Tidy Data

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Quote from the book "R for Data Science", the author said

> R is an old language, and some things that were useful 10 or 20 years ago now get in your way. It's difficult to change base R without breaking existing code, so most innovation occurs in packages.

What is tidyverse?

- base R's functions are often slow and the implementations are often not consistent
- writing code in `tidyverse` style usually is more elegant
- the operations would be easily chained together using piping (more below)

So what is tidyverse?

- It is a collection of R packages which are designed to be used together.
  - `ggplot2`, for data visualisation
  - `dplyr`, for data manipulation
  - `tidyr`, for data tidying
  - `readr`, for data import
  - `purrr`, for functional programming
  - `tibble`, for tibbles, a modern re-imagining of data frames
  - `stringr`, for strings
  - `forcats`, for factors

dplyr basics

- It offers five basic verbs
  - `select`: picks variables based on their names
  - `filter`: picks cases based on their values
  - `mutate`: adds new variables that are functions of existing variables
  - `arrange`: changes the ordering of the rows
  - `summarize` or `summarise`: reduces multiple values down to a single summary
- These all combine naturally with `group_by` which allows you to perform any operation "by group".

Obtain some Data

First of all, we need some data to work with. If the data is stored in a `csv`,

```
flights <- read_csv("flights.csv")
```

We are using the `tidyverse` function `read_csv` to import the `flights.csv` instead of the obsolete base function `read.csv`. - `read_csv` imports data as `tibble` which has better output - `read_csv` is often faster than `read.csv` - `read_csv` handles unicode characters better

The datasets are actually obtained from the R package `nycflights13`

```
# Airline on-time data for all flights departing NYC in 2013.
library(nycflights13)
flights
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      554            600        -6      812            837       -25 DL         4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6         
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

`select`: picks variables based on their names.

To select arrival and departure times,

```
# old way to do it
# flights[, c("arr_time", "dep_time")]
select(flights, arr_time, dep_time)
```

```
## # A tibble: 336,776 x 2
##    arr_time dep_time
##       <int>    <int>
##  1      830      517
##  2      850      533
##  3      923      542
##  4     1004      544
##  5      812      554
##  6      740      554
##  7      913      555
##  8      709      557
##  9      838      557
## 10      753      558
## # ... with 336,766 more rows
```

I don't see why it's useful

`dplyr` provides a lot of helper functions,

```
# colon `:` specifies all the variables between the columns of `dep_time` and `arr_time`
select(flights, dep_time:arr_time)
```

```
## # A tibble: 336,776 x 4
```

```
##    dep_time sched_dep_time dep_delay arr_time
##       <int>          <int>     <dbl>    <int>
##  1      517            515         2      830
##  2      533            529         4      850
##  3      542            540         2      923
##  4      544            545        -1     1004
##  5      554            600        -6      812
##  6      554            558        -4      740
##  7      555            600        -5      913
##  8      557            600        -3      709
##  9      557            600        -3      838
## 10      558            600        -2      753
## # ... with 336,766 more rows
```

```
# all the columns start with arr_
select(flights, starts_with("arr_"))
```

```
## # A tibble: 336,776 x 2
##    arr_time arr_delay
##       <int>     <dbl>
##  1      830        11
##  2      850        20
##  3      923        33
##  4     1004       -18
##  5      812       -25
##  6      740        12
##  7      913        19
##  8      709       -14
##  9      838        -8
## 10      753         8
## # ... with 336,766 more rows
```

```
# all the columns end with _time
select(flights, ends_with("_time"))
```

```
## # A tibble: 336,776 x 5
##    dep_time sched_dep_time arr_time sched_arr_time air_time
##       <int>          <int>    <int>          <int>    <dbl>
##  1      517            515      830            819      227
##  2      533            529      850            830      227
##  3      542            540      923            850      160
##  4      544            545     1004           1022      183
##  5      554            600      812            837      116
##  6      554            558      740            728      150
##  7      555            600      913            854      158
##  8      557            600      709            723       53
##  9      557            600      838            846      140
## 10      558            600      753            745      138
## # ... with 336,766 more rows
```

```
# all the columns contain dep
select(flights, contains("dep"))
```

```
## # A tibble: 336,776 x 3
##    dep_time sched_dep_time dep_delay
##       <int>          <int>     <dbl>
##  1      517            515         2
##  2      533            529         4
##  3      542            540         2
##  4      544            545        -1
##  5      554            600        -6
##  6      554            558        -4
##  7      555            600        -5
##  8      557            600        -3
##  9      557            600        -3
## 10      558            600        -2
## # ... with 336,766 more rows
```

