Data Wrangling in R with the Tidyverse

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slides: bit.ly/berd_tidy
pdf: bit.ly/berd_tidy_pdf

Pre-course homework

Open these slides bit.ly/berd_tidy

Open the homework: find it here

Learning objectives

Part 1:

- What is data wrangling?
- A few good practices in R/RStudio
- What is tidy data?
- What is tidyverse?
- Reshape and manipulate data frames

Part 2:

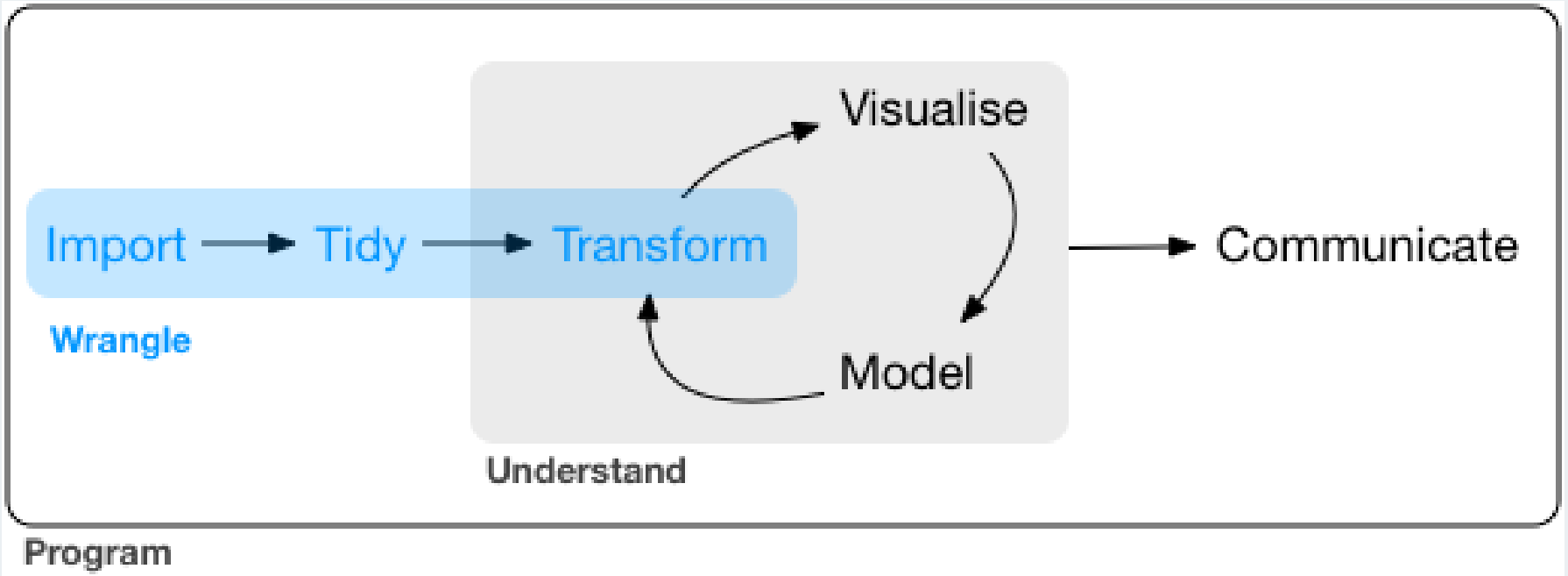
- Some data cleaning

Getting started

What is data wrangling?

- "data janitor work"
- importing data
- cleaning data
- changing shape of data

- fixing errors and poorly formatted data elements
- transforming columns and rows
- filtering, subsetting



G. Grolemond & H. Wickham's R for Data Science

Good practices in RStudio

- Use "projects" (read this)
    - Create an RStudio project for each data analysis project
    - A project is associated with a directory folder
        - Keep data files there
        - Keep scripts there; edit them, run them in bits or as a whole
        - Save your outputs (plots and cleaned data) there
- Only use relative paths, never absolute paths
    - realtive (good): `read_csv("data/mydata.csv")`
    - absolute (bad): `read_csv("/home/yourname/Documents/stuff/mydata.csv")`

Advantages of using projects

- standardize file paths
- keep everything together
- a whole folder can be shared and run on another computer

RStudio projects

Create new project

- Open RStudio
- File -> New Project
- Choose which folder you want to create the project in

Open existing project

- click on `.Rproj` file in your folder

Useful keyboard shortcuts

action	mac	windows/linux
run line of code	cmd + enter	ctrl + enter
<-	option + -	alt + -
%>%	cmd+shift+m	ctrl + shift + m

Try typing and running

```
y <- iris %>% count(Species)
y
```

Now, in console, press up arrow multiple times.

