# Tidy data & dplyr

## Lecture 06

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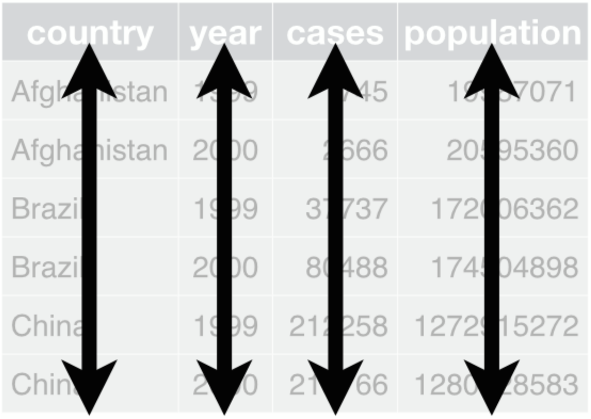
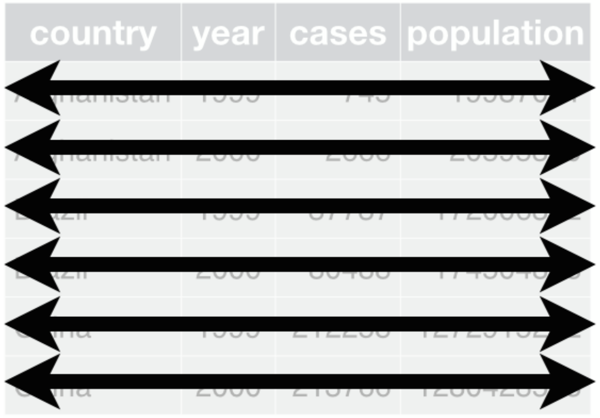
Sta 323 - Spring 2024

tidyverse
www.rstudio.com

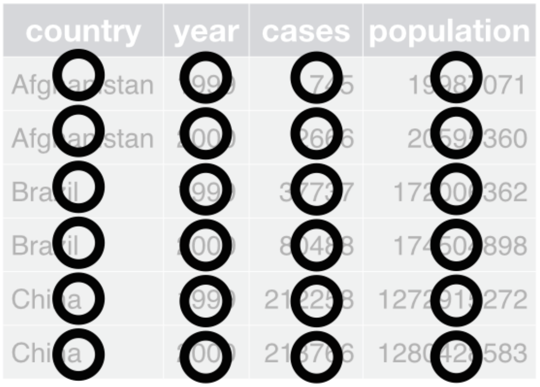
# Tidy data



variables



observations



values

# 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.entered   wk1   wk2   wk3   wk4
   <chr>          <chr>                <date>       <dbl> <dbl> <dbl> <dbl>
 1 2 Pac          Baby Don't Cry (Kee… 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 Ni… 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.Width Petal.Length
          <dbl>       <dbl>        <dbl>
 1          5.1         3.5          1.4
 2          4.9         3            1.4
 3          4.7         3.2          1.3
 4          4.6         3.1          1.5
 5          5           3.6          1.4
 6          5.4         3.9          1.7
 7          4.6         3.4          1.4
 8          5           3.4          1.5
 9          4.4         2.9          1.4
10          4.9         3.1          1.5
# ℹ 140 more rows
# ℹ 2 more variables: Petal.Width <dbl>,
#   Species <fct>
```

# 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 
```

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

```
# A tibble: 150 × 1
   Sepal.Length
          <dbl>
 1          5.1
 2          4.9
 3          4.7
 4          4.6
 5          5
 6          5.4
 7          4.6
 8          5
 9          4.4
10          4.9
# ℹ 140 more rows
```

```r
head(tbl_iris[[1]])
```

```
[1] 5.1 4.9 4.7 4.6 5.0 5.4
```

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

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

# No 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
```

# Tibbles and length coercion

Only vectors with length 1 will undergo length coercion / recycling - 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 in `tibble()`:
! 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
     3.0058       0.9831
```

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,

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

```r
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:

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

Piped:

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

Intermediate:

