COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

GR5206: lecture 5

Computational Statistics
And Introduction to Data Science

Thibault Vatter

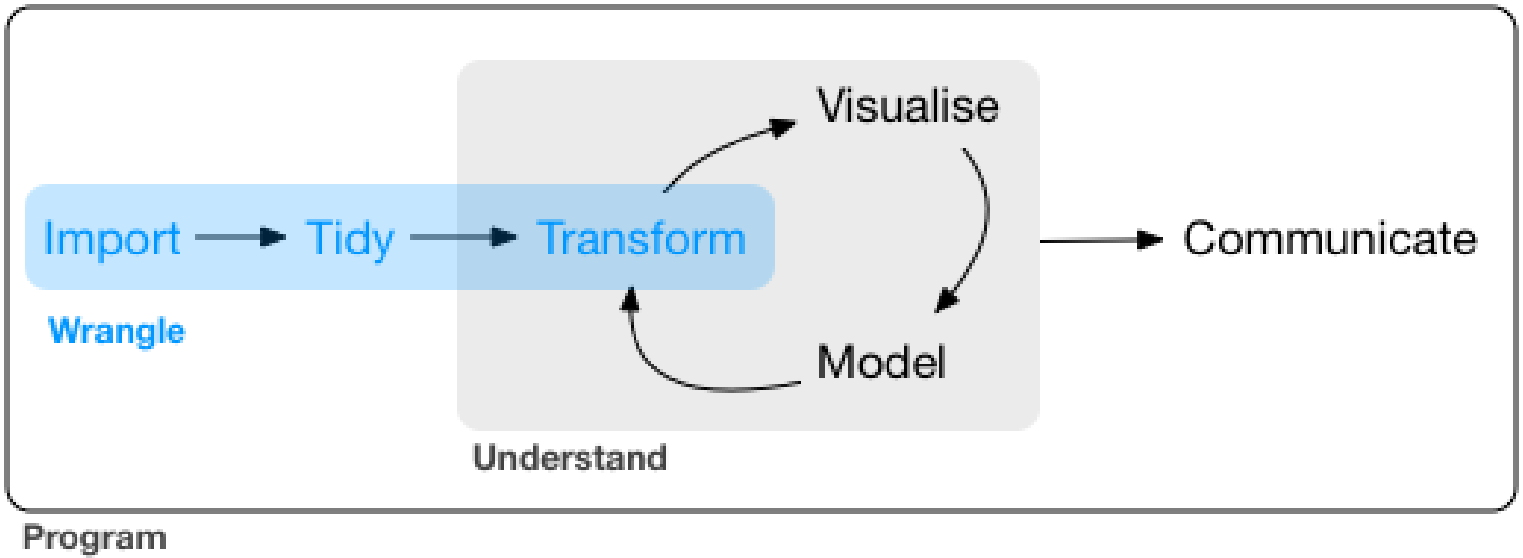
Department of Statistics, Columbia University

10/04/2019

Outline

Outline

Today



Most of the material (e.g., the picture above) is borrowed from

R for data science

Data manipulation with `dplyr`

- When working with data you must:
  - Figure out what you want to do.
  - Describe those tasks in the form of a computer program.
  - Execute the program.
- The `dplyr` package makes these steps fast and easy:
  - By constraining your options, it helps you think about your data manipulation challenges.
  - It provides simple "verbs", functions that correspond to the most common data manipulation tasks, to help you translate your thoughts into code.
  - It uses efficient backends, so you spend less time waiting for the computer.

A grammar of data manipulation

- 5 verbs to solve common data manipulation challenges:
  - `filter()` to select observations based on their values.
  - `arrange()` to reorder the observations.
  - `select()` to select variables based on their names.
  - `mutate()` to add variables as functions of existing variables.
  - `summarize()` to collapse many values down to a single summary.
- Two important features:
  - Verbs can be used with `group_by()` to operate groupwise.
  - Verbs work similarly:
    1. First argument is a data frame.
    2. Other arguments describe what to do with it using variable names.
    3. Result is a new data frame.

nycflights13

All 336,776 flights that departed from NYC in 2013 (US BTS):

```
nycflights13::flights
#> # A tibble: 336,776 x 19
#>     year month   day dep_time sched_dep_time dep_delay arr_time
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     1      517            515         2      830
#>  2  2013     1     1      533            529         4      850
#>  3  2013     1     1      542            540         2      923
#>  4  2013     1     1      544            545        -1     1004
#>  5  2013     1     1      554            600        -6      812
#>  6  2013     1     1      554            558        -4      740
#>  7  2013     1     1      555            600        -5      913
#>  8  2013     1     1      557            600        -3      709
#>  9  2013     1     1      557            600        -3      838
#> 10  2013     1     1      558            600        -2      753
#> # ... with 336,766 more rows, and 12 more variables:
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#> #   time_hour <dttm>
```

Outline

Filter rows with `filter()`

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
filter(flights, month == 1, day == 1)
#> # A tibble: 842 x 19
#>     year month   day dep_time sched_dep_time dep_delay arr_time
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     1      517            515         2      830
#>  2  2013     1     1      533            529         4      850
#>  3  2013     1     1      542            540         2      923
#>  4  2013     1     1      544            545        -1     1004
#>  5  2013     1     1      554            600        -6      812
#>  6  2013     1     1      554            558        -4      740
#>  7  2013     1     1      555            600        -5      913
#>  8  2013     1     1      557            600        -3      709
#>  9  2013     1     1      557            600        -3      838
#> 10  2013     1     1      558            600        -2      753
#> # ... with 832 more rows, and 12 more variables:
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#> #   time_hour <dttm>
```

Comparisons

- The standard suite: >, >=, <, <=, !=, and ==.
- Most common mistake:

```
filter(flights, month = 1)
```

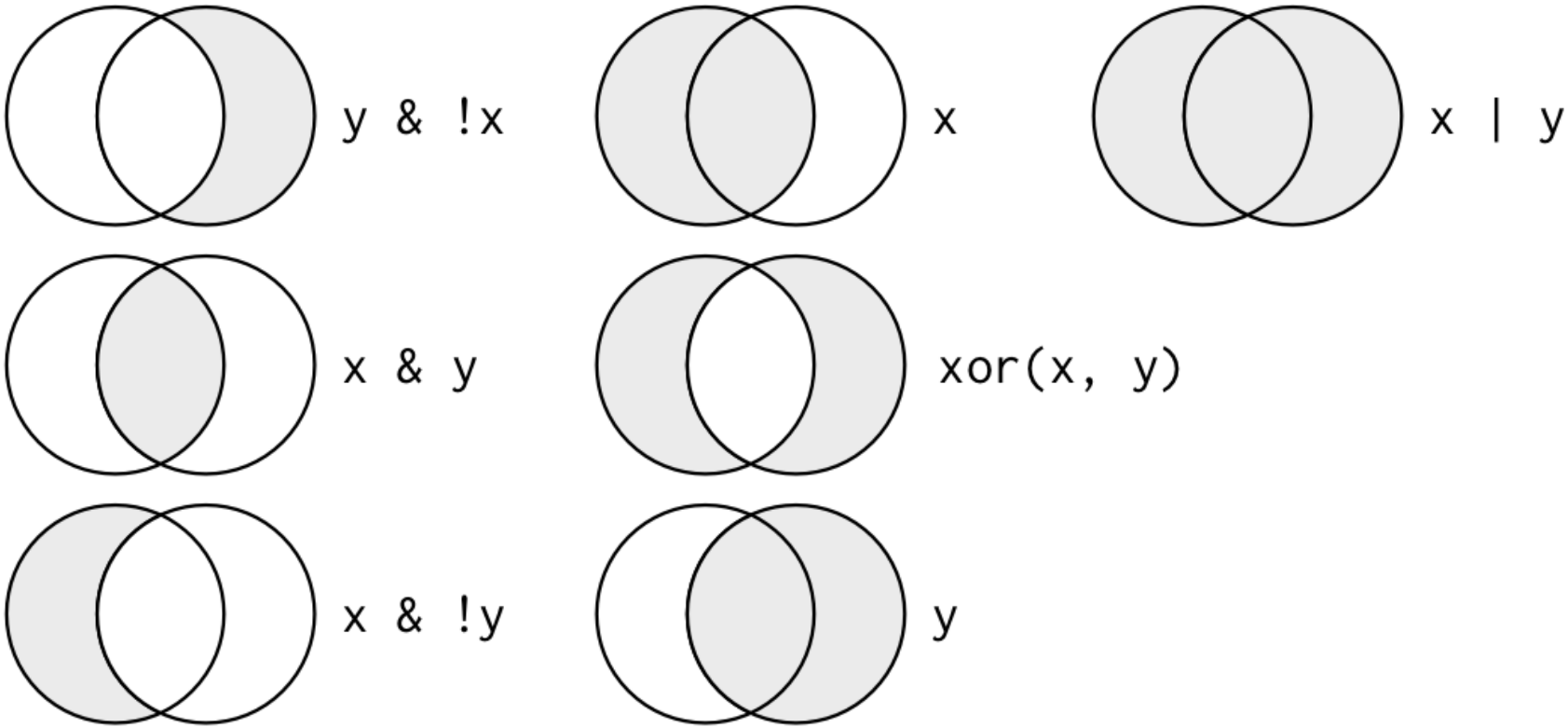
- What happens in the following?

