "summary", fun.y = "mean") +
  coord_flip() + theme_wsj()+ facet_wrap(~crop) +
  theme(legend.position = "none", axis.title = element_text(), strip.text = element_text(size=15, face="bold")) + labs(y="Weed Control (%)", x="") +
  ggsave("Kolby.pdf", height = 6, width = 12)
```

# RStudio interface



```
library(dplyr)
library(ggsn)
library(choroplethr)
```

```{r}
states = map_data("state")
df_all <- subset(states)
```

```{r}
counties <- map_data("county")
county_all <- subset(counties)
county_all
#write.csv(county_all, "county.csv")
```

```{r}
base_all <- ggplot(data = df_all, mapping = aes(x = long, y = lat, group = group)) +
  coord_fixed(1.3) +
```

Data

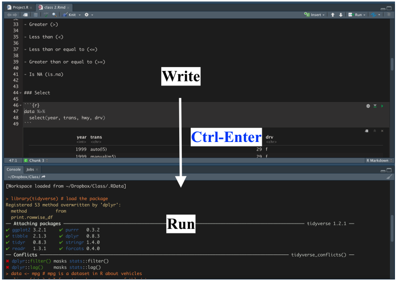
| | |
|---|---|
| base_all | Large gg (9 elements, 740.2 Kb) |
| df_all | 15537 obs. of 6 variables |
| Res | 19 obs. of 2 variables |
| states | 15537 obs. of 6 variables |

```
Registered S3 method overwritten by 'htmlwidgets':
  method           from
  print.htmlwidget tools:rstudio
Registered S3 method overwritten by 'data.table':
  method           from
  print.data.table
Choroplethr has a free course: www.CensusMappingCourse.com
> Res=read.csv("watres.csv")
> states = map_data("state")
> df_all <- subset(states)
> base_all <- ggplot(data = df_all, mapping = aes(x = long, y = lat, group = group)) +
+   coord_fixed(1.3) +
+   geom_polygon(color = "black", fill = "white")
> base_all + theme_nothing()
>
```

| Name | Size | Modified |
|---|---|---|
| .. | | |
| .RData | 999.3 KB | Aug 21, 2019, 3:34 PM |
| .Rhistory | 31.6 KB | Aug 21, 2019, 3:34 PM |
| Archive.zip | 5.1 MB | Dec 11, 2018, 4:22 PM |
| county.csv | 5.4 MB | Mar 11, 2019, 11:19 AM |
| county_all | 7.6 KB | Dec 11, 2018, 2:03 PM |
| Glylma.pdf | 48.8 KB | Aug 12, 2019, 2:41 PM |
| Glyphosate.pdf | 48.9 KB | Aug 12, 2019, 2:46 PM |
| herbicide resistance.p | | Mar 13, 2019, 2:19 PM |
| Imaz.pdf | | Aug 12, 2019, 2:53 PM |
| Imazethapyr.csv | | Aug 12, 2019, 2:51 PM |
| Map hebricide resistance.Rmd | 2.3 KB | Mar 13, 2019, 2:22 PM |
| map.csv | 6.2 KB | Dec 11, 2018, 12:45 PM |
| map.png.zip | 525.8 KB | Dec 11, 2018, 12:55 PM |
| map1.png | 629.1 KB | Aug 21, 2019, 3:27 PM |
| map2.csv | 214 B | Dec 11, 2018, 1:17 PM |
| map3.csv | 5.6 KB | Dec 11, 2018, 2:42 PM |
| map3.png | 1005.3 KB | Aug 21, 2019, 3:34 PM |
| map4.png | 2.8 MB | Jan 16, 2019, 11:36 AM |

# Script vs Console

- Both accept commands
- Console: runs the commands
- Script: commands you want to save for later;
    - Must be run in console
    - Ctrl+enter to run



~~~
- Greater (>)

- Less than (<)

- Less than or equal to (<=)

- Greater than or equal to (>=)

- Is NA (is.na)


### Select

```{r}
data %>%
  select(year, trans, hwy, drv)
```
~~~

```
 year  trans                 drv
<int>  <chr>                 <chr>
 1999  auto(l5)           29 f
 1999  manual(m5)         29 f
```