```
# all the columns do not contain dep
select(flights, -contains("dep"))
```

```
## # A tibble: 336,776 x 16
##     year month   day arr_time sched_arr_time arr_delay carrier flight tailnum origin dest  air_time
##    <int> <int> <int>    <int>          <int>     <dbl> <chr>    <int> <chr>   <chr>  <chr>    <dbl>
##  1  2013     1     1      830            819        11 UA        1545 N14228  EWR    IAH        227
##  2  2013     1     1      850            830        20 UA        1714 N24211  LGA    IAH        227
##  3  2013     1     1      923            850        33 AA        1141 N619AA  JFK    MIA        160
##  4  2013     1     1     1004           1022       -18 B6         725 N804JB  JFK    BQN        183
##  5  2013     1     1      812            837       -25 DL         461 N668DN  LGA    ATL        116
##  6  2013     1     1      740            728        12 UA        1696 N39463  EWR    ORD        150
##  7  2013     1     1      913            854        19 B6         507 N516JB  EWR    FLL        158
##  8  2013     1     1      709            723       -14 EV        5708 N829AS  LGA    IAD         53
##  9  2013     1     1      838            846        -8 B6          79 N593JB  JFK    MCO        140
## 10  2013     1     1      753            745         8 AA         301 N3ALAA  LGA    ORD        138
## # ... with 336,766 more rows
```

```
# using regular expression
select(flights, matches("^(arr|dep)_"))
```

```
## # A tibble: 336,776 x 4
##    dep_time dep_delay arr_time arr_delay
##       <int>     <dbl>    <int>     <dbl>
##  1      517         2      830        11
##  2      533         4      850        20
##  3      542         2      923        33
##  4      544        -1     1004       -18
##  5      554        -6      812       -25
##  6      554        -4      740        12
##  7      555        -5      913        19
##  8      557        -3      709       -14
##  9      557        -3      838        -8
## 10      558        -2      753         8
## # ... with 336,766 more rows
```

```
# of course, we could select everything
select(flights, everything())
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        1
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      554            600        -6      812            837       -25 DL        4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6         
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

```
# move air_time to the front
select(flights, air_time, everything())
```

```
## # A tibble: 336,776 x 19
##    air_time  year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay ca
##       <dbl> <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <ch
##  1      227  2013     1     1      517            515         2      830            819        11 UA
##  2      227  2013     1     1      533            529         4      850            830        20 UA
##  3      160  2013     1     1      542            540         2      923            850        33 AA
##  4      183  2013     1     1      544            545        -1     1004           1022       -18 B6
##  5      116  2013     1     1      554            600        -6      812            837       -25 DL
##  6      150  2013     1     1      554            558        -4      740            728        12 UA
##  7      158  2013     1     1      555            600        -5      913            854        19 B6
##  8       53  2013     1     1      557            600        -3      709            723       -14 EV
##  9      140  2013     1     1      557            600        -3      838            846        -8 B6
## 10      138  2013     1     1      558            600        -2      753            745         8 AA
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

Remarks: - if you just need a single variable, you could use `pull`. - you could use `rename` to rename columns

`filter`: picks cases based on their values

```
filter(flights, origin == "JFK")
```

```
## # A tibble: 111,279 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      542            540         2      923            850        33 AA        1
##  2  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  3  2013     1     1      557            600        -3      838            846        -8 B6         
##  4  2013     1     1      558            600        -2      849            851        -2 B6         
##  5  2013     1     1      558            600        -2      853            856        -3 B6
```

```
##  6  2013     1     1      558            600        -2      924            917         7 UA
##  7  2013     1     1      559            559         0      702            706        -4 B6
##  8  2013     1     1      606            610        -4      837            845        -8 DL
##  9  2013     1     1      611            600        11      945            931        14 UA
## 10  2013     1     1      613            610         3      925            921         4 B6
## # ... with 111,269 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

```
filter(flights, distance > 1000)
```

```
## # A tibble: 147,105 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      555            600        -5      913            854        19 B6         5
##  6  2013     1     1      558            600        -2      849            851        -2 B6         
##  7  2013     1     1      558            600        -2      853            856        -3 B6         
##  8  2013     1     1      558            600        -2      924            917         7 UA         
##  9  2013     1     1      558            600        -2      923            937       -14 UA        11
## 10  2013     1     1      559            600        -1      941            910        31 AA         
## # ... with 147,095 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

```
# note that we are using a single `&` instead of `&&` as in base R
filter(flights, origin == "JFK" & distance > 1000)
```

```
## # A tibble: 62,071 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      542            540         2      923            850        33 AA        11
##  2  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  3  2013     1     1      558            600        -2      849            851        -2 B6         
##  4  2013     1     1      558            600        -2      853            856        -3 B6         
##  5  2013     1     1      558            600        -2      924            917         7 UA         
##  6  2013     1     1      611            600        11      945            931        14 UA         
##  7  2013     1     1      613            610         3      925            921         4 B6         
##  8  2013     1     1      615            615         0     1039           1100       -21 B6         
##  9  2013     1     1      627            630        -3     1018           1018         0 US         
## 10  2013     1     1      628            630        -2     1137           1140        -3 AA         
## # ... with 62,061 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_hou
```

```
filter(flights, distance < 500 | distance > 1000)
```

```
## # A tibble: 227,322 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      555            600        -5      913            854        19 B6         5
```

```
##  6  2013     1     1      557            600        -3      709            723       -14 EV        5
##  7  2013     1     1      558            600        -2      849            851        -2 B6
##  8  2013     1     1      558            600        -2      853            856        -3 B6
##  9  2013     1     1      558            600        -2      924            917         7 UA
## 10  2013     1     1      558            600        -2      923            937       -14 UA        1
## # ... with 227,312 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
filter(flights, !between(distance, 500, 1000))
```