```
sqrt(2) ^ 2 == 2
#> [1] FALSE
1/49 * 49 == 1
#> [1] FALSE
near(sqrt(2) ^ 2,  2)
#> [1] TRUE
near(1 / 49 * 49, 1)
#> [1] TRUE
```

Logical operators

Multiple arguments to `filter()` are combined with:

- `&` for "and"
- `|` for "or"
- `!` for "not"



What is this code doing?


```
filter(flights, month == 11 | month == 12)
```

What is this code doing?


```
filter(flights, month == 11 | month == 12)
```

- Literally "finds all flights that departed in November or December".
- `... filter(flights, month == 11 | 12)` ?

What is this code doing?


```
filter(flights, month == 11 | month == 12)
```

- Literally "finds all flights that departed in November or December".
- `... filter(flights, month == 11 | 12)` ?
- No, but a solution:

```
filter(flights, month %in% c(11, 12))
```

De Morgan's law

- `!(x & y)` is the same as `!x | !y`
- `!(x | y)` is the same as `!x & !y`

```
all.equal(
  filter(flights, !(arr_delay > 120 | dep_delay > 120)),
  filter(flights, arr_delay <= 120, dep_delay <= 120)
  )
#> [1] TRUE
```

Missing values and `filter()`


```
df <- tibble(x = c(1, NA, 3))
filter(df, x > 1)
#> # A tibble: 1 x 1
#>       x
#>   <dbl>
#> 1     3
filter(df, is.na(x) | x > 1)
#> # A tibble: 2 x 1
#>       x
#>   <dbl>
#> 1    NA
#> 2     3
```

Outline

Arrange rows with arrange()

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
arrange(flights, year, month, day)
#> # A tibble: 336,776 x 19
#>     year month   day dep_time sched_dep_time dep_delay arr_time
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     1      517            515         2      830
#>  2  2013     1     1      533            529         4      850
#>  3  2013     1     1      542            540         2      923
#>  4  2013     1     1      544            545        -1     1004
#>  5  2013     1     1      554            600        -6      812
#>  6  2013     1     1      554            558        -4      740
#>  7  2013     1     1      555            600        -5      913
#>  8  2013     1     1      557            600        -3      709
#>  9  2013     1     1      557            600        -3      838
#> 10  2013     1     1      558            600        -2      753
#> # ... with 336,766 more rows, and 12 more variables:
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#> #   time_hour <dttm>
```

arrange() and desc()

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
arrange(flights, desc(arr_delay))
#> # A tibble: 336,776 x 19
#>     year month   day dep_time sched_dep_time dep_delay arr_time
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     9      641            900      1301     1242
#>  2  2013     6    15     1432           1935      1137     1607
#>  3  2013     1    10     1121           1635      1126     1239
#>  4  2013     9    20     1139           1845      1014     1457
#>  5  2013     7    22      845           1600      1005     1044
#>  6  2013     4    10     1100           1900       960     1342
#>  7  2013     3    17     2321            810       911      135
#>  8  2013     7    22     2257            759       898      121
#>  9  2013    12     5      756           1700       896     1058
#> 10  2013     5     3     1133           2055       878     1250
#> # ... with 336,766 more rows, and 12 more variables:
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#> #   time_hour <dttm>
```

arrange() and missing values

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
df <- tibble(x = c(5, NA, 2))
arrange(df, x)
#> # A tibble: 3 x 1
#>       x
#>   <dbl>
#> 1     2
#> 2     5
#> 3    NA
arrange(df, desc(x))
#> # A tibble: 3 x 1
#>       x
#>   <dbl>
#> 1     5
#> 2     2
#> 3    NA
```

Outline

Select columns with `select()`

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
select(flights, year, month, day)
#> # A tibble: 336,776 x 3
#>     year month   day
#>    <int> <int> <int>
#>  1  2013     1     1
#>  2  2013     1     1
#>  3  2013     1     1
#>  4  2013     1     1
#>  5  2013     1     1
#>  6  2013     1     1
#>  7  2013     1     1
#>  8  2013     1     1
#>  9  2013     1     1
#> 10  2013     1     1
#> # ... with 336,766 more rows
```

All columns between year and day

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
select(flights, year:day)
#> # A tibble: 336,776 x 3
#>     year month   day
#>    <int> <int> <int>
#>  1  2013     1     1
#>  2  2013     1     1
#>  3  2013     1     1
#>  4  2013     1     1
#>  5  2013     1     1
#>  6  2013     1     1
#>  7  2013     1     1
#>  8  2013     1     1
#>  9  2013     1     1
#> 10  2013     1     1
#> # ... with 336,766 more rows
```

All columns except from year to day


```
select(flights, -(year:day))
#> # A tibble: 336,776 x 16
#>    dep_time sched_dep_time dep_delay arr_time sched_arr_time
#>       <int>          <int>     <dbl>    <int>          <int>
#>  1      517            515         2      830            819
#>  2      533            529         4      850            830
#>  3      542            540         2      923            850
#>  4      544            545        -1     1004           1022
#>  5      554            600        -6      812            837
#>  6      554            558        -4      740            728
#>  7      555            600        -5      913            854
#>  8      557            600        -3      709            723
#>  9      557            600        -3      838            846
#> 10      558            600        -2      753            745
#> # ... with 336,766 more rows, and 11 more variables:
#> #   arr_delay <dbl>, carrier <chr>, flight <int>, tailnum <chr>,
#> #   origin <chr>, dest <chr>, air_time <dbl>, distance <dbl>,
#> #   hour <dbl>, minute <dbl>, time_hour <dttm>
```

select() and everything()

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
select(flights, time_hour, air_time, everything())
#> # A tibble: 336,776 x 19
#>    time_hour           air_time  year month   day dep_time
#>    <dttm>                 <dbl> <int> <int> <int>    <int>
#>  1 2013-01-01 05:00:00      227  2013     1     1      517
#>  2 2013-01-01 05:00:00      227  2013     1     1      533
#>  3 2013-01-01 05:00:00      160  2013     1     1      542
#>  4 2013-01-01 05:00:00      183  2013     1     1      544
#>  5 2013-01-01 06:00:00      116  2013     1     1      554
#>  6 2013-01-01 05:00:00      150  2013     1     1      554
#>  7 2013-01-01 06:00:00      158  2013     1     1      555
#>  8 2013-01-01 06:00:00       53  2013     1     1      557
#>  9 2013-01-01 06:00:00      140  2013     1     1      557
#> 10 2013-01-01 06:00:00      138  2013     1     1      558
#> # ... with 336,766 more rows, and 13 more variables:
#> #   sched_dep_time <int>, dep_delay <dbl>, arr_time <int>,
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   distance <dbl>, hour <dbl>, minute <dbl>
```

More on select

- Helper functions you can use within `select()`:
  - `starts_with("abc")`: matches names that begin with "abc".
  - `ends_with("xyz")`: matches names that end with "xyz".
  - `contains("ijk")`: matches names that contain "ijk".
  - `matches("(.)\\1")`: selects variables that match a regular expression (this one matches any variables that contain repeated characters).
  - `num_range("x", 1:3)` matches `x1`, `x2` and `x3`.
- `select()` can be used to rename variables, but it drops all of the variables not explicitly mentioned. Instead, use `rename()`
- See `?select` for more details.

Outline

Create a narrower dataset