```
[Workspace loaded from ~/Dropbox/Class/.RData]

> library(tidyverse) # load the package
Registered S3 method overwritten by 'dplyr':
  method           from
  print.rowwise_df
— Attaching packages ——————————————————————————————————————— tidyverse 1.2.1 —
✔ ggplot2 3.2.1     ✔ purrr   0.3.2
✔ tibble  2.1.3     ✔ dplyr   0.8.3
✔ tidyr   0.8.3     ✔ stringr 1.4.0
✔ readr   1.3.1     ✔ forcats 0.4.0
— Conflicts ——————————————————————————————————————————— tidyverse_conflicts() —
✖ dplyr::filter() masks stats::filter()
✖ dplyr::lag()    masks stats::lag()
> data <- mpg # mpg is a dataset in R about vehicles
```

# Let’s start coding!

- Operators: Arithmetic, assignment, extraction, logical
- Functions: names, arguments, output
- Data types: classes, vectors, data frames

# Let’s start coding!

| textbf | What it does | Symbol |
|---|---|---|
| Arithmetic | Math on numbers | + - * / ˆ |
| Assignment | Creates objects (left) with | <- |
| Extraction | Take out or replace part of an object | [ ] $ |
| Logical | Compares values, returns TRUE/FALSE | ><== ! %in% & \| |

# Let's start coding!

- Does math
  - Add: 2+2
  - Subtract: 3-1
  - Multiply: 4*4
  - Divide: 5/2
- Sends results to the console
  - CTRL+Enter

+ -

* /

# Assignment operator

- Saves values into objects
  - object <- value
  - weightkg <- 55
- Overwrites previous values
- Combine with arithmetic operators:
  - weightlb <- 2.2*weightkg

<-

# Exercise: Operators

What are the values of each variable after each statement?

```
mass <- 47.5                         # mass?
age <- 122                           # age?
mass <- mass * 2.0                   # mass?
age <- age - 20                      # age?
\textcolor{purple}{mass_index}       # \text-
<- mass/age                          color{purple}{mass_index}?
```

# Functions and arguments

- A sequence of instructions that perform a task
  - Have names
  - Accepts arguments (input)
  - Return a value (output)

| Input | Output |
|---|---|
| sqrt(9) | 3 |
| round(3.14159) | 3 |
| round(x=3.14159), digits=2 | 3 |

# Getting help

- Documentation

```
?round # Opens a page for round
```

```
args(round) # display arguments
```

```
## function (x, digits = 0)
## NULL
```

- **Google “R +”function name"**
- Other websites
  - Stack overfolow (Q&A)
  - R bloggers (tutorials)

## Data types

- R guesses what type of data is sotred in an object
- Basic types:

  Numeric?

  Character

  Logical
- Can be easy to tell

Examples:

- x <- 32 (Numeric)
- x <- “car” (Character)
- x <- TRUE (Logical)

# Data structures

| **Data structure** | **Description** | Function |
|---|---|---|
| vector | Multiple values of the same type | c(), vector |
| factor | Multiple integers with text labels | factor |
| data frame | Multiple vectors of the same length grouped to make columns | read.csv(), data frame |

# Vector

- Most common data type
- Series of one data type
- Concatenate function: c()

  **Input**: values separately by commas

  **Output**: a vector object

```r
# Exemple: a list of yields
yield_ha <- c(3000, 2890, 3100, 2990)
# Exemple: a list of cars
cars <- c("audi", "toyota", "ford")
```

# Inspecting vectors

- Vectors have characteristics:
  - **Length**: number of values
  - **Class**: type of values

```
length(yield_ha)  # Try with length(cars)
```

```
## [1] 4
```

```
class(cars)      # Try with class(yield_ha)
```

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

```
str(yield_ha)   # Try with str(cars)
```

```
##  num [1:4] 3000 2890 3100 2990
```

# Adding values to a vector

- Use an existing vector as an argument to c()
- Put it in the order you want them to appear in the output vector

