Tidy data & dplyr

Lecture 06

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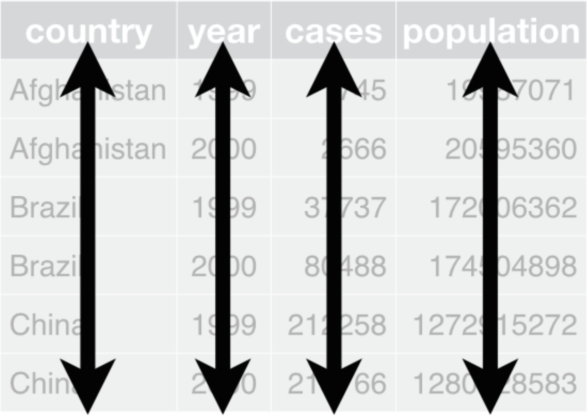
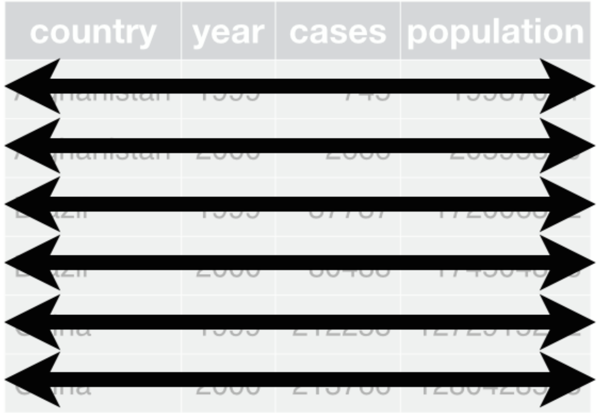
tidyverse
www.rstudio.com

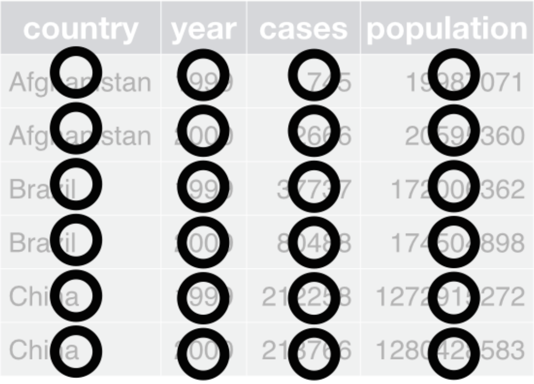
Tidy data



variables



observations



values

From R4DS - tidy data

Tidy vs Untidy

> Happy families are all alike; every unhappy family is unhappy in its own way
>
> — Leo Tolstoy, Anna Karenina

```
# A tibble: 317 × 7
   artist         track                   date.ent…¹   wk1   wk2   wk3   wk4
   <chr>          <chr>                   <date>     <dbl> <dbl> <dbl> <dbl>
 1 2 Pac          Baby Don't Cry (Keep.… 2000-02-26    87    82    72    77
 2 2Ge+her        The Hardest Part Of …  2000-09-02    91    87    92    NA
 3 3 Doors Down   Kryptonite              2000-04-08    81    70    68    67
 4 3 Doors Down   Loser                   2000-10-21    76    76    72    69
 5 504 Boyz       Wobble Wobble           2000-04-15    57    34    25    17
 6 98^0           Give Me Just One Nig.… 2000-08-19    51    39    34    26
 7 A*Teens        Dancing Queen           2000-07-08    97    97    96    95
 8 Aaliyah        I Don't Wanna           2000-01-29    84    62    51    41
 9 Aaliyah        Try Again               2000-03-18    59    53    38    28
10 Adams, Yolanda Open My Heart           2000-08-26    76    76    74    69
```

Is the above data set tidy?

More tidy vs untidy

Is the following data tidy?

```
List of 3
 $ :List of 8
  ..$ name      : chr "Luke Skywalker"
  ..$ height    : chr "172"
  ..$ mass      : chr "77"
  ..$ hair_color: chr "blond"
  ..$ skin_color: chr "fair"
  ..$ eye_color : chr "blue"
  ..$ birth_year: chr "19BBY"
  ..$ gender    : chr "male"
 $ :List of 8
  ..$ name      : chr "C-3PO"
  ..$ height    : chr "167"
```

```
List of 3
 $ :List of 8
  ..$ name      : chr "Darth Vader"
  ..$ height    : chr "202"
  ..$ mass      : chr "136"
  ..$ hair_color: chr "none"
  ..$ skin_color: chr "white"
  ..$ eye_color : chr "yellow"
  ..$ birth_year: chr "41.9BBY"
  ..$ gender    : chr "male"
 $ :List of 8
  ..$ name      : chr "Leia Organa"
  ..$ height    : chr "150"
```