```
(flights_sml <- select(flights,
  year:day,
  ends_with("delay"),
  distance,
  air_time))
#> # A tibble: 336,776 x 7
#>     year month   day dep_delay arr_delay distance air_time
#>    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl>
#>  1  2013     1     1         2        11     1400      227
#>  2  2013     1     1         4        20     1416      227
#>  3  2013     1     1         2        33     1089      160
#>  4  2013     1     1        -1       -18     1576      183
#>  5  2013     1     1        -6       -25      762      116
#>  6  2013     1     1        -4        12      719      150
#>  7  2013     1     1        -5        19     1065      158
#>  8  2013     1     1        -3       -14      229       53
#>  9  2013     1     1        -3        -8      944      140
#> 10  2013     1     1        -2         8      733      138
#> # ... with 336,766 more rows
```

Add new variables with `mutate()`

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
mutate(flights_sml,
  gain = arr_delay - dep_delay,
  speed = distance / air_time * 60)
#> # A tibble: 336,776 x 9
#>     year month   day dep_delay arr_delay distance air_time  gain
#>    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl> <dbl>
#>  1  2013     1     1         2        11     1400      227     9
#>  2  2013     1     1         4        20     1416      227    16
#>  3  2013     1     1         2        33     1089      160    31
#>  4  2013     1     1        -1       -18     1576      183   -17
#>  5  2013     1     1        -6       -25      762      116   -19
#>  6  2013     1     1        -4        12      719      150    16
#>  7  2013     1     1        -5        19     1065      158    24
#>  8  2013     1     1        -3       -14      229       53   -11
#>  9  2013     1     1        -3        -8      944      140    -5
#> 10  2013     1     1        -2         8      733      138    10
#> # ... with 336,766 more rows, and 1 more variable: speed <dbl>
```

Refer to columns just created

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
mutate(flights_sml,
  gain = arr_delay - dep_delay,
  hours = air_time / 60,
  gain_per_hour = gain / hours)
#> # A tibble: 336,776 x 10
#>     year month   day dep_delay arr_delay distance air_time  gain
#>    <int> <int> <int>     <dbl>     <dbl>    <dbl>    <dbl> <dbl>
#>  1  2013     1     1         2        11     1400      227     9
#>  2  2013     1     1         4        20     1416      227    16
#>  3  2013     1     1         2        33     1089      160    31
#>  4  2013     1     1        -1       -18     1576      183   -17
#>  5  2013     1     1        -6       -25      762      116   -19
#>  6  2013     1     1        -4        12      719      150    16
#>  7  2013     1     1        -5        19     1065      158    24
#>  8  2013     1     1        -3       -14      229       53   -11
#>  9  2013     1     1        -3        -8      944      140    -5
#> 10  2013     1     1        -2         8      733      138    10
#> # ... with 336,766 more rows, and 2 more variables: hours <dbl>,
#> #   gain_per_hour <dbl>
```

transmute()


```
transmute(flights,
  gain = arr_delay - dep_delay,
  hours = air_time / 60,
  gain_per_hour = gain / hours)
#> # A tibble: 336,776 x 3
#>     gain hours gain_per_hour
#>    <dbl> <dbl>         <dbl>
#>  1     9 3.78           2.38
#>  2    16 3.78           4.23
#>  3    31 2.67          11.6
#>  4   -17 3.05          -5.57
#>  5   -19 1.93          -9.83
#>  6    16 2.5            6.4
#>  7    24 2.63           9.11
#>  8   -11 0.883        -12.5
#>  9    -5 2.33          -2.14
#> 10    10 2.3            4.35
#> # ... with 336,766 more rows
```

Useful creation functions I

Any vectorized function would work, but frequently useful are:

- Arithmetic operators: `+`, `-`, `*`, `/`, `^`.
  - Vectorized with "recycling rules" (e.g., `air_time / 60`).
  - Useful in conjunction with aggregate functions (e.g., `x / sum(x)` or `y - mean(y)`).
- Modular arithmetic: `%/%` (integer division) and `%%` (remainder), where `x == y * (x %/% y) + (x %% y)`.
  - Allows you to break integers up into pieces (e.g., `hour = dep_time %/% 100` and `minute = dep_time %% 100`)
- Logs: `log()`, `log2()`, `log10()`.
  - Useful for data ranging across multiple orders of magnitude.
  - Convert multiplicative relationships to additive.

Useful creation functions II

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Offsets: `lead()` and `lag()`:
  - Refer to lead-/lagging values (e.g., compute running differences `x - lag(x)` or find values change `x != lag(x)`).

```
x <- 1:10
lag(x)
#>  [1] NA  1  2  3  4  5  6  7  8  9
lead(x)
#>  [1]  2  3  4  5  6  7  8  9 10 NA
```

- Cumulative aggregates: `cumsum()`, `cumprod()`, `cummin()`, `cummax()`, `cummean()`.

```
cumsum(x)
#>  [1]  1  3  6 10 15 21 28 36 45 55
cummean(x)
#>  [1] 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5
```

Useful creation functions III

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Logical comparisons, <, <=, >, >=, !=
- Ranking functions: `min_rank()`, `row_number()`, `dense_rank()`, `percent_rank()`, `cume_dist()`, `ntile()`

```
y <- c(1, 2, 2, NA, 3, 4)
min_rank(y)
#> [1]  1  2  2 NA  4  5
min_rank(desc(y))
#> [1]  5  3  3 NA  2  1
row_number(y)
#> [1]  1  2  3 NA  4  5
dense_rank(y)
#> [1]  1  2  2 NA  3  4
percent_rank(y)
#> [1] 0.00 0.25 0.25   NA 0.75 1.00
cume_dist(y)
#> [1] 0.2 0.6 0.6  NA 0.8 1.0
```

Outline

Collapse values with `summarize()`

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
summarize(flights, delay = mean(dep_delay, na.rm = TRUE))
#> # A tibble: 1 x 1
#>   delay
#>   <dbl>
#> 1  12.6
```

summarize() paired with group_by()

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
by_day <- group_by(flights, year, month, day)
summarize(by_day, delay = mean(dep_delay, na.rm = TRUE))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day delay
#>    <int> <int> <int> <dbl>
#>  1  2013     1     1 11.5
#>  2  2013     1     2 13.9
#>  3  2013     1     3 11.0
#>  4  2013     1     4  8.95
#>  5  2013     1     5  5.73
#>  6  2013     1     6  7.15
#>  7  2013     1     7  5.42
#>  8  2013     1     8  2.55
#>  9  2013     1     9  2.28
#> 10  2013     1    10  2.84
#> # ... with 355 more rows
```

What is this code doing?

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
a1 <- group_by(flights, year, month, day)
a2 <- select(a1, arr_delay, dep_delay)
a3 <- summarize(a2,
                arr = mean(arr_delay, na.rm = TRUE),
                dep = mean(dep_delay, na.rm = TRUE))
filter(a3, arr > 30 | dep > 30)
#> # A tibble: 49 x 5
#> # Groups:   year, month [11]
#>     year month   day   arr   dep
#>    <int> <int> <int> <dbl> <dbl>
#>  1  2013     1    16  34.2  24.6
#>  2  2013     1    31  32.6  28.7
#>  3  2013     2    11  36.3  39.1
#>  4  2013     2    27  31.3  37.8
#>  5  2013     3     8  85.9  83.5
#>  6  2013     3    18  41.3  30.1
#>  7  2013     4    10  38.4  33.0
#>  8  2013     4    12  36.0  34.8
#>  9  2013     4    18  36.0  34.9
#> 10  2013     4    19  47.9  46.1
#> # ... with 39 more rows
```

Same code (no unnecessary objects)