Others: (see list)

action	mac	windows/linux
interrupt currently executing command	esc	esc
in console, go to previously run code	up/down	up/down
keyboard shortcut help	option+shift+k	alt+shift+k

Tibbles

We learned about *data frames*

```
data.frame(name = c("Sarah","Ana","Jose"),
           rank = 1:3,
           age = c(35.5, 25, 58),
           city = c(NA,"New York","LA"))
```

```
   name rank  age      city
1 Sarah    1 35.5      <NA>
2   Ana    2 25.0 New York
3  Jose    3 58.0        LA
```

A *tibble* is a data frame but with perks

```
tibble(name = c("Sarah","Ana","Jose"),
       rank = 1:3,
       age = c(35.5, 25, 58),
       city = c(NA,"New York","LA"))
```

```
# A tibble: 3 x 4
  name   rank   age city
  <chr> <int> <dbl> <chr>
1 Sarah     1  35.5 <NA>
2 Ana       2  25   New York
3 Jose      3  58   LA
```

Tibble perks

- better printing methods
- doesn't print 10000 rows
- tells you the variable type (character, factor, double, integer, boolean, date)
- can be used anywhere a `data.frame` is needed
- `read_*()` functions don't read character columns as factors (no surprises)

Import as `data.frame` (try this)

Base R functions import `data.frame`

```
mydata_df <- read.csv("data/small_data.csv")
mydata_df
```

```
        id                  age    sex grade                    race4
1   335340          17 years old Female  10th                    White
2   638618          16 years old Female   9th                     <NA>
3   922382          14 years old   Male   9th                    White
4   923122          15 years old   Male   9th                    White
5   923963          15 years old   Male  10th Black or African American
6   925603          16 years old   Male  10th           All other races
7   933724          16 years old Female  10th           All other races
8   935435          17 years old Female  12th           All other races
9  1096564          15 years old   Male  10th           All other races
10 1108114          17 years old Female   9th Black or African American
11 1306150          16 years old   Male  10th           Hispanic/Latino
12 1307481          17 years old   Male  12th           Hispanic/Latino
13 1307872          17 years old   Male  11th           Hispanic/Latino
14 1311617          15 years old Female  10th           Hispanic/Latino
15 1313153          16 years old Female  11th           Hispanic/Latino
16 1313291          16 years old Female  11th                    White
```

Import as `tibble` (try this)

`tidyverse` functions import as tibbles (`read_csv`, `read_excel()`, etc)

```
mydata_tib <- read_csv("data/small_data.csv")
mydata_tib
```

