BU R Workshop 2021

Summarizing and Transforming Data in R

Saving you time and sanity

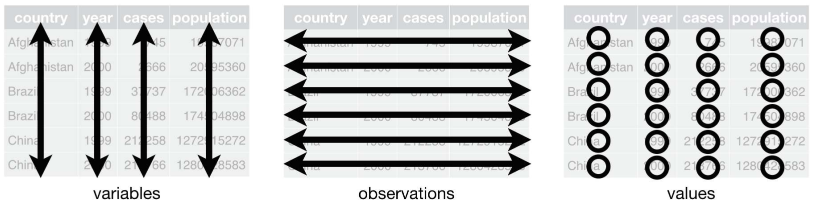

Image from R for Data Science

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Types of Modifications

1. **Subset**

- Subset by groups (i.e., rows)
- Subset by variables (i.e., columns)

2. **Joining data sets**

3. **Creating new columns**

- Creating categories
- Column calculations
- By group

4. **Summarize existing columns**

- Summarizing by group

5. **Transpose**

- Going between **wide** and **long** data formats
- Transposing for analysis
- Transposing for visualizations

Getting ready

Using packages:

```
library(tidyverse)
library(skimr)
```

Using data sets:

- grain_size2.csv (download here)
- grain_meta.csv (download here)

```
size <- read_csv("./data/grain_size2.csv")
size
```

```
## # A tibble: 114 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP01     4        13.0        17.4      19.7        14.1       11.2       8.17  16.3
## 2 CSP01    12        10.7        16.9      19.2        14.1       11.7       9.03  18.4
## 3 CSP01    35        12.1        17.8      16.1        10.3        9.51      7.47  26.7
## 4 CSP01    53        17.6        18.2      14.3         9.4        9.1       8.7   22.7
## 5 CSP01    83        21.0        18.4      14.3         9.79       8.79      7.29  20.4
## 6 CSP01   105        19.0        18.4      14.4        10.8        9.4       8.22  19.7
## 7 CSP08    10        11.6        17.1      20.8        16.3        9.55      6.23  18.4
## 8 CSP08    27        15.4        16.2      17.8        14.3       10.4       6.1   19.6
## # … with 106 more rows
```

skim() our data

```
## ── Data Summary ────────────────────────
##                            Values
## Name                       size
## Number of rows             114
## Number of columns          9
## _______________________
## Column type frequency:
##   character                1
##   numeric                  8
## ________________________
## Group variables            None
##
## ── Variable type: character ────────────────────────────────────────────────────────────────────
##   skim_variable n_missing complete_rate   min   max empty n_unique whitespace
## 1 plot                  0             1     5     5     0       27          0
##
## ── Variable type: numeric ──────────────────────────────────────────────────────────────────────
##   skim_variable n_missing complete_rate  mean    sd    p0   p25   p50   p75  p100 hist
## 1 depth                 0             1 45.2  40.5   2     13    33     68.8 190  ▇▃▂▁▁
## 2 coarse_sand           0             1 14.0   7.52  1.71  8.05 13.1   18.8  40.0 ▆▇▅▂▁
## 3 medium_sand           0             1 12.4   4.83  2.7   8.44 12.7   16.2  22.2 ▅▇▇▇▃
## 4 fine_sand             0             1 13.2   3.46  5.52 10.9  13.0   15.5  20.8 ▂▆▇▅▃
## 5 coarse_silt           0             1 15.7   6.65  6.73 10.7  14.1   18.1  42.8 ▇▆▂▁▁
## 6 medium_silt           0             1 14.1   4.09  7.85 11.2  13.0   16.4  28.0 ▇▇▅▂▁
```

skim() our data

```
##
## ── Variable type: character ────────────────────────────────────────────────────────────────────
##   skim_variable n_missing complete_rate   min   max empty n_unique whitespace
## 1 plot                  0             1     5     5     0       27          0
##
## ── Variable type: numeric ──────────────────────────────────────────────────────────────────────
##   skim_variable n_missing complete_rate  mean    sd    p0   p25   p50   p75  p100 hist
## 1 depth                 0             1 45.2  40.5   2     13    33     68.8 190  ▇▃▂▁▁
## 2 coarse_sand           0             1 14.0   7.52  1.71  8.05 13.1   18.8  40.0 ▆▇▅▂▁
## 3 medium_sand           0             1 12.4   4.83  2.7   8.44 12.7   16.2  22.2 ▅▇▇▇▃
## 4 fine_sand             0             1 13.2   3.46  5.52 10.9  13.0   15.5  20.8 ▂▆▇▅▃
## 5 coarse_silt           0             1 15.7   6.65  6.73 10.7  14.1   18.1  42.8 ▇▆▂▁▁
## 6 medium_silt           0             1 14.1   4.09  7.85 11.2  13.0   16.4  28.0 ▇▇▅▂▁
## 7 fine_silt             0             1  9.21  2.47  3.94  7.45  8.70  10.6  15.3 ▂▇▇▃▂
## 8 clay                  0             1 21.3   5.01  4     18.1  21.2   24.8  31.6 ▁▁▇▇▅
```

Subsetting

By rows and column

Subsetting: By rows

`filter()` (`tidyverse` function, specifically from `dplyr` package)

```
filter(data, expression1, expression2, etc.)
```

- **`tidyverse`** functions always start with **data**
- **Column** expressions reference actual **columns** in **data**
- Here logical statments relating to **column** values

Subsetting: By rows

Subset by group (i.e., by categorical value)

```
filter(size, plot %in% c("CSP11", "CSP13"))
```

```
## # A tibble: 9 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP13     2        22.1        17.5      18.3        11.9        7.92      6.05  16.3
## 2 CSP13    10        12.1        14.9      18          13.1       10.4       7.92  23.6
## 3 CSP13    25        13.7        12.7      14.3        11.7        9.67      6.31  31.6
## 4 CSP13    60        27.1         9.74     11.1         9.69       9.79      7.82  24.8
## 5 CSP13   140        10.4        15.3      16.0        12.4       12.4      10.2   23.5
## 6 CSP11    20         6.67        3.94      5.52       23.7       23        14.8   22.3
## 7 CSP11    30         5.27        4.23      6.11       23.6       23.9      15.3   21.6
## 8 CSP11    47         4.34        4.03      6.62       24.5       25.5      13.8   21.3
## 9 CSP11   143         5.28        4.26      7.07       22.8       28.0      12.4   20.2
```

Subsetting: By rows

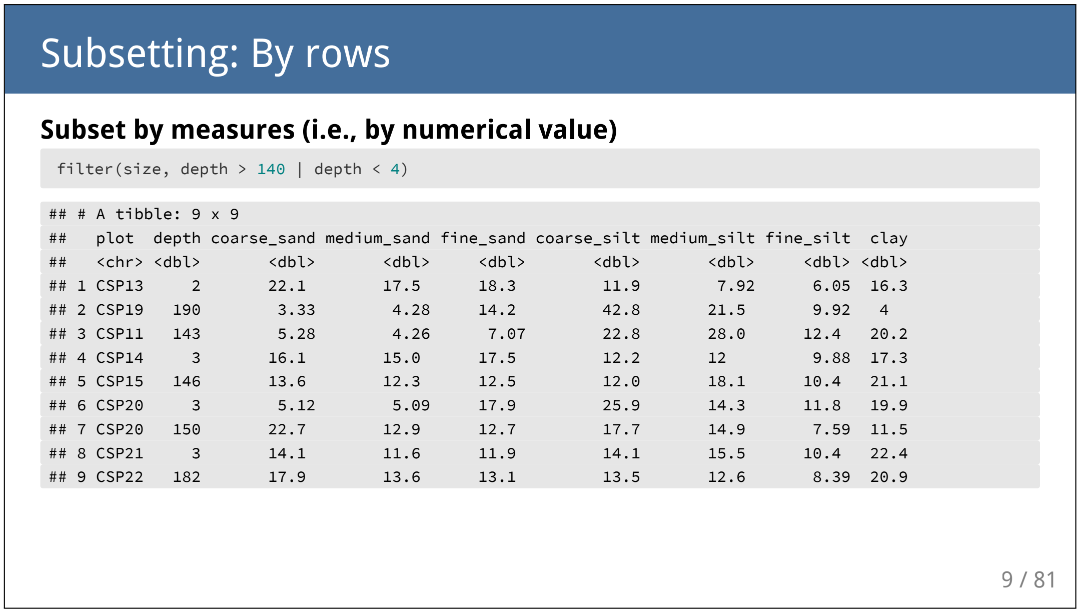
Subset by group (i.e., by categorical value)

```
filter(size, plot %in% c("CSP11", "CSP13"))
```

```
## # A tibble: 9 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP13     2        22.1        17.5      18.3        11.9        7.92      6.05  16.3
## 2 CSP13    10        12.1        14.9      18          13.1       10.4       7.92  23.6
## 3 CSP13    25        13.7        12.7      14.3        11.7        9.67      6.31  31.6
## 4 CSP13    60        27.1         9.74     11.1         9.69       9.79      7.82  24.8
## 5 CSP13   140        10.4        15.3      16.0        12.4       12.4      10.2   23.5
## 6 CSP11    20         6.67        3.94      5.52       23.7       23        14.8   22.3
## 7 CSP11    30         5.27        4.23      6.11       23.6       23.9      15.3   21.6
## 8 CSP11    47         4.34        4.03      6.62       24.5       25.5      13.8   21.3
## 9 CSP11   143         5.28        4.26      7.07       22.8       28.0      12.4   20.2
```

> Note: To save this as a separate object, don't forget assignments:

```
size_sub <- filter(size, plot %in% c("CSP11", "CSP13"))
```

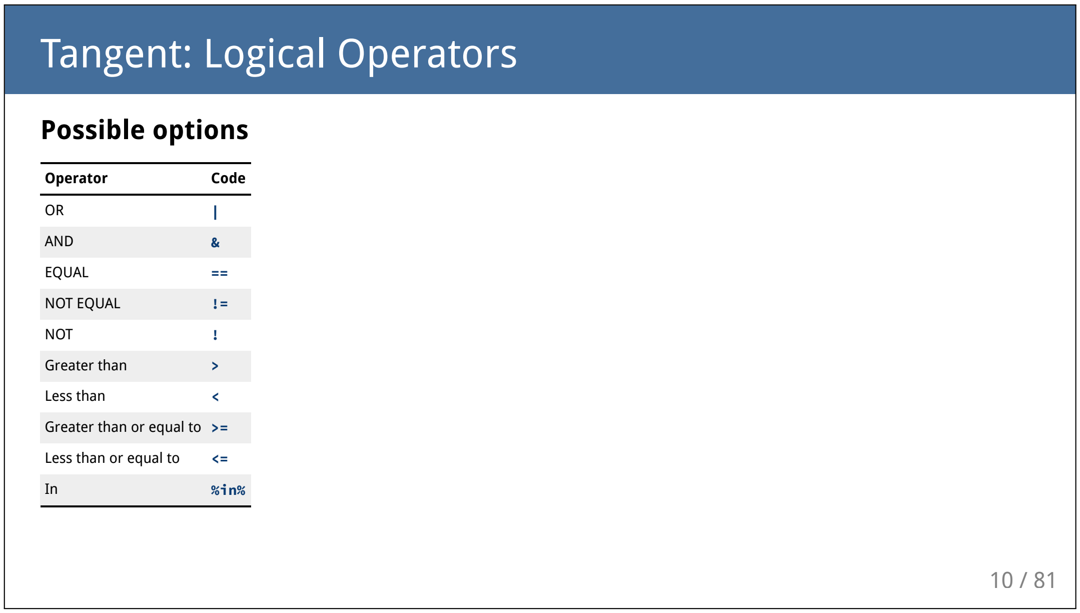


Subsetting: By rows

Subset by measures (i.e., by numerical value)

```
filter(size, depth > 140 | depth < 4)
```

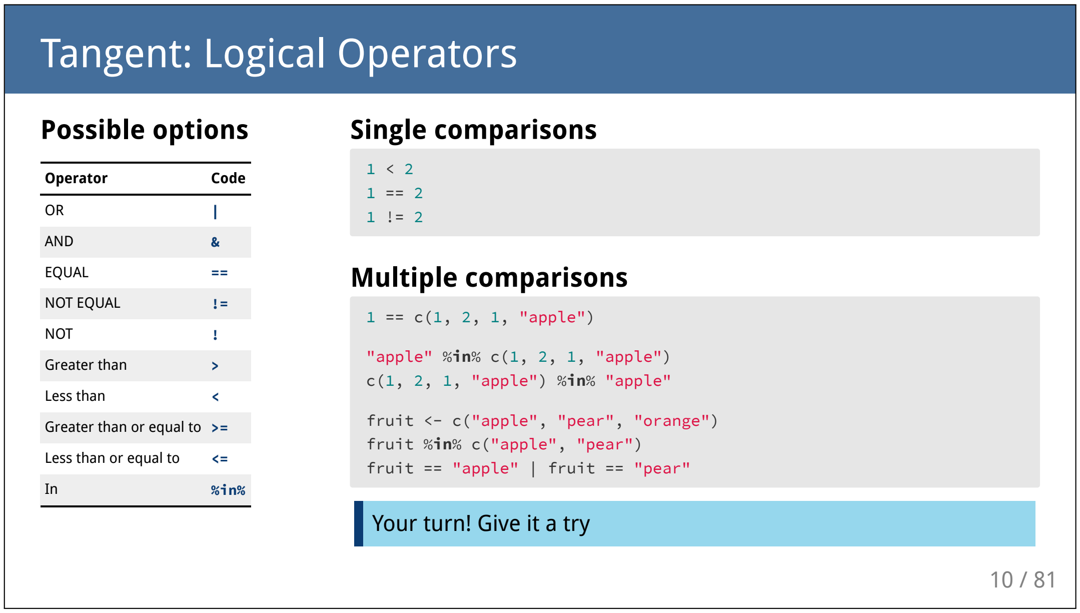
```
## # A tibble: 9 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP13     2       22.1        17.5      18.3         11.9         7.92      6.05  16.3
## 2 CSP19   190        3.33        4.28     14.2         42.8        21.5       9.92   4
## 3 CSP11   143        5.28        4.26      7.07        22.8        28.0      12.4   20.2
## 4 CSP14     3       16.1        15.0      17.5         12.2        12         9.88  17.3
## 5 CSP15   146       13.6        12.3      12.5         12.0        18.1      10.4   21.1
## 6 CSP20     3        5.12        5.09     17.9         25.9        14.3      11.8   19.9
## 7 CSP20   150       22.7        12.9      12.7         17.7        14.9       7.59  11.5
## 8 CSP21     3       14.1        11.6      11.9         14.1        15.5      10.4   22.4
## 9 CSP22   182       17.9        13.6      13.1         13.5        12.6       8.39  20.9
```



Tangent: Logical Operators

Possible options

Operator	Code
OR	`|`
AND	`&`
EQUAL	`==`
NOT EQUAL	`!=`
NOT	`!`
Greater than	`>`
Less than	`<`
Greater than or equal to	`>=`
Less than or equal to	`<=`
In	`%in%`



Tangent: Logical Operators

Possible options

Operator	Code
OR	`|`
AND	`&`
EQUAL	`==`
NOT EQUAL	`!=`
NOT	`!`
Greater than	`>`
Less than	`<`
Greater than or equal to	`>=`
Less than or equal to	`<=`
In	`%in%`

Single comparisons

```
1 < 2
1 == 2
1 != 2
```

Multiple comparisons

```
1 == c(1, 2, 1, "apple")

"apple" %in% c(1, 2, 1, "apple")
c(1, 2, 1, "apple") %in% "apple"

fruit <- c("apple", "pear", "orange")
fruit %in% c("apple", "pear")
fruit == "apple" | fruit == "pear"
```