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
filter(summarize(select(group_by(flights, year, month, day),
            arr_delay, dep_delay),
    arr = mean(arr_delay, na.rm = TRUE),
    dep = mean(dep_delay, na.rm = TRUE)),
    arr > 30 | dep > 30)
#> # A tibble: 49 x 5
#> # Groups:   year, month [11]
#>     year month   day   arr   dep
#>    <int> <int> <int> <dbl> <dbl>
#>  1  2013     1    16  34.2  24.6
#>  2  2013     1    31  32.6  28.7
#>  3  2013     2    11  36.3  39.1
#>  4  2013     2    27  31.3  37.8
#>  5  2013     3     8  85.9  83.5
#>  6  2013     3    18  41.3  30.1
#>  7  2013     4    10  38.4  33.0
#>  8  2013     4    12  36.0  34.8
#>  9  2013     4    18  36.0  34.9
#> 10  2013     4    19  47.9  46.1
#> # ... with 39 more rows
```

... Or use %>%


```
flights %>%
  group_by(year, month, day) %>%
  select(arr_delay, dep_delay) %>%
  summarize(arr = mean(arr_delay, na.rm = TRUE),
            dep = mean(dep_delay, na.rm = TRUE)) %>%
  filter(arr > 30 | dep > 30)
#> # A tibble: 49 x 5
#> # Groups:   year, month [11]
#>    year month   day   arr   dep
#>   <int> <int> <int> <dbl> <dbl>
#> 1  2013     1    16  34.2  24.6
#> 2  2013     1    31  32.6  28.7
#> 3  2013     2    11  36.3  39.1
#> 4  2013     2    27  31.3  37.8
#> 5  2013     3     8  85.9  83.5
#> 6  2013     3    18  41.3  30.1
#> 7  2013     4    10  38.4  33.0
#> 8  2013     4    12  36.0  34.8
#> 9  2013     4    18  36.0  34.9
#> 10 2013     4    19  47.9  46.1
#> # ... with 39 more rows
```

What is happening here?


```
flights %>%
  group_by(year, month, day) %>%
  summarize(mean = mean(dep_delay))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day  mean
#>    <int> <int> <int> <dbl>
#>  1  2013     1     1    NA
#>  2  2013     1     2    NA
#>  3  2013     1     3    NA
#>  4  2013     1     4    NA
#>  5  2013     1     5    NA
#>  6  2013     1     6    NA
#>  7  2013     1     7    NA
#>  8  2013     1     8    NA
#>  9  2013     1     9    NA
#> 10  2013     1    10    NA
#> # ... with 355 more rows
```

Use na.rm = TRUE

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
flights %>%
  group_by(year, month, day) %>%
  summarize(mean = mean(dep_delay, na.rm = TRUE))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day  mean
#>    <int> <int> <int> <dbl>
#>  1  2013     1     1 11.5
#>  2  2013     1     2 13.9
#>  3  2013     1     3 11.0
#>  4  2013     1     4  8.95
#>  5  2013     1     5  5.73
#>  6  2013     1     6  7.15
#>  7  2013     1     7  5.42
#>  8  2013     1     8  2.55
#>  9  2013     1     9  2.28
#> 10  2013     1    10  2.84
#> # ... with 355 more rows
```

Or pre-filter the dataset


```
not_cancelled <- flights %>%
  filter(!is.na(dep_delay), !is.na(arr_delay))
not_cancelled %>%
  group_by(year, month, day) %>%
  summarize(mean = mean(dep_delay))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day  mean
#>    <int> <int> <int> <dbl>
#>  1  2013     1     1 11.4
#>  2  2013     1     2 13.7
#>  3  2013     1     3 10.9
#>  4  2013     1     4  8.97
#>  5  2013     1     5  5.73
#>  6  2013     1     6  7.15
#>  7  2013     1     7  5.42
#>  8  2013     1     8  2.56
#>  9  2013     1     9  2.30
#> 10  2013     1    10  2.84
#> # ... with 355 more rows
```

Useful summary functions I

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Measures of location: `mean()`, `median()`.
- Measures of spread: `sd()`, `IQR()`, `mad()`.
- Measures of rank: `min(x)`, `quantile(x, 0.25)`, `max(x)`.

```
not_cancelled %>%
  group_by(year, month, day) %>%
  summarize(first = min(dep_time), last = max(dep_time))
#> # A tibble: 365 x 5
#> # Groups:   year, month [12]
#>     year month   day first  last
#>    <int> <int> <int> <int> <int>
#>  1  2013     1     1   517  2356
#>  2  2013     1     2    42  2354
#>  3  2013     1     3    32  2349
#>  4  2013     1     4    25  2358
#>  5  2013     1     5    14  2357
#>  6  2013     1     6    16  2355
#>  7  2013     1     7    49  2359
#>  8  2013     1     8   454  2351
#>  9  2013     1     9     2  2252
#> 10  2013     1    10     3  2320
#> # ... with 355 more rows
```

Useful summary functions II

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Measures of position: `first(x)`, `nth(x, 2)`, `last(x)`.

```
not_cancelled %>%
  group_by(year, month, day) %>%
  summarize(first_dep = first(dep_time), last_dep = last(dep_time))
#> # A tibble: 365 x 5
#> # Groups:   year, month [12]
#>     year month   day first_dep last_dep
#>    <int> <int> <int>     <int>    <int>
#>  1  2013     1     1       517     2356
#>  2  2013     1     2        42     2354
#>  3  2013     1     3        32     2349
#>  4  2013     1     4        25     2358
#>  5  2013     1     5        14     2357
#>  6  2013     1     6        16     2355
#>  7  2013     1     7        49     2359
#>  8  2013     1     8       454     2351
#>  9  2013     1     9         2     2252
#> 10  2013     1    10         3     2320
#> # ... with 355 more rows
```

Useful summary functions III

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Counts: `n(x)`, `sum(!is.na(x))`, `n_distinct(x)`.

```
not_cancelled %>%
  group_by(dest) %>%
  summarize(carriers = n_distinct(carrier)) %>%
  arrange(desc(carriers))
#> # A tibble: 104 x 2
#>    dest  carriers
#>    <chr>    <int>
#>  1 ATL          7
#>  2 BOS          7
#>  3 CLT          7
#>  4 ORD          7
#>  5 TPA          7
#>  6 AUS          6
#>  7 DCA          6
#>  8 DTW          6
#>  9 IAD          6
#> 10 MSP          6
#> # ... with 94 more rows
```

Useful summary functions IV

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- A simple helper function for counts:

```
not_cancelled %>% count(dest)
#> # A tibble: 104 x 2
#>    dest      n
#>    <chr> <int>
#>  1 ABQ     254
#>  2 ACK     264
#>  3 ALB     418
#>  4 ANC       8
#>  5 ATL   16837
#>  6 AUS    2411
#>  7 AVL     261
#>  8 BDL     412
#>  9 BGR     358
#> 10 BHM     269
#> # ... with 94 more rows
```

Useful summary functions V

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Counts with an optional weight variable:

```
not_cancelled %>% count(tailnum, wt = distance)
#> # A tibble: 4,037 x 2
#>    tailnum      n
#>    <chr>    <dbl>
#>  1 D942DN    3418
#>  2 N0EGMQ  239143
#>  3 N10156  109664
#>  4 N102UW   25722
#>  5 N103US   24619
#>  6 N104UW   24616
#>  7 N10575  139903
#>  8 N105UW   23618
#>  9 N107US   21677
#> 10 N108UW   32070
#> # ... with 4,027 more rows
```

Useful summary functions VI

- Counts of logical values: e.g., `sum(x > 10)`.

```
not_cancelled %>%
  group_by(year, month, day) %>%
  summarize(n_early = sum(dep_time < 500))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day n_early
#>    <int> <int> <int>   <int>
#>  1  2013     1     1       0
#>  2  2013     1     2       3
#>  3  2013     1     3       4
#>  4  2013     1     4       3
#>  5  2013     1     5       3
#>  6  2013     1     6       2
#>  7  2013     1     7       2
#>  8  2013     1     8       1
#>  9  2013     1     9       3
#> 10  2013     1    10       3
#> # ... with 355 more rows
```

