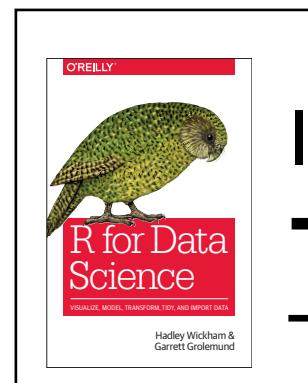
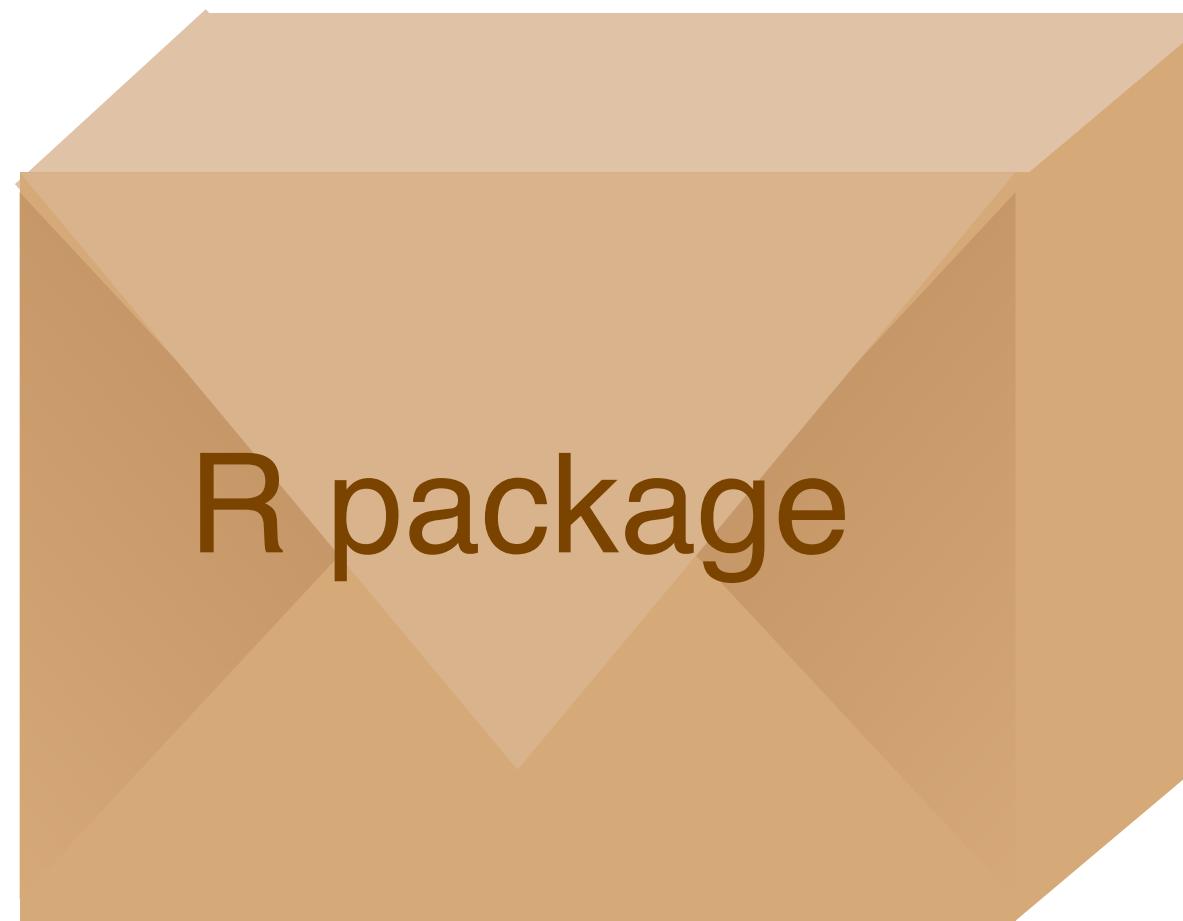


Transform Data with



In R4DS
Transforming Data

babynames



R package

Names of male and female babies born
in the US from 1880 to 2015. 1.8M rows.

```
library(babynames)
```

babynames

year	sex	name	n	prop
<dbl>	<chr>	<chr>	<int>	<dbl>
1880	F	Mary	7065	7.238433e-02
1880	F	Anna	2604	2.667923e-02
1880	F	Emma	2003	2.052170e-02
1880	F	Elizabeth	1939	1.986599e-02
1880	F	Minnie	1746	1.788861e-02
1880	F	Margaret	1578	1.616737e-02
1880	F	Ida	1472	1.508135e-02
1880	F	Alice	1414	1.448711e-02
1880	F	Bertha	1320	1.352404e-02
1880	F	Sarah	1288	1.319618e-02

1-10 of 1,858,689 rows

Previous

1

2

3

4

5

6

...