```r
# Add to the end of the vector
yield_ha <- c(yield_ha, 3315)
```

```r
# Add to the beginning of the vector
yield_ha <- c(3050, yield_ha)
```

## Class coercion

- What happens if you mix types?
- R converts to a type that works for all elements
- Use *class()* to see what R picked

| Type | As character | As numeric | As logical |
|---|---|---|---|
| logical | “TRUE” | 1 | TRUE |
| numeric | “35” | 35 | NA |
| character | “Paulista” | NA | NA |

# Exercises

```r
num_char <- c(1, 2, 3, "a")
num_logical <- c(1, 2, 3, TRUE)
char_logical <- c("a", "b", "c", TRUE)
tricky <- c(1, 2, 3, "4")
```

Hint: use *class()*

# Factors

- Represent categorical data
  - Stored as integers with text labels
  - Data frames convert character columns to factors
- *factor()* - create a factor
- Create a character vector

```r
sex <- c("male", "female", "female", "male")
```

- Change vector to a factor

```r
sex <- factor(sex)
```

# Levels

- Unique text labels of a factor object
- *levels()* - displays labels
- *nlevels()* - displays number of levels

| **Function** | **Output** |
|---|---|
| levels(sex) | “female”, “male” |
| nlevels(sex) | 2 |
| factor(sex, levels = c("male", female"))<br>levels(sex) | “male”, “female” |

# Exercises

```r
ranks <- c("2", "5", "7", "3", "3")
f_ranks <- factor(ranks)
n_ranks <- as.numeric(f_ranks)
```

- What result do you expect to get?
- What do you get when you run the code?

# Subsetting vectors

- Subset by position
- Syntax: square brackets [ ]
- Combine with c()

```r
animals<-c("cat", "dog", "pig")
```

```r
animals[] #Display second value
```

```
## [1] "cat" "dog" "pig"
```

```r
animals[c(3,2)] #Display multiple values
```

```
## [1] "pig" "dog"
```

```r
animals[c(1,2,3,2,1)] #Display repeated values
```

```
## [1] "cat" "dog" "pig" "dog" "cat"
```

# Logical expressions

- Make comparisons
- Evaluates each element in a vector against a value
- Output: TRUE or FALSE
    - For each vector value

# Logical expressions

| Logical operator | Meaning |
|---|---|
| > | Greater than |
| < | Less than |
| == | Equal to |
| != | Not equal to |
| & | and |
| \| | or |
| ! | not |
| %in% | Contained in |

# Example: logical expressions

- Create a weight variable:

```
biomass_g <- c(22, 33, 37, 51, 59)
```

- Evaluate each weight:

```
biomass_h <- biomass_g > 50
biomass_h
```

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

# Conditional subsetting

- Keep TRUE, drop FALSE
- Input: a logical expression
- **Output**: vector with elements that match the logical expression
- Subset using TRUE/FALSE vector

```
biomass_g[biomass_h]
```

```
## [1] 51 59
```

- Same as

```
biomass_g[biomass_g>50]
```

```
## [1] 51 59
```

# Combining logical expressions

- Combine multiple conditionals
- | = or (either)
- & = and (both)
- Biomass under 30 or over 50:

```
biomass_g[biomass_g<30 | biomass_g>50]
```

```
## [1] 22 51 59
```

- Biomass over 30 and under 50:

```
biomass_g[biomass_g>30 & biomass_g<50]
```

```
## [1] 33 37
```

# Conditional subsetting: characters (==)

- == operator
- Compares each value in a vector with a character string
- Combine with | for multiple

Make a character vector

```
crops <- c("corn", "soybean", "wheat", "alfalfa")
```

Crops that are corn

```
crops[crops=="corn"]
```

```
## [1] "corn"
```

Crops that are corn or cats

```
crops[crops=="corn" | crops=="wheat"]
```

```
## [1] "corn"  "wheat"
```

# Conditional subsetting: characters (%in%)

- \textcolor{blue}{%in%} operator
- Selects elements of the first vector that are in the second vector
- **Input**: vectors
- **Output**: a TRUE/FALSE list

Which values in animals are in the right hand vector?

```
crops %in% c("corn", "soybean", "hemp", "wheat", "beans")
```

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

Use TRUE/FALSE vector to subset

```
crops[crops %in% c("corn", "soybean", "hemp", "wheat", "beans")]
```

```
## [1] "corn"    "soybean" "wheat"
```

# Missing data

- NA - harder to overlook missing data
- Argument: na.rm = TRUE

```
na.rm = TRUE #Ignores missing data
```

```
heights <- c(2, 4, 4, NA, 6, 7) #create a dataset
```

- Mean of a missing value?