Useful summary functions VII

- Proportions of logical values: e.g., `mean(y == 0)`.

```
not_cancelled %>%
  group_by(year, month, day) %>%
  summarize(hour_perc = mean(arr_delay > 60))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day hour_perc
#>    <int> <int> <int>     <dbl>
#>  1  2013     1     1    0.0722
#>  2  2013     1     2    0.0851
#>  3  2013     1     3    0.0567
#>  4  2013     1     4    0.0396
#>  5  2013     1     5    0.0349
#>  6  2013     1     6    0.0470
#>  7  2013     1     7    0.0333
#>  8  2013     1     8    0.0213
#>  9  2013     1     9    0.0202
#> 10  2013     1    10    0.0183
#> # ... with 355 more rows
```

Grouping by multiple variables I

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
daily <- group_by(flights, year, month, day)
(per_day   <- summarize(daily, flights = n()))
#> # A tibble: 365 x 4
#> # Groups:   year, month [12]
#>     year month   day flights
#>    <int> <int> <int>   <int>
#>  1  2013     1     1     842
#>  2  2013     1     2     943
#>  3  2013     1     3     914
#>  4  2013     1     4     915
#>  5  2013     1     5     720
#>  6  2013     1     6     832
#>  7  2013     1     7     933
#>  8  2013     1     8     899
#>  9  2013     1     9     902
#> 10  2013     1    10     932
#> # ... with 355 more rows
```

Grouping by multiple variables II

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
(per_month <- summarize(per_day, flights = sum(flights)))
(per_year  <- summarize(per_month, flights = sum(flights)))
#> # A tibble: 12 x 3
#> # Groups:   year [1]
#>    year month flights
#>   <int> <int>   <int>
#>  1  2013     1   27004
#>  2  2013     2   24951
#>  3  2013     3   28834
#>  4  2013     4   28330
#>  5  2013     5   28796
#>  6  2013     6   28243
#>  7  2013     7   29425
#>  8  2013     8   29327
#>  9  2013     9   27574
#> 10  2013    10   28889
#> 11  2013    11   27268
#> 12  2013    12   28135
#> # A tibble: 1 x 2
#>    year flights
#>   <int>   <int>
#> 1  2013  336776
```

Ungrouping


```
daily %>%
  ungroup() %>%               # no longer grouped by date
  summarize(flights = n())   # all flights
#> # A tibble: 1 x 1
#>   flights
#>     <int>
#> 1  336776
```

Grouped filters

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
(popular_dests <- flights %>%
    group_by(dest) %>%
    filter(n() > 365))
#> # A tibble: 332,577 x 19
#> # Groups:   dest [77]
#>     year month   day dep_time sched_dep_time dep_delay arr_time
#>    <int> <int> <int>    <int>          <int>     <dbl>    <int>
#>  1  2013     1     1      517            515         2      830
#>  2  2013     1     1      533            529         4      850
#>  3  2013     1     1      542            540         2      923
#>  4  2013     1     1      544            545        -1     1004
#>  5  2013     1     1      554            600        -6      812
#>  6  2013     1     1      554            558        -4      740
#>  7  2013     1     1      555            600        -5      913
#>  8  2013     1     1      557            600        -3      709
#>  9  2013     1     1      557            600        -3      838
#> 10  2013     1     1      558            600        -2      753
#> # ... with 332,567 more rows, and 12 more variables:
#> #   sched_arr_time <int>, arr_delay <dbl>, carrier <chr>,
#> #   flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#> #   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#> #   time_hour <dttm>
```

Grouped mutates

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
popular_dests %>%
  filter(arr_delay > 0) %>%
  mutate(prop_delay = arr_delay / sum(arr_delay)) %>%
  select(year:day, dest, arr_delay, prop_delay)
#> # A tibble: 131,106 x 6
#> # Groups:   dest [77]
#>     year month   day dest  arr_delay prop_delay
#>    <int> <int> <int> <chr>     <dbl>      <dbl>
#>  1  2013     1     1 IAH          11  0.000111
#>  2  2013     1     1 IAH          20  0.000201
#>  3  2013     1     1 MIA          33  0.000235
#>  4  2013     1     1 ORD          12  0.0000424
#>  5  2013     1     1 FLL          19  0.0000938
#>  6  2013     1     1 ORD           8  0.0000283
#>  7  2013     1     1 LAX           7  0.0000344
#>  8  2013     1     1 DFW          31  0.000282
#>  9  2013     1     1 ATL          12  0.0000400
#> 10  2013     1     1 DTW          16  0.000116
#> # ... with 131,096 more rows
```

Outline

Tidy data

> *"Happy families are all alike; every unhappy family is unhappy in its own way."* —- *Leo Tolstoy*

> *"Tidy datasets are all alike, but every messy dataset is messy in its own way."* —- *Hadley Wickham*

To learn more about the underlying theory, see the Tidy Data paper.

Which representation is "best"?

- First representation?

```
table1
#> # A tibble: 6 x 4
#>   country      year  cases population
#>   <chr>       <int>  <int>      <int>
#> 1 Afghanistan  1999    745   19987071
#> 2 Afghanistan  2000   2666   20595360
#> 3 Brazil       1999  37737  172006362
#> 4 Brazil       2000  80488  174504898
#> 5 China        1999 212258 1272915272
#> 6 China        2000 213766 1280428583
```

- Second representation?

```
table2
#> # A tibble: 12 x 4
#>    country      year type            count
#>    <chr>       <int> <chr>           <int>
#>  1 Afghanistan  1999 cases             745
#>  2 Afghanistan  1999 population   19987071
#>  3 Afghanistan  2000 cases            2666
#>  4 Afghanistan  2000 population   20595360
#>  5 Brazil       1999 cases           37737
#>  6 Brazil       1999 population  172006362
#>  7 Brazil       2000 cases           80488
#>  8 Brazil       2000 population  174504898
#>  9 China        1999 cases          212258
#> 10 China        1999 population 1272915272
#> 11 China        2000 cases          213766
#> 12 China        2000 population 1280428583
```

- Third representation?

```
table3
#> # A tibble: 6 x 3
#>   country      year rate
#> * <chr>       <int> <chr>
#> 1 Afghanistan  1999 745/19987071
#> 2 Afghanistan  2000 2666/20595360
#> 3 Brazil       1999 37737/172006362
#> 4 Brazil       2000 80488/174504898
#> 5 China        1999 212258/1272915272
#> 6 China        2000 213766/1280428583
```

- Fourth representation?

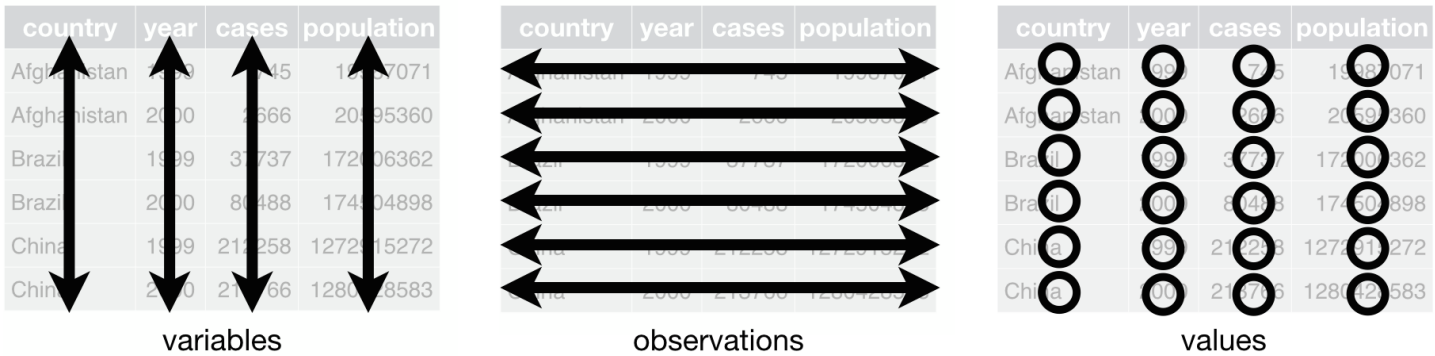
```
table4a  # cases
#> # A tibble: 3 x 3
#>   country     `1999` `2000`
#> * <chr>        <int>  <int>
#> 1 Afghanistan    745   2666
#> 2 Brazil       37737  80488
#> 3 China       212258 213766
table4b  # population
#> # A tibble: 3 x 3
#>   country         `1999`     `2000`
#> * <chr>            <int>      <int>
#> 1 Afghanistan   19987071   20595360
#> 2 Brazil       172006362  174504898
#> 3 China       1272915272 1280428583
```

What makes a dataset tidy?