```
## # A tibble: 227,322 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         1
##  5  2013     1     1      555            600        -5      913            854        19 B6         5
##  6  2013     1     1      557            600        -3      709            723       -14 EV        57
##  7  2013     1     1      558            600        -2      849            851        -2 B6
##  8  2013     1     1      558            600        -2      853            856        -3 B6
##  9  2013     1     1      558            600        -2      924            917         7 UA
## 10  2013     1     1      558            600        -2      923            937       -14 UA        1
## # ... with 227,312 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
# only keep the complete cases
filter(flights, complete.cases(flights))
```

```
## # A tibble: 327,346 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         1
##  5  2013     1     1      554            600        -6      812            837       -25 DL         4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 327,336 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

Chaining and piping

Very often, we will need to use multiple `dplyr` verbs, for example

```
filter(select(flights, origin, arr_time), origin == "JFK")
```

```
## # A tibble: 111,279 x 2
##    origin arr_time
##    <chr>     <int>
```

```
##  1 JFK         923
##  2 JFK        1004
##  3 JFK         838
##  4 JFK         849
##  5 JFK         853
##  6 JFK         924
##  7 JFK         702
##  8 JFK         837
##  9 JFK         945
## 10 JFK         925
## # ... with 111,269 more rows
```

```
# the pipe operator %>% increases readability
flights %>%
  select(origin, air_time) %>%
  filter(origin == "JFK") %>%
  filter(air_time < 500) %>%
  rename(airtime = air_time)
```

```
## # A tibble: 108,737 x 2
##    origin airtime
##    <chr>    <dbl>
##  1 JFK        160
##  2 JFK        183
##  3 JFK        140
##  4 JFK        149
##  5 JFK        158
##  6 JFK        345
##  7 JFK         44
##  8 JFK        128
##  9 JFK        366
## 10 JFK        175
## # ... with 108,727 more rows
```

```
# a few more examples
flights %>%
  select(origin, air_time) %>%
  filter(origin == "JFK", air_time < mean(air_time, na.rm = TRUE))
```

```
## # A tibble: 55,521 x 2
##    origin air_time
##    <chr>     <dbl>
##  1 JFK         140
##  2 JFK         149
##  3 JFK          44
##  4 JFK         128
##  5 JFK          41
##  6 JFK          63
##  7 JFK         142
##  8 JFK         147
##  9 JFK          64
## 10 JFK          54
## # ... with 55,511 more rows
```

```r
mean_air_time <- flights %>%
  pull(air_time) %>%
  mean(na.rm = TRUE)
flights %>%
  select(origin, air_time) %>%
  filter(origin == "JFK", air_time > mean_air_time)
```

```
## # A tibble: 53,558 x 2
##    origin air_time
##    <chr>     <dbl>
##  1 JFK         160
##  2 JFK         183
##  3 JFK         158
##  4 JFK         345
##  5 JFK         366
##  6 JFK         175
##  7 JFK         182
##  8 JFK         330
##  9 JFK         192
## 10 JFK         323
## # ... with 53,548 more rows
```

```r
# what if there is a name colision?
air_time <- flights %>%
  pull(air_time) %>%
  mean(na.rm = TRUE)
flights %>%
  select(origin, air_time) %>%
  filter(origin == "JFK", air_time > {{ air_time }})
```

```
## # A tibble: 53,558 x 2
##    origin air_time
##    <chr>     <dbl>
##  1 JFK         160
##  2 JFK         183
##  3 JFK         158
##  4 JFK         345
##  5 JFK         366
##  6 JFK         175
##  7 JFK         182
##  8 JFK         330
##  9 JFK         192
## 10 JFK         323
## # ... with 53,548 more rows
```

```r
# you could use . to represent the working data frame
flights %>%
  filter(complete.cases(.))
```

```
## # A tibble: 327,346 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
```

```
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        1
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      554            600        -6      812            837       -25 DL         
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6         
## 10  2013     1     1      558            600        -2      753            745         8 AA         
## # ... with 327,336 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

In fact, this pipe operator is exported from the package `magrittr` and could be used solely

```
x1 <- 1:5
x2 <- 2:6
sqrt(sum((x2 - x1)^2))
```

```
## [1] 2.236068
```

```
(x2 - x1)^2 %>%
  sum() %>%
  sqrt()
```

```
## [1] 2.236068
```

```
# computer the binomial coefficients
n <- 5
x <- 0:5
choose(n, x)
```

```
## [1]  1  5 10 10  5  1
```

```
n %>% choose(x)
```

```
## [1]  1  5 10 10  5  1
```

```
x %>% choose(n, .)
```

```
## [1]  1  5 10 10  5  1
```

```
list(n = 5, x = 0:5) %>% {
  choose(.$n, .$x)
}
```

```
## [1]  1  5 10 10  5  1
```

PS: use `slice` if you want particular rows

```
flights %>% slice(100:105)
```

```
## # A tibble: 6 x 19
##    year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <int
## 1  2013     1     1      752            759        -7      955            959        -4 US        173
## 2  2013     1     1      753            755        -2     1056           1110       -14 AA        220
## 3  2013     1     1      754            759        -5     1039           1041        -2 DL        204
## 4  2013     1     1      754            755        -1     1103           1030        33 WN         73
## 5  2013     1     1      758            800        -2     1053           1054        -1 B6         51
## 6  2013     1     1      759            800        -1     1057           1127       -30 DL        184
## # ... with 3 more variables: hour <dbl>, minute <dbl>, time_hour <dttm>
```

`mutate`: adds new variables that are functions of existing variables