```
mean(heights)
```

```
## [1] NA
```

- Remove the missing data

```
mean(heights, na.rm = TRUE)
```

```
## [1] 4.6
```

# Remove missing data

- is.na() - Returns TRUE if the value is NA
- complete.cases() - returns FALSE if missing
- na.omit() - returns object with missing values removed

**Remove NAs 3 ways:**

```
heights[!is.na(heights)]
```

```
## [1] 2 4 4 6 7
```

```
heights[complete.cases(heights)]
```

```
## [1] 2 4 4 6 7
```

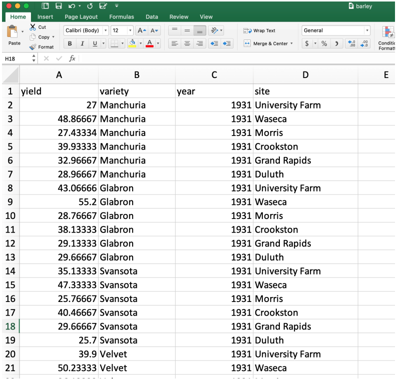
```
na.omit(heights)
```

```
## [1] 2 4 4 6 7
## attr(,"na.action")
## [1] 4
## attr(,"class")
## [1] "omit"
```

# Starting with data!

- How to load data tables into R
- Data set: barley yield in Minnesota, USA

- Stored in a **.csv** file
- **Rows**: observations of individual treatments
- **Columns**: Variables that describe the study
- factor() - create a factor



|  | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | yield | variety | year | site |  |
| 2 | 27 | Manchuria | 1931 | University Farm |  |
| 3 | 48.86667 | Manchuria | 1931 | Waseca |  |
| 4 | 27.43334 | Manchuria | 1931 | Morris |  |
| 5 | 39.93333 | Manchuria | 1931 | Crookston |  |
| 6 | 32.96667 | Manchuria | 1931 | Grand Rapids |  |
| 7 | 28.96667 | Manchuria | 1931 | Duluth |  |
| 8 | 43.06666 | Glabron | 1931 | University Farm |  |
| 9 | 55.2 | Glabron | 1931 | Waseca |  |
| 10 | 28.76667 | Glabron | 1931 | Morris |  |
| 11 | 38.13333 | Glabron | 1931 | Crookston |  |
| 12 | 29.13333 | Glabron | 1931 | Grand Rapids |  |
| 13 | 29.66667 | Glabron | 1931 | Duluth |  |
| 14 | 35.13333 | Svansota | 1931 | University Farm |  |
| 15 | 47.33333 | Svansota | 1931 | Waseca |  |
| 16 | 25.76667 | Svansota | 1931 | Morris |  |
| 17 | 40.46667 | Svansota | 1931 | Crookston |  |
| 18 | 29.66667 | Svansota | 1931 | Grand Rapids |  |
| 19 | 25.7 | Svansota | 1931 | Duluth |  |
| 20 | 39.9 | Velvet | 1931 | University Farm |  |
| 21 | 50.23333 | Velvet | 1931 | Waseca |  |

# Download the data file

- Download data here - Link
- Right click (barley.csv) > Download Linked File
- Save it to your project folder

# Tables to data frames

- **R** can read data tables
- Read tables using *read.csv()* or *read.csv2*
- **Input**: a file name
- **Output**: table stored in a data frame