TIBBLE
www.rstudio.com

Modern data frames

The tidyverse includes the tibble package that extends data frames to be a bit more modern. The core features of tibbles is to have a nicer printing method as well as being “surly” and “lazy”.

```r
library(tibble)
```

```r
iris
```

```
   Sepal.Length Sepal.Width Petal.Length
1           5.1         3.5          1.4
2           4.9         3.0          1.4
3           4.7         3.2          1.3
4           4.6         3.1          1.5
5           5.0         3.6          1.4
6           5.4         3.9          1.7
7           4.6         3.4          1.4
8           5.0         3.4          1.5
9           4.4         2.9          1.4
10          4.9         3.1          1.5
11          5.4         3.7          1.5
12          4.8         3.4          1.6
13          4.8         3.0          1.4
14          4.3         3.0          1.1
15          5.8         4.0          1.2
16          5.7         4.4          1.5
```

```r
(tbl_iris = as_tibble(iris))
```

```
# A tibble: 150 × 5
   Sepal.Length Sepal.Wi…¹ Petal…² Petal…³ Species
          <dbl>      <dbl>   <dbl>   <dbl> <fct>
 1          5.1        3.5     1.4     0.2 setosa
 2          4.9        3       1.4     0.2 setosa
 3          4.7        3.2     1.3     0.2 setosa
 4          4.6        3.1     1.5     0.2 setosa
 5          5          3.6     1.4     0.2 setosa
 6          5.4        3.9     1.7     0.4 setosa
 7          4.6        3.4     1.4     0.3 setosa
 8          5          3.4     1.5     0.2 setosa
 9          4.4        2.9     1.4     0.2 setosa
10          4.9        3.1     1.5     0.1 setosa
# … with 140 more rows, and abbreviated variable
#   names ¹Sepal.Width, ²Petal.Length,
#   ³Petal.Width
```

Tibbles are lazy

By default, subsetting tibbles always results in another tibble (`$` or `[[` can still be used to subset for a specific column). I.e. tibble subsets are always preserving and therefore type consistent.

```r
tbl_iris[1,]
```

```
# A tibble: 1 × 5
  Sepal.Length Sepal.Width Petal.Length Petal.Width Species
         <dbl>       <dbl>        <dbl>       <dbl> <fct>
1          5.1         3.5          1.4         0.2 setosa
```

More laziness - partial matching

Tibbles do not use partial matching when the `$` operator is used.

```r
head( iris$Species )
```

```
[1] setosa setosa setosa setosa setosa
setosa
Levels: setosa versicolor virginica
```

```r
head( iris$Sp )
```

```
[1] setosa setosa setosa setosa setosa
setosa
Levels: setosa versicolor virginica
```

```r
head( tbl_iris$Species )
```

```
[1] setosa setosa setosa setosa setosa
setosa
Levels: setosa versicolor virginica
```

```r
head( tbl_iris$Sp )
```

```
NULL
```

More laziness - stringsAsFactors

Tibbles also have always had `stringsAsFactors = FALSE` as default behavior.

```r
(t = tibble(
  x = 1:3,
  y = c("A","B","C"),
  z = factor(c("X","Y","Z"))
))
```

```
# A tibble: 3 × 3
      x y     z    
  <int> <chr> <fct>
1     1 A     X    
2     2 B     Y    
3     3 C     Z    
```

Tibbles and length coercion

Only vectors with length 1 will undergo length coercion - everything else will throw an error.

```r
data.frame(x = 1:4, y = 1)
```

```
  x y
1 1 1
2 2 1
3 3 1
4 4 1
```

```r
tibble(x = 1:4, y = 1)
```

```
# A tibble: 4 × 2
      x     y
  <int> <dbl>
1     1     1
2     2     1
3     3     1
4     4     1
```

```r
data.frame(x = 1:4, y = 1:2)
```

```
  x y
1 1 1
2 2 2
3 3 1
4 4 2
```

```r
tibble(x = 1:4, y = 1:2)
```

```
Error:
! Tibble columns must have compatible
sizes.
• Size 4: Existing data.
• Size 2: Column `y`.
ℹ Only values of size one are recycled.
```

Tibbles and S3

```r
t = tibble(
  x = 1:3,
  y = c("A","B","C")
)

class(t)
```

```
[1] "tbl_df"     "tbl"        "data.frame"
```

```r
d = data.frame(
  x = 1:3,
  y = c("A","B","C")
)

class(d)
```

```
[1] "data.frame"
```

```r
methods(class="tbl_df")
```

```
 [1] [             [[            [[<-          [<-           $            
 [6] $<-           as.data.frame coerce        initialize    names<-      
[11] Ops           row.names<-   show          slotsFromS3   str          
[16] tbl_sum      
see '?methods' for accessing help and source code
```

```r
methods(class="tbl")
```

```
 [1] [[<-        [<-         $<-         coerce      format     
 [6] glimpse     initialize  Ops         print       show       
[11] slotsFromS3 tbl_sum    
see '?methods' for accessing help and source code
```

Supporting tibbles?

```r
d = tibble(
  x = rnorm(100),
  y = 3 + x + rnorm(100, sd = 0.1)
)
```

```r
lm(y~x, data = d)
```

```

Call:
lm(formula = y ~ x, data = d)

Coefficients:
(Intercept)            x  
     2.9947       0.9954  
```

Why did this work?

magrittr

What is a pipe

> In software engineering, a pipeline consists of a chain of processing elements (processes, threads, coroutines, functions, etc.), arranged so that the output of each element is the input of the next; - Wikipedia - Pipeline (software)

Magrittr’s pipe is a new infix operator that allows us to link two functions together in a way that is readable from left to right.