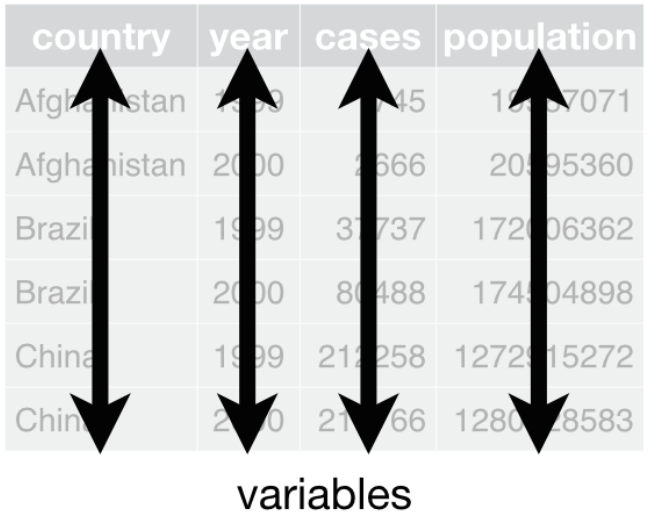
```
# A tibble: 20 x 11
       id age   sex    grade race4   bmi weight_kg text_while_driv…
    <dbl> <chr> <chr>  <chr> <chr> <dbl>     <dbl> <chr>
 1 3.35e5 17 y… Fema… 10th  White  27.6      66.2 <NA>
 2 6.39e5 16 y… Fema… 9th   <NA>   29.3      84.8 <NA>
 3 9.22e5 14 y… Male  9th   White  18.2      57.6 <NA>
 4 9.23e5 15 y… Male  9th   White  21.4      60.3 <NA>
 5 9.24e5 15 y… Male  10th  Blac…  19.6      63.5 <NA>
 6 9.26e5 16 y… Male  10th  All …  22.2      70.3 <NA>
 7 9.34e5 16 y… Fema… 10th  All …  21.0      45.4 <NA>
 8 9.35e5 17 y… Fema… 12th  All …  17.5      43.1 <NA>
 9 1.10e6 15 y… Male  10th  All …  22.5      79.4 <NA>
10 1.11e6 17 y… Fema… 9th   Blac…  26.6      68.0 <NA>
11 1.31e6 16 y… Male  10th  Hisp…  21.2      67.1 0 days
12 1.31e6 17 y… Male  12th  Hisp…  19.5      56.2 1 or 2 days
13 1.31e6 17 y… Male  11th  Hisp…  20.6      61.7 1 or 2 days
14 1.31e6 15 y… Fema… 10th  Hisp…  27.5      70.3 0 days
```

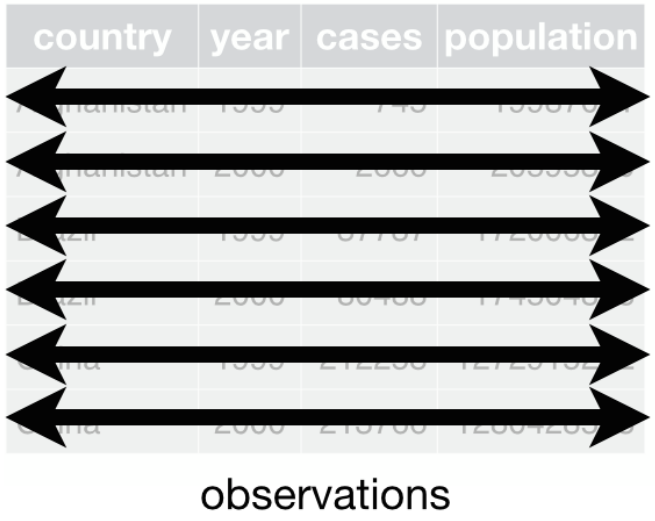
Run this code

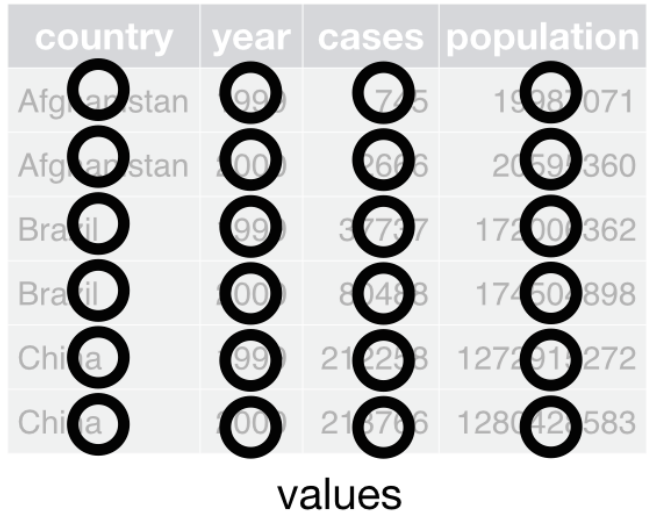
```
mydata <- read_csv("data/small_data.csv")
mydata
glimpse(mydata)
str(mydata)
head(mydata)
summary(mydata)
class(mydata)
```