```
barley <- read.csv("barley.csv")
barley
```

```
##        yield          variety year            site
## 1   27.00000        Manchuria 1931 University Farm
## 2   48.86667        Manchuria 1931          Waseca
## 3   27.43334        Manchuria 1931          Morris
## 4   39.93333        Manchuria 1931       Crookston
## 5   32.96667        Manchuria 1931    Grand Rapids
## 6   28.96667        Manchuria 1931          Duluth
## 7   43.06666          Glabron 1931 University Farm
## 8   55.20000          Glabron 1931          Waseca
## 9   28.76667          Glabron 1931          Morris
## 10  38.13333          Glabron 1931       Crookston
## 11  29.13333          Glabron 1931    Grand Rapids
## 12  29.66667          Glabron 1931          Duluth
## 13  35.13333         Svansota 1931 University Farm
```

# Storing data in data frame

1 - Rows = observations

2 - Columns = variables

3 - All values in a column must be the same data type

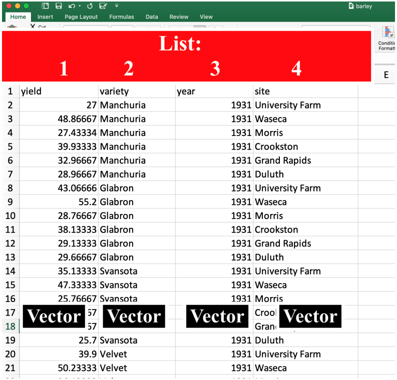
4 - Must have same # rows in each column

# Structure of a data frame

- A list of vectors
- Each column
- Is a vector
- Has a name
- Has a data type
- Is a subject to coercion
- List: any data type - every column can have a different data type

# Structure of a data frame

- Stored in a **.csv** file
- **Rows**: observations of individual treatments
- **Columns**: Variables that describe the study
- factor() - create a factor



| | | | | |
|---|---|---|---|---|
| 1 | yield | variety | year | site |
| 2 | 27 | Manchuria | 1931 | University Farm |
| 3 | 48.86667 | Manchuria | 1931 | Waseca |
| 4 | 27.43334 | Manchuria | 1931 | Morris |
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| 14 | 35.13333 | Svansota | 1931 | University Farm |
| 15 | 47.33333 | Svansota | 1931 | Waseca |
| 16 | 25.76667 | Svansota | 1931 | Morris |
| 17 | 57 | | | Croo |
| 18 | 57 | | | Gran |
| 19 | 25.7 | Svansota | 1931 | Duluth |
| 20 | 39.9 | Velvet | 1931 | University Farm |
| 21 | 50.23333 | Velvet | 1931 | Waseca |

## Inspecting data frames

| Function | Output |
|---|---|
| class | Class of the object |
| fstr | structure: # rows, cols, data types |
| head | look at first 6 rows (all columns) |
| nrow/ncol | number of rows/columns |
| names | column names |
| summary | summary stats for each column |

# Subsetting data frames

- Use the extraction operator [ ]
- Row column format: data[row, column]
- Select entire row/col: data[, column]
- Ranges: data[a:b, column]

# Subsetting data frames

- First row, second col:

```
barley[1,2]
```

```
## [1] Manchuria
## 10 Levels: Glabron Manchuria No. 457 No. 462 No. 475 Peatland ... Wisconsin No. 38
```

- First row, all cols:

```
barley[1,]
```

```
##   yield   variety year            site
## 1    27 Manchuria 1931 University Farm
```

- Rows 1-3, 3 column:

```
barley[1:3, 3]
```

```
## [1] 1931 1931 1931
```

# Subsetting data frames

- First column, all rows:

```
barley[,3]
```

```
##   [1] 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931
##  [15] 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931
##  [29] 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931
##  [43] 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931 1931
##  [57] 1931 1931 1931 1931 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932
##  [71] 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932
##  [85] 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932
##  [99] 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932 1932
## [113] 1932 1932 1932 1932 1932 1932 1932 1932
```

# Subsetting data frames

| | |
|---|---|
| barley[“variety”] | Result is a data.frame |
| barley[, “variety”] | Result is a vector |
| barley[[“variety”]] | Result is a vector |
| barley$variety | Result is a vector |

# Exercise: subsetting

**1)** Create a data frame (barley70) containing only the observations from rows 1 to 70 of the surveys dataset.

**2)** Use *nrow()* to subset the last row in barley70.

**3)** Use *nrow()* to extract the row that is in the middle barley70. Store in a variable called barleymid.

# Saving Data as .csv

- write.csv()
- Input: data frame, destination file
- Output: a file to the specified location
- write.csv(x = barley70, file = “barley70.csv”)

# Need help

- **Email**: max.oliveira@wisc.edu
- Base R Cheat sheet: Link