The two code examples below are equivalent,

```
f(g(x=1, y=2), n=2)
```

```
g(x=1, y=2) %>% f(n=2)
```

Readability

Consider the following sequence of actions that describe the process of getting to campus in the morning:

I need to find my key, then unlock my car, then start my car, then drive to school, then park.

Expressed as a set of nested functions in R pseudocode this would look like:

```r
park(drive(start_car(find("keys")), to="campus"))
```

Writing it out using pipes give it a more natural (and easier to read) structure:

```r
find("keys") %>%
    start_car() %>%
    drive(to="campus") %>%
    park()
```

Approaches

All of the following are fine, it comes down to personal preference:

Nested:

```r
h( g( f(x), y=1), z=1 )
```

Piped:

```r
f(x) %>%
  g(y=1) %>%
  h(z=1)
```

Intermediate:

```r
res = f(x)
res = g(res, y=1)
res = h(res, z=1)
```

What about other arguments?

Sometimes we want to send our results to an function argument other than first one or we want to use the previous result for multiple arguments. In these cases we can refer to the previous result using `.`.

```r
data.frame(a = 1:3, b = 3:1) %>% lm(a~b, data=.)
```

```

Call:
lm(formula = a ~ b, data = .)

Coefficients:
(Intercept)            b  
          4           -1  
```

```r
data.frame(a = 1:3, b = 3:1) %>% .[[1]]
```

```
[1] 1 2 3
```

```r
data.frame(a = 1:3, b = 3:1) %>% .[[length(.)]]
```

```
[1] 3 2 1
```

The base R pipe

As of R v4.1.0 a pipe operator has been added to the base language in R, it is implemented as `|>`.

```r
1:10 |> cumsum()
```

```
 [1]  1  3  6 10 15 21 28 36 45 55
```

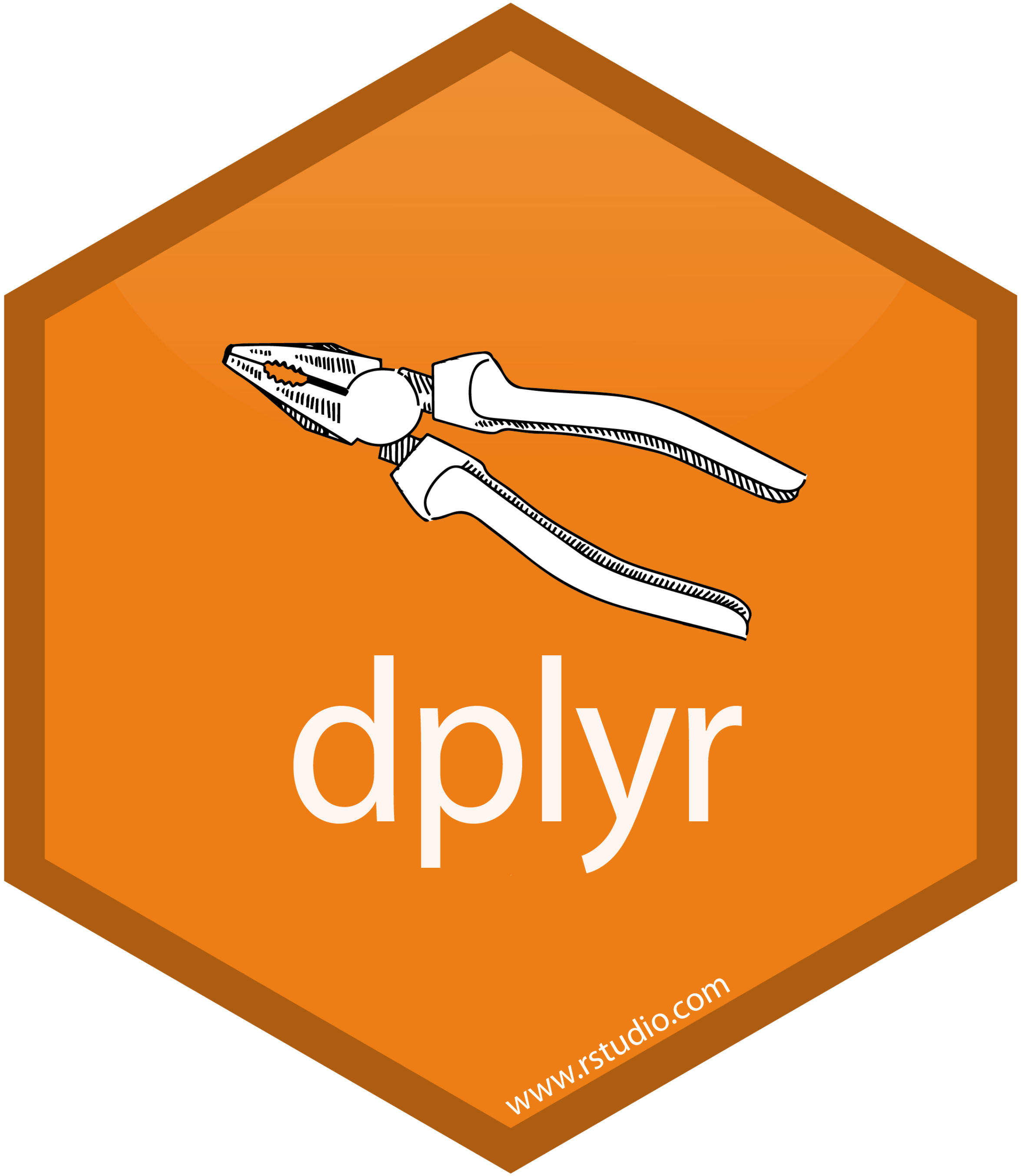
```r
1:10 |> cumsum() |> mean()
```

```
[1] 22
```