```
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 native pipe operator was 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()
```

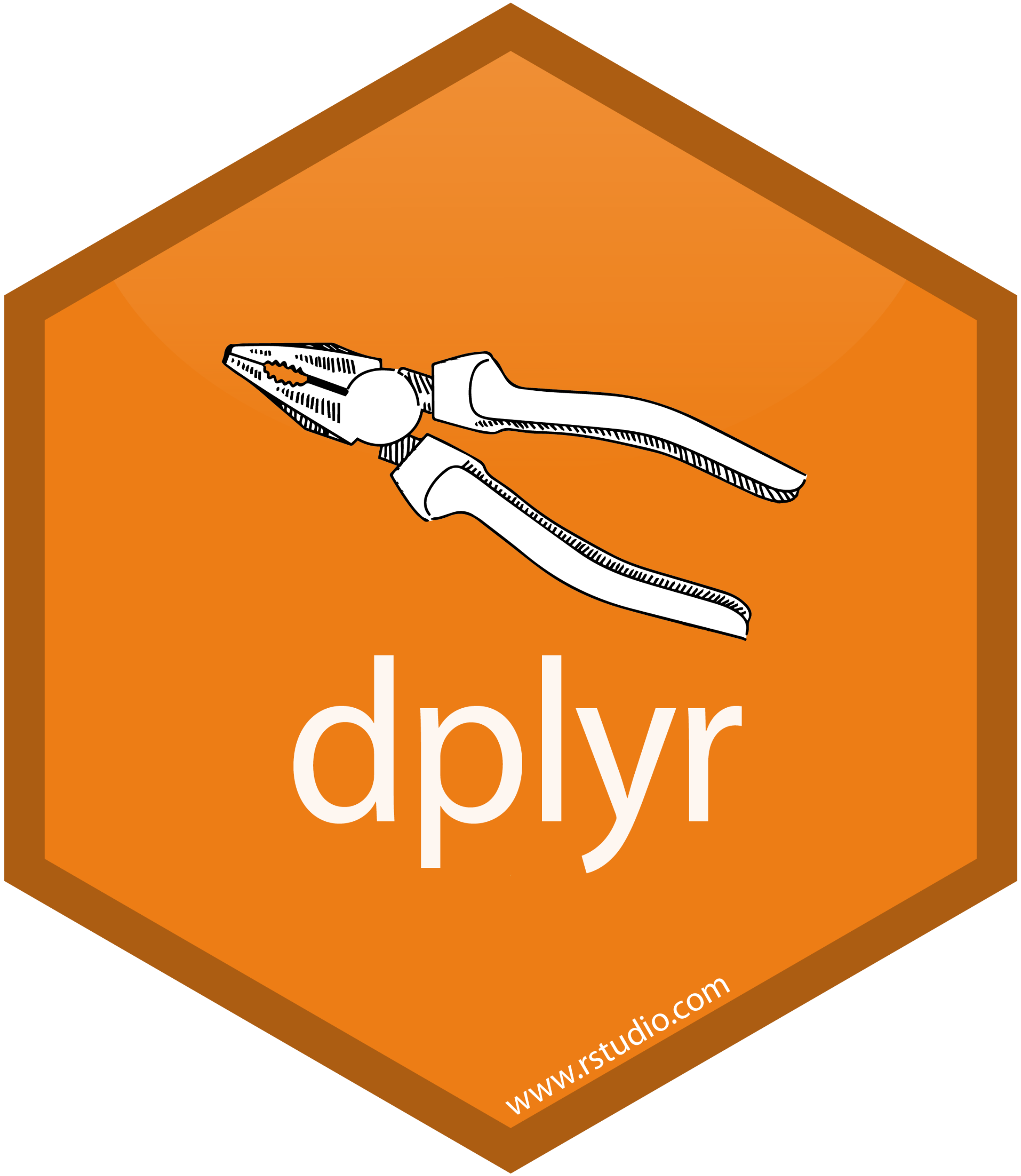
```
[1] 22
```

The current version of RStudio on the departmental servers is v4.3.2 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
- `|>` 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 (but only for named arguments)

Generally we will prefer the base pipe in this class, but using either is fine.


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 mental model / rules

1. First argument is *always* a data frame
2. Subsequent arguments say what to do with the data frame
3. *Always* return a data frame
4. Don’t modify in place
5. Magic via lazy evaluation and S3

# 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_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     1     1      517            515         2      830
 2  2013     1     1      533            529         4      850
 3  2013     1     1      542            540         2      923
 4  2013     1     1      544            545        -1     1004
 5  2013     1     1      554            600        -6      812
 6  2013     1     1      554            558        -4      740
 7  2013     1     1      555            600        -5      913
 8  2013     1     1      557            600        -3      709
 9  2013     1     1      557            600        -3      838
10  2013     1     1      558            600        -2      753
# ℹ 336,766 more rows
```

# filter() - March flights

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

```
# A tibble: 28,834 × 19
    year month   day dep_time sched_dep_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     3     1        4           2159       125      318
 2  2013     3     1       50           2358        52      526
 3  2013     3     1      117           2245       152      223
 4  2013     3     1      454            500        -6      633
 5  2013     3     1      505            515       -10      746
 6  2013     3     1      521            530        -9      813
 7  2013     3     1      537            540        -3      856
 8  2013     3     1      541            545        -4     1014
 9  2013     3     1      549            600       -11      639
10  2013     3     1      550            600       -10      747
```