Your turn! Give it a try

Subsetting: By rows

Which values are greater than 100 OR less than 4?

```
size$depth > 140 | size$depth < 4
```

```
##   [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [19] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [37]  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [55]  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
##  [73] FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE  TRUE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE  TRUE
##  [91] FALSE FALSE FALSE  TRUE  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE FALSE FALSE
## [109] FALSE FALSE FALSE FALSE FALSE FALSE
```

Return only rows with **TRUE**

```
filter(size, depth > 140 | depth < 4)
```

Subsetting: By rows

Subset by combination

```
filter(size,
       depth > 100,
       plot %in% c("CSP11", "CSP13"))
```

```
## # A tibble: 2 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP13   140       10.4        15.3      16.0         12.4        12.4      10.2  23.5
## 2 CSP11   143        5.28        4.26      7.07        22.8        28.0      12.4  20.2
```

Subsetting: By rows

Subset by combination

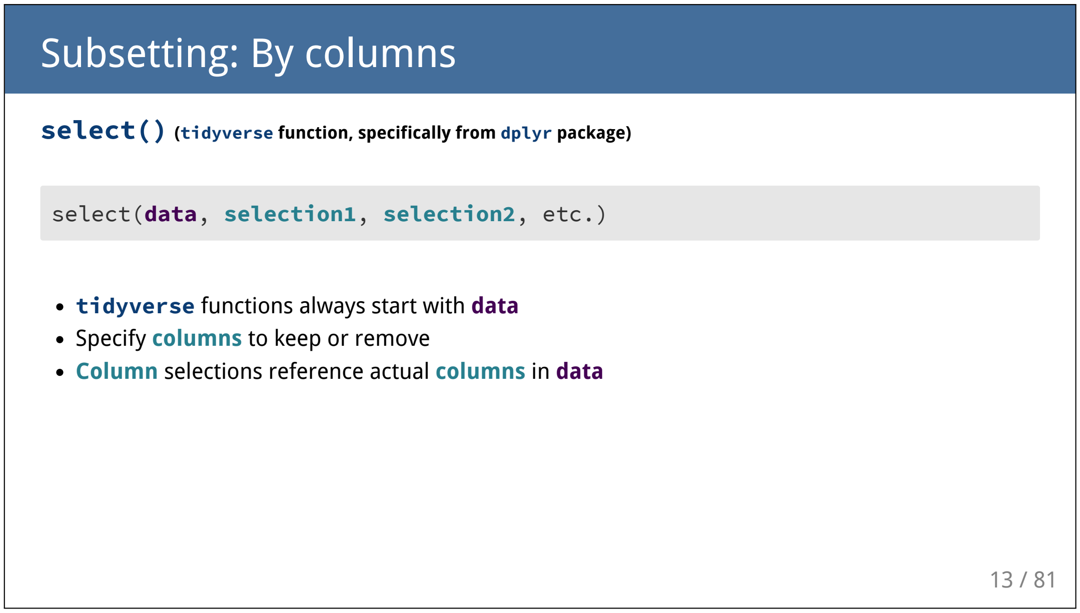
```
filter(size,
       depth > 100,
       plot %in% c("CSP11", "CSP13"))
```

```
## # A tibble: 2 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>
## 1 CSP13   140       10.4        15.3      16.0         12.4        12.4      10.2  23.5
## 2 CSP11   143        5.28        4.26      7.07        22.8        28.0      12.4  20.2
```

Equivalent

```
filter(size,
       depth > 100 &
       plot %in% c("CSP11", "CSP13"))
```

Separate arguments in `filter` act like **AND (&)**

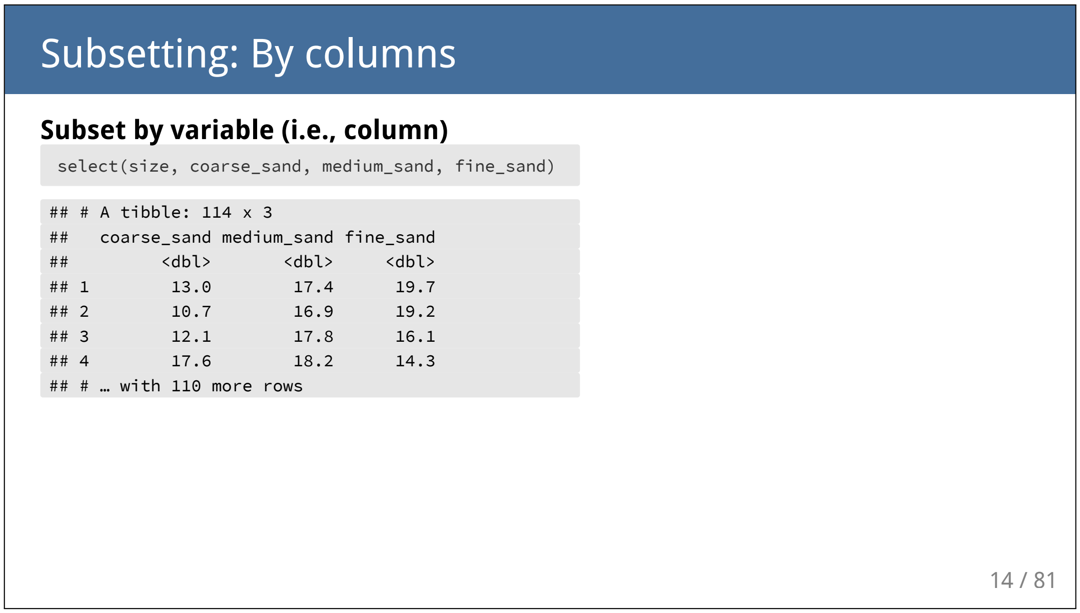


Subsetting: By columns

`select()` (**`tidyverse`** **function, specifically from** **`dplyr`** **package)**

```
select(data, selection1, selection2, etc.)
```

- **`tidyverse`** functions always start with **data**
- Specify **columns** to keep or remove
- **Column** selections reference actual **columns** in **data**

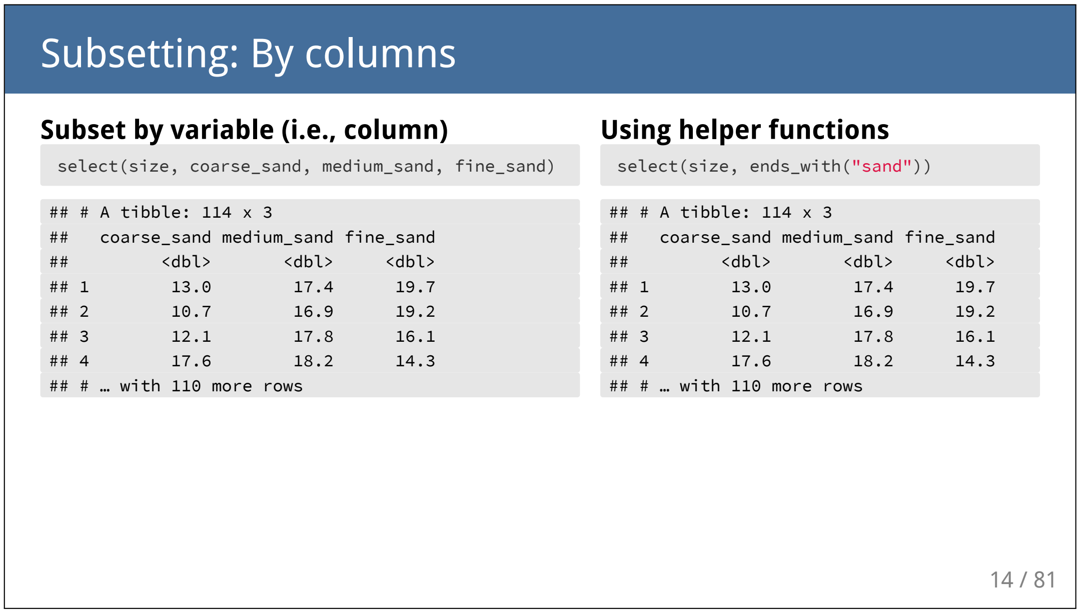


Subsetting: By columns

Subset by variable (i.e., column)

```
select(size, coarse_sand, medium_sand, fine_sand)
```

```
## # A tibble: 114 x 3
##   coarse_sand medium_sand fine_sand
##         <dbl>       <dbl>     <dbl>
## 1        13.0        17.4      19.7
## 2        10.7        16.9      19.2
## 3        12.1        17.8      16.1
## 4        17.6        18.2      14.3
## # … with 110 more rows
```



Subsetting: By columns

Subset by variable (i.e., column)

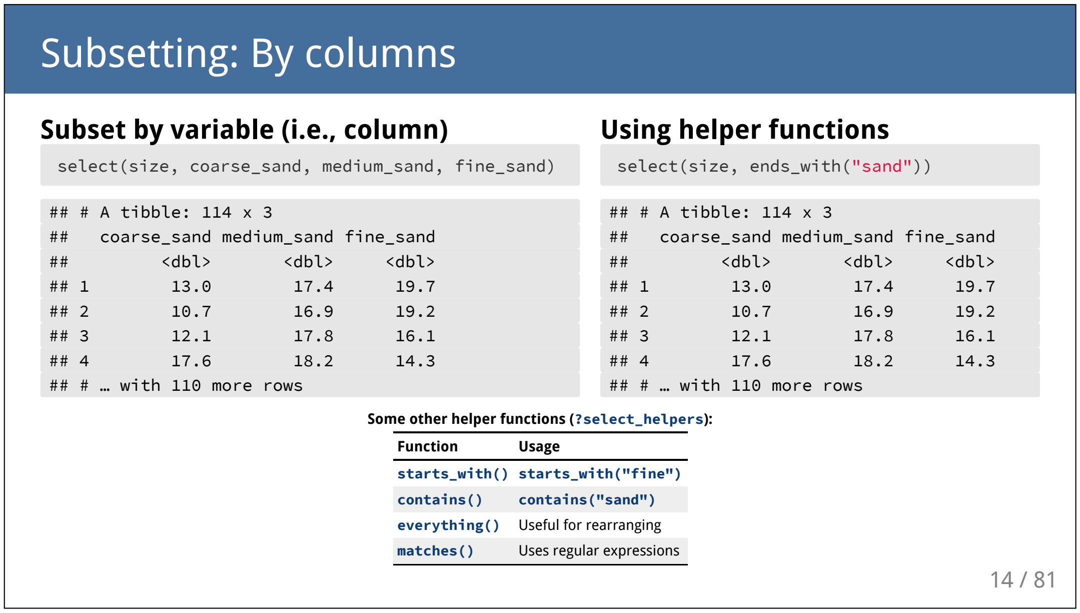
```
select(size, coarse_sand, medium_sand, fine_sand)
```

```
## # A tibble: 114 x 3
##   coarse_sand medium_sand fine_sand
##         <dbl>       <dbl>     <dbl>
## 1        13.0        17.4      19.7
## 2        10.7        16.9      19.2
## 3        12.1        17.8      16.1
## 4        17.6        18.2      14.3
## # … with 110 more rows
```

Using helper functions

```
select(size, ends_with("sand"))
```

```
## # A tibble: 114 x 3
##   coarse_sand medium_sand fine_sand
##         <dbl>       <dbl>     <dbl>
## 1        13.0        17.4      19.7
## 2        10.7        16.9      19.2
## 3        12.1        17.8      16.1
## 4        17.6        18.2      14.3
## # … with 110 more rows
```



Subsetting: By columns

Subset by variable (i.e., column)

```
select(size, coarse_sand, medium_sand, fine_sand)
```

```
## # A tibble: 114 x 3
##   coarse_sand medium_sand fine_sand
##         <dbl>       <dbl>     <dbl>
## 1        13.0        17.4      19.7
## 2        10.7        16.9      19.2
## 3        12.1        17.8      16.1
## 4        17.6        18.2      14.3
## # … with 110 more rows
```

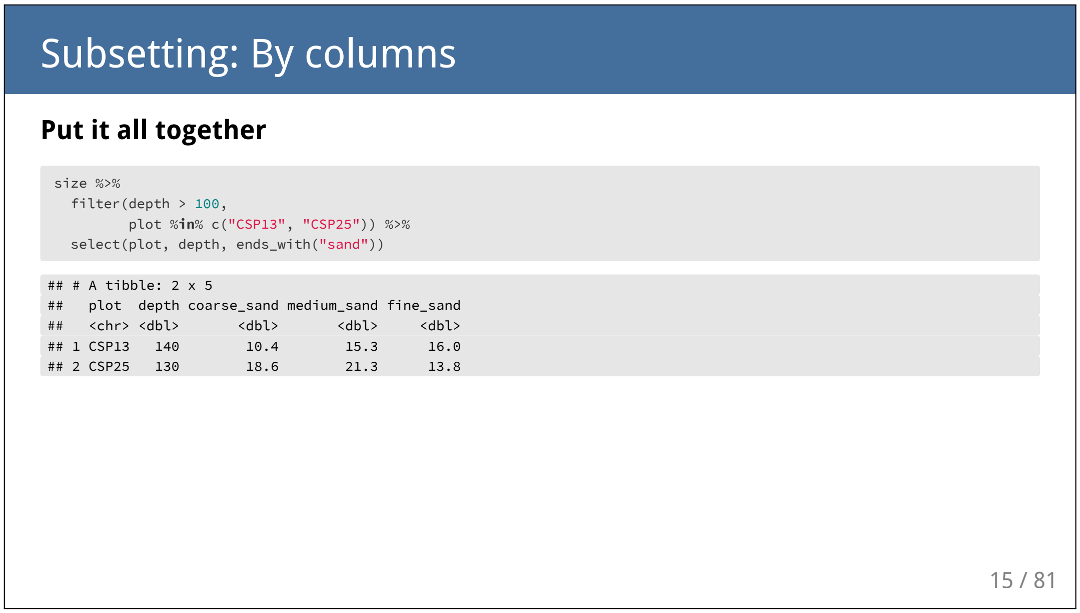
Using helper functions

```
select(size, ends_with("sand"))
```

```
## # A tibble: 114 x 3
##   coarse_sand medium_sand fine_sand
##         <dbl>       <dbl>     <dbl>
## 1        13.0        17.4      19.7
## 2        10.7        16.9      19.2
## 3        12.1        17.8      16.1
## 4        17.6        18.2      14.3
## # … with 110 more rows
```

Some other helper functions (`?select_helpers`):

Function	Usage
`starts_with()`	`starts_with("fine")`
`contains()`	`contains("sand")`
`everything()`	Useful for rearranging
`matches()`	Uses regular expressions