The current version of RStudio on the departmental servers is v4.1 so you are welcome to try it out.

Base R pipe considerations:

- Depending an R version >= 4.1 is a harder dependency than depending on the magrittr package
- `|>` does not support using `.` to pass returned values to other argument positions
- `|>` will likely have less overhead than `%>%` but the difference is unlikely to matter in practice
- `|>` supports an equivalent to `.` using `_` as of R v4.2


dplyr
www.rstudio.com

A Grammar of Data Manipulation

dplyr is based on the concepts of functions as verbs that manipulate data frames.

Core single data frame functions / verbs:

- `filter()` / `slice()`: pick rows based on criteria
- `select()` / `rename()`: select columns by name
- `pull()`: grab a column as a vector
- `arrange()`: reorder rows
- `mutate()` / `transmute()`: create or modify columns
- `distinct()`: filter for unique rows
- `summarise()` / `count()`: reduce variables to values
- `group_by()` / `ungroup()`: modify other verbs to act on subsets
- `relocate()`: change column order
- … (many more)

dplyr heuristics

1. First argument is *always* a data frame
2. Subsequent arguments say what to do with that data frame
3. *Always* return a data frame
4. Don’t modify in place
5. Magic via lazy evaluation

Example Data

We will demonstrate dplyr’s functionality using the nycflights13 data.

```r
library(dplyr)
library(nycflights13)
```

```r
flights
```

```
# A tibble: 336,776 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     1     1      517           515       2     830     819      11
 2  2013     1     1      533           529       4     850     830      20
 3  2013     1     1      542           540       2     923     850      33
 4  2013     1     1      544           545      -1    1004    1022     -18
 5  2013     1     1      554           600      -6     812     837     -25
 6  2013     1     1      554           558      -4     740     728      12
 7  2013     1     1      555           600      -5     913     854      19
 8  2013     1     1      557           600      -3     709     723     -14
 9  2013     1     1      557           600      -3     838     846      -8
10  2013     1     1      558           600      -2     753     745       8
# … with 336,766 more rows, 10 more variables: carrier <chr>,
```

filter() - March flights

```r
flights %>% filter(month == 3)
```

```
# A tibble: 28,834 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     3     1        4          2159     125     318      56     142
 2  2013     3     1       50          2358      52     526     438      48
 3  2013     3     1      117          2245     152     223    2354     149
 4  2013     3     1      454           500      -6     633     648     -15
 5  2013     3     1      505           515     -10     746     810     -24
 6  2013     3     1      521           530      -9     813     827     -14
 7  2013     3     1      537           540      -3     856     850       6
 8  2013     3     1      541           545      -4    1014    1023      -9
 9  2013     3     1      549           600     -11     639     703     -24
10  2013     3     1      550           600     -10     747     801     -14
```

filter() - Flights in the first 7 days of March

```r
flights %>% filter(month == 3, day <= 7)
```

```
# A tibble: 6,530 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     3     1        4          2159     125     318      56     142
 2  2013     3     1       50          2358      52     526     438      48
 3  2013     3     1      117          2245     152     223    2354     149
 4  2013     3     1      454           500      -6     633     648     -15
 5  2013     3     1      505           515     -10     746     810     -24
 6  2013     3     1      521           530      -9     813     827     -14
 7  2013     3     1      537           540      -3     856     850       6
 8  2013     3     1      541           545      -4    1014    1023      -9
 9  2013     3     1      549           600     -11     639     703     -24
10  2013     3     1      550           600      10     747     801      14
```