Tidy Data

1. Each variable forms a column.
2. Each observation forms a row.
3. Each type of observational unit forms a table.







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Untidy data: example 1

```
untidy_data <- tibble(
  name = c("Ana","Bob","Cara"),
  wt_07_01_2018 = c(100, 150, 140),
  wt_08_01_2018 = c(104, 155, 138),
  wt_09_01_2018 = c(NA, 160, 142)
)
untidy_data
```

```
# A tibble: 3 x 4
  name  wt_07_01_2018 wt_08_01_2018 wt_09_01_2018
  <chr>          <dbl>          <dbl>          <dbl>
1 Ana              100            104             NA
2 Bob              150            155            160
3 Cara             140            138            142
```

Tidy data: example 1

You will learn how to do this!

```
untidy_data %>% gather(key = "date", value = "weight", -name) %>%
  mutate(date = str_remove(date,"wt_"),
         date = dmy(date))
```

```
# A tibble: 9 x 3
  name  date       weight
  <chr> <date>        <dbl>
1 Ana   2018-01-07    100
2 Bob   2018-01-07    150
3 Cara  2018-01-07    140
4 Ana   2018-01-08    104
5 Bob   2018-01-08    155
6 Cara  2018-01-08    138
7 Ana   2018-01-09     NA
8 Bob   2018-01-09    160
9 Cara  2018-01-09    142
```

Untidy data: example 2

```
untidy_data <- tibble(
  name = c("Ana","Bob","Cara"),
  meds = c("advil 500mg 2xday","tylenol 1000mg 1xday", "advil 200mg 3xday")
)
untidy_data
```

```
# A tibble: 3 x 2
  name  meds
  <chr> <chr>
1 Ana   advil 500mg 2xday
2 Bob   tylenol 1000mg 1xday
3 Cara  advil 200mg 3xday
```

Tidy data: example 2

You will learn how to do this!

```
untidy_data %>%
  separate(col = meds, into = c("med_name","dose_mg","times_per_day"), sep=" ") %>%
  mutate(times_per_day = as.numeric(str_remove(times_per_day, "xday")),
         dose_mg = as.numeric(str_remove(dose_mg, "mg")))
```

```
# A tibble: 3 x 4
  name  med_name dose_mg times_per_day
  <chr> <chr>      <dbl>         <dbl>
1 Ana   advil        500             2
2 Bob   tylenol     1000             1
3 Cara  advil        200             3
```

How to tidy?

The pipe operator %>%

- a function performed on (usually) a data frame or tibble used somewhat like a `+`
- "add" functions together
- the result is a transformed data set as a `tibble`
- Suppose you want to perform a series of operations on a data.frame or tibble `mydata` using hypothetical functions `f()`, `g()`, `h()`:
  - Perform `f(mydata)`
  - use the output as an argument to `g()`
  - use the output as an argument to `h()`

One option:

```
h(g(f(mydata)))
```

A long tedious option:

```
fout <- f(mydata)
gout <- g(fout)
h(gout)
```

Use the pipe %>%

Instead, we can use the pipe operator (pronounced "then")

- Take `mydata` then
- perform `f()` then
- perform `g()` then
- perform `h()`

```
mydata %>%
  f() %>%
  g() %>%
  h()
```

Why use the pipe?

- makes code more readable
- `h(f(g(mydata)))` can get complicated with multiple arguments
  - i.e. `h(f(g(mydata, na.rm=T), print=FALSE), type = "mean")`

A real example:

```
mydata_new <- mydata %>% select(id, weight_kg, bmi) %>%
  mutate(height_m = sqrt(weight_kg /bmi))
mydata_new %>% head(n=3)
```

```
# A tibble: 3 x 4
      id weight_kg   bmi height_m
   <dbl>     <dbl> <dbl>    <dbl>
1 335340      66.2  27.6     1.55
2 638618      84.8  29.3     1.70
3 922382      57.6  18.2     1.78
```

Let's wrangle!