```
flights %>% mutate(
  gain = arr_delay - dep_delay,
  speed = distance / air_time * 60
)
```

```
## # A tibble: 336,776 x 21
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         1
##  5  2013     1     1      554            600        -6      812            837       -25 DL         4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 336,766 more rows, and 6 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
```

```
# we could refer to the columns just created
flights %>% mutate(
  gain = arr_delay - dep_delay,
  gain_per_hour = gain / (air_time / 60)
)
```

```
## # A tibble: 336,776 x 21
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         1
##  5  2013     1     1      554            600        -6      812            837       -25 DL         4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
```

```
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 336,766 more rows, and 6 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_ho
## #   gain_per_hour <dbl>
```

```
# `transmute` only keep the new variables
flights %>% transmute(
  gain = arr_delay - dep_delay,
  gain_per_hour = gain / (air_time / 60)
)
```

```
## # A tibble: 336,776 x 2
##     gain gain_per_hour
##    <dbl>         <dbl>
##  1     9          2.38
##  2    16          4.23
##  3    31         11.6
##  4   -17         -5.57
##  5   -19         -9.83
##  6    16          6.4
##  7    24          9.11
##  8   -11        -12.5
##  9    -5         -2.14
## 10    10          4.35
## # ... with 336,766 more rows
```

Six variations on ranking functions

- `row_number`: equivalent to `rank(ties.method = "first")`
- `min_rank`: equivalent to `rank(ties.method = "min")`
- `dense_rank`: like `min_rank()`, but with no gaps between ranks
- `percent_rank`: a number between 0 and 1 computed by rescaling min_rank to [0, 1]
- `cume_dist`: a cumulative distribution function. Proportion of all values less than or equal to the current rank.
- `ntile`: a rough rank, which breaks the input vector into n buckets

```
some_data <- tibble(
  x = c(3, 4, 1, 3, 1)
)
some_data %>% mutate(row_number(), row_number(x), min_rank(x), percent_rank(x))
```

```
## # A tibble: 5 x 5
##       x `row_number()` `row_number(x)` `min_rank(x)` `percent_rank(x)`
##   <dbl>          <int>           <int>         <int>              <dbl>
## 1     3              1               3             3                0.5
## 2     4              2               5             5                1
## 3     1              3               1             1                0
## 4     3              4               4             3                0.5
## 5     1              5               2             1                0
```

lead and lag

```
some_data2 <- tibble(
  time = 1:5,
  value = c(3, 4, 1, 3, 1)
)
some_data2 %>% mutate(diff1 = value - lag(value), diff2 = lead(value) - value)
```

```
## # A tibble: 5 x 4
##    time value diff1 diff2
##   <int> <dbl> <dbl> <dbl>
## 1     1     3    NA     1
## 2     2     4     1    -3
## 3     3     1    -3     2
## 4     4     3     2    -2
## 5     5     1    -2    NA
```

Conditional mutation

```
flights %>% transmute(arr_delay,
  status = if_else(arr_delay > 0, "delayed", "on time")
)
```

```
## # A tibble: 336,776 x 2
##    arr_delay status
##        <dbl> <chr>
##  1        11 delayed
##  2        20 delayed
##  3        33 delayed
##  4       -18 on time
##  5       -25 on time
##  6        12 delayed
##  7        19 delayed
##  8       -14 on time
##  9        -8 on time
## 10         8 delayed
## # ... with 336,766 more rows
```

```
flight_distances <- flights %>%
  transmute(distance,
    distance_type = case_when(
      distance < 500 ~ "short",
      distance < 1000 ~ "mid",
      TRUE ~ "long"
    )
  )
flight_distances
```

```
## # A tibble: 336,776 x 2
```

```
##    distance distance_type
##       <dbl> <chr>
##  1     1400 long
##  2     1416 long
##  3     1089 long
##  4     1576 long
##  5      762 mid
##  6      719 mid
##  7     1065 long
##  8      229 short
##  9      944 mid
## 10      733 mid
## # ... with 336,766 more rows
```

recode values

```
flight_distances %>% mutate(distance_type = recode(distance_type,
  long = "long-distance",
  mid = "mid-distance",
  short = "short-distance"
))
```

```
## # A tibble: 336,776 x 2
##    distance distance_type
##       <dbl> <chr>
##  1     1400 long-distance
##  2     1416 long-distance
##  3     1089 long-distance
##  4     1576 long-distance
##  5      762 mid-distance
##  6      719 mid-distance
##  7     1065 long-distance
##  8      229 short-distance
##  9      944 mid-distance
## 10      733 mid-distance
## # ... with 336,766 more rows
```

arrange: changes the ordering of the rows

```
flights %>% arrange(year, month, day)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier fli
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <i
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        1
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      554            600        -6      812            837       -25 DL        4
```