filter() - Flights to LAX *or* JFK in March

```r
flights %>% filter(dest == "LAX" | dest == "JFK", month==3)
```

```
# A tibble: 1,178 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     3     1      607           610      -3     832     925     -53
 2  2013     3     1      629           632      -3     844     952     -68
 3  2013     3     1      657           700      -3     953    1034     -41
 4  2013     3     1      714           715      -1     939    1037     -58
 5  2013     3     1      716           710       6     958    1035     -37
 6  2013     3     1      727           730      -3    1007    1100     -53
 7  2013     3     1      836           840      -4    1111    1157     -46
 8  2013     3     1      857           900      -3    1202    1221     -19
 9  2013     3     1      903           900       3    1157    1220     -23
10  2013     3     1      904           831      33    1150    1151       1
```

slice() - First 10 flights

```r
flights %>% slice(1:10)
```

```
# A tibble: 10 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     1     1      517           515       2     830     819      11
 2  2013     1     1      533           529       4     850     830      20
 3  2013     1     1      542           540       2     923     850      33
 4  2013     1     1      544           545      -1    1004    1022     -18
 5  2013     1     1      554           600      -6     812     837     -25
 6  2013     1     1      554           558      -4     740     728      12
 7  2013     1     1      555           600      -5     913     854      19
 8  2013     1     1      557           600      -3     709     723     -14
 9  2013     1     1      557           600      -3     838     846      -8
10  2013     1     1      558           600      -2     753     745       8
```

slice() - Last 5 flights

```r
flights %>% slice((n()-4):n())
```

```
# A tibble: 5 × 19
   year month   day dep_t…¹ sched…² dep_d…³ arr_t…⁴ sched…⁵ arr_d…⁶ carrier
  <int> <int> <int>   <int>   <int>   <dbl>   <int>   <int>   <dbl> <chr>  
1  2013     9    30      NA    1455      NA      NA    1634      NA 9E     
2  2013     9    30      NA    2200      NA      NA    2312      NA 9E     
3  2013     9    30      NA    1210      NA      NA    1330      NA MQ     
4  2013     9    30      NA    1159      NA      NA    1344      NA MQ     
5  2013     9    30      NA     840      NA      NA    1020      NA MQ     
# … with 9 more variables: flight <int>, tailnum <chr>, origin <chr>,
#   dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#   time_hour <dttm>, and abbreviated variable names ¹dep_time,
#   ²sched_dep_time, ³dep_delay, ⁴arr_time, ⁵sched_arr_time, ⁶arr_delay
```

slice_tail() - Last 5 flights

```r
flights %>% slice_tail(n = 5)
```

```
# A tibble: 5 × 19
   year month   day dep_t…¹ sched…² dep_d…³ arr_t…⁴ sched…⁵ arr_d…⁶ carrier
  <int> <int> <int>   <int>   <int>   <dbl>   <int>   <int>   <dbl> <chr>  
1  2013     9    30      NA    1455      NA      NA    1634      NA 9E     
2  2013     9    30      NA    2200      NA      NA    2312      NA 9E     
3  2013     9    30      NA    1210      NA      NA    1330      NA MQ     
4  2013     9    30      NA    1159      NA      NA    1344      NA MQ     
5  2013     9    30      NA     840      NA      NA    1020      NA MQ     
# … with 9 more variables: flight <int>, tailnum <chr>, origin <chr>,
#   dest <chr>, air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#   time_hour <dttm>, and abbreviated variable names ¹dep_time,
#   ²sched_dep_time, ³dep_delay, ⁴arr_time, ⁵sched_arr_time, ⁶arr_delay
```

select() - Individual Columns

```r
flights %>% select(year, month, day)
```

```
# A tibble: 336,776 × 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
```

select() - Exclude Columns

```r
flights %>% select(-year, -month, -day)
```

```
# A tibble: 336,776 × 16
   dep_time sched_…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵ carrier flight tailnum
      <int>    <int>   <dbl>   <int>   <int>   <dbl> <chr>    <int> <chr>  
 1      517      515       2     830     819      11 UA        1545 N14228 
 2      533      529       4     850     830      20 UA        1714 N24211 
 3      542      540       2     923     850      33 AA        1141 N619AA 
 4      544      545      -1    1004    1022     -18 B6         725 N804JB 
 5      554      600      -6     812     837     -25 DL         461 N668DN 
 6      554      558      -4     740     728      12 UA        1696 N39463 
 7      555      600      -5     913     854      19 B6         507 N516JB 
 8      557      600      -3     709     723     -14 EV        5708 N829AS 
 9      557      600      -3     838     846      -8 B6          79 N593JB 
10      558      600      -2     753     745       8 AA         301 N3ALAA 
```

select() - Ranges

```r
flights %>% select(year:day)
```

```
# A tibble: 336,776 × 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
```