About the data

Data from the CDC's Youth Risk Behavior Surveillance System (YRBSS)

- complex survey data
- national school-based survey conducted by CDC and state, territorial, tribal, and local surveys conducted by state, territorial, and local education and health agencies and tribal governments
- monitors six categories of health-related behaviors that contribute to the leading causes of death and disability among youth and adults (including alcohol & drug use, unhealthy & dangerous behaviors, sexuality, physical activity); see Questionnaires
- this data is a subset of data in the R package `yrbss` which includes YRBSS from 1991-2013

Import Data

Open your RStudio project. Open a new script, copy and paste this code, and run.

```
demo_data <- read_csv("data/yrbss_demo.csv")
qn_data <- read_csv("data/yrbss_qn.csv")

glimpse(demo_data)
glimpse(qn_data)
```

Look at your "Environment" tab, you should have the data there.

Tidyverse functions

- `tidyverse` is a suite of packages that implement `tidy` methods for data importing, cleaning and wrangling
- functions like `filter()`, `select()`, `mutate()` are part of the `tidyverse`
  - first argument is always the data frame
  - can be used in pipes `%>%`

All equivalent:

```
select(.data = demo_data, "record")
select(demo_data, "record")
select(demo_data, record)
demo_data %>% select(record)
```

Output:

```
# A tibble: 20,000 x 1
    record
     <dbl>
 1  931897
 2  333862
 3   36253
 4 1095530
 5 1303997
 6  261619
 7  926649
 8 1309082
 9  506337
10  180494
```

Subsetting data

Subset by rows

tidyverse data wrangling cheatsheet

`filter()` ~ rows

- filter data based on rows
- use logical cues:
  - double = for "is equal to"
  - use `&` (and) or `|` (or)
  - `!` in front negates the statement, as in `!=` or `!(grade=="9th")`
- use math
  - `> < >= <=`
- use the `is.na()` function to filter based on missing values

```
demo_data %>% filter(bmi > 20)
```

```
# A tibble: 10,375 x 8
    record age          sex    grade race4          race7           bmi stweight
     <dbl> <chr>        <chr>  <chr> <chr>          <chr>         <dbl>    <dbl>
 1  333862 17 years o… Fema… 12th  White          White          20.2      57.2
 2 1095530 15 years o… Male  10th  Black or Af… Black or Af…  28.0      85.7
 3 1303997 14 years o… Male  9th   All other r… Multiple - …  24.5      66.7
 4  926649 16 years o… Male  11th  All other r… Asian          20.5      70.3
 5  506337 18 years o… Male  12th  Hispanic/La… Hispanic/La…  33.1     123.
 6 1307180 16 years o… Male  10th  Hispanic/La… Hispanic/La…  21.8      66.7
 7 1312128 15 years o… Fema… 10th  White          White          22.0      65.8
```

Compare to base R

Bracket method, need for repeating data frame names, need to use `$`. Very nested and confusing to read.

```
demo_data[demo_data$grade=="9th",]
```

```
# A tibble: 5,625 x 8
    record age       sex    grade race4
     <dbl> <chr>     <chr>  <chr> <chr>
 1 1303997 14 years… Male   9th   All other
 2  261619 17 years… Male   9th   All other
 3 1096939 15 years… Male   9th   <NA>
 4  180968 15 years… Male   9th   White
 5  924270 15 years… Male   9th   All other
 6  330828 15 years… Female 9th   Hispanic/
 7 1311252 15 years… Female 9th   Hispanic/
 8   36853 14 years… Female 9th   All other
 9 1310689 14 years… Female 9th   Hispanic/
10 1310726 14 years… Female 9th   All other
# … with 5,615 more rows
```

No `$` needed. Uses "non-standard evaluation" so `filter()` knows `grade` is a column in `demo_data`.

```
demo_data %>% filter(grade=="9th")
```