```
##  6  2013     1     1      554            558        -4      740            728        12 UA        1
##  7  2013     1     1      555            600        -5      913            854        19 B6        
##  8  2013     1     1      557            600        -3      709            723       -14 EV        5
##  9  2013     1     1      557            600        -3      838            846        -8 B6        
## 10  2013     1     1      558            600        -2      753            745         8 AA        
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
flights %>% arrange(desc(dep_delay))
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     9      641            900      1301     1242           1530      1272 HA        
##  2  2013     6    15     1432           1935      1137     1607           2120      1127 MQ        3
##  3  2013     1    10     1121           1635      1126     1239           1810      1109 MQ        3
##  4  2013     9    20     1139           1845      1014     1457           2210      1007 AA        
##  5  2013     7    22      845           1600      1005     1044           1815       989 MQ        3
##  6  2013     4    10     1100           1900       960     1342           2211       931 DL        2
##  7  2013     3    17     2321            810       911      135           1020       915 DL        2
##  8  2013     6    27      959           1900       899     1236           2226       850 DL        2
##  9  2013     7    22     2257            759       898      121           1026       895 DL        2
## 10  2013    12     5      756           1700       896     1058           2020       878 AA        
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

summarize and group_by operations

```
flights %>%
  group_by(tailnum) %>%
  summarize()
```

```
## # A tibble: 4,044 x 1
##    tailnum
##    <chr>
##  1 D942DN
##  2 N0EGMQ
##  3 N10156
##  4 N102UW
##  5 N103US
##  6 N104UW
##  7 N10575
##  8 N105UW
##  9 N107US
## 10 N108UW
## # ... with 4,034 more rows
```

```
flights %>%
  group_by(tailnum) %>%
  tally() # shorthand
```

```
## # A tibble: 4,044 x 2
```

```
##    tailnum     n
##    <chr>   <int>
##  1 D942DN      4
##  2 N0EGMQ    371
##  3 N10156    153
##  4 N102UW     48
##  5 N103US     46
##  6 N104UW     47
##  7 N10575    289
##  8 N105UW     45
##  9 N107US     41
## 10 N108UW     60
## # ... with 4,034 more rows
```

```
flights %>% count(tailnum) # another shorthand
```

```
## # A tibble: 4,044 x 2
##    tailnum     n
##    <chr>   <int>
##  1 D942DN      4
##  2 N0EGMQ    371
##  3 N10156    153
##  4 N102UW     48
##  5 N103US     46
##  6 N104UW     47
##  7 N10575    289
##  8 N105UW     45
##  9 N107US     41
## 10 N108UW     60
## # ... with 4,034 more rows
```

```
flights %>%
  group_by(tailnum) %>%
  summarize(
    count = n(),
    dist = mean(distance, na.rm = TRUE),
    delay = mean(arr_delay, na.rm = TRUE)
  )
```

```
## # A tibble: 4,044 x 4
##    tailnum count  dist  delay
##    <chr>   <int> <dbl>  <dbl>
##  1 D942DN      4  854. 31.5
##  2 N0EGMQ    371  676.  9.98
##  3 N10156    153  758. 12.7
##  4 N102UW     48  536.  2.94
##  5 N103US     46  535. -6.93
##  6 N104UW     47  535.  1.80
##  7 N10575    289  520. 20.7
##  8 N105UW     45  525. -0.267
##  9 N107US     41  529. -5.73
## 10 N108UW     60  534. -1.25
## # ... with 4,034 more rows
```

```r
flights %>%
  group_by(dest) %>%
  summarize(
    planes = n_distinct(tailnum),
    flights = n()
  )
```

```
## # A tibble: 105 x 3
##    dest  planes flights
##    <chr>  <int>   <int>
##  1 ABQ      108     254
##  2 ACK       58     265
##  3 ALB      172     439
##  4 ANC        6       8
##  5 ATL     1180   17215
##  6 AUS      993    2439
##  7 AVL      159     275
##  8 BDL      186     443
##  9 BGR       46     375
## 10 BHM       45     297
## # ... with 95 more rows
```

```r
# group multiple variables

(per_day <- flights %>%
  group_by(year, month, day) %>%
  summarize(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
```

```r
(per_month <- per_day %>%
  summarize(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
```

```
(per_year <- per_month %>%
  summarize(flights = sum(flights)))
```

```
## # A tibble: 1 x 2
##    year flights
##   <int>   <int>
## 1  2013  336776
```