100

Next

```
skim(babynames)
```

Skim summary statistics

n obs: 1924665

n variables: 5

— Variable type: character

variable	missing	complete	n	min	max	empty	n_unique
name	0	1924665	1924665	2	15	0	97310
sex	0	1924665	1924665	1	1	0	2

— Variable type: integer

```
variable missing complete      n    mean      sd p0 p25 p50 p75 p100      hist
      n          0 1924665 1924665 180.87 1533.34  5   7  12  32 99686
```

— Variable type: numeric

variable	missing	complete	n	mean	sd	p0	p25	p50	p75	p100	hist
prop	0	1924665	1924665	0.00014	0.0012	2.3e-06	3.9e-06	7.3e-06	2.3e-05	0.082	
year	0	1924665	1924665	1974.85	34.03	1880	1951	1985	2003	2017	



Sometimes, you don't want all the summary statistics `skimr` gives you. You can use `skim_with()` to remove them

```
skim_with(integer = list(p25 = NULL, p75=NULL))
```

`skim_with()` can also be used to add additional summary statistics (e.g. a trimmed mean) but we won't discuss this

If you change your mind about your changes, use `skim_with_defaults()` to put them back

```
skim_with_defaults()
```

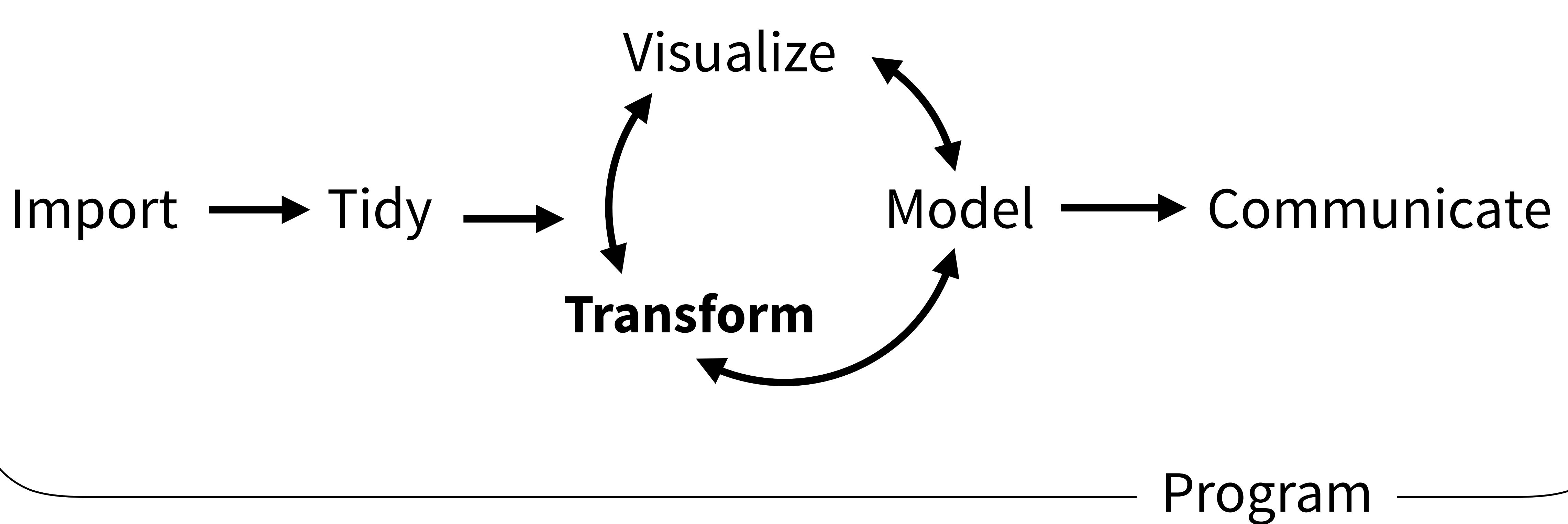


Your turn 1

Run the `skim_with()` command, and
then try skimming `babynames` again to
see how the output is different



(Applied) Data Science



dplyr



dplyr



A package that transforms data.

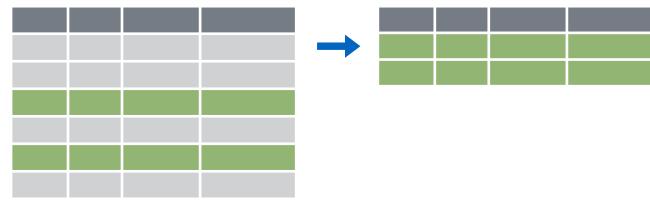
dplyr implements a *grammar* for transforming tabular data.