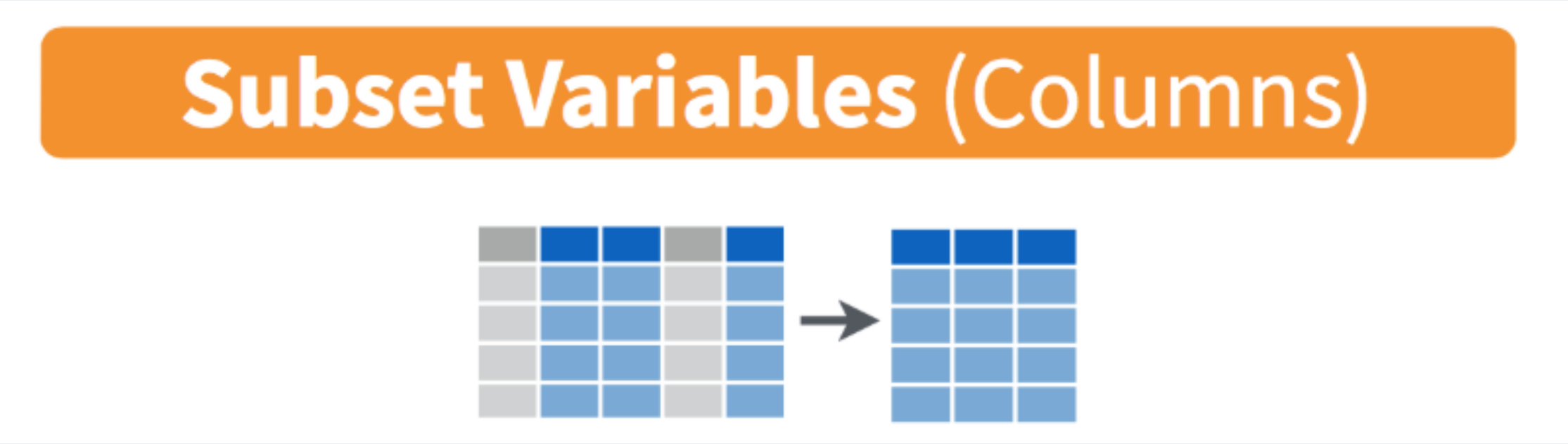
```
# A tibble: 5,219 x 8
    record age       sex    grade race4
     <dbl> <chr>     <chr>  <chr> <chr>
 1 1303997 14 years… Male   9th   All other
 2  261619 17 years… Male   9th   All other
 3 1096939 15 years… Male   9th   <NA>
 4  180968 15 years… Male   9th   White
 5  924270 15 years… Male   9th   All other
 6  330828 15 years… Female 9th   Hispanic/
 7 1311252 15 years… Female 9th   Hispanic/
 8   36853 14 years… Female 9th   All other
 9 1310689 14 years… Female 9th   Hispanic/
10 1310726 14 years… Female 9th   All other
# … with 5,209 more rows
```

`filter()` practice

What do these commands do? Try:

```
demo_data %>% filter(record==506901)
demo_data %>% filter(sex=="Male")
demo_data %>% filter(grade %in% c("10th","11th"))
demo_data %>% filter(!(grade=="9th"))
demo_data %>% filter(bmi < 20, stweight < 50, sex=="Female") # filter on multiple
demo_data %>% filter(is.na(bmi))
demo_data %>% filter(!is.na(bmi))
demo_data %>% filter(bmi < 5)
demo_data %>% filter(bmi/stweight < 0.5) # can do math
demo_data %>% filter((bmi<15)|(bmi>50))
```

Subset by columns



tidyverse data wrangling cheatsheet

`select()` ~ columns

- select columns/variables
- uses special syntax (next slide) that is flexible, no quotes needed
- can be used to rearrange columns (useful to use `everything()`)

```
demo_data %>% select(record, grade)
```

```
# A tibble: 20,000 x 2
    record grade
     <dbl> <chr>
 1  931897 10th
 2  333862 12th
 3   36253 11th
 4 1095530 10th
 5 1303997 9th
 6  261619 9th
 7  926649 11th
 8 1309082 12th
 9  506337 12th
10  180494 10th
# … with 19,990 more rows
```

Column selection syntax:

There are many ways to select a set of variable names:

- `var1:var20`: all the columns from `var1` to `var20`
- `one_of(c("a","b","c"))`: if you have a character vector of column names, you can use it here
- `-var1`: *not* `var1`, remove it
- `-(var1:var20)`: remove all the columns from `var1` to `var20`
- `contains("date")`, `contains("_")`: all variable names that contain a specified string
- `starts_with("a")` or `ends_with("last")`: all variable names that start or end with a string
- `demo_data %>% select(1:3)`: can still use column numbers

See other examples in the data wrangling cheatsheet.