# 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_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     3     1        4           2159       125      318
 2  2013     3     1       50           2358        52      526
 3  2013     3     1      117           2245       152      223
 4  2013     3     1      454            500        -6      633
 5  2013     3     1      505            515       -10      746
 6  2013     3     1      521            530        -9      813
 7  2013     3     1      537            540        -3      856
 8  2013     3     1      541            545        -4     1014
 9  2013     3     1      549            600       -11      639
10  2013     3     1      550            600       -10      747
```

# 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_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     3     1      607            610        -3      832
 2  2013     3     1      629            632        -3      844
 3  2013     3     1      657            700        -3      953
 4  2013     3     1      714            715        -1      939
 5  2013     3     1      716            710         6      958
 6  2013     3     1      727            730        -3     1007
 7  2013     3     1      836            840        -4     1111
 8  2013     3     1      857            900        -3     1202
 9  2013     3     1      903            900         3     1157
10  2013     3     1      904            831        33     1150
```

# slice() - First 10 flights

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

```
# A tibble: 10 × 19
    year month   day dep_time sched_dep_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     1     1      517            515         2      830
 2  2013     1     1      533            529         4      850
 3  2013     1     1      542            540         2      923
 4  2013     1     1      544            545        -1     1004
 5  2013     1     1      554            600        -6      812
 6  2013     1     1      554            558        -4      740
 7  2013     1     1      555            600        -5      913
 8  2013     1     1      557            600        -3      709
 9  2013     1     1      557            600        -3      838
10  2013     1     1      558            600        -2      753
```

# slice() - Last 5 flights

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

```
# A tibble: 5 × 19
   year month   day dep_time sched_dep_time dep_delay arr_time
  <int> <int> <int>    <int>          <int>     <dbl>    <int>
1  2013     9    30       NA           1455        NA       NA
2  2013     9    30       NA           2200        NA       NA
3  2013     9    30       NA           1210        NA       NA
4  2013     9    30       NA           1159        NA       NA
5  2013     9    30       NA            840        NA       NA
# ℹ 12 more variables: sched_arr_time <int>, arr_delay <dbl>,
#   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#   time_hour <dttm>
```

# slice_tail() - Last 5 flights

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

```
# A tibble: 5 × 19
   year month   day dep_time sched_dep_time dep_delay arr_time
  <int> <int> <int>    <int>          <int>     <dbl>    <int>
1  2013     9    30       NA           1455        NA       NA
2  2013     9    30       NA           2200        NA       NA
3  2013     9    30       NA           1210        NA       NA
4  2013     9    30       NA           1159        NA       NA
5  2013     9    30       NA            840        NA       NA
# ℹ 12 more variables: sched_arr_time <int>, arr_delay <dbl>,
#   carrier <chr>, flight <int>, tailnum <chr>, origin <chr>, dest <chr>,
#   air_time <dbl>, distance <dbl>, hour <dbl>, minute <dbl>,
#   time_hour <dttm>
```

# 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_dep_time dep_delay arr_time sched_arr_time arr_delay
      <int>          <int>     <dbl>    <int>          <int>     <dbl>
 1      517            515         2      830            819        11
 2      533            529         4      850            830        20
 3      542            540         2      923            850        33
 4      544            545        -1     1004           1022       -18
 5      554            600        -6      812            837       -25
 6      554            558        -4      740            728        12
 7      555            600        -5      913            854        19
 8      557            600        -3      709            723       -14
 9      557            600        -3      838            846        -8
10      558            600         2      753            745         8
```

# 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_dep_time dep_delay arr_time sched_arr_time arr_delay
      <int>          <int>     <dbl>    <int>          <int>     <dbl>
 1      517            515         2      830            819        11
 2      533            529         4      850            830        20
 3      542            540         2      923            850        33
 4      544            545        -1     1004           1022       -18
 5      554            600        -6      812            837       -25
 6      554            558        -4      740            728        12
 7      555            600        -5      913            854        19
 8      557            600        -3      709            723       -14
 9      557            600        -3      838            846        -8
10      558            600         2      753            745         8
```

# 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_time arr_delay
      <int>          <int>     <dbl>    <int>          <int>     <dbl>
 1      517            515         2      830            819        11
 2      533            529         4      850            830        20
 3      542            540         2      923            850        33
 4      544            545        -1     1004           1022       -18
 5      554            600        -6      812            837       -25
 6      554            558        -4      740            728        12
 7      555            600        -5      913            854        19
 8      557            600        -3      709            723       -14
 9      557            600        -3      838            846        -8
10      558            600        -2      753            745         8
```

# 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:

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

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

```
# A tibble: 336,776 × 14
    year month   day dep_time sched_dep_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     1     1      517            515         2      830
 2  2013     1     1      533            529         4      850
 3  2013     1     1      542            540         2      923
 4  2013     1     1      544            545        -1     1004
 5  2013     1     1      554            600        -6      812
 6  2013     1     1      554            558        -4      740
 7  2013     1     1      555            600        -5      913
 8  2013     1     1      557            600        -3      709
 9  2013     1     1      557            600        -3      838
10  2013     1     1      558            600        -2      753
# ℹ 336,766 more rows
```

# 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
# ℹ 336,766 more rows
```