Other useful functions

```
flights %>% glimpse()
```

```
## Observations: 336,776
## Variables: 19
## $ year           <int> 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013, 2013,
## $ month          <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
## $ day            <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
## $ dep_time       <int> 517, 533, 542, 544, 554, 554, 555, 557, 557, 558, 558, 558, 558, 558, 559, 559
## $ sched_dep_time <int> 515, 529, 540, 545, 600, 558, 600, 600, 600, 600, 600, 600, 600, 600, 600, 559
## $ dep_delay      <dbl> 2, 4, 2, -1, -6, -4, -5, -3, -3, -2, -2, -2, -2, -2, -1, 0, -1, 0, 0, 1, -8,
## $ arr_time       <int> 830, 850, 923, 1004, 812, 740, 913, 709, 838, 753, 849, 853, 924, 923, 941, 7
## $ sched_arr_time <int> 819, 830, 850, 1022, 837, 728, 854, 723, 846, 745, 851, 856, 917, 937, 910, 7
## $ arr_delay      <dbl> 11, 20, 33, -18, -25, 12, 19, -14, -8, 8, -2, -3, 7, -14, 31, -4, -8, -7, 12,
## $ carrier        <chr> "UA", "UA", "AA", "B6", "DL", "UA", "B6", "EV", "B6", "AA", "B6", "B6", "UA",
## $ flight         <int> 1545, 1714, 1141, 725, 461, 1696, 507, 5708, 79, 301, 49, 71, 194, 1124, 707,
## $ tailnum        <chr> "N14228", "N24211", "N619AA", "N804JB", "N668DN", "N39463", "N516JB", "N829AS
## $ origin         <chr> "EWR", "LGA", "JFK", "JFK", "LGA", "EWR", "EWR", "LGA", "JFK", "LGA", "JFK",
## $ dest           <chr> "IAH", "IAH", "MIA", "BQN", "ATL", "ORD", "FLL", "IAD", "MCO", "ORD", "PBI",
## $ air_time       <dbl> 227, 227, 160, 183, 116, 150, 158, 53, 140, 138, 149, 158, 345, 361, 257, 44,
## $ distance       <dbl> 1400, 1416, 1089, 1576, 762, 719, 1065, 229, 944, 733, 1028, 1005, 2475, 2565
## $ hour           <dbl> 5, 5, 5, 5, 6, 5, 6, 6, 6, 6, 6, 6, 6, 6, 6, 5, 6, 6, 6, 6, 6, 6, 6, 6, 6,
## $ minute         <dbl> 15, 29, 40, 45, 0, 58, 0, 0, 0, 0, 0, 0, 0, 0, 0, 59, 0, 0, 0, 0, 10, 5, 10,
## $ time_hour      <dttm> 2013-01-01 05:00:00, 2013-01-01 05:00:00, 2013-01-01 05:00:00, 2013-01-01 05
```

```
flights %>% sample_n(5)
```

```
## # A tibble: 5 x 19
##    year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
```

```
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
## 1  2013     2     1      956            957        -1     1129           1125         4 EV        418
## 2  2013     7     1       NA            955        NA       NA           1115        NA MQ        367
## 3  2013     2     9     2010           2000        10     2148           2146         2 9E        331
## 4  2013     8    30     2058           1829       149     2232           2010       142 UA          20
## 5  2013     1    26     1811           1810         1     2044           2035         9 9E        354
## # ... with 3 more variables: hour <dbl>, minute <dbl>, time_hour <dttm>
```

```
## rows with smallest values of air_time with the original order preserved
flights %>% top_n(3, air_time)
```

```
## # A tibble: 4 x 19
##    year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##   <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
## 1  2013     2     6      853            900        -7     1542           1540         2 HA           5
## 2  2013     3    15     1001           1000         1     1551           1530        21 HA           5
## 3  2013     3    17     1006           1000         6     1607           1530        37 HA           5
## 4  2013     3    17     1337           1335         2     1937           1836        61 UA           1
## # ... with 3 more variables: hour <dbl>, minute <dbl>, time_hour <dttm>
```