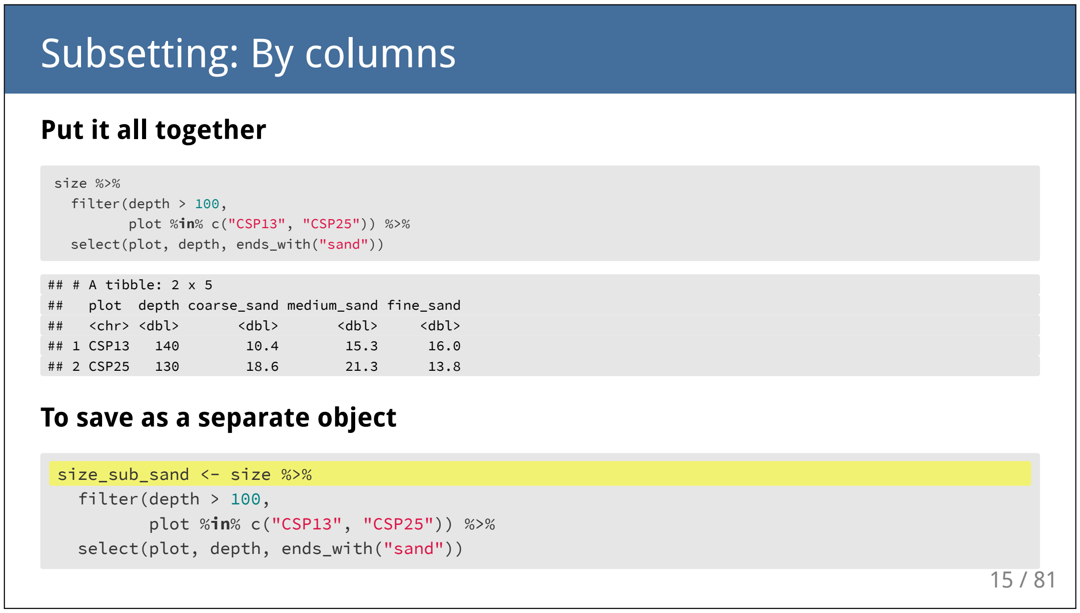


Subsetting: By columns

Put it all together

```
size %>%
  filter(depth > 100,
         plot %in% c("CSP13", "CSP25")) %>%
  select(plot, depth, ends_with("sand"))
```

```
## # A tibble: 2 x 5
##   plot  depth coarse_sand medium_sand fine_sand
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>
## 1 CSP13   140        10.4        15.3      16.0
## 2 CSP25   130        18.6        21.3      13.8
```



Subsetting: By columns

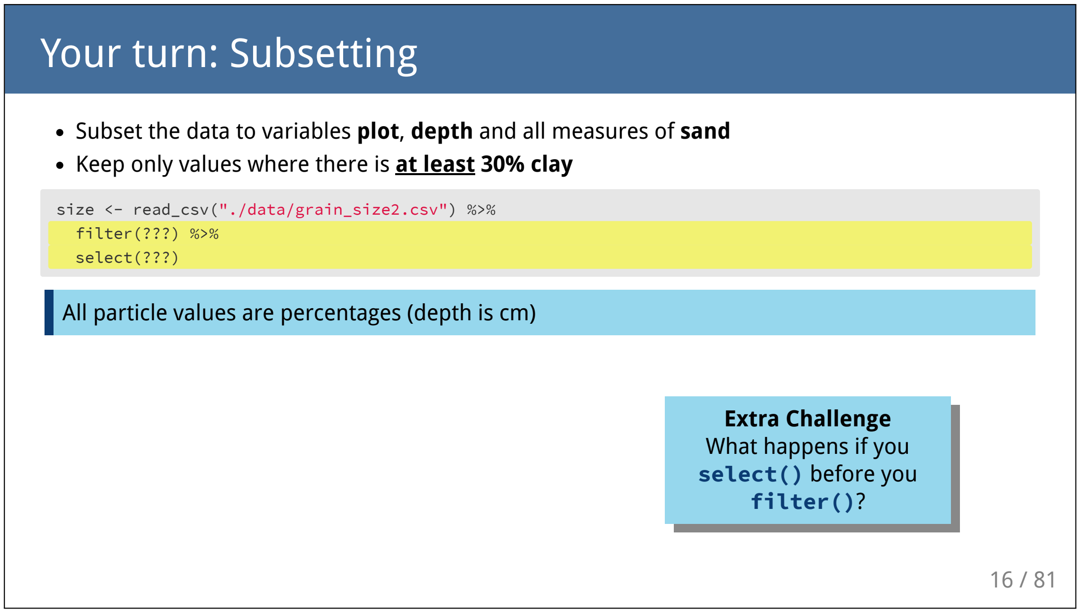
Put it all together

```
size %>%
  filter(depth > 100,
         plot %in% c("CSP13", "CSP25")) %>%
  select(plot, depth, ends_with("sand"))
```

```
## # A tibble: 2 x 5
##   plot  depth coarse_sand medium_sand fine_sand
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>
## 1 CSP13   140        10.4        15.3      16.0
## 2 CSP25   130        18.6        21.3      13.8
```

To save as a separate object

```
size_sub_sand <- size %>%
  filter(depth > 100,
         plot %in% c("CSP13", "CSP25")) %>%
  select(plot, depth, ends_with("sand"))
```



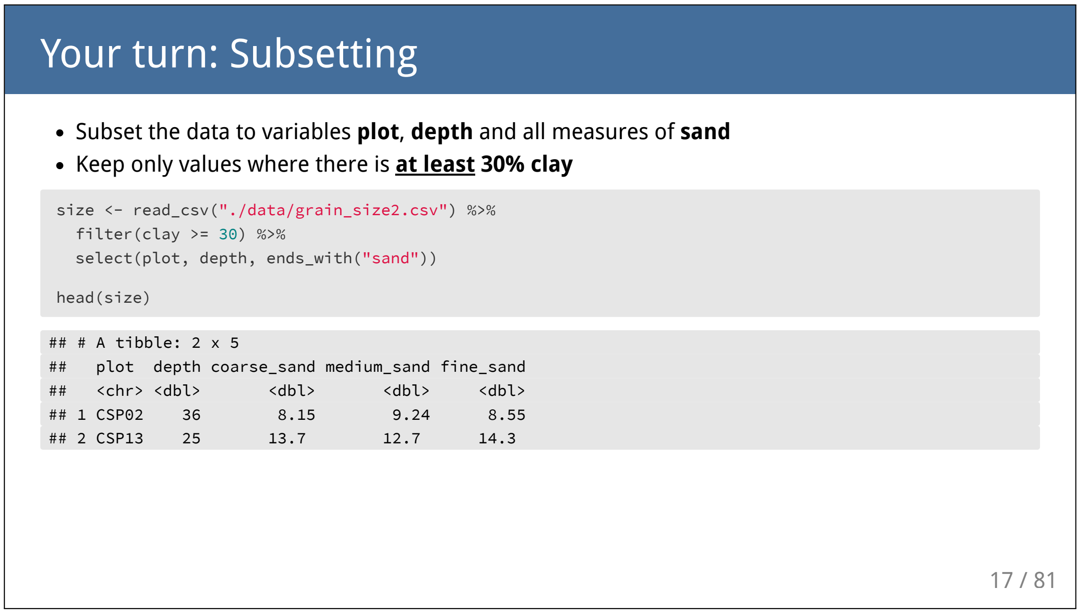
Your turn: Subsetting

- Subset the data to variables **plot**, **depth** and all measures of **sand**
- Keep only values where there is **at least 30% clay**

```
size <- read_csv("./data/grain_size2.csv") %>%
  filter(???) %>%
  select(???)
```

All particle values are percentages (depth is cm)

Extra Challenge
What happens if you **`select()`** before you **`filter()`**?

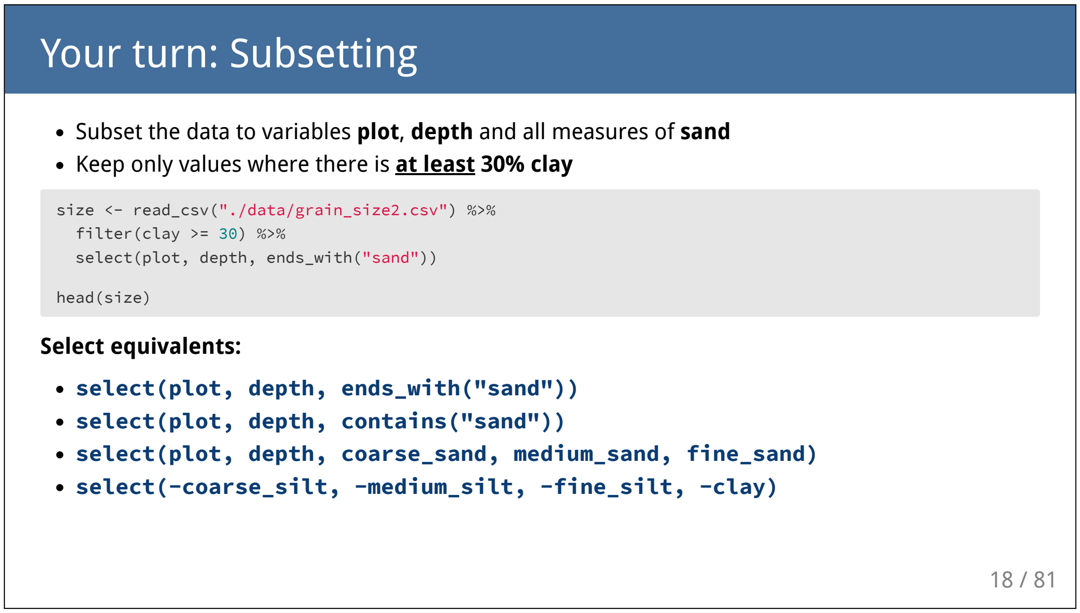


Your turn: Subsetting

- Subset the data to variables **plot**, **depth** and all measures of **sand**
- Keep only values where there is **at least 30% clay**

```
size <- read_csv("./data/grain_size2.csv") %>%
  filter(clay >= 30) %>%
  select(plot, depth, ends_with("sand"))

head(size)
```

```
## # A tibble: 2 x 5
##   plot  depth coarse_sand medium_sand fine_sand
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>
## 1 CSP02    36        8.15        9.24      8.55
## 2 CSP13    25       13.7        12.7      14.3
```



Your turn: Subsetting

- Subset the data to variables **plot**, **depth** and all measures of **sand**
- Keep only values where there is **at least 30% clay**

```
size <- read_csv("./data/grain_size2.csv") %>%
  filter(clay >= 30) %>%
  select(plot, depth, ends_with("sand"))

head(size)
```

Select equivalents:

- **`select(plot, depth, ends_with("sand"))`**
- **`select(plot, depth, contains("sand"))`**
- **`select(plot, depth, coarse_sand, medium_sand, fine_sand)`**
- **`select(-coarse_silt, -medium_silt, -fine_silt, -clay)`**

Your turn: Subsetting (Extra Challenge)

What happens if you `select()` before you `filter()`?

```
size <- read_csv("./data/grain_size2.csv") %>%
  select(plot, depth, ends_with("sand")) %>%
  filter(clay >= 30)
```

```
## Error: Problem with `filter()` input `..1`.
## x object 'clay' not found
## ℹ Input `..1` is `clay >= 30`.
```

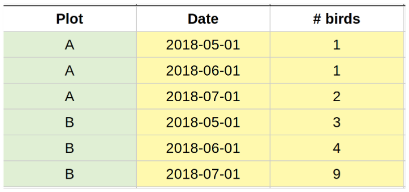
- Lines are sequential
- First `select()` removes column `clay`
- Then `filter()` cannot find `clay`

Joining/Merging

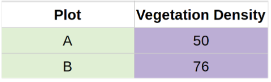
Joining data sets

Two data sets

- Measurements
- Metadata



Plot	Date	# birds
A	2018-05-01	1
A	2018-06-01	1
A	2018-07-01	2
B	2018-05-01	3
B	2018-06-01	4
B	2018-07-01	9



Plot	Vegetation Density
A	50
B	76

Joining data sets

Two data sets

- Measurements
- Metadata

Plot	Date	# birds
A	2018-05-01	1
A	2018-06-01	1
A	2018-07-01	2
B	2018-05-01	3
B	2018-06-01	4
B	2018-07-01	9

Plot	Vegetation Density
A	50
B	76

Joining them together

- Duplicate metadata to line up with measurements

Plot	Date	# birds	Vegetation Density
A	2018-05-01	1	50
A	2018-06-01	1	50
A	2018-07-01	2	50
B	2018-05-01	3	76
B	2018-06-01	4	76
B	2018-07-01	9	76

Joining data sets

Index or Metadata

```
meta <- read_csv("./data/grain_meta.csv")
head(meta)
```

```
## # A tibble: 6 x 4
##   plot  habitat   technician date
##   <chr> <chr>     <chr>      <date>
## 1 CSP01 forest    Catharine  2009-02-17
## 2 CSP02 clearcut  Catharine  2008-07-13
## 3 CSP03 forest    Jason      2008-09-29
## 4 CSP04 forest    Catharine  2008-07-01
## 5 CSP05 grassland Catharine  2009-04-23
## 6 CSP06 grassland Jason      2008-12-28
```

Measurements

```
size <- read_csv("./data/grain_size2.csv")
head(size)
```

```
## # A tibble: 6 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>
## 1 CSP01     4        13.0        17.4      19.7        14.1
## 2 CSP01    12        10.7        16.9      19.2        14.1
## 3 CSP01    35        12.1        17.8      16.1        10.3
## 4 CSP01    53        17.6        18.2      14.3         9.4
## 5 CSP01    83        21.0        18.4      14.3         9.79
## 6 CSP01   105        19.0        18.4      14.4        10.8
## # … with 3 more variables: medium_silt <dbl>, fine_silt <dbl>,
## #   clay <dbl>
```

Joining data sets

Index or Metadata

```
meta <- read_csv("./data/grain_meta.csv")
head(meta)
```

```
## # A tibble: 6 x 4
##   plot  habitat   technician date
##   <chr> <chr>     <chr>      <date>
## 1 CSP01 forest    Catharine  2009-02-17
## 2 CSP02 clearcut  Catharine  2008-07-13
## 3 CSP03 forest    Jason      2008-09-29
## 4 CSP04 forest    Catharine  2008-07-01
## 5 CSP05 grassland Catharine  2009-04-23
## 6 CSP06 grassland Jason      2008-12-28
```

Measurements

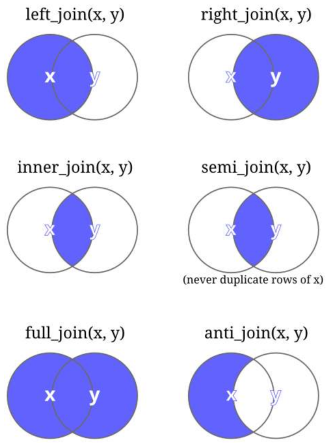
```
size <- read_csv("./data/grain_size2.csv")
head(size)
```

```
## # A tibble: 6 x 9
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>
## 1 CSP01     4        13.0        17.4      19.7        14.1
## 2 CSP01    12        10.7        16.9      19.2        14.1
## 3 CSP01    35        12.1        17.8      16.1        10.3
## 4 CSP01    53        17.6        18.2      14.3         9.4
## 5 CSP01    83        21.0        18.4      14.3         9.79
## 6 CSP01   105        19.0        18.4      14.4        10.8
## # … with 3 more variables: medium_silt <dbl>, fine_silt <dbl>,
## #   clay <dbl>
```

Types of Join: Which rows to keep?

`left_join(x, y)`

- Keep all rows in **x**
- Keep rows in **y** only if they're also in **x**



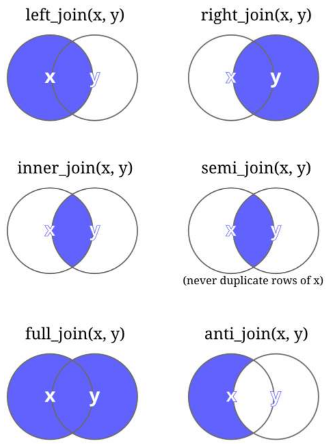
Types of Join: Which rows to keep?

`left_join(x, y)`

- Keep all rows in **x**
- Keep rows in **y** only if they're also in **x**

`right_join(x, y)`

- Keep all rows in **y**
- Keep rows in **x** only if they're also in **y**



Types of Join: Which rows to keep?