Compare to base R

Need brackets, quotes around column names.

```
demo_data[, c("record","age","sex")]
```

```
# A tibble: 20,000 x 3
    record age                    sex
     <dbl> <chr>                  <chr>
 1  931897 15 years old           Female
 2  333862 17 years old           Female
 3   36253 18 years old or older Male
 4 1095530 15 years old           Male
 5 1303997 14 years old           Male
 6  261619 17 years old           Male
 7  926649 16 years old           Male
 8 1309082 17 years old           Male
 9  506337 18 years old or older Male
10  180494 14 years old           Male
# … with 19,990 more rows
```

No quotes needed, easier to read. More flexible. Either of these work:

```
demo_data %>% select(record, age, sex)
demo_data %>% select(record:sex)
```

```
# A tibble: 20,000 x 3
    record age                    sex
     <dbl> <chr>                  <chr>
 1  931897 15 years old           Female
 2  333862 17 years old           Female
 3   36253 18 years old or older Male
 4 1095530 15 years old           Male
 5 1303997 14 years old           Male
 6  261619 17 years old           Male
 7  926649 16 years old           Male
 8 1309082 17 years old           Male
 9  506337 18 years old or older Male
10  180494 14 years old           Male
# … with 19,990 more rows
# A tibble: 20,000 x 3
```

`select()` practice

What do these commands do? Try:

```
demo_data %>% select(-grade,-sex)
demo_data %>% select(record:sex)
demo_data %>% select(-(record:sex))
demo_data %>% select(contains("race"))
demo_data %>% select(record, race4, race7, everything())
demo_data %>% select(one_of(c("age","stweight")))
demo_data %>% select(starts_with("r"))
demo_data %>% select(-contains("r"))
demo_data %>% select(1:3)
```

`rename()` ~ columns

- renames column variables

```
demo_data %>% rename(id = record)
```

```
# A tibble: 20,000 x 8
        id age          sex    grade race4          race7           bmi stweight
     <dbl> <chr>        <chr>  <chr> <chr>          <chr>         <dbl>    <dbl>
 1  931897 15 years o… Fema… 10th  White          White          17.2     54.4
 2  333862 17 years o… Fema… 12th  White          White          20.2     57.2
 3   36253 18 years o… Male  11th  Hispanic/La… Hispanic/La…  NA       NA
 4 1095530 15 years o… Male  10th  Black or Af… Black or Af…  28.0     85.7
 5 1303997 14 years o… Male  9th   All other r… Multiple - …  24.5     66.7
 6  261619 17 years o… Male  9th   All other r… <NA>           NA       NA
 7  926649 16 years o… Male  11th  All other r… Asian          20.5     70.3
 8 1309082 17 years o… Male  12th  White          White          19.3     59.0
 9  506337 18 years o… Male  12th  Hispanic/La… Hispanic/La…  33.1    123.
10  180494 14 years o… Male  10th  Black or Af… Black or Af…  NA       NA
# … with 19,990 more rows
```

`select_*()` and `rename_*()` practice

- scoped variants of `select()` and `rename()` operate on a selection of columns
- which columns depends on a predicate, can be:
  - variable names through `vars()`, or
  - a function that returns TRUE/FALSE like `is.numeric()`

What do these commands do? Try:

```
demo_data %>% select_if(is.numeric)
demo_data %>% rename_if(is.character, toupper) # toupper() is a function
demo_data %>% rename_all(toupper)
demo_data %>% rename_at(vars(contains("race")), toupper)
demo_data %>% rename_if(is.numeric, funs(paste0(.,"_num")))
```

Practice

1. Import `demo_data.csv` in the `data/` folder
2. Convert all column names to upper case, save the result as `newdata`
3. For `newdata`, select only character variables, save again as `newdata`.
4. Filter this data to only keep Asian or Native Hawaiian/other PI subjects in the 9th grade.
5. Filter this data to remove subjects younger than 13.
6. Remove the column `RACE4`.
7. How many rows does the resulting `newdata` have? How many columns?