select() - Exclusion Ranges

```r
flights %>% select(-(year:day))
```

```
# A tibble: 336,776 × 16
   dep_time sched_…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵ carrier flight tailnum
      <int>    <int>   <dbl>   <int>   <int>   <dbl> <chr>    <int> <chr>  
 1      517      515       2     830     819      11 UA        1545 N14228 
 2      533      529       4     850     830      20 UA        1714 N24211 
 3      542      540       2     923     850      33 AA        1141 N619AA 
 4      544      545      -1    1004    1022     -18 B6         725 N804JB 
 5      554      600      -6     812     837     -25 DL         461 N668DN 
 6      554      558      -4     740     728      12 UA        1696 N39463 
 7      555      600      -5     913     854      19 B6         507 N516JB 
 8      557      600      -3     709     723     -14 EV        5708 N829AS 
 9      557      600      -3     838     846      -8 B6          79 N593JB 
10      558      600       2     753     745       8 AA         301 N3ALAA 
```

select() - Matching contains()

```r
flights %>% select(contains("dep"),
                   contains("arr"))
```

```
# A tibble: 336,776 × 7
   dep_time sched_dep_time dep_delay arr_time sched_arr_t…¹ arr_d…² carrier
      <int>          <int>     <dbl>    <int>         <int>   <dbl> <chr>  
 1      517            515         2      830           819      11 UA     
 2      533            529         4      850           830      20 UA     
 3      542            540         2      923           850      33 AA     
 4      544            545        -1     1004          1022     -18 B6     
 5      554            600        -6      812           837     -25 DL     
 6      554            558        -4      740           728      12 UA     
 7      555            600        -5      913           854      19 B6     
 8      557            600        -3      709           723     -14 EV     
 9      557            600        -3      838           846      -8 B6     
10      558            600        -2      753           745       8 AA     
```

select() - Matching starts_with()

```r
flights %>% select(starts_with("dep"),
                   starts_with("arr"))
```

```
# A tibble: 336,776 × 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
```

Other helpers provide by tidyselect:

`starts_with`, `ends_with`, `everything`, `matches`, `num_range`, `one_of`, `everything`, `last_col`.

select() + where() - Get numeric columns

```r
flights %>% select(where(is.numeric))
```

```
# A tibble: 336,776 × 14
    year month   day dep_t…¹ sched…² dep_d…³ arr_t…⁴ sched…⁵ arr_d…⁶ flight
   <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, 4 more variables: air_time <dbl>,
```

select() + where() - Get non-numeric columns

```r
flights %>% select(where(function(x) !is.numeric(x)))
```

```
# A tibble: 336,776 × 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
```

relocate - to the front

```r
flights %>% relocate(carrier, origin, dest)
```

```
# A tibble: 336,776 × 19
   carrier origin dest   year month   day dep_time sched_…¹ dep_d…² arr_t…³
   <chr>   <chr>  <chr> <int> <int> <int>    <int>    <int>   <dbl>   <int>
 1 UA      EWR    IAH    2013     1     1      517      515       2     830
 2 UA      LGA    IAH    2013     1     1      533      529       4     850
 3 AA      JFK    MIA    2013     1     1      542      540       2     923
 4 B6      JFK    BQN    2013     1     1      544      545      -1    1004
 5 DL      LGA    ATL    2013     1     1      554      600      -6     812
 6 UA      EWR    ORD    2013     1     1      554      558      -4     740
 7 B6      EWR    FLL    2013     1     1      555      600      -5     913
 8 EV      LGA    IAD    2013     1     1      557      600      -3     709
 9 B6      JFK    MCO    2013     1     1      557      600      -3     838
10 AA      LGA    ORD    2013     1     1      558      600      -2     753
```

relocate - to the end

```r
flights %>%
  relocate(year, month, day, .after = last_col())
```

```
# A tibble: 336,776 × 19
   dep_time sched_…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵ carrier flight tailnum
      <int>    <int>   <dbl>   <int>   <int>   <dbl> <chr>    <int> <chr>  
 1      517      515       2     830     819      11 UA        1545 N14228 
 2      533      529       4     850     830      20 UA        1714 N24211 
 3      542      540       2     923     850      33 AA        1141 N619AA 
 4      544      545      -1    1004    1022     -18 B6         725 N804JB 
 5      554      600      -6     812     837     -25 DL         461 N668DN 
 6      554      558      -4     740     728      12 UA        1696 N39463 
 7      555      600      -5     913     854      19 B6         507 N516JB 
 8      557      600      -3     709     723     -14 EV        5708 N829AS 
 9      557      600      -3     838     846      -8 B6          79 N593JB 
10      558      600      -2     753     745       8 AA         301 N3ALAA 
```

rename() - Change column names

```r
flights %>% rename(tail_number = tailnum)
```

```
# A tibble: 336,776 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     1     1      517           515       2     830     819      11
 2  2013     1     1      533           529       4     850     830      20
 3  2013     1     1      542           540       2     923     850      33
 4  2013     1     1      544           545      -1    1004    1022     -18
 5  2013     1     1      554           600      -6     812     837     -25
 6  2013     1     1      554           558      -4     740     728      12
 7  2013     1     1      555           600      -5     913     854      19
 8  2013     1     1      557           600      -3     709     723     -14
 9  2013     1     1      557           600      -3     838     846      -8
10  2013     1     1      558           600      -2     753     745       8
```