Some variations of verbs

`tidyverse` also ships with some variations of verbs which could be useful.

```
# only select columns which are numerical
flights %>% select_if(is.numeric)
```

```
## # A tibble: 336,776 x 14
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay flight air_
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl>  <int>    <
##  1  2013     1     1      517            515         2      830            819        11   1545
##  2  2013     1     1      533            529         4      850            830        20   1714
##  3  2013     1     1      542            540         2      923            850        33   1141
##  4  2013     1     1      544            545        -1     1004           1022       -18    725
##  5  2013     1     1      554            600        -6      812            837       -25    461
##  6  2013     1     1      554            558        -4      740            728        12   1696
##  7  2013     1     1      555            600        -5      913            854        19    507
##  8  2013     1     1      557            600        -3      709            723       -14   5708
##  9  2013     1     1      557            600        -3      838            846        -8     79
## 10  2013     1     1      558            600        -2      753            745         8    301
## # ... with 336,766 more rows
```

```
flights %>% select_if(~ is.numeric(.))
```

```
## # A tibble: 336,776 x 14
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay flight air_
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl>  <int>    <
##  1  2013     1     1      517            515         2      830            819        11   1545
##  2  2013     1     1      533            529         4      850            830        20   1714
##  3  2013     1     1      542            540         2      923            850        33   1141
##  4  2013     1     1      544            545        -1     1004           1022       -18    725
```

```
##  5  2013     1     1      554            600        -6      812            837       -25    461
##  6  2013     1     1      554            558        -4      740            728        12   1696
##  7  2013     1     1      555            600        -5      913            854        19    507
##  8  2013     1     1      557            600        -3      709            723       -14   5708
##  9  2013     1     1      557            600        -3      838            846        -8     79
## 10  2013     1     1      558            600        -2      753            745         8    301
## # ... with 336,766 more rows
```

```
flights %>% select_if(~ !is.numeric(.))
```

```
## # A tibble: 336,776 x 5
##    carrier tailnum origin dest  time_hour
##    <chr>   <chr>   <chr>  <chr> <dttm>
##  1 UA      N14228  EWR    IAH   2013-01-01 05:00:00
##  2 UA      N24211  LGA    IAH   2013-01-01 05:00:00
##  3 AA      N619AA  JFK    MIA   2013-01-01 05:00:00
##  4 B6      N804JB  JFK    BQN   2013-01-01 05:00:00
##  5 DL      N668DN  LGA    ATL   2013-01-01 06:00:00
##  6 UA      N39463  EWR    ORD   2013-01-01 05:00:00
##  7 B6      N516JB  EWR    FLL   2013-01-01 06:00:00
##  8 EV      N829AS  LGA    IAD   2013-01-01 06:00:00
##  9 B6      N593JB  JFK    MCO   2013-01-01 06:00:00
## 10 AA      N3ALAA  LGA    ORD   2013-01-01 06:00:00
## # ... with 336,766 more rows
```

```
flights %>% rename_if(is.numeric, toupper)
```

```
## # A tibble: 336,776 x 19
##     YEAR MONTH   DAY DEP_TIME SCHED_DEP_TIME DEP_DELAY ARR_TIME SCHED_ARR_TIME ARR_DELAY carrier FLI
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <i
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        11
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6         
##  5  2013     1     1      554            600        -6      812            837       -25 DL         4
##  6  2013     1     1      554            558        -4      740            728        12 UA        10
##  7  2013     1     1      555            600        -5      913            854        19 B6         5
##  8  2013     1     1      557            600        -3      709            723       -14 EV        57
##  9  2013     1     1      557            600        -3      838            846        -8 B6         
## 10  2013     1     1      558            600        -2      753            745         8 AA         3
## # ... with 336,766 more rows, and 4 more variables: DISTANCE <dbl>, HOUR <dbl>, MINUTE <dbl>, time_ho
```

```
flights %>% mutate_if(
  ~ is.numeric(.) && is.double(.),
  round
)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <i
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
```

```
##  3  2013     1     1      542            540         2      923            850        33 AA        1
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6        
##  5  2013     1     1      554            600        -6      812            837       -25 DL        
##  6  2013     1     1      554            558        -4      740            728        12 UA        1
##  7  2013     1     1      555            600        -5      913            854        19 B6        
##  8  2013     1     1      557            600        -3      709            723       -14 EV        5
##  9  2013     1     1      557            600        -3      838            846        -8 B6        
## 10  2013     1     1      558            600        -2      753            745         8 AA        
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
flights %>% filter_if(
  ~ is.numeric(.),
  any_vars(. != 2013)
)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier flig
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <in
##  1  2013     1     1      517            515         2      830            819        11 UA        15
##  2  2013     1     1      533            529         4      850            830        20 UA        17
##  3  2013     1     1      542            540         2      923            850        33 AA        1
##  4  2013     1     1      544            545        -1     1004           1022       -18 B6        
##  5  2013     1     1      554            600        -6      812            837       -25 DL        
##  6  2013     1     1      554            558        -4      740            728        12 UA        16
##  7  2013     1     1      555            600        -5      913            854        19 B6        
##  8  2013     1     1      557            600        -3      709            723       -14 EV        5
##  9  2013     1     1      557            600        -3      838            846        -8 B6        
## 10  2013     1     1      558            600        -2      753            745         8 AA        
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
flights %>% rename_at(
  vars(starts_with("arr_")),
  ~ str_replace(., "arr_", "arrival_")
)
```

```
## # A tibble: 336,776 x 19
##     year month   day dep_time sched_dep_time dep_delay arrival_time sched_arr_time arrival_delay cari
##    <int> <int> <int>    <int>          <int>     <dbl>        <int>          <int>         <dbl> <ch
##  1  2013     1     1      517            515         2          830            819            11 UA
##  2  2013     1     1      533            529         4          850            830            20 UA
##  3  2013     1     1      542            540         2          923            850            33 AA
##  4  2013     1     1      544            545        -1         1004           1022           -18 B6
##  5  2013     1     1      554            600        -6          812            837           -25 DL
##  6  2013     1     1      554            558        -4          740            728            12 UA
##  7  2013     1     1      555            600        -5          913            854            19 B6
##  8  2013     1     1      557            600        -3          709            723           -14 EV
##  9  2013     1     1      557            600        -3          838            846            -8 B6
## 10  2013     1     1      558            600        -2          753            745             8 AA
## # ... with 336,766 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

```
flights %>% filter_at(
  vars(ends_with("_time"), -air_time),
  all_vars(. >= 1200)
)
```