`left_join(x, y)`

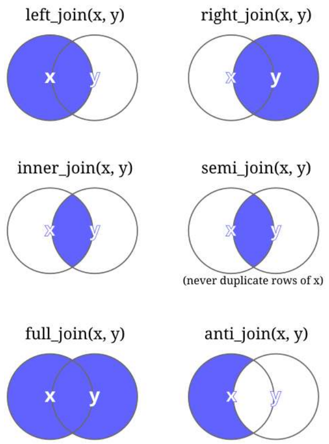
- Keep all rows in **x**
- Keep rows in **y** only if they're also in **x**

`right_join(x, y)`

- Keep all rows in **y**
- Keep rows in **x** only if they're also in **y**

`inner_join(x, y)`

- Keep **only** rows that exist in **both** data frames



Types of Join: Which rows to keep?

`left_join(x, y)`

- Keep all rows in **x**
- Keep rows in **y** only if they're also in **x**

`right_join(x, y)`

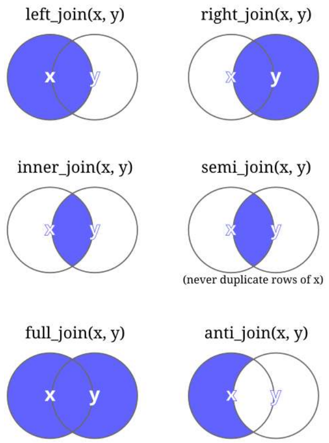
- Keep all rows in **y**
- Keep rows in **x** only if they're also in **y**

`inner_join(x, y)`

- Keep **only** rows that exist in **both** data frames

`full_join(x, y)`

- Keep **all** rows that exist in **either** **x** *or* **y**



Jared Cross, https://rpubs.com/jcross

Joining data sets

`left_join()` **(`tidyverse` function, specifically from `dplyr` package)**

(applies to other joins as well)

```
left_join(x = data, y = data_to_join, by = c("column1", "column2"), ...)
```

- **`tidyverse`** functions always start with **data**
- Here, also reference second **`data_to_join`**
- **by** refers **columns** in **data** and **`data_to_join`** used to join

Joining data sets

Keep all measurements, only keep meta if we have a measurement

```
size <- left_join(x = size, y = meta, by = "plot")
```

Joining data sets

Keep all measurements, only keep meta if we have a measurement

```
size <- left_join(x = size, y = meta, by = "plot")
```

OR

```
size <- right_join(x = meta, y = size, by = "plot")
```

Joining data sets

Keep all measurements, only keep meta if we have a measurement

```
size <- left_join(x = size, y = meta, by = "plot")
```

OR

```
size <- right_join(x = meta, y = size, by = "plot")
```

```
## # A tibble: 6 x 12
##   plot  habitat technician date       depth coarse_sand medium_sand fine_sand coarse_silt medium_silt
##   <chr> <chr>   <chr>      <date>     <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>
## 1 CSP01 forest  Catharine  2009-02-17     4        13.0        17.4      19.7       14.1        11.2
## 2 CSP01 forest  Catharine  2009-02-17    12        10.7        16.9      19.2       14.1        11.7
## 3 CSP01 forest  Catharine  2009-02-17    35        12.1        17.8      16.1       10.3         9.51
## 4 CSP01 forest  Catharine  2009-02-17    53        17.6        18.2      14.3        9.4         9.1
## 5 CSP01 forest  Catharine  2009-02-17    83        21.0        18.4      14.3        9.79        8.79
## 6 CSP01 forest  Catharine  2009-02-17   105        19.0        18.4      14.4       10.8         9.4
## # … with 2 more variables: fine_silt <dbl>, clay <dbl>
```

> For more information see R for Data Science Chapter 13.4 Mutating joins

Creating columns with `mutate()`

Artwork by @allison_horst

Creating new columns

`mutate()` (`tidyverse` function, specifically from `dplyr` package)

```
mutate(data, column1 = expression1, column2 = expression2)
```

- **`tidyverse`** functions always start with **data**
- Create new or modify existing **columns** in the **data**
- **Columns** filled according to **expression**

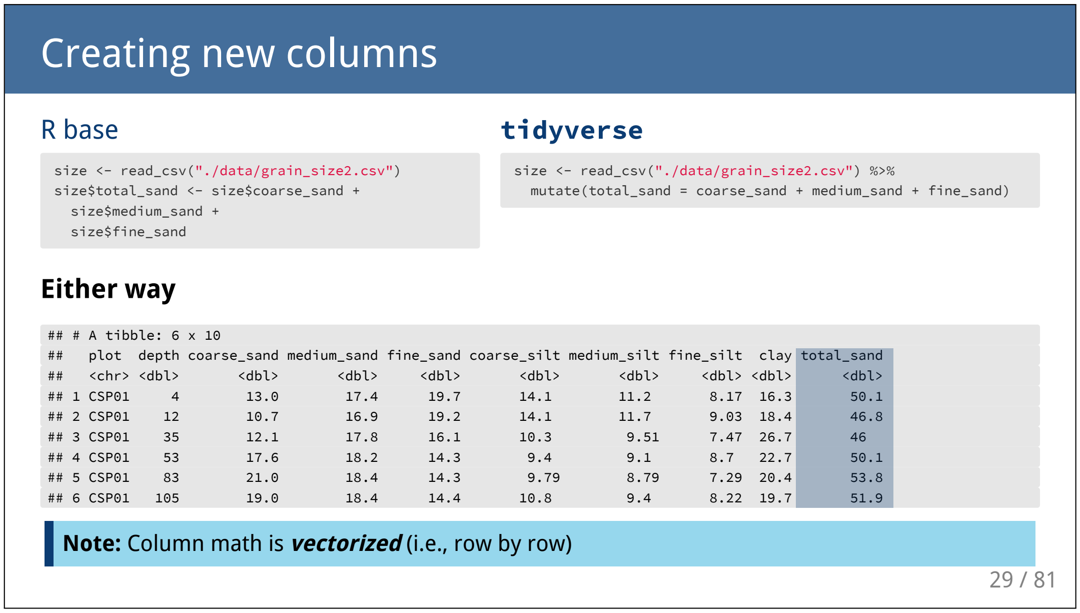
Creating new columns

R base

```
size <- read_csv("./data/grain_size2.csv")
size$total_sand <- size$coarse_sand +
  size$medium_sand +
  size$fine_sand
```

tidyverse

```
size <- read_csv("./data/grain_size2.csv") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand)
```



Creating new columns

R base

```
size <- read_csv("./data/grain_size2.csv")
size$total_sand <- size$coarse_sand +
  size$medium_sand +
  size$fine_sand
```

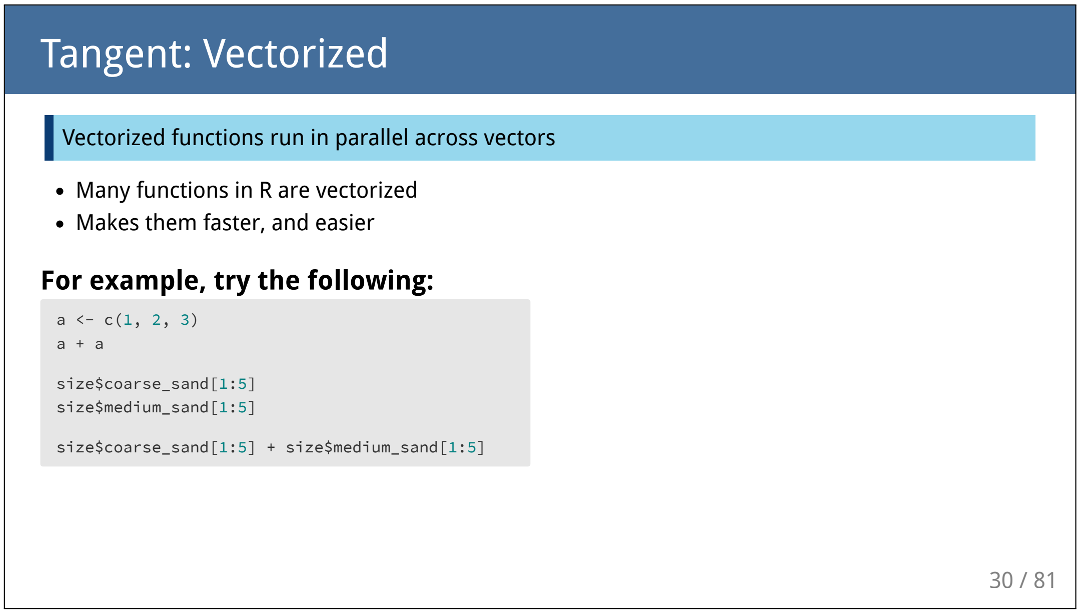
tidyverse

```
size <- read_csv("./data/grain_size2.csv") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand)
```

Either way

```
## # A tibble: 6 x 10
##   plot  depth coarse_sand medium_sand fine_sand coarse_silt medium_silt fine_silt  clay total_sand
##   <chr> <dbl>       <dbl>       <dbl>     <dbl>       <dbl>       <dbl>     <dbl> <dbl>      <dbl>
## 1 CSP01     4        13.0        17.4      19.7        14.1        11.2      8.17  16.3       50.1
## 2 CSP01    12        10.7        16.9      19.2        14.1        11.7      9.03  18.4       46.8
## 3 CSP01    35        12.1        17.8      16.1        10.3         9.51     7.47  26.7       46
## 4 CSP01    53        17.6        18.2      14.3         9.4         9.1      8.7   22.7       50.1
## 5 CSP01    83        21.0        18.4      14.3         9.79        8.79     7.29  20.4       53.8
## 6 CSP01   105        19.0        18.4      14.4        10.8         9.4      8.22  19.7       51.9
```

Note: Column math is ***vectorized*** (i.e., row by row)



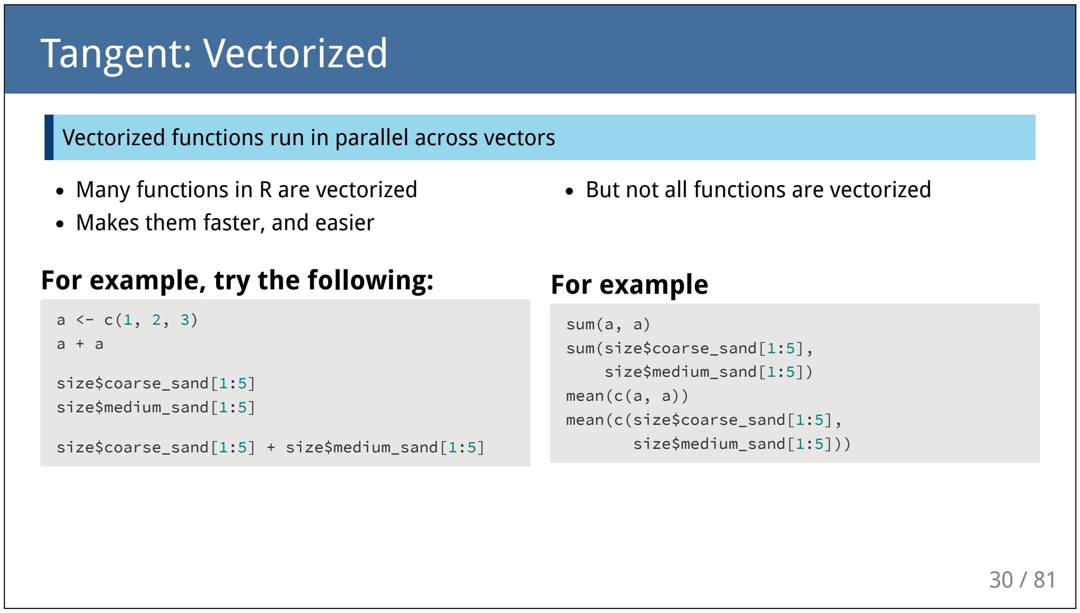
Tangent: Vectorized

Vectorized functions run in parallel across vectors

- Many functions in R are vectorized
- Makes them faster, and easier

For example, try the following:

```
a <- c(1, 2, 3)
a + a

size$coarse_sand[1:5]
size$medium_sand[1:5]

size$coarse_sand[1:5] + size$medium_sand[1:5]
```



Tangent: Vectorized

Vectorized functions run in parallel across vectors

- Many functions in R are vectorized
- Makes them faster, and easier

For example, try the following:

```
a <- c(1, 2, 3)
a + a

size$coarse_sand[1:5]
size$medium_sand[1:5]

size$coarse_sand[1:5] + size$medium_sand[1:5]
```

- But not all functions are vectorized

For example

```
sum(a, a)
sum(size$coarse_sand[1:5],
    size$medium_sand[1:5])
mean(c(a, a))
mean(c(size$coarse_sand[1:5],
       size$medium_sand[1:5]))
```

Your turn: Creating new columns

- Add a calculation for **total** **`silt`**
- Check your work

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         ???)
```

Extra Challenge
What happens if you add
`total_sand` and **`total_silt`**
together in the same **`mutate()`**
function?

Your turn: Creating new columns

- Add a calculation for **total** **`silt`**
- Check your work

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt)
```

Your turn: Creating new columns

- Add a calculation for **total** **`silt`**
- Check your work

```
select(size, contains("silt"))
```

```
## # A tibble: 114 x 4
##    coarse_silt medium_silt fine_silt total_silt
##          <dbl>       <dbl>     <dbl>      <dbl>
##  1        14.1        11.2      8.17       33.5
##  2        14.1        11.7      9.03       34.8
##  3        10.3         9.51     7.47       27.3
##  4         9.4         9.1      8.7        27.2
##  5         9.79        8.79     7.29       25.9
##  6        10.8         9.4      8.22       28.4
##  7        16.3         9.55     6.23       32.1
##  8        14.3        10.4      6.1        30.8
##  9        15.1        11.5      7.56       34.2
## 10        12.0        18.3     15.2        45.4
## # … with 104 more rows
```

Your turn: Creating new columns

- Add a calculation for **total `silt`**
- Check your work

```
select(size, contains("silt")) %>%
  as.data.frame()
```

```
##    coarse_silt medium_silt fine_silt total_silt
## 1        14.12       11.25      8.17      33.54
## 2        14.13       11.68      9.03      34.84
## 3        10.33        9.51      7.47      27.31
## 4         9.40        9.10      8.70      27.20
## 5         9.79        8.79      7.29      25.87
## 6        10.79        9.40      8.22      28.41
## 7        16.30        9.55      6.23      32.08
## 8        14.27       10.44      6.10      30.81
## 9        15.13       11.54      7.56      34.23
## 10       11.96       18.27     15.22      45.45
## 11       10.70       18.33     14.30      43.33
## 12       10.68       18.96     14.45      44.09
## 13       11.08       17.95     13.74      42.77
```

Your turn: Creating new columns (Extra Challenge)

What happens if you add `total_sand` and `total_silt` together in the same `mutate()`?