select() vs. rename()

```r
flights %>% select(tail_number = tailnum)
```

```
# A tibble: 336,776 × 1
   tail_number
   <chr>      
 1 N14228     
 2 N24211     
 3 N619AA     
 4 N804JB     
 5 N668DN     
 6 N39463     
 7 N516JB     
 8 N829AS     
 9 N593JB     
10 N3ALAA     
# … with 336,766 more rows
```

```r
flights %>% rename(tail_number = tailnum)
```

```
# A tibble: 336,776 × 19
    year month   day dep_time sched_dep_…¹ dep_d…²
   <int> <int> <int>    <int>        <int>   <dbl>
 1  2013     1     1      517          515       2
 2  2013     1     1      533          529       4
 3  2013     1     1      542          540       2
 4  2013     1     1      544          545      -1
 5  2013     1     1      554          600      -6
 6  2013     1     1      554          558      -4
 7  2013     1     1      555          600      -5
 8  2013     1     1      557          600      -3
 9  2013     1     1      557          600      -3
10  2013     1     1      558          600      -2
# … with 336,766 more rows, 13 more variables:
#   arr_time <int>, sched_arr_time <int>,
#   arr_delay <dbl>, carrier <chr>, flight <int>,
#   tail_number <chr>, origin <chr>, dest <chr>,
```

pull()

```r
names(flights)
```

```
 [1] "year"           "month"          "day"            "dep_time"
 [5] "sched_dep_time" "dep_delay"      "arr_time"       "sched_arr_time"
 [9] "arr_delay"      "carrier"        "flight"         "tailnum"
[13] "origin"         "dest"           "air_time"       "distance"
[17] "hour"           "minute"         "time_hour"
```

```r
flights %>% pull("year") %>% head()
```

```
[1] 2013 2013 2013 2013 2013 2013
```

```r
flights %>% pull(1) %>% head()
```

```
[1] 2013 2013 2013 2013 2013 2013
```

```r
flights %>% pull(-1) %>% head()
```

```
[1] "2013-01-01 05:00:00 EST" "2013-01-01 05:00:00 EST"
[3] "2013-01-01 05:00:00 EST" "2013-01-01 05:00:00 EST"
[5] "2013-01-01 06:00:00 EST" "2013-01-01 05:00:00 EST"
```

arrange() - Sort data

```r
flights %>% filter(month==3,day==2) %>% arrange(origin, dest)
```

```
# A tibble: 765 × 19
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     3     2     1336          1329       7    1426    1432      -6
 2  2013     3     2      628           629      -1     837     849     -12
 3  2013     3     2      637           640      -3     903     915     -12
 4  2013     3     2      743           745      -2     945    1010     -25
 5  2013     3     2      857           900      -3    1117    1126      -9
 6  2013     3     2     1027          1030      -3    1234    1247     -13
 7  2013     3     2     1134          1145     -11    1332    1359     -27
 8  2013     3     2     1412          1415      -3    1636    1630       6
 9  2013     3     2     1633          1636      -3    1848    1908     -20
10  2013     3     2     1655          1700      -5    1857    1924     -27
```

arrange() & desc() - Descending order

```r
flights %>%
  filter(month==3, day==2) %>%
  arrange(desc(origin), dest) %>%
  select(origin, dest, tailnum)
```

```
# A tibble: 765 × 3
   origin dest  tailnum
   <chr>  <chr> <chr>
 1 LGA    ATL   N928AT
 2 LGA    ATL   N623DL
 3 LGA    ATL   N680DA
 4 LGA    ATL   N996AT
 5 LGA    ATL   N510MQ
 6 LGA    ATL   N663DN
 7 LGA    ATL   N942DL
 8 LGA    ATL   N511MQ
 9 LGA    ATL   N910DE
10 LGA    ATL   N902DE
```

distinct() - Find unique rows

```r
flights %>%
  select(origin, dest) %>%
  distinct() %>%
  arrange(origin,dest)
```

```
# A tibble: 224 × 2
   origin dest 
   <chr>  <chr>
 1 EWR    ALB  
 2 EWR    ANC  
 3 EWR    ATL  
 4 EWR    AUS  
 5 EWR    AVL  
 6 EWR    BDL  
 7 EWR    BNA  
 8 EWR    BOS  
 9 EWR    BQN  
10 EWR    BTV  
```

mutate() - Modify / create columns

```r
flights %>%
  select(year:day) %>%
  mutate(date = paste(year, month, day, sep="/"))
```

```
# A tibble: 336,776 × 4
    year month   day date    
   <int> <int> <int> <chr>   
 1  2013     1     1 2013/1/1
 2  2013     1     1 2013/1/1
 3  2013     1     1 2013/1/1
 4  2013     1     1 2013/1/1
 5  2013     1     1 2013/1/1
 6  2013     1     1 2013/1/1
 7  2013     1     1 2013/1/1
 8  2013     1     1 2013/1/1
 9  2013     1     1 2013/1/1
10  2013     1     1 2013/1/1
```