```
## # A tibble: 183,159 x 19
##     year month   day dep_time sched_dep_time dep_delay arr_time sched_arr_time arr_delay carrier fli
##    <int> <int> <int>    <int>          <int>     <dbl>    <int>          <int>     <dbl> <chr>    <i
##  1  2013     1     1     1200           1200         0     1408           1356        12 US        1
##  2  2013     1     1     1202           1207        -5     1318           1314         4 EV        4
##  3  2013     1     1     1203           1205        -2     1501           1437        24 EV        3
##  4  2013     1     1     1203           1200         3     1519           1545       -26 VX
##  5  2013     1     1     1204           1200         4     1500           1448        12 B6
##  6  2013     1     1     1205           1200         5     1503           1505        -2 UA        1
##  7  2013     1     1     1206           1209        -3     1325           1328        -3 EV        4
##  8  2013     1     1     1211           1215        -4     1423           1413        10 EV        4
##  9  2013     1     1     1217           1220        -3     1414           1350        24 MQ        3
## 10  2013     1     1     1217           1218        -1     1525           1529        -4 UA
## # ... with 183,149 more rows, and 4 more variables: distance <dbl>, hour <dbl>, minute <dbl>, time_h
```

Two-table verbs

There are 4 types of joins.

- `inner_join(x, y)` only includes observations that match in both x and y
- `left_join(x, y)` includes all observations in x, regardless of whether they match or not.
- `right_join(x, y)` equivalent to left_join(y, x)
- `full_join(x, y)` includes all observations from x and y

```
df1 <- tibble(x = c(1, 2), y = 2:1)
df2 <- tibble(x = c(1, 3), a = 10, b = "a")
```

```
df1 %>% inner_join(df2)
```

```
## Joining, by = "x"
```

```
## # A tibble: 1 x 4
##       x     y     a b
##   <dbl> <int> <dbl> <chr>
## 1     1     2    10 a
```

```
df1 %>% left_join(df2)
```

```
## Joining, by = "x"
```

```
## # A tibble: 2 x 4
##       x     y     a b
##   <dbl> <int> <dbl> <chr>
## 1     1     2    10 a
## 2     2     1    NA <NA>
```

```
df1 %>% right_join(df2)
```

```
## Joining, by = "x"
```

```
## # A tibble: 2 x 4
##       x     y     a b
##   <dbl> <int> <dbl> <chr>
## 1     1     2    10 a
## 2     3    NA    10 a
```

```
df1 %>% full_join(df2)
```

```
## Joining, by = "x"
```

```
## # A tibble: 3 x 4
##       x     y     a b
##   <dbl> <int> <dbl> <chr>
## 1     1     2    10 a
## 2     2     1    NA <NA>
## 3     3    NA    10 a
```

Tidy Data

There are three interrelated rules which make a dataset tidy

- Each variable must have its own column (long format).
- Each observation must have its own row (wide format).
- Each value must have its own cell.

Using the datasets from R for Data Science to show that the same data could be organised in different ways.

```
# make sure you have tidyr 1.0
library(tidyr)
```

Privot longer

```
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
```

```
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
```

Privot wider

```
fish_encounters %>% pivot_wider(
  names_from = station,
  values_from = seen,
  values_fill = list(seen = 0)
)
```

```
## # A tibble: 19 x 12
##    fish  Release I80_1 Lisbon  Rstr Base_TD   BCE   BCW  BCE2  BCW2   MAE   MAW
##    <fct>   <int> <int>  <int> <int>   <int> <int> <int> <int> <int> <int> <int>
##  1 4842        1     1      1     1       1     1     1     1     1     1     1
##  2 4843        1     1      1     1       1     1     1     1     1     1     1
##  3 4844        1     1      1     1       1     1     1     1     1     1     1
##  4 4845        1     1      1     1       1     0     0     0     0     0     0
##  5 4847        1     1      1     0       0     0     0     0     0     0     0
##  6 4848        1     1      1     1       0     0     0     0     0     0     0
##  7 4849        1     1      0     0       0     0     0     0     0     0     0
##  8 4850        1     1      0     1       1     1     1     0     0     0     0
##  9 4851        1     1      0     0       0     0     0     0     0     0     0
## 10 4854        1     1      0     0       0     0     0     0     0     0     0
## 11 4855        1     1      1     1       1     0     0     0     0     0     0
## 12 4857        1     1      1     1       1     1     1     1     1     0     0
## 13 4858        1     1      1     1       1     1     1     1     1     1     1
## 14 4859        1     1      1     1       1     0     0     0     0     0     0
## 15 4861        1     1      1     1       1     1     1     1     1     1     1
```

```
## 16 4862        1     1      1     1       1     1     1     1     1     0     0
## 17 4863        1     1      0     0       0     0     0     0     0     0     0
## 18 4864        1     1      0     0       0     0     0     0     0     0     0
## 19 4865        1     1      1     0       0     0     0     0     0     0     0
```

```
us_rent_income %>%
  pivot_wider(names_from = variable, values_from = c(estimate, moe))
```

```
## # A tibble: 52 x 6
##    GEOID NAME                 estimate_income estimate_rent moe_income moe_rent
##    <chr> <chr>                          <dbl>         <dbl>      <dbl>    <dbl>
##  1 01    Alabama                        24476           747        136        3
##  2 02    Alaska                         32940          1200        508       13
##  3 04    Arizona                        27517           972        148        4
##  4 05    Arkansas                       23789           709        165        5
##  5 06    California                     29454          1358        109        3
##  6 08    Colorado                       32401          1125        109        5
##  7 09    Connecticut                    35326          1123        195        5
##  8 10    Delaware                       31560          1076        247       10
##  9 11    District of Columbia           43198          1424        681       17
## 10 12    Florida                        25952          1077         70        3
## # ... with 42 more rows
```

Reference:

- Documentation of dplyr https://dplyr.tidyverse.org/
- R for Data Science http://r4ds.had.co.nz/tidy-data.html