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt,
         total = total_sand + total_silt)
```

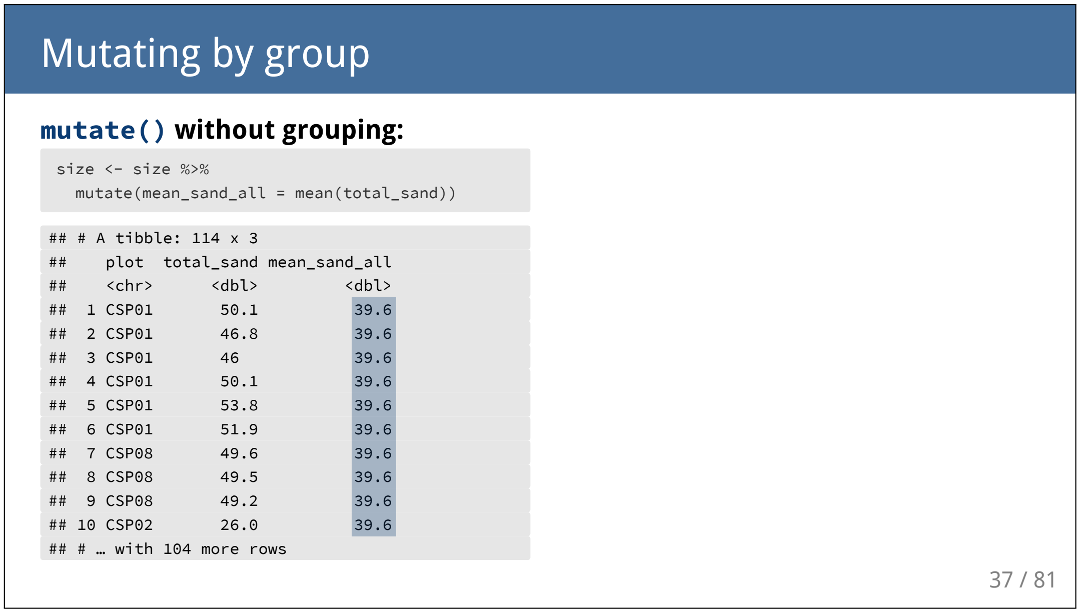
- You get the sum!
- Lines within `mutate()` run sequentially
- You can create `total_sand` and `total_silt` in the first two lines then use them in the 3rd
- But you could not create `total_sand` and `total_silt` *after* using them

Mutating by group

`group_by()` and `ungroup()` **(`tidyverse` functions, specifically from `dplyr` package)**

```
group_by(data, column1, column2)
ungroup(data)
```

- `tidyverse` functions always start with **data**
- `group_by()` applies grouping according to specified **data columns**
- `ungroup()` removes grouping

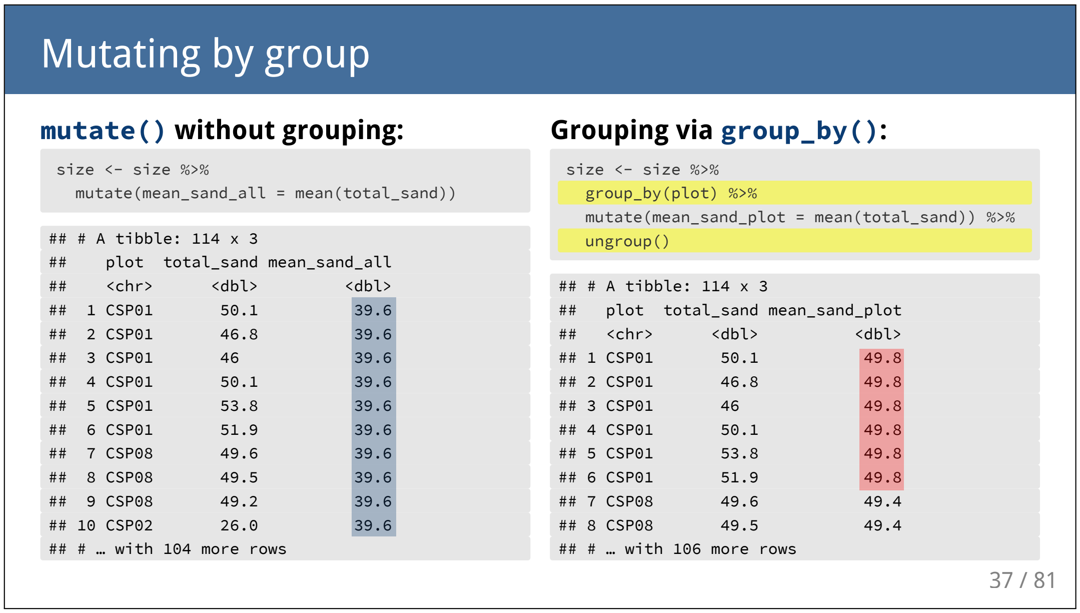


Mutating by group

`mutate()` without grouping:

```
size <- size %>%
  mutate(mean_sand_all = mean(total_sand))
```

```
## # A tibble: 114 x 3
##    plot  total_sand mean_sand_all
##    <chr>      <dbl>         <dbl>
##  1 CSP01       50.1          39.6
##  2 CSP01       46.8          39.6
##  3 CSP01       46            39.6
##  4 CSP01       50.1          39.6
##  5 CSP01       53.8          39.6
##  6 CSP01       51.9          39.6
##  7 CSP08       49.6          39.6
##  8 CSP08       49.5          39.6
##  9 CSP08       49.2          39.6
## 10 CSP02       26.0          39.6
## # … with 104 more rows
```



Mutating by group

`mutate()` without grouping:

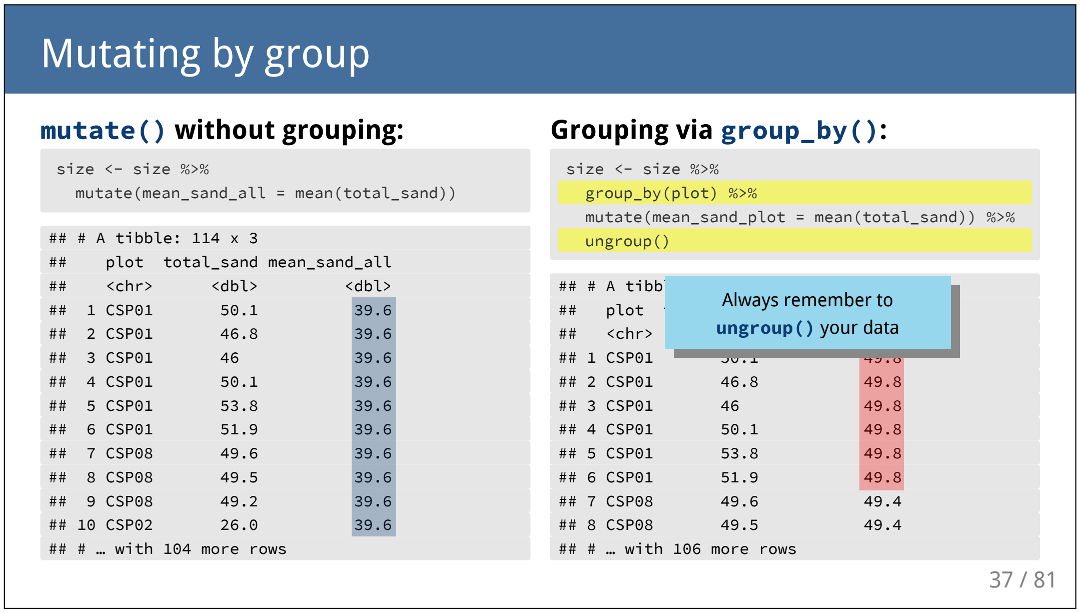
```
size <- size %>%
  mutate(mean_sand_all = mean(total_sand))
```

```
## # A tibble: 114 x 3
##    plot  total_sand mean_sand_all
##    <chr>      <dbl>         <dbl>
##  1 CSP01       50.1          39.6
##  2 CSP01       46.8          39.6
##  3 CSP01       46            39.6
##  4 CSP01       50.1          39.6
##  5 CSP01       53.8          39.6
##  6 CSP01       51.9          39.6
##  7 CSP08       49.6          39.6
##  8 CSP08       49.5          39.6
##  9 CSP08       49.2          39.6
## 10 CSP02       26.0          39.6
## # … with 104 more rows
```

Grouping via `group_by()`:

```
size <- size %>%
  group_by(plot) %>%
  mutate(mean_sand_plot = mean(total_sand)) %>%
  ungroup()
```

```
## # A tibble: 114 x 3
##   plot  total_sand mean_sand_plot
##   <chr>      <dbl>          <dbl>
## 1 CSP01       50.1           49.8
## 2 CSP01       46.8           49.8
## 3 CSP01       46             49.8
## 4 CSP01       50.1           49.8
## 5 CSP01       53.8           49.8
## 6 CSP01       51.9           49.8
## 7 CSP08       49.6           49.4
## 8 CSP08       49.5           49.4
## # … with 106 more rows
```



Mutating by group

`mutate()` without grouping:

```
size <- size %>%
  mutate(mean_sand_all = mean(total_sand))
```

```
## # A tibble: 114 x 3
##    plot  total_sand mean_sand_all
##    <chr>      <dbl>         <dbl>
##  1 CSP01       50.1          39.6
##  2 CSP01       46.8          39.6
##  3 CSP01       46            39.6
##  4 CSP01       50.1          39.6
##  5 CSP01       53.8          39.6
##  6 CSP01       51.9          39.6
##  7 CSP08       49.6          39.6
##  8 CSP08       49.5          39.6
##  9 CSP08       49.2          39.6
## 10 CSP02       26.0          39.6
## # … with 104 more rows
```

Grouping via `group_by()`:

```
size <- size %>%
  group_by(plot) %>%
  mutate(mean_sand_plot = mean(total_sand)) %>%
  ungroup()
```

```
## # A tibb
##   plot
##   <chr>
## 1 CSP01
## 2 CSP01       46.8           49.8
## 3 CSP01       46             49.8
## 4 CSP01       50.1           49.8
## 5 CSP01       53.8           49.8
## 6 CSP01       51.9           49.8
## 7 CSP08       49.6           49.4
## 8 CSP08       49.5           49.4
## # … with 106 more rows
```

Always remember to `ungroup()` your data

Artwork by @allison_horst

Your turn: Mutating by group

Add a column containing the **mean amount of total silt *per* plot**

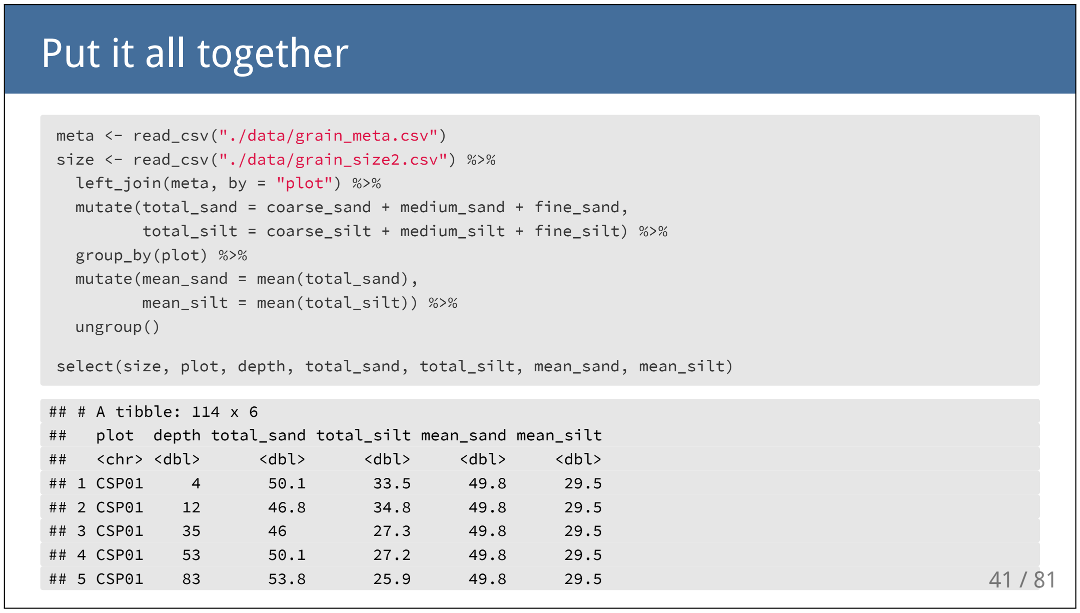
```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt) %>%
  ??? %>%
  ??? %>%
  ???
```

Your turn: Mutating by group

Add a column containing the **mean amount of total silt *per* plot**

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt) %>%
  group_by(plot) %>%
  mutate(mean_silt = mean(total_silt)) %>%
  ungroup()
```

```
## # A tibble: 114 x 6
##   plot  coarse_silt medium_silt fine_silt total_silt mean_silt
##   <chr>       <dbl>       <dbl>     <dbl>      <dbl>     <dbl>
## 1 CSP01        14.1       11.2       8.17       33.5      29.5
## 2 CSP01        14.1       11.7       9.03       34.8      29.5
## 3 CSP01        10.3        9.51      7.47       27.3      29.5
## 4 CSP01         9.4        9.1       8.7        27.2      29.5
## # … with 110 more rows
```

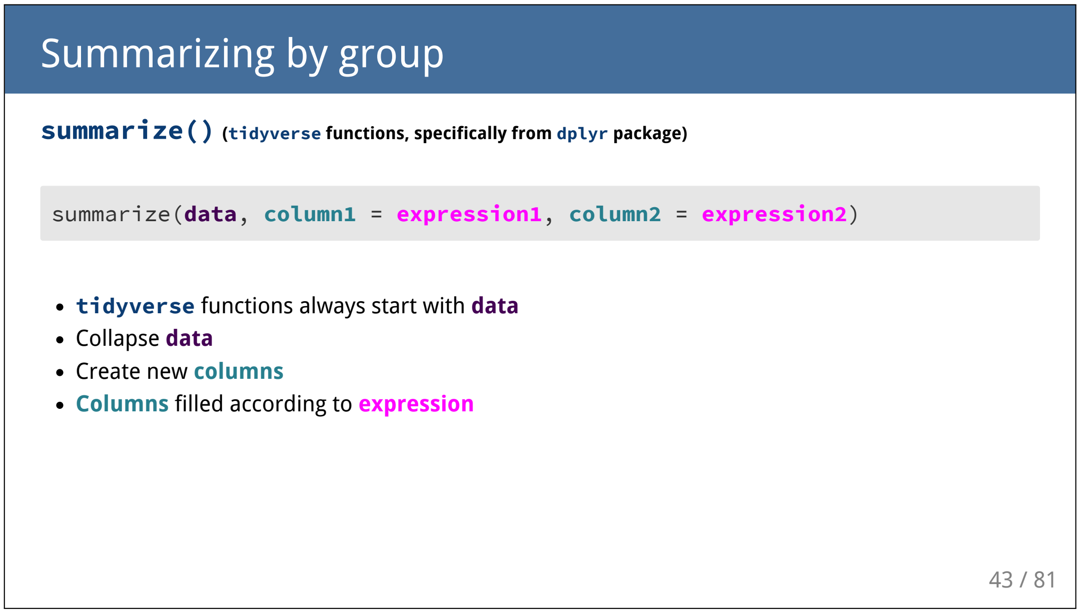


Put it all together

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt) %>%
  group_by(plot) %>%
  mutate(mean_sand = mean(total_sand),
         mean_silt = mean(total_silt)) %>%
  ungroup()

select(size, plot, depth, total_sand, total_silt, mean_sand, mean_silt)
```

```
## # A tibble: 114 x 6
##    plot  depth total_sand total_silt mean_sand mean_silt
##    <chr> <dbl>      <dbl>      <dbl>     <dbl>     <dbl>
## 1 CSP01      4       50.1       33.5      49.8      29.5
## 2 CSP01     12       46.8       34.8      49.8      29.5
## 3 CSP01     35       46         27.3      49.8      29.5
## 4 CSP01     53       50.1       27.2      49.8      29.5
## 5 CSP01     83       53.8       25.9      49.8      29.5
```

Summarizing

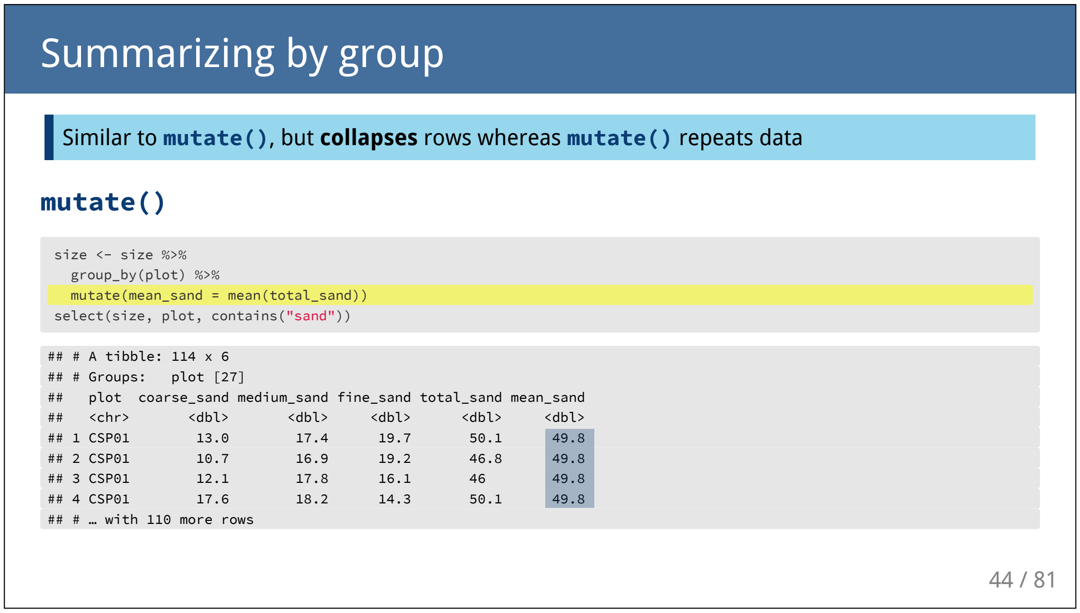


Summarizing by group

`summarize()` **(`tidyverse` functions, specifically from `dplyr` package)**