# relocate - to the front

```
flights |> relocate(carrier, origin, dest)
```

```
# A tibble: 336,776 × 19
   carrier origin dest   year month   day dep_time sched_dep_time dep_delay
   <chr>   <chr>  <chr> <int> <int> <int>    <int>          <int>     <dbl>
 1 UA      EWR    IAH    2013     1     1      517            515         2
 2 UA      LGA    IAH    2013     1     1      533            529         4
 3 AA      JFK    MIA    2013     1     1      542            540         2
 4 B6      JFK    BQN    2013     1     1      544            545        -1
 5 DL      LGA    ATL    2013     1     1      554            600        -6
 6 UA      EWR    ORD    2013     1     1      554            558        -4
 7 B6      EWR    FLL    2013     1     1      555            600        -5
 8 EV      LGA    IAD    2013     1     1      557            600        -3
 9 B6      JFK    MCO    2013     1     1      557            600        -3
10 AA      LGA    ORD    2013     1     1      558            600        -2
```

# relocate - to the end

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

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

# rename() - Change column names

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

```
# A tibble: 336,776 × 19
    year month   day dep_time sched_dep_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     1     1      517            515         2      830
 2  2013     1     1      533            529         4      850
 3  2013     1     1      542            540         2      923
 4  2013     1     1      544            545        -1     1004
 5  2013     1     1      554            600        -6      812
 6  2013     1     1      554            558        -4      740
 7  2013     1     1      555            600        -5      913
 8  2013     1     1      557            600        -3      709
 9  2013     1     1      557            600        -3      838
10  2013     1     1      558            600         2      753
```

# select() vs. rename()

```
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
# ℹ 336,766 more rows
```

```
flights |> rename(tail_number = tailnum)
```

```
# A tibble: 336,776 × 19
    year month   day dep_time sched_dep_time
   <int> <int> <int>    <int>          <int>
 1  2013     1     1      517            515
 2  2013     1     1      533            529
 3  2013     1     1      542            540
 4  2013     1     1      544            545
 5  2013     1     1      554            600
 6  2013     1     1      554            558
 7  2013     1     1      555            600
 8  2013     1     1      557            600
 9  2013     1     1      557            600
10  2013     1     1      558            600
# ℹ 336,766 more rows
# ℹ 14 more variables: dep_delay <dbl>,
#   arr_time <int>, sched_arr_time <int>,
#   arr_delay <dbl>, carrier <chr>, flight <int>,
```

# 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_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     3     2     1336           1329         7     1426
 2  2013     3     2      628            629        -1      837
 3  2013     3     2      637            640        -3      903
 4  2013     3     2      743            745        -2      945
 5  2013     3     2      857            900        -3     1117
 6  2013     3     2     1027           1030        -3     1234
 7  2013     3     2     1134           1145       -11     1332
 8  2013     3     2     1412           1415        -3     1636
 9  2013     3     2     1633           1636        -3     1848
10  2013     3     2     1655           1700        -5     1857
```

# arrange() w/ 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_time dep_delay arr_time
   <int> <int> <int>    <int>          <int>     <dbl>    <int>
 1  2013     1     1      517            515         2      830
 2  2013     1     1      533            529         4      850
 3  2013     1     1      542            540         2      923
 4  2013     1     1      544            545        -1     1004
 5  2013     1     1      554            600        -6      812
 6  2013     1     1      554            558        -4      740
 7  2013     1     1      555            600        -5      913
 8  2013     1     1      557            600        -3      709
 9  2013     1     1      557            600        -3      838
```

# 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
    max_dep_delay = max(dep_delay, na.rm
    .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
    max_dep_delay = max(dep_delay, na.rm
    .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
```

# The .by argument

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

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

The `.by` and `by` arguments are used for per operation grouping while `group_by()` is intended for persistent

# count()

```
flights |>
  summarize(
    n = n(),
    .by = c(origin, carrier
  )
```

```
# A tibble: 35 × 3
   origin carrier     n
   <chr>  <chr>   <int>
 1 EWR    UA      46087
 2 LGA    UA       8044
 3 JFK    AA      13783
 4 JFK    B6      42076
 5 LGA    DL      23067
 6 EWR    B6       6557
 7 LGA    EV       8826
 8 LGA    AA      15459
 9 JFK    UA       4534
10 LGA    B6       6002
```

```
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 .by

```r
flights |>
  mutate(n = n(), .by = origin) |>
  select(origin, n)
```

```
# A tibble: 336,776 × 2
   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
10 LGA    104662
```

# 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?