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Three interrelated rules:

- Each variable must have its own column.
- Each observation must have its own row.
- Each value must have its own cell.



Because it's impossible to only satisfy two of the three:

- Put each dataset in a tibble.
- Put each variable in a column.

Why ensure that your data is tidy?

- Why?
  - With consistent data structure, it's easier to learn the tools that work with it because they have an underlying uniformity.
  - Placing variables in columns allows R's vectorized nature to shine.
- Tidy data principles seem obvious, BUT:
  - Most people aren't familiar with them.
  - Data often organized to facilitate something different than analysis.
- Hence, you'll most likely need to do some tidying.

The two steps of tidying

- Figure out what the variables and observations are.
- Resolve one of two common problems:
  - One variable might be spread across multiple columns.
  - One observation might be scattered across multiple rows.

... To fix these problems, you'll need `gather()` and `spread()`.

Gathering with gather()


```
table4a
#> # A tibble: 3 x 3
#>   country     `1999` `2000`
#> * <chr>        <int>  <int>
#> 1 Afghanistan    745   2666
#> 2 Brazil       37737  80488
#> 3 China       212258 213766
```

```
table4a %>%
  gather(`1999`, `2000`,
         key = "year", value = "cases")
#> # A tibble: 6 x 3
#>   country     year   cases
#>   <chr>       <chr>  <int>
#> 1 Afghanistan 1999     745
#> 2 Brazil      1999   37737
#> 3 China       1999  212258
#> 4 Afghanistan 2000    2666
#> 5 Brazil      2000   80488
#> 6 China       2000  213766
```

Spreading with `spread()`


```
table2
#> # A tibble: 12 x 4
#>    country      year type            count
#>    <chr>       <int> <chr>           <int>
#>  1 Afghanistan  1999 cases             745
#>  2 Afghanistan  1999 population    19987071
#>  3 Afghanistan  2000 cases            2666
#>  4 Afghanistan  2000 population    20595360
#>  5 Brazil       1999 cases            37737
#>  6 Brazil       1999 population   172006362
#>  7 Brazil       2000 cases            80488
#>  8 Brazil       2000 population   174504898
#>  9 China        1999 cases           212258
#> 10 China        1999 population  1272915272
#> 11 China        2000 cases           213766
#> 12 China        2000 population  1280428583
```

```
table2 %>% spread(key = type,
                  value = count)
#> # A tibble: 6 x 4
#>   country      year  cases population
#>   <chr>       <int>  <int>      <int>
#> 1 Afghanistan  1999    745   19987071
#> 2 Afghanistan  2000   2666   20595360
#> 3 Brazil       1999  37737  172006362
#> 4 Brazil       2000  80488  174504898
#> 5 China        1999 212258 1272915272
#> 6 China        2000 213766 1280428583
```

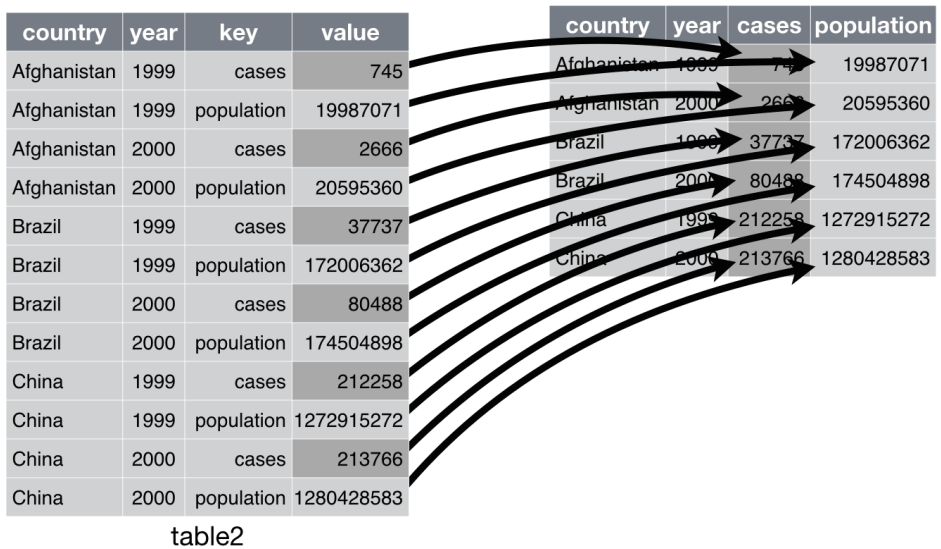


table2

Separate a column with `separate()`

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
table3
#> # A tibble: 6 x 3
#>   country      year rate
#> * <chr>       <int> <chr>
#> 1 Afghanistan  1999 745/19987071
#> 2 Afghanistan  2000 2666/20595360
#> 3 Brazil       1999 37737/172006362
#> 4 Brazil       2000 80488/174504898
#> 5 China        1999 212258/1272915272
#> 6 China        2000 213766/1280428583
```

```
table3 %>% separate(rate,
                    into = c("cases",
                             "population"))
#> # A tibble: 6 x 4
#>   country      year cases  population
#>   <chr>       <int> <chr>  <chr>
#> 1 Afghanistan  1999 745    19987071
#> 2 Afghanistan  2000 2666   20595360
#> 3 Brazil       1999 37737  172006362
#> 4 Brazil       2000 80488  174504898
#> 5 China        1999 212258 1272915272
#> 6 China        2000 213766 1280428583
```

country	year	rate
Afghanistan	1999	**745** / 19987071
Afghanistan	2000	**2666** / 20595360
Brazil	1999	**37737** / 172006362
Brazil	2000	**80488** / 174504898
China	1999	**212258** / 1272915272
China	2000	**213766** / 1280428583

table3

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

separate() using convert = TRUE

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
table3 %>%
  separate(rate, into = c("cases", "population"), convert = TRUE)
#> # A tibble: 6 x 4
#>   country      year  cases population
#>   <chr>       <int>  <int>      <int>
#> 1 Afghanistan  1999    745   19987071
#> 2 Afghanistan  2000   2666   20595360
#> 3 Brazil       1999  37737  172006362
#> 4 Brazil       2000  80488  174504898
#> 5 China        1999 212258 1272915272
#> 6 China        2000 213766 1280428583
```

Unite two columns with `unite()`


```
table5
#> # A tibble: 6 x 4
#>   country     century year  rate
#> * <chr>       <chr>   <chr> <chr>
#> 1 Afghanistan 19      99    745/19987071
#> 2 Afghanistan 20      00    2666/20595360
#> 3 Brazil      19      99    37737/172006362
#> 4 Brazil      20      00    80488/174504898
#> 5 China       19      99    212258/1272915272
#> 6 China       20      00    213766/1280428583
```

```
table5 %>%
  unite(new, century, year, sep = "")
#> # A tibble: 6 x 3
#>   country     new   rate
#>   <chr>       <chr> <chr>
#> 1 Afghanistan 1999  745/19987071
#> 2 Afghanistan 2000  2666/20595360
#> 3 Brazil      1999  37737/172006362
#> 4 Brazil      2000  80488/174504898
#> 5 China       1999  212258/1272915272
#> 6 China       2000  213766/1280428583
```

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

country	century	year	rate
Afghanistan	19	99	745 / 19987071
Afghanistan	20	0	2666 / 20595360
Brazil	19	99	37737 / 172006362
Brazil	20	0	80488 / 174504898
China	19	99	212258 / 1272915272
China	20	0	213766 / 1280428583

table6

Missing values and tidy data

- A value can be missing in one of two possible ways:
  - **Explicitly**, i.e. flagged with `NA`.
  - **Implicitly**, i.e. simply not present in the data.