```
summarize(data, column1 = expression1, column2 = expression2)
```

- **`tidyverse`** functions always start with **data**
- Collapse **data**
- Create new **columns**
- **Columns** filled according to **expression**



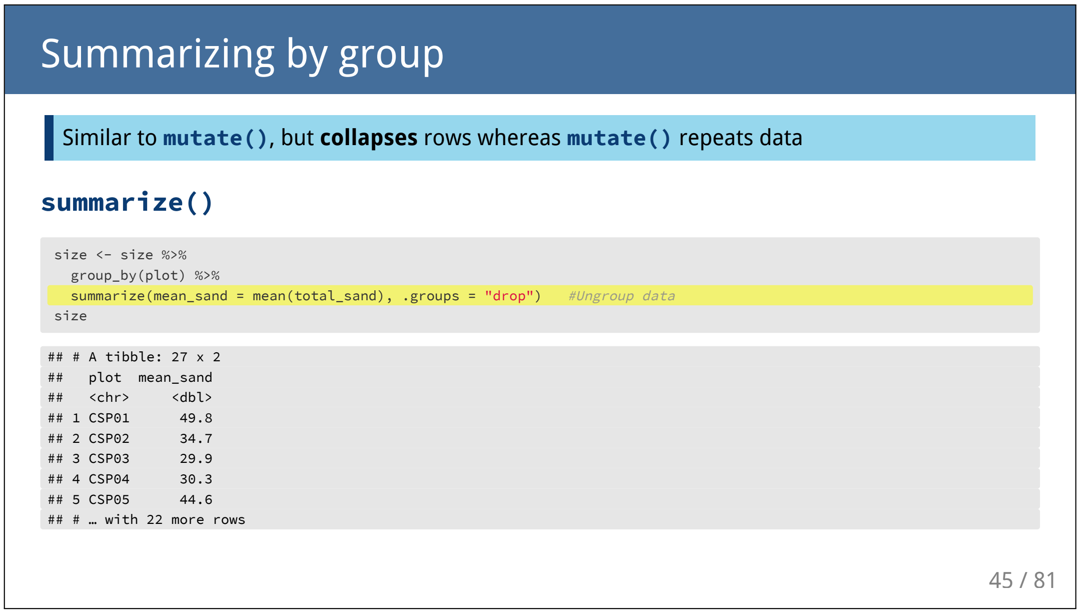
Summarizing by group

> Similar to **`mutate()`**, but **collapses** rows whereas **`mutate()`** repeats data

`mutate()`

```
size <- size %>%
  group_by(plot) %>%
  mutate(mean_sand = mean(total_sand))
select(size, plot, contains("sand"))
```

```
## # A tibble: 114 x 6
## # Groups:   plot [27]
##   plot  coarse_sand medium_sand fine_sand total_sand mean_sand
##   <chr>       <dbl>       <dbl>     <dbl>      <dbl>     <dbl>
## 1 CSP01        13.0        17.4      19.7       50.1      49.8
## 2 CSP01        10.7        16.9      19.2       46.8      49.8
## 3 CSP01        12.1        17.8      16.1       46        49.8
## 4 CSP01        17.6        18.2      14.3       50.1      49.8
## # … with 110 more rows
```



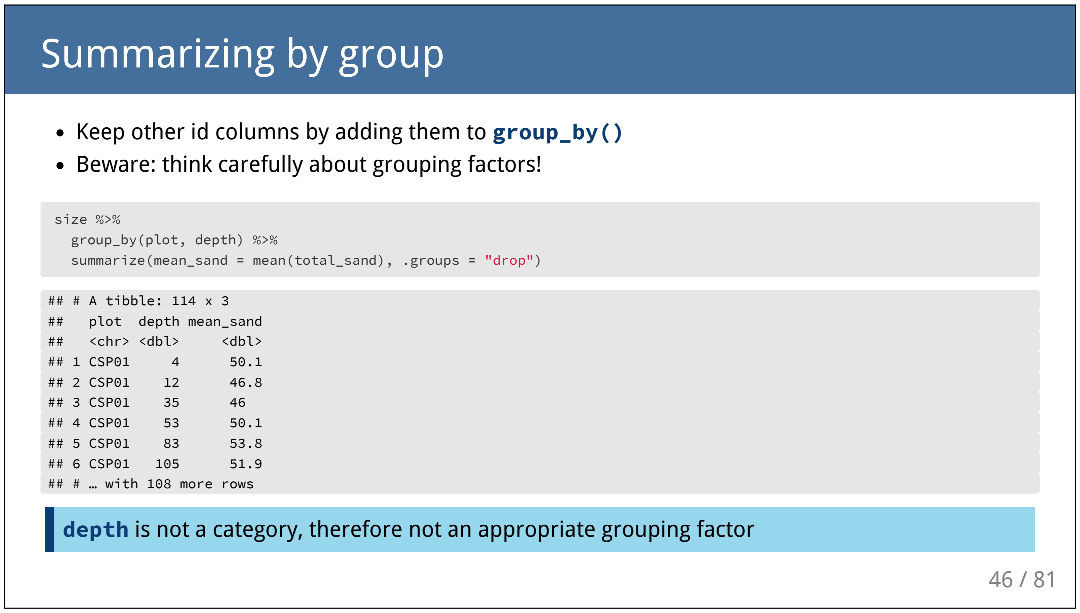
Summarizing by group

> Similar to **`mutate()`**, but **collapses** rows whereas **`mutate()`** repeats data

`summarize()`

```
size <- size %>%
  group_by(plot) %>%
  summarize(mean_sand = mean(total_sand), .groups = "drop")   #Ungroup data
size
```

```
## # A tibble: 27 x 2
##   plot  mean_sand
##   <chr>     <dbl>
## 1 CSP01      49.8
## 2 CSP02      34.7
## 3 CSP03      29.9
## 4 CSP04      30.3
## 5 CSP05      44.6
## # … with 22 more rows
```



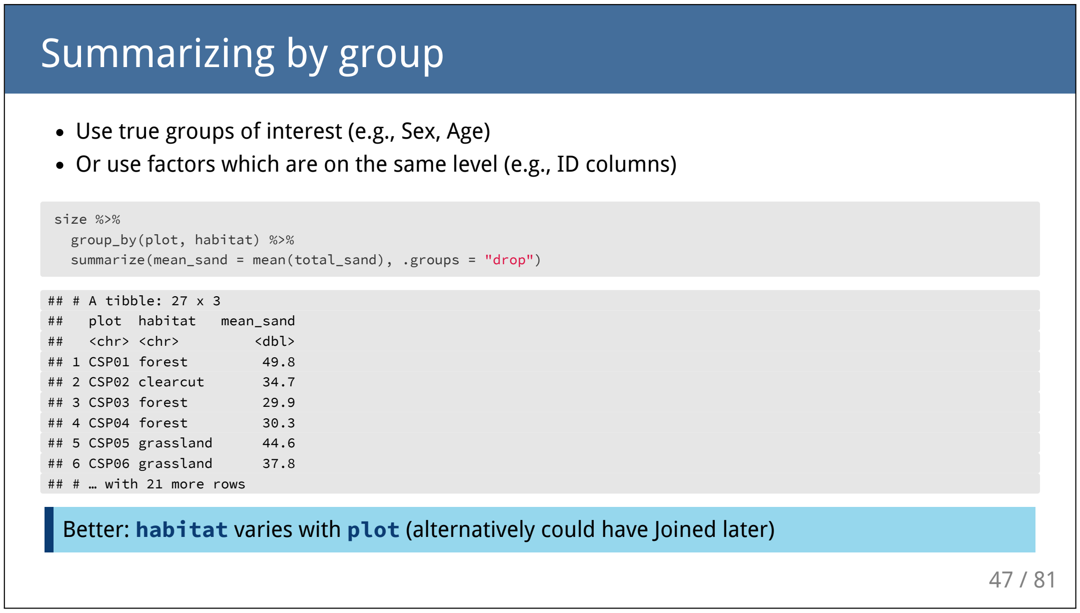
Summarizing by group

- Keep other id columns by adding them to **`group_by()`**
- Beware: think carefully about grouping factors!

```
size %>%
  group_by(plot, depth) %>%
  summarize(mean_sand = mean(total_sand), .groups = "drop")
```

```
## # A tibble: 114 x 3
##   plot  depth mean_sand
##   <chr> <dbl>     <dbl>
## 1 CSP01     4      50.1
## 2 CSP01    12      46.8
## 3 CSP01    35      46
## 4 CSP01    53      50.1
## 5 CSP01    83      53.8
## 6 CSP01   105      51.9
## # … with 108 more rows
```

> **`depth`** is not a category, therefore not an appropriate grouping factor



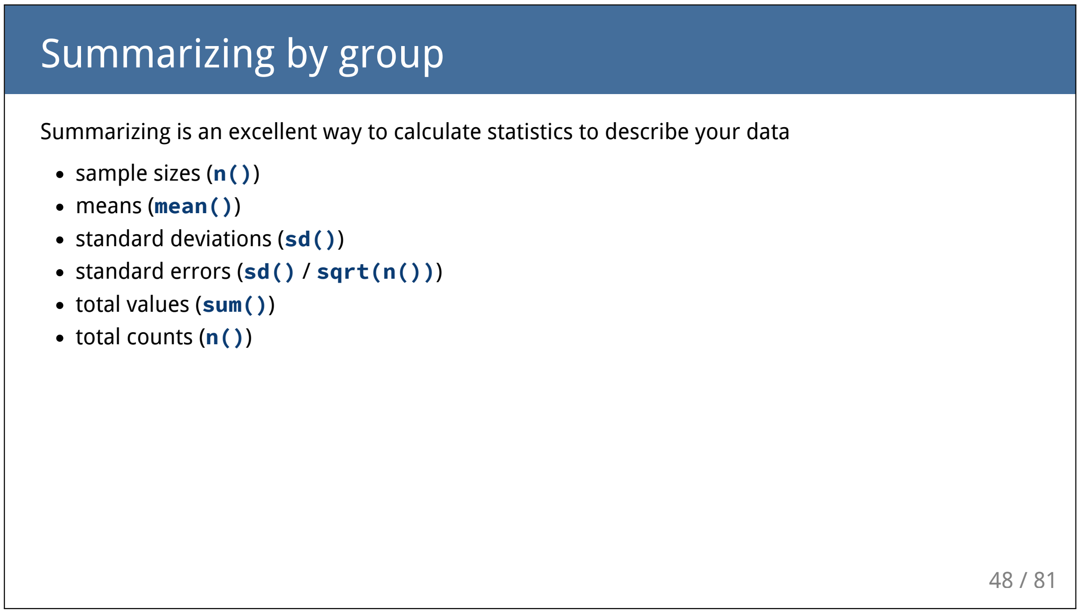
Summarizing by group

- Use true groups of interest (e.g., Sex, Age)
- Or use factors which are on the same level (e.g., ID columns)

```
size %>%
  group_by(plot, habitat) %>%
  summarize(mean_sand = mean(total_sand), .groups = "drop")
```

```
## # A tibble: 27 x 3
##    plot  habitat   mean_sand
##    <chr> <chr>         <dbl>
## 1 CSP01 forest         49.8
## 2 CSP02 clearcut       34.7
## 3 CSP03 forest         29.9
## 4 CSP04 forest         30.3
## 5 CSP05 grassland      44.6
## 6 CSP06 grassland      37.8
## # … with 21 more rows
```

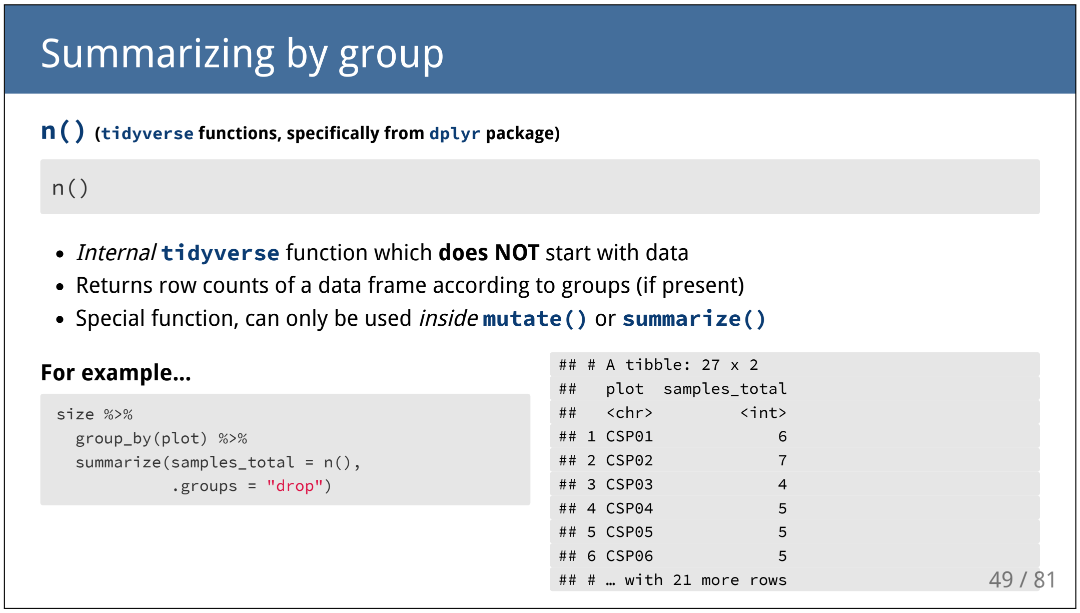
> Better: **`habitat`** varies with **`plot`** (alternatively could have Joined later)



Summarizing by group

Summarizing is an excellent way to calculate statistics to describe your data

- sample sizes (**`n()`**)
- means (**`mean()`**)
- standard deviations (**`sd()`**)
- standard errors (**`sd()`** / **`sqrt(n())`**)
- total values (**`sum()`**)
- total counts (**`n()`**)



Summarizing by group

`n()` **(`tidyverse` functions, specifically from `dplyr` package)**

```
n()
```

- *Internal* **`tidyverse`** function which **does NOT** start with data
- Returns row counts of a data frame according to groups (if present)
- Special function, can only be used *inside* **`mutate()`** or **`summarize()`**

For example...