Changing the data

Make new variables

tidyverse data wrangling cheatsheet

mutate()

EXPLAIN MUTATE

```
newdata <- demo_data %>%
  select(record, bmi:stweight) %>%
  mutate(height_m = sqrt(stweight /bmi))
newdata
```

```
# A tibble: 20,000 x 4
    record   bmi stweight height_m
     <dbl> <dbl>    <dbl>    <dbl>
 1  931897  17.2     54.4     1.78
 2  333862  20.2     57.2     1.68
 3   36253  NA       NA      NA
 4 1095530  28.0     85.7     1.75
 5 1303997  24.5     66.7     1.65
 6  261619  NA       NA      NA
 7  926649  20.5     70.3     1.85
 8 1309082  19.3     59.0     1.75
 9  506337  33.1    123.      1.93
10  180494  NA       NA      NA
# … with 19,990 more rows
```

mutate() practice

Try these:

```
demo_data %>% mutate(bmi_high = bmi > 30)
demo_data %>% mutate(male = 1*(sex=="Male"))
demo_data %>% mutate(grade_num = as.numeric(str_remove(grade,"th")))
```

case_when() with mutate()

EXPLAIN CASE WHEN

```
demo_data2 <- demo_data %>%
  mutate(
    age_int = case_when(
      age=="12 years old or younger" ~ 12,
      age=="18 years old or older" ~ 18,
      TRUE ~ as.numeric(str_remove(age, " years old"))
  ))
demo_data2 %>% tabyl(age,age_int)
```

```
                     age  12 13   14   15   16   17   18 NA_
 12 years old or younger 137  0    0    0    0    0    0   0
            13 years old   0 96    0    0    0    0    0   0
            14 years old   0  0 2026    0    0    0    0   0
            15 years old   0  0    0 4290    0    0    0   0
            16 years old   0  0    0    0 4924    0    0   0
            17 years old   0  0    0    0    0 4988    0   0
   18 years old or older   0  0    0    0    0    0 3334   0
                    <NA>   0  0    0    0    0    0    0 205
```

`separate()` and `unite()`

Dealing with missing or duplicated data

```
demo_data %>% distinct()
```

```
# A tibble: 20,000 x 8
    record age          sex    grade race4          race7           bmi stweight
     <dbl> <chr>        <chr>  <chr> <chr>          <chr>         <dbl>    <dbl>
 1  931897 15 years o… Fema… 10th  White          White          17.2     54.4
 2  333862 17 years o… Fema… 12th  White          White          20.2     57.2
 3   36253 18 years o… Male  11th  Hispanic/La… Hispanic/La…  NA       NA
 4 1095530 15 years o… Male  10th  Black or Af… Black or Af…  28.0     85.7
 5 1303997 14 years o… Male  9th   All other r… Multiple - …  24.5     66.7
 6  261619 17 years o… Male  9th   All other r… <NA>           NA       NA
 7  926649 16 years o… Male  11th  All other r… Asian          20.5     70.3
 8 1309082 17 years o… Male  12th  White          White          19.3     59.0
 9  506337 18 years o… Male  12th  Hispanic/La… Hispanic/La…  33.1    123.
10  180494 14 years o… Male  10th  Black or Af… Black or Af…  NA       NA
# … with 19,990 more rows
```

Removes *all* rows with *any* missing (`NA`) values in *any* row

```
demo_data %>% na.omit()
```

Joining/merging data

Resources - Tidyverse & Data Wrangling

Links

- Learn the tidyverse
- Data wrangling cheatsheet

Some of this is drawn from materials in online books/lessons:

- R for Data Science - by Garrett Grolemund & Hadley Wickham
- Modern Dive - An Introduction to Statistical and Data Sciences via R by Chester Ismay & Albert Kim
- A gRadual intRoduction to the tidyverse - Workshop for Cascadia R 2017 by Chester Ismay and Ted Laderas
- Cookbook for R by Winston Chang
- "Tidy Data" by Hadley Wickham

Possible Future Workshop Topics?

- reproducible reports in R
- tables
- ggplot2 visualization
- advanced tidyverse: functions, purrr
- statistical modeling in R

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This workshop info:

- Code for these slides on github: jminnier/berd_r_courses
- all the R code in an R script
- answers to practice problems can be found here: html, pdf