  "An explicit missing value is the presence of an absence; an implicit missing value is the absence of a presence." Hadley Wickham

- Are there missing values in this dataset?

```
stocks <- tibble(
  year   = c(2015, 2015, 2015, 2015, 2016, 2016, 2016),
  qtr    = c(   1,    2,    3,    4,    2,    3,    4),
  return = c(1.88, 0.59, 0.35,   NA, 0.92, 0.17, 2.66)
)
```

Implicit to explicit and conversely

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

- Implicit to explicit:

```
stocks %>%
  spread(year, return)
#> # A tibble: 4 x 3
#>     qtr `2015` `2016`
#>   <dbl>  <dbl>  <dbl>
#> 1     1   1.88  NA
#> 2     2   0.59   0.92
#> 3     3   0.35   0.17
#> 4     4  NA      2.66
```

- Explicit to implicit:

```
stocks %>%
  spread(year, return) %>%
  gather(year, return,
         `2015`:`2016`, na.rm = TRUE)
#> # A tibble: 6 x 3
#>     qtr year  return
#>   <dbl> <chr>  <dbl>
#> 1     1 2015    1.88
#> 2     2 2015    0.59
#> 3     3 2015    0.35
#> 4     2 2016    0.92
#> 5     3 2016    0.17
#> 6     4 2016    2.66
```

Implicit to explicit with `complete()`

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
stocks %>% complete(year, qtr)
#> # A tibble: 8 x 3
#>    year   qtr return
#>   <dbl> <dbl>  <dbl>
#> 1  2015     1   1.88
#> 2  2015     2   0.59
#> 3  2015     3   0.35
#> 4  2015     4  NA
#> 5  2016     1  NA
#> 6  2016     2   0.92
#> 7  2016     3   0.17
#> 8  2016     4   2.66
```

Fill in missing values with `fill()`

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
treatment <- tribble(
  ~ person,           ~ treatment, ~response,
  "Derrick Whitmore", 1,           7,
  NA,                 2,           10,
  NA,                 3,           9,
  "Katherine Burke",  1,           4
)
treatment %>%
  fill(person)
#> # A tibble: 4 x 3
#>   person           treatment response
#>   <chr>                <dbl>    <dbl>
#> 1 Derrick Whitmore         1        7
#> 2 Derrick Whitmore         2       10
#> 3 Derrick Whitmore         3        9
#> 4 Katherine Burke          1        4
```

Pivotting

- Since `tidyr` 1.0:
  - `pivot_longer()` and `pivot_wider()` to convert between long and wide forms
- The goal:
  - Improve on `spread()` and `gather()`!
- `vignette("pivot")` for more details

pivot_longer()

- Makes datasets **longer** by increasing the number of rows and decreasing the number of columns.
- Commonly needed to tidy datasets optimized for ease of data entry or ease of comparison rather than ease of analysis.

```
relig_income %>% print(n = 10)
#> # A tibble: 18 x 11
#>    religion `<$10k` `$10-20k` `$20-30k` `$30-40k` `$40-50k` `$50-75k`
#>    <chr>      <dbl>     <dbl>     <dbl>     <dbl>     <dbl>     <dbl>
#>  1 Agnostic      27        34        60        81        76       137
#>  2 Atheist       12        27        37        52        35        70
#>  3 Buddhist      27        21        30        34        33        58
#>  4 Catholic     418       617       732       670       638      1116
#>  5 Don't k~      15        14        15        11        10        35
#>  6 Evangel~     575       869      1064       982       881      1486
#>  7 Hindu          1         9         7         9        11        34
#>  8 Histori~     228       244       236       238       197       223
#>  9 Jehovah~      20        27        24        24        21        30
#> 10 Jewish        19        19        25        25        30        95
#> # ... with 8 more rows, and 4 more variables: `$75-100k` <dbl>,
#> #   `$100-150k` <dbl>, `>150k` <dbl>, `Don't know/refused` <dbl>
```

pivot_longer() cont'd


```
relig_income %>%
  pivot_longer(-religion, names_to = "income", values_to = "count")
#> # A tibble: 180 x 3
#>    religion income             count
#>    <chr>    <chr>              <dbl>
#>  1 Agnostic <$10k                27
#>  2 Agnostic $10-20k              34
#>  3 Agnostic $20-30k              60
#>  4 Agnostic $30-40k              81
#>  5 Agnostic $40-50k              76
#>  6 Agnostic $50-75k             137
#>  7 Agnostic $75-100k            122
#>  8 Agnostic $100-150k           109
#>  9 Agnostic >150k                84
#> 10 Agnostic Don't know/refused   96
#> # ... with 170 more rows
```

- First argument:the dataset to reshape
- Second argument: which columns need to be reshaped.
- `names_to`/`values_to`: the name of the variable created from the data stored in the column names/cell value.

Numeric data in column names

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

```
billboard
#> # A tibble: 317 x 79
#>    artist track date.entered   wk1   wk2   wk3   wk4   wk5   wk6
#>    <chr>  <chr> <date>       <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
#>  1 2 Pac  Baby~ 2000-02-26      87    82    72    77    87    94
#>  2 2Ge+h~ The ~ 2000-09-02      91    87    92    NA    NA    NA
#>  3 3 Doo~ Kryp~ 2000-04-08      81    70    68    67    66    57
#>  4 3 Doo~ Loser 2000-10-21      76    76    72    69    67    65
#>  5 504 B~ Wobb~ 2000-04-15      57    34    25    17    17    31
#>  6 98^0   Give~ 2000-08-19      51    39    34    26    26    19
#>  7 A*Tee~ Danc~ 2000-07-08      97    97    96    95   100    NA
#>  8 Aaliy~ I Do~ 2000-01-29      84    62    51    41    38    35
#>  9 Aaliy~ Try ~ 2000-03-18      59    53    38    28    21    18
#> 10 Adams~ Open~ 2000-08-26      76    76    74    69    68    67
#> # ... with 307 more rows, and 70 more variables: wk7 <dbl>,
#> #   wk8 <dbl>, wk9 <dbl>, wk10 <dbl>, wk11 <dbl>, wk12 <dbl>,
#> #   wk13 <dbl>, wk14 <dbl>, wk15 <dbl>, wk16 <dbl>, wk17 <dbl>,
#> #   wk18 <dbl>, wk19 <dbl>, wk20 <dbl>, wk21 <dbl>, wk22 <dbl>,
#> #   wk23 <dbl>, wk24 <dbl>, wk25 <dbl>, wk26 <dbl>, wk27 <dbl>,
#> #   wk28 <dbl>, wk29 <dbl>, wk30 <dbl>, wk31 <dbl>, wk32 <dbl>,
#> #   wk33 <dbl>, wk34 <dbl>, wk35 <dbl>, wk36 <dbl>, wk37 <dbl>,
#> #   wk38 <dbl>, wk39 <dbl>, wk40 <dbl>, wk41 <dbl>, wk42 <dbl>,
#> #   wk43 <dbl>, wk44 <dbl>, wk45 <dbl>, wk46 <dbl>, wk47 <dbl>,
#> #   wk48 <dbl>, wk49 <dbl>, wk50 <dbl>, wk51 <dbl>, wk52 <dbl>,
#> #   wk53 <dbl>, wk54 <dbl>, wk55 <dbl>, wk56 <dbl>, wk57 <dbl>,
#> #   wk58 <dbl>, wk59 <dbl>, wk60 <dbl>, wk61 <dbl>, wk62 <dbl>,
#> #   wk63 <dbl>, wk64 <dbl>, wk65 <dbl>, wk66 <lgl>, wk67 <lgl>,
#> #   wk68 <lgl>, wk69 <lgl>, wk70 <lgl>, wk71 <lgl>, wk72 <lgl>,
#> #   wk73 <lgl>, wk74 <lgl>, wk75 <lgl>, wk76 <lgl>
```

Numeric data in column names cont'd


```
billboard %>%
  pivot_longer(
    cols = starts_with("wk"),
    names_to = "week",
    values_to = "rank",
    values_drop_na = TRUE
  )
#> # A tibble: 5,307 x 5
#>    artist  track                   date.entered week   rank
#>    <chr>   <chr>                   <date>       <chr> <dbl>
#>  1 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk1      87
#>  2 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk2      82
#>  3 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk3      72
#>  4 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk4      77
#>  5 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk5      87
#>  6 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk6      94
#>  7 2 Pac   Baby Don't Cry (Keep... 2000-02-26   wk7      99
#>  8 2Ge+her The Hardest Part Of ... 2000-09-02   wk1      91
#>  9 2Ge+her The Hardest Part Of ... 2000-09-02   wk2      87
#> 10 2Ge+her The Hardest Part Of ... 2000-09-02   wk3      92
#> # ... with 5,297 more rows
```