```
size %>%
  group_by(plot) %>%
  summarize(samples_total = n(),
            .groups = "drop")
```

```
## # A tibble: 27 x 2
##   plot  samples_total
##   <chr>         <int>
## 1 CSP01             6
## 2 CSP02             7
## 3 CSP03             4
## 4 CSP04             5
## 5 CSP05             5
## 6 CSP06             5
## # … with 21 more rows
```

Your Turn: Calculate summary statistics

For each plot and habitat, calculate

- sample sizes with `n()`
- means (`mean()`) for **total_sand** and **total_silt**
- standard deviations (`sd()`) for **total_sand** and **total_silt**
- standard errors (`sd()/sqrt(n())`) for **total_sand** and **total_silt**

Extra Challenge
Calculate summary statistics for your own data

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt)

size_sum <- size %>%
  group_by(plot, habitat) %>%
  ???
```

Your Turn: Calculate summary statistics

For each plot and habitat, calculate

- sample sizes with `n()`
- means (`mean()`) for **total_sand** and **total_silt**
- standard deviations (`sd()`) for **total_sand** and **total_silt**
- standard errors (`sd()/sqrt(n())`) for **total_sand** and **total_silt**

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt)

size_sum <- size %>%
  group_by(plot, habitat) %>%
  summarize(sample_size = n(),
            mean_sand = mean(total_sand),
            sd_sand = sd(total_sand),
            se_sand = sd_sand / sqrt(sample_size),
            mean_silt = mean(total_silt),
            sd_silt = sd(total_silt),
            se_silt = sd_silt / sqrt(sample_size))
```

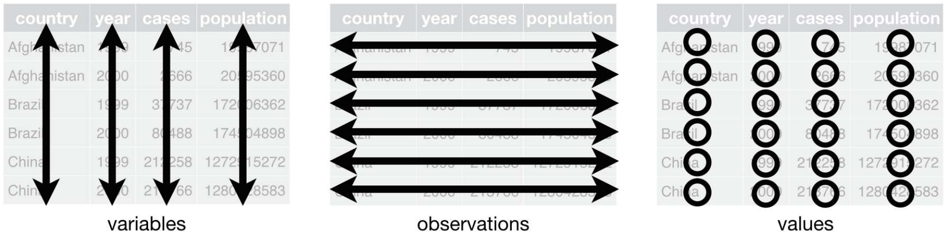
Your Turn: Calculate summary statistics

```
size_sum
```

```
## # A tibble: 27 x 9
## # Groups:   plot [27]
##    plot  habitat   sample_size mean_sand sd_sand se_sand mean_silt sd_silt se_silt
##    <chr> <chr>           <int>     <dbl>   <dbl>   <dbl>     <dbl>   <dbl>   <dbl>
##  1 CSP01 forest              6      49.8   2.96    1.21       29.5   3.72    1.52
##  2 CSP02 clearcut            7      34.7  10.8     4.06       40.9   4.29    1.62
##  3 CSP03 forest              4      29.9   4.89    2.45       43.6   3.25    1.63
##  4 CSP04 forest              5      30.3   2.18    0.973      43.0   0.544   0.243
##  5 CSP05 grassland           5      44.6   5.52    2.47       31.8   1.81    0.811
##  6 CSP06 grassland           5      37.8   4.10    1.83       48.1   3.32    1.49
##  7 CSP07 clearcut            3      36.6   7.30    4.21       39.8   1.05    0.609
##  8 CSP08 grassland           3      49.4   0.176   0.102      32.4   1.73    0.998
##  9 CSP09 grassland           5      37.9   2.98    1.33       38.4   1.17    0.524
## 10 CSP10 grassland           3      34.6   9.71    5.61       44.1   5.41    3.13
## # … with 17 more rows
```

Transposing

Tidy Data



R for Data Science

Tidy Data

Not Tidy

country	**1999**	**2000**
Afghanistan	745	2666
Brazil	37737	80488
China	212258	213766

(wide data)

Tidy Data

Not Tidy

country	1999	2000
Afghanistan	745	2666
Brazil	37737	80488
China	212258	213766

(wide data)

Tidy

country	year	cases
Afghanistan	1999	745
Afghanistan	2000	2666
Brazil	1999	37737
Brazil	2000	80488
China	1999	212258
China	2000	213766

(long data)

Why do we care?

How would you plot the untidy data?

(No. of cases by country for each year)

```
ggplot(data = table4a, aes(x = ???, y = ???)) +
  ???
```

Note

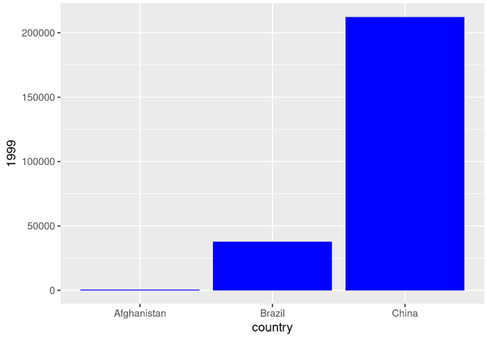
- **table4a** is a built-in data frame
- Type **table4a** in the console to take a look
- Type **?table4a** to pull up the help file with information

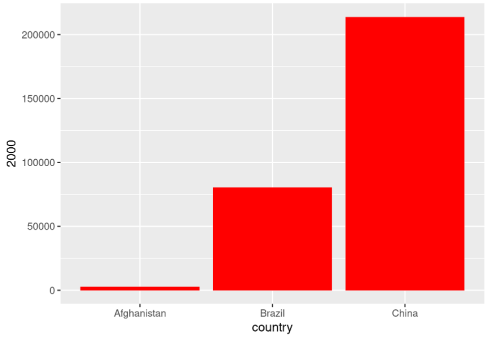
Why do we care?

With un-tidy data

```
ggplot(data = table4a, aes(x = country, y = `1999`)) +
  geom_bar(stat = "identity", fill = "blue")
```

```
ggplot(data = table4a, aes(x = country, y = `2000`)) +
  geom_bar(stat = "identity", fill = "red")
```

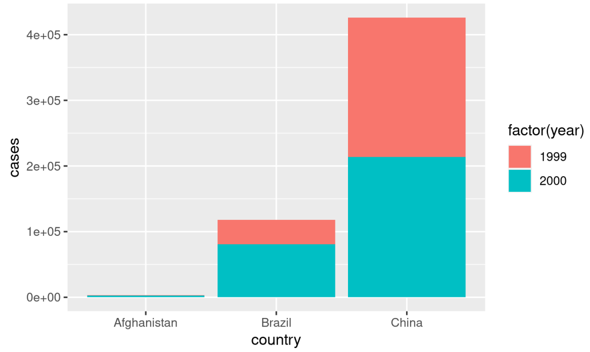




Why do we care?

With tidy data

```
ggplot(data = table1, aes(x = country, y = cases, fill = factor(year))) +
  geom_bar(stat = "identity")
```



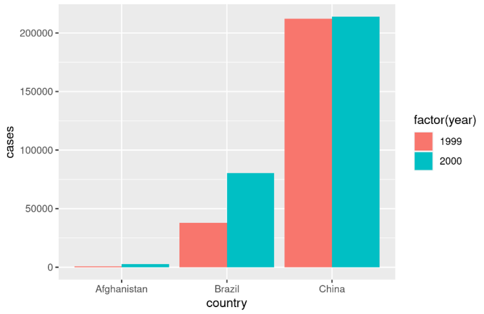
Why do we care?

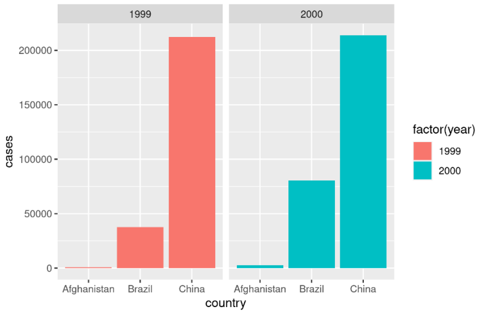
With tidy data

```
g <- ggplot(data = table1, aes(x = country, y = cases, fill = factor(year)))
```

```
g + geom_bar(stat = "identity", position = "dodge")
```

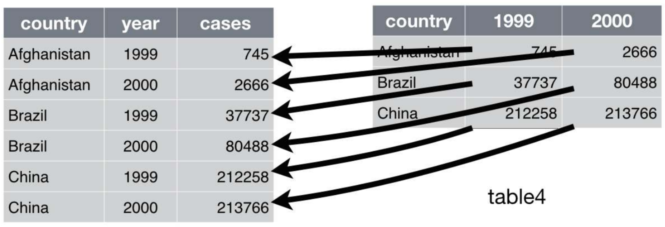
```
g + geom_bar(stat = "identity") + facet_wrap(~year)
```





Going long

`pivot_longer()`



country	year	cases
Afghanistan	1999	745
Afghanistan	2000	2666
Brazil	1999	37737
Brazil	2000	80488
China	1999	212258
China	2000	213766

country	1999	2000
Afghanistan	745	2666
Brazil	37737	80488
China	212258	213766

table4

R for Data Science

Going long

Wide

```
## # A tibble: 15 x 6
##    plot  depth coarse_silt medium_silt fine_silt total_silt
##    <chr> <dbl>       <dbl>       <dbl>     <dbl>      <dbl>
##  1 CSP01     4       14.1        11.2       8.17       33.5
##  2 CSP01    12       14.1        11.7       9.03       34.8
##  3 CSP01    35       10.3         9.51      7.47       27.3
##  4 CSP01    53        9.4         9.1       8.7        27.2
##  5 CSP01    83        9.79        8.79      7.29       25.9
##  6 CSP01   105       10.8         9.4       8.22       28.4
##  7 CSP08    10       16.3         9.55      6.23       32.1
##  8 CSP08    27       14.3        10.4       6.1        30.8
##  9 CSP08    90       15.1        11.5       7.56       34.2
## 10 CSP02     5       12.0        18.3      15.2        45.4
## 11 CSP02    11       10.7        18.3      14.3        43.3
## 12 CSP02    36       10.7        19.0      14.4        44.1
## 13 CSP02    56       11.1        18.0      13.7        42.8
## 14 CSP02    70       11.2        16.8      13.0        41
## 15 CSP02    78        9.97       13.8      11.0        34.7
```

Going long

Wide

```
## # A tibble: 15 x 6
##    plot  depth coarse_silt medium_silt fine_silt total_silt
##    <chr> <dbl>       <dbl>       <dbl>     <dbl>      <dbl>
##  1 CSP01     4       14.1        11.2       8.17       33.5
##  2 CSP01    12       14.1        11.7       9.03       34.8
##  3 CSP01    35       10.3         9.51      7.47       27.3
##  4 CSP01    53        9.4         9.1       8.7        27.2
##  5 CSP01    83        9.79        8.79      7.29       25.9
##  6 CSP01   105       10.8         9.4       8.22       28.4
##  7 CSP08    10       16.3         9.55      6.23       32.1
##  8 CSP08    27       14.3        10.4       6.1        30.8
##  9 CSP08    90       15.1        11.5       7.56       34.2
## 10 CSP02     5       12.0        18.3      15.2        45.4
## 11 CSP02    11       10.7        18.3      14.3        43.3
## 12 CSP02    36       10.7        19.0      14.4        44.1
## 13 CSP02    56       11.1        18.0      13.7        42.8
## 14 CSP02    70       11.2        16.8      13.0        41
## 15 CSP02    78        9.97       13.8      11.0        34.7
```

Long

```
## # A tibble: 15 x 4
##    plot  depth type        amount
##    <chr> <dbl> <chr>        <dbl>
##  1 CSP01     4 coarse_silt  14.1
##  2 CSP01     4 medium_silt  11.2
##  3 CSP01     4 fine_silt     8.17
##  4 CSP01     4 total_silt   33.5
##  5 CSP01    12 coarse_silt  14.1
##  6 CSP01    12 medium_silt  11.7
##  7 CSP01    12 fine_silt     9.03
##  8 CSP01    12 total_silt   34.8
##  9 CSP01    35 coarse_silt  10.3
## 10 CSP01    35 medium_silt   9.51
## 11 CSP01    35 fine_silt     7.47
## 12 CSP01    35 total_silt   27.3
## 13 CSP01    53 coarse_silt   9.4
## 14 CSP01    53 medium_silt   9.1
## 15 CSP01    53 fine_silt     8.7
```

Going long

`pivot_longer()` **(`tidyverse` function, specifically from `tidyr` package)**

```
pivot_longer(data, cols = c(column1, column2),
             names_to = "categorical_column",
             values_to = "numerical_column")
```

- **`tidyverse`** functions always start with **data**
- Takes columns and converts to long **data**
- Column names ('**column1**' and '**column2**') go into **"categorical_column"**
- Column values (*values* of **column1** and **column2**) go into **"numerical_column"**

Going long

pivot_longer() (**tidyverse** **function, specifically from** **tidyr** **package)**

```
pivot_longer(data, cols = c(column1, column2),
             names_to = "categorical_column",
             values_to = "numerical_column")
```

In our example:

- **data** = **size**
- **cols** = **c(-plot, -depth, -habitat, -technician, -date)**
    - Here, easiest to exclude columns
- **names_to** = **"type"**
- **values_to** = **"amount"**

Going long

```
size_long <- pivot_longer(size, cols = c(-plot, -depth, -habitat, -technician, -date),
                          names_to = "type", values_to = "amount")
```

```
## # A tibble: 1,026 x 7
##    plot  depth habitat technician date       type        amount
##    <chr> <dbl> <chr>   <chr>      <date>     <chr>        <dbl>
##  1 CSP01     4 forest  Catharine  2009-02-17 coarse_sand  13.0 
##  2 CSP01     4 forest  Catharine  2009-02-17 medium_sand  17.4 
##  3 CSP01     4 forest  Catharine  2009-02-17 fine_sand    19.7 
##  4 CSP01     4 forest  Catharine  2009-02-17 coarse_silt  14.1 
##  5 CSP01     4 forest  Catharine  2009-02-17 medium_silt  11.2 
##  6 CSP01     4 forest  Catharine  2009-02-17 fine_silt     8.17
##  7 CSP01     4 forest  Catharine  2009-02-17 clay         16.3 
##  8 CSP01     4 forest  Catharine  2009-02-17 total_sand   50.1 
##  9 CSP01     4 forest  Catharine  2009-02-17 total_silt   33.5 
## 10 CSP01    12 forest  Catharine  2009-02-17 coarse_sand  10.7 
## 11 CSP01    12 forest  Catharine  2009-02-17 medium_sand  16.9 
## 12 CSP01    12 forest  Catharine  2009-02-17 fine_sand    19.2 
## # … with 1,014 more rows
```

Your turn: Lengthen data

- Practice transforming a summarized sand data
- Gather all variables except plot and sample_size into a long format