summarise() - Arregate rows

```r
flights %>%
  summarize(n(), min(dep_delay), max(dep_delay))
```

```
# A tibble: 1 × 3
   `n()` `min(dep_delay)` `max(dep_delay)`
   <int>            <dbl>            <dbl>
1 336776               NA               NA
```

```r
flights %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm = TRUE),
    max_dep_delay = max(dep_delay, na.rm = TRUE)
  )
```

```
# A tibble: 1 × 3
       n min_dep_delay max_dep_delay
   <int>         <dbl>         <dbl>
1 336776           -43          1301
```

group_by()

```r
flights %>% group_by(origin)
```

```
# A tibble: 336,776 × 19
# Groups:   origin [3]
    year month   day dep_time sched_dep_t…¹ dep_d…² arr_t…³ sched…⁴ arr_d…⁵
   <int> <int> <int>    <int>         <int>   <dbl>   <int>   <int>   <dbl>
 1  2013     1     1      517           515       2     830     819      11
 2  2013     1     1      533           529       4     850     830      20
 3  2013     1     1      542           540       2     923     850      33
 4  2013     1     1      544           545      -1    1004    1022     -18
 5  2013     1     1      554           600      -6     812     837     -25
 6  2013     1     1      554           558      -4     740     728      12
 7  2013     1     1      555           600      -5     913     854      19
 8  2013     1     1      557           600      -3     709     723     -14
 9  2013     1     1      557           600       3     838     846       8
```

summarise() with group_by()

```r
flights %>%
  group_by(origin) %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm = TRUE),
    max_dep_delay = max(dep_delay, na.rm = TRUE)
  )
```

```
# A tibble: 3 × 4
  origin      n min_dep_delay max_dep_delay
  <chr>   <int>         <dbl>         <dbl>
1 EWR    120835           -25          1126
2 JFK    111279           -43          1301
3 LGA    104662           -33           911
```

Groups after summarise

```r
flights %>%
  group_by(origin) %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm=TRUE),
    max_dep_delay = max(dep_delay, na.rm=TRUE),
    .groups = "drop_last"
  )
```

```
# A tibble: 3 × 4
  origin      n min_dep_delay max_dep_delay
  <chr>   <int>         <dbl>         <dbl>
1 EWR    120835           -25          1126
2 JFK    111279           -43          1301
3 LGA    104662           -33           911
```

```r
flights %>%
  group_by(origin) %>%
  summarize(
    n = n(),
    min_dep_delay = min(dep_delay, na.rm=TRUE),
    max_dep_delay = max(dep_delay, na.rm=TRUE),
    .groups = "keep"
  )
```

```
# A tibble: 3 × 4
# Groups:   origin [3]
  origin      n min_dep_delay max_dep_delay
  <chr>   <int>         <dbl>         <dbl>
1 EWR    120835           -25          1126
2 JFK    111279           -43          1301
3 LGA    104662           -33           911
```

count()

```r
flights %>%
  group_by(origin, carrier) %>%
  summarize(
    n = n(),
    .groups = "drop"
  )
```

```
# A tibble: 35 × 3
   origin carrier     n
   <chr>  <chr>   <int>
 1 EWR    9E       1268
 2 EWR    AA       3487
 3 EWR    AS        714
 4 EWR    B6       6557
 5 EWR    DL       4342
 6 EWR    EV      43939
 7 EWR    MQ       2276
 8 EWR    OO          6
 9 EWR    UA      46087
10 EWR    US       4405
```

```r
flights %>%
  count(origin, carrier)
```

```
# A tibble: 35 × 3
   origin carrier     n
   <chr>  <chr>   <int>
 1 EWR    9E       1268
 2 EWR    AA       3487
 3 EWR    AS        714
 4 EWR    B6       6557
 5 EWR    DL       4342
 6 EWR    EV      43939
 7 EWR    MQ       2276
 8 EWR    OO          6
 9 EWR    UA      46087
10 EWR    US       4405
```

mutate() with group_by()

```r
flights %>% group_by(origin) %>%
  mutate(
    n = n(),
  ) %>%
  select(origin, n)
```

```
# A tibble: 336,776 × 2
# Groups:   origin [3]
   origin      n
   <chr>   <int>
 1 EWR    120835
 2 LGA    104662
 3 JFK    111279
 4 JFK    111279
 5 LGA    104662
 6 EWR    120835
 7 EWR    120835
 8 LGA    104662
 9 JFK    111279
```

Exercises / Examples

1. How many flights to Los Angeles (LAX) did each of the legacy carriers (AA, UA, DL or US) have in May from JFK, and what was their average duration?
2. What was the shortest flight out of each airport in terms of distance? In terms of duration?
3. Which plane (check the tail number) flew out of each New York airport the most?
4. Which date should you fly on if you want to have the lowest possible average departure delay? What about arrival delay?