Numeric data in column names cont'd


```
billboard %>%
  pivot_longer(
    cols = starts_with("wk"),
    names_to = "week",
    names_prefix = "wk",
    names_ptypes = list(week = integer()),
    values_to = "rank",
    values_drop_na = TRUE,
  )
#> # A tibble: 5,307 x 5
#>    artist  track                   date.entered  week  rank
#>    <chr>   <chr>                   <date>       <int> <dbl>
#>  1 2 Pac   Baby Don't Cry (Keep... 2000-02-26       1    87
#>  2 2 Pac   Baby Don't Cry (Keep... 2000-02-26       2    82
#>  3 2 Pac   Baby Don't Cry (Keep... 2000-02-26       3    72
#>  4 2 Pac   Baby Don't Cry (Keep... 2000-02-26       4    77
#>  5 2 Pac   Baby Don't Cry (Keep... 2000-02-26       5    87
#>  6 2 Pac   Baby Don't Cry (Keep... 2000-02-26       6    94
#>  7 2 Pac   Baby Don't Cry (Keep... 2000-02-26       7    99
#>  8 2Ge+her The Hardest Part Of ... 2000-09-02       1    91
#>  9 2Ge+her The Hardest Part Of ... 2000-09-02       2    87
#> 10 2Ge+her The Hardest Part Of ... 2000-09-02       3    92
#> # ... with 5,297 more rows
```

pivot_wider()

- The opposite of `pivot_longer()`
- Makes a dataset **wider** by increasing the number of columns and decreasing the number of rows.
- Rare to need it to tidy data, useful to create summary tables for presentation, or data in a format needed by other tools.

```
fish_encounters
#> # A tibble: 114 x 3
#>    fish  station  seen
#>    <fct> <fct>   <int>
#>  1 4842  Release     1
#>  2 4842  I80_1       1
#>  3 4842  Lisbon      1
#>  4 4842  Rstr        1
#>  5 4842  Base_TD     1
#>  6 4842  BCE         1
#>  7 4842  BCW         1
#>  8 4842  BCE2        1
#>  9 4842  BCW2        1
#> 10 4842  MAE         1
#> # ... with 104 more rows
```

pivot_wider() cont'd


```
fish_encounters %>%
  pivot_wider(names_from = station, values_from = seen) %>%
  print(n = 10)
#> # A tibble: 19 x 12
#>    fish  Release I80_1 Lisbon  Rstr Base_TD   BCE   BCW  BCE2  BCW2
#>    <fct>   <int> <int>  <int> <int>   <int> <int> <int> <int> <int>
#>  1 4842        1     1      1     1       1     1     1     1     1
#>  2 4843        1     1      1     1       1     1     1     1     1
#>  3 4844        1     1      1     1       1     1     1     1     1
#>  4 4845        1     1      1     1       1    NA    NA    NA    NA
#>  5 4847        1     1      1    NA      NA    NA    NA    NA    NA
#>  6 4848        1     1      1     1      NA    NA    NA    NA    NA
#>  7 4849        1     1     NA    NA      NA    NA    NA    NA    NA
#>  8 4850        1     1     NA     1       1     1     1    NA    NA
#>  9 4851        1     1     NA    NA      NA    NA    NA    NA    NA
#> 10 4854        1     1     NA    NA      NA    NA    NA    NA    NA
#> # ... with 9 more rows, and 2 more variables: MAE <int>, MAW <int>
```

pivot_wider()

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

```
fish_encounters %>%
  pivot_wider(
    names_from = station,
    values_from = seen,
    values_fill = list(seen = 0)
  ) %>%
  print(n = 10)
#> # A tibble: 19 x 12
#>    fish  Release I80_1 Lisbon  Rstr Base_TD   BCE   BCW  BCE2  BCW2
#>    <fct>   <int> <int>  <int> <int>   <int> <int> <int> <int> <int>
#>  1 4842        1     1      1     1       1     1     1     1     1
#>  2 4843        1     1      1     1       1     1     1     1     1
#>  3 4844        1     1      1     1       1     1     1     1     1
#>  4 4845        1     1      1     1       1     0     0     0     0
#>  5 4847        1     1      1     0       0     0     0     0     0
#>  6 4848        1     1      1     1       0     0     0     0     0
#>  7 4849        1     1      0     0       0     0     0     0     0
#>  8 4850        1     1      0     1       1     1     1     0     0
#>  9 4851        1     1      0     0       0     0     0     0     0
#> 10 4854        1     1      0     0       0     0     0     0     0
#> # ... with 9 more rows, and 2 more variables: MAE <int>, MAW <int>
```

Aggregation


```
warpbreaks <- warpbreaks %>%
  as_tibble() %>%
  select(wool, tension, breaks)
warpbreaks
#> # A tibble: 54 x 3
#>    wool  tension breaks
#>    <fct> <fct>    <dbl>
#>  1 A     L           26
#>  2 A     L           30
#>  3 A     L           54
#>  4 A     L           25
#>  5 A     L           70
#>  6 A     L           52
#>  7 A     L           51
#>  8 A     L           26
#>  9 A     L           67
#> 10 A     M           18
#> # ... with 44 more rows
```

```
warpbreaks %>%
  count(wool, tension)
#> # A tibble: 6 x 3
#>   wool  tension     n
#>   <fct> <fct>   <int>
#> 1 A     L           9
#> 2 A     M           9
#> 3 A     H           9
#> 4 B     L           9
#> 5 B     M           9
#> 6 B     H           9
```

Aggregation cont'd


```
warpbreaks %>%
  pivot_wider(
    names_from = wool,
    values_from = breaks,
    values_fn = list(breaks = mean)
  )
#> # A tibble: 3 x 3
#>   tension     A     B
#>   <fct>   <dbl> <dbl>
#> 1 L        44.6  28.2
#> 2 M        24    28.8
#> 3 H        24.6  18.8
```

Generate column names


```
production <- expand_grid(
    product = c("A", "B"),
    country = c("AI", "EI"),
    year = 2000:2014
  ) %>%
  filter((product == "A" & country == "AI") | product == "B") %>%
  mutate(production = rnorm(nrow(.)))
production
#> # A tibble: 45 x 4
#>    product country  year production
#>    <chr>   <chr>   <int>      <dbl>
#>  1 A       AI       2000   -1.40
#>  2 A       AI       2001    0.255
#>  3 A       AI       2002   -2.44
#>  4 A       AI       2003   -0.00557
#>  5 A       AI       2004    0.622
#>  6 A       AI       2005    1.15
#>  7 A       AI       2006   -1.82
#>  8 A       AI       2007   -0.247
#>  9 A       AI       2008   -0.244
#> 10 A       AI       2009   -0.283
#> # ... with 35 more rows
```

Generate column names cont'd


```
production %>% pivot_wider(
  names_from = c(product, country),
  values_from = production
)
#> # A tibble: 15 x 4
#>     year     A_AI    B_AI    B_EI
#>    <int>    <dbl>   <dbl>   <dbl>
#>  1  2000 -1.40    -1.86    0.935
#>  2  2001  0.255   -0.522   0.176
#>  3  2002 -2.44    -0.0526  0.244
#>  4  2003 -0.00557  0.543   1.62
#>  5  2004  0.622   -0.914   0.112
#>  6  2005  1.15     0.468  -0.134
#>  7  2006 -1.82     0.363  -1.91
#>  8  2007 -0.247   -1.30   -0.279
#>  9  2008 -0.244    0.738  -0.313
#> 10  2009 -0.283    1.89    1.07
#> 11  2010 -0.554   -0.0974  0.0700
#> 12  2011  0.629   -0.936  -0.639
#> 13  2012  2.07    -0.0160 -0.0500
#> 14  2013 -1.63    -0.827  -0.251
#> 15  2014  0.512   -1.51    0.445
```