```
sand_sum <- read_csv("./data/grain_size2.csv") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand) %>%
  group_by(plot) %>%
  summarize(sample_size = n(),
            mean_sand = mean(total_sand),
            sd_sand = sd(total_sand),
            se_sand = sd_sand / sqrt(sample_size))

sand_long <- pivot_longer(sand_sum, ???)
```

Your turn: Lengthen data

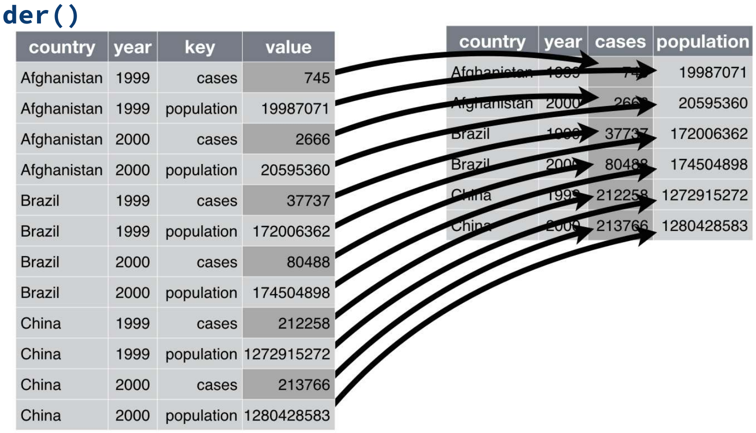
- Practice transforming a summarized sand data
- Gather all variables except plot and sample_size into a long format

```
sand_sum <- read_csv("./data/grain_size2.csv") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand) %>%
  group_by(plot) %>%
  summarize(sample_size = n(),
            mean_sand = mean(total_sand),
            sd_sand = sd(total_sand),
            se_sand = sd_sand / sqrt(sample_size))

sand_long <- pivot_longer(sand_sum, cols = contains("sand"),
                          names_to = "type",
                          values_to = "amount")
```

```
## # A tibble: 81 x 4
##   plot  sample_size type      amount
##   <chr>       <int> <chr>      <dbl>
## 1 CSP01           6 mean_sand  49.8
## 2 CSP01           6 sd_sand     2.96
## 3 CSP01           6 se_sand     1.21
## 4 CSP02           7 mean_sand  34.7
```

Going wide

`pivot_wider()`



country	year	key	value
Afghanistan	1999	cases	745
Afghanistan	1999	population	19987071
Afghanistan	2000	cases	2666
Afghanistan	2000	population	20595360
Brazil	1999	cases	37737
Brazil	1999	population	172006362
Brazil	2000	cases	80488
Brazil	2000	population	174504898
China	1999	cases	212258
China	1999	population	1272915272
China	2000	cases	213766
China	2000	population	1280428583

country	year	cases	population
Afghanistan	1999	745	19987071
Afghanistan	2000	2666	20595360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	213766	1280428583

table2

R for Data Science

Going wide

Long

```
## # A tibble: 15 x 4
##    plot  depth type          amount
##    <chr> <dbl> <chr>          <dbl>
##  1 CSP01     4 coarse_silt  14.1
##  2 CSP01     4 medium_silt  11.2
##  3 CSP01     4 fine_silt     8.17
##  4 CSP01     4 total_silt   33.5
##  5 CSP01    12 coarse_silt  14.1
##  6 CSP01    12 medium_silt  11.7
##  7 CSP01    12 fine_silt     9.03
##  8 CSP01    12 total_silt   34.8
##  9 CSP01    35 coarse_silt  10.3
## 10 CSP01    35 medium_silt   9.51
## 11 CSP01    35 fine_silt     7.47
## 12 CSP01    35 total_silt   27.3
## 13 CSP01    53 coarse_silt   9.4
## 14 CSP01    53 medium_silt   9.1
## 15 CSP01    53 fine_silt     8.7
```

Going wide

Long

```
## # A tibble: 15 x 4
##    plot  depth type        amount
##    <chr> <dbl> <chr>        <dbl>
##  1 CSP01     4 coarse_silt  14.1
##  2 CSP01     4 medium_silt  11.2
##  3 CSP01     4 fine_silt     8.17
##  4 CSP01     4 total_silt   33.5
##  5 CSP01    12 coarse_silt  14.1
##  6 CSP01    12 medium_silt  11.7
##  7 CSP01    12 fine_silt     9.03
##  8 CSP01    12 total_silt   34.8
##  9 CSP01    35 coarse_silt  10.3
## 10 CSP01    35 medium_silt   9.51
## 11 CSP01    35 fine_silt     7.47
## 12 CSP01    35 total_silt   27.3
## 13 CSP01    53 coarse_silt   9.4
## 14 CSP01    53 medium_silt   9.1
## 15 CSP01    53 fine_silt     8.7
```

Wide

```
## # A tibble: 15 x 6
##    plot  depth coarse_silt medium_silt fine_silt total_silt
##    <chr> <dbl>       <dbl>       <dbl>     <dbl>      <dbl>
##  1 CSP01     4       14.1        11.2       8.17       33.5
##  2 CSP01    12       14.1        11.7       9.03       34.8
##  3 CSP01    35       10.3         9.51      7.47       27.3
##  4 CSP01    53        9.4         9.1       8.7        27.2
##  5 CSP01    83        9.79        8.79      7.29       25.9
##  6 CSP01   105       10.8         9.4       8.22       28.4
##  7 CSP08    10       16.3         9.55      6.23       32.1
##  8 CSP08    27       14.3        10.4       6.1        30.8
##  9 CSP08    90       15.1        11.5       7.56       34.2
## 10 CSP02     5       12.0        18.3      15.2        45.4
## 11 CSP02    11       10.7        18.3      14.3        43.3
## 12 CSP02    36       10.7        19.0      14.4        44.1
## 13 CSP02    56       11.1        18.0      13.7        42.8
## 14 CSP02    70       11.2        16.8      13.0        41
## 15 CSP02    78        9.97       13.8      11.0        34.7
```

Going wide

`pivot_wider()` (**`tidyverse` function, specifically from `tidyr` package**)

```
pivot_wider(data,
            names_from = categorical_column,
            values_from = numerical_column)
```

- **`tidyverse`** functions always start with **data**
- Takes columns and converts to wide **data**
- Values in **categorical_column** become column names
- Values in **numerical_column** become column values

Going wide

`pivot_wider()` (**`tidyverse` function, specifically from `tidyr` package**)

```
pivot_wider(data,
            names_from = categorical_column,
            values_from = numerical_column)
```

In our example:

- **data** = **`size`**
- **names_from** = **`type`**
- **values_from** = **`amount`**

Going wide

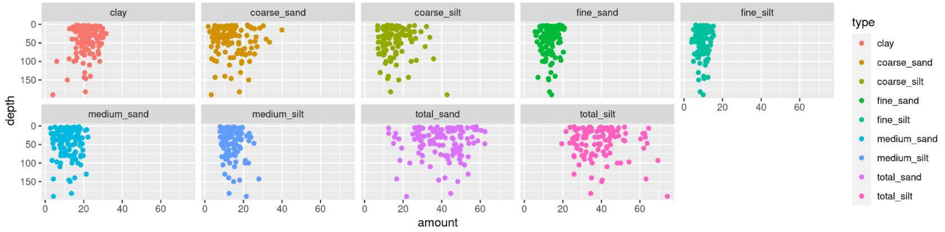
```
size_wide <- size_long %>%
  pivot_wider(names_from = type, values_from = amount)
```

```
## # A tibble: 114 x 14
##    plot  depth habitat technician date       coarse_sand medium_sand fine_sand coarse_silt medium_silt
##    <chr> <dbl> <chr>   <chr>      <date>           <dbl>       <dbl>     <dbl>       <dbl>       <dbl>
##  1 CSP01     4 forest  Catharine  2009-02-17       13.0        17.4      19.7        14.1        11.2
##  2 CSP01    12 forest  Catharine  2009-02-17       10.7        16.9      19.2        14.1        11.7
##  3 CSP01    35 forest  Catharine  2009-02-17       12.1        17.8      16.1        10.3         9.51
##  4 CSP01    53 forest  Catharine  2009-02-17       17.6        18.2      14.3         9.4         9.1
##  5 CSP01    83 forest  Catharine  2009-02-17       21.0        18.4      14.3         9.79        8.79
##  6 CSP01   105 forest  Catharine  2009-02-17       19.0        18.4      14.4        10.8         9.4
##  7 CSP08    10 grassl… Catharine  2009-02-05       11.6        17.1      20.8        16.3         9.55
##  8 CSP08    27 grassl… Catharine  2009-02-05       15.4        16.2      17.8        14.3        10.4
##  9 CSP08    90 grassl… Catharine  2009-02-05       14.9        15.8      18.6        15.1        11.5
## 10 CSP02     5 clearc… Catharine  2008-07-13        8.75        8.64      8.66       12.0        18.3
## # … with 104 more rows, and 4 more variables: fine_silt <dbl>, clay <dbl>, total_sand <dbl>, total_silt <dbl>
```

Again: Why transpose?

Figures: Long data are great for graphing

```
size_long <- pivot_longer(size, cols = c(-plot, -depth, -technician, -habitat, -date),
                          names_to = "type", values_to = "amount")

ggplot(data = size_long, aes(y = depth, x = amount, colour = type)) +
  geom_point() +
  scale_y_reverse() +
  facet_wrap(~ type, nrow = 2)
```



Again: Why transpose?

Figures: Take it to the next step

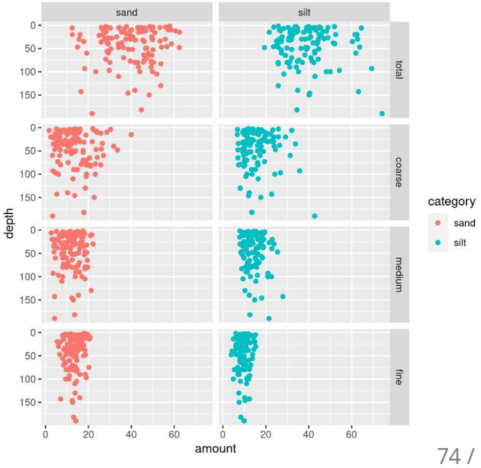
```
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt)

size_long <- pivot_longer(size, cols = c(-plot, -depth, -technician, -habitat, -date, -clay),
                          names_to = c("size", "category"), values_to = "amount",
                          names_sep = "_") %>%
  mutate(size = factor(size, levels = c("total", "coarse", "medium", "fine")))
```

```
## # A tibble: 912 x 9
##   plot  depth  clay habitat technician date       size   category amount
##   <chr> <dbl> <dbl> <chr>   <chr>      <date>     <fct>  <chr>     <dbl>
## 1 CSP01     4  16.3 forest  Catharine  2009-02-17 coarse sand      13.0
## 2 CSP01     4  16.3 forest  Catharine  2009-02-17 medium sand      17.4
## 3 CSP01     4  16.3 forest  Catharine  2009-02-17 fine   sand      19.7
## 4 CSP01     4  16.3 forest  Catharine  2009-02-17 coarse silt      14.1
## 5 CSP01     4  16.3 forest  Catharine  2009-02-17 medium silt      11.2
## 6 CSP01     4  16.3 forest  Catharine  2009-02-17 fine   silt       8.17
## # … with 906 more rows
```

Again: Why transpose?

Figures

```
ggplot(data = size_long,
       aes(y = depth, x = amount, colour = category)) +
  geom_point() +
  scale_y_reverse() +
  facet_grid(size ~ category)
```



Again: Why transpose?

Analyses

Linear models `lm(y ~ x, data)`

Use **`pivot_longer()`** in analysis where grouping variables are important

- i.e., do amounts of different size classes differ with depth? (need size classes in "type" column)

```
lm(amount ~ type + depth, data = size_long)
```

Use **`pivot_wider()`** in analyses where each variable must be in it's own column

- i.e., does the amount of sand differ with depth? (need size classes in separate columns)

```
lm(total_sand ~ depth, data = size_wide)
```

Again: Why transpose?

Analyses

Linear models `lm(y ~ x, data)`

Use **`pivot_longer()`** in analysis where grouping variables are important

- i.e., do amounts of different size classes differ with depth? (need size classes in "type" column)

```
lm(amount ~ type + depth, data = size_long)
```

Use **`pivot_wider()`** in analyses where each variable must be in it's own column

- i.e., does the amount of sand differ with depth? (need size classes in separate columns)

```
lm(total_sand ~ depth, data = size_wide)
```

> If you can't figure out how to plot or analyse your data, they probably need to be transposed

Your Turn: Transpose for plotting

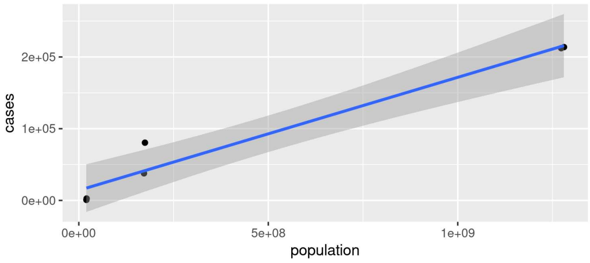
Plot the number of Tuberculosis cases (`cases`) vs. the `population` in data frame `table2`

```
temp <- table2 %>%
  ???(???)

ggplot(data = temp, ???) +
  ???
```

Your Turn: Transpose for plotting

Plot the number of Tuberculosis cases (`cases`) vs. the `population` in data frame `table2`

```
temp <- table2 %>%
  pivot_wider(names_from = "type", values_from = "count")

ggplot(data = temp, aes(x = population, y = cases)) +
  geom_point() +
  stat_smooth(method = "lm")
```



Put it all together

```
meta <- read_csv("./data/grain_meta.csv")
size <- read_csv("./data/grain_size2.csv") %>%
  left_join(meta, by = "plot") %>%
  mutate(total_sand = coarse_sand + medium_sand + fine_sand,
         total_silt = coarse_silt + medium_silt + fine_silt)

size_sum <- size %>%
  group_by(plot, habitat) %>%
  summarize(sample_size = n(),
            total_sand = sum(total_sand),
            mean_sand = mean(total_sand),
            sd_sand = sd(total_sand),
            se_sand = sd_sand / sqrt(sample_size),
            total_silt = sum(total_silt),
            mean_silt = mean(total_silt),
            sd_silt = sd(total_silt),
            se_silt = sd_silt / sqrt(sample_size))

size_long <- size %>%
  pivot_longer(cols = c(-plot, -depth, -technician, -habitat, -date, -clay),
               values_to = "amount", names_to = c("size", "category"), names_sep = "_") %>%
  mutate(size = factor(size, levels = c("total", "coarse", "medium", "fine")))
```

Put it all together: Save your data

```
write_csv(size, "./Datasets/size_total.csv")
write_csv(size_sum, "./Datasets/size_summary.csv")
write_csv(size_long, "./Datasets/size_long.csv")
```

Keep yourself organized

- Keep your R-created data in a different folder from your 'raw' data
- If you have a lot going on, split your work into several scripts, and number the data sets produced:
    - 1_cleaned.csv
    - 2_summarized.csv
    - 3_graphing.csv

Wrapping up: Common mistakes

- `select()` doesn't work
    - You may have the `MASS` package loaded, it also has a select
    - make sure you loaded `tidyverse` or `dplyr` packages
    - try using `dplyr::select()`
- I can't figure out how to `pivot_wider()` my data in the way I want it
    - Sometimes you need to `pivot_longer()` your data before you can widen it
- `mutate()` is giving me weird results
    - Is your data grouped when it shouldn't be?
    - Try using `ungroup()` first
- I get a warning when I join data sets
    - Often, this refers to mismatched factor levels
    - This happens if the factor levels in one data frame do not match the factor levels in the other
    - They will be transformed to character
    - If that's a problem, use `as.factor()` to turn them back

Wrapping up: Further reading

- R for Data Science
    - Chapter 5: Transforming data
    - Chapter 12: Tidy data
    - Chapter 13: Relational data
- RStudio Data Manipulation with **`dplyr`**, tidyr
    - Or Help > Cheatsheets > Data Manipulation with dplyr, tidyr