Isolating data



Extract variables with **select()**



Extract cases with **filter()**



Arrange cases, with **arrange()**.



select()



select()

Extract columns by name.

```
select(.data, ...)
```

**data frame to
transform**

**name(s) of columns to extract
(or a select helper function)**



select()

Extract columns by name.

```
select(babynames, name, prop)
```

babynames				
year	sex	name	n	prop
1880	M	John	9655	0.0815
1880	M	William	9532	0.0805
1880	M	James	5927	0.0501
1880	M	Charles	5348	0.0451
1880	M	Garrett	13	0.0001
1881	M	John	8769	0.081

→

name	prop
John	0.0815
William	0.0805
James	0.0501
Charles	0.0451
Garrett	0.0001
John	0.081



Your Turn 2

Alter the code to select just the **n** column:

```
select(babynames, name, prop)
```



```
select(babynames, n)
```

```
#       n
```

```
# <int>
```

```
# 1 7065
```

```
# 2 2604
```

```
# 3 2003
```

```
# 4 1939
```

```
# 5 1746
```

```
# ... ...
```



select() helpers

: - Select range of columns

```
select(storms, storm:pressure)
```

- - Select every column but

```
select(storms, -c(storm, pressure))
```

starts_with() - Select columns that start with...

```
select(storms, starts_with("w"))
```

ends_with() - Select columns that end with...

```
select(storms, ends_with("e"))
```



select() helpers

contains() - Select columns whose names contain...

```
select(storms, contains("d"))
```

matches() - Select columns whose names match regular expression

```
select(storms, matches("^.{4}"))
```

one_of() - Select columns whose names are one of a set

```
select(storms, one_of(c("storm", "storms", "Storm")))
```

num_range() - Select columns named in prefix, number style

```
select(storms, num_range("x", 1:5))
```



select() helpers

Data Transformation with dplyr :: CHEAT SHEET

dplyr functions work with pipes and expect **tidy data**. In tidy data:

- Each variable is in its own column
- Each observation, or case, is in its own row
- x %>% f(y) becomes f(x, y)

Manipulate Cases

EXTRACT CASES

Row functions return a subset of rows as a new table. Use a variant that ends in _ for non-standard evaluation friendly code.

- filter(data, ...)
- distinct(data, ..., keep_all = FALSE)
- sample_frac(tbl, size = 1, replace = FALSE, weight = NULL, env = parent.frame())
- sample_n(tbl, size = 1, replace = FALSE, weight = NULL, env = parent.frame())
- slice(data, ...)
- top_n(x, n, wt)

Column functions return a set of columns as a new table. Use a variant that ends in _ for non-standard evaluation friendly code.

- select(.data, ...)
- contains(match)
- ends_with(match)
- matches(match)

MAKE NEW VARIABLES

These apply **vectorized functions** to columns. Vectorized funs take vectors as input and return vectors of the same length as output (see back).

- mutate(data, ...)
- transmute(data, ...)
- mutate_all(tbl, funs, ...)
- mutate_at(tbl, cols, funs, ...)
- mutate_if(tbl, predicate, funs, ...)
- add_row(data, ..., before = NULL, after = NULL)
- add_column(data, ..., before = NULL, after = NULL)
- rename(data, ...)

Logical and boolean operators to use with filter()

- <
- <=
- is.na()
- %in%
- !
- &

ARRANGE CASES

- arrange(data, ...)
- arrange(tbl, desc(...))

ADD CASES

- add_row(data, ..., before = NULL, after = NULL)
- add_column(data, ..., before = NULL, after = NULL)
- rename(data, ...)

VARIATIONS

- summarise_all()
- summarise_at()
- summarise_if()

Group Cases

Use group_by() to create a "grouped" copy of a table. dplyr functions will manipulate each "group" separately and then combine the results.

- mtcars %>% group_by(cyl) %>% summarise(avg = mean(mpg))
- group_by(data, ..., add = FALSE)
- group_by(tbl, ..., add = TRUE)
- ungroup(x, ...)
- ungroup(g_iris)
- g_iris <- group_by(iris, Species)

R Studio

RStudio® is a trademark of RStudio, Inc. • CC BY SA RStudio • info@rstudio.com • 844-448-1212 • rstudio.com • Learn more with browseVignettes(package = c("dplyr", "tibble")) • dplyr 0.5.0 • tibble 1.2.0 • Updated: 2017-01

Column functions return a set of columns as a new table. Use a variant that ends in _ for non-standard evaluation friendly code.



select(.data, ...)
Extract columns by name. Also **select_if()**
select(iris, Sepal.Length, Species)

Use these helpers with **select ()**,
e.g. **select(iris, starts_with("Sepal"))**

contains(match) **num_range(prefix, range)** : e.g. mpg:cyl
ends_with(match) **one_of(...)** - e.g. -Species
matches(match) **starts_with(match)**



Consider

Which of these is NOT a way to select the **name** and **n** columns together?

`select(babynames, -c(year, sex, prop))`

`select(babynames, name:n)`

`select(babynames, starts_with("n"))`

`select(babynames, ends_with("n"))`

Consider

Which of these is NOT a way to select the **name** and **n** columns together?

`select(babynames, -c(year, sex, prop))`

`select(babynames, name:n)`

`select(babynames, starts_with("n"))`

`select(babynames, ends_with("n"))`

filter()



filter()

Extract rows that meet logical criteria.

```
filter(.data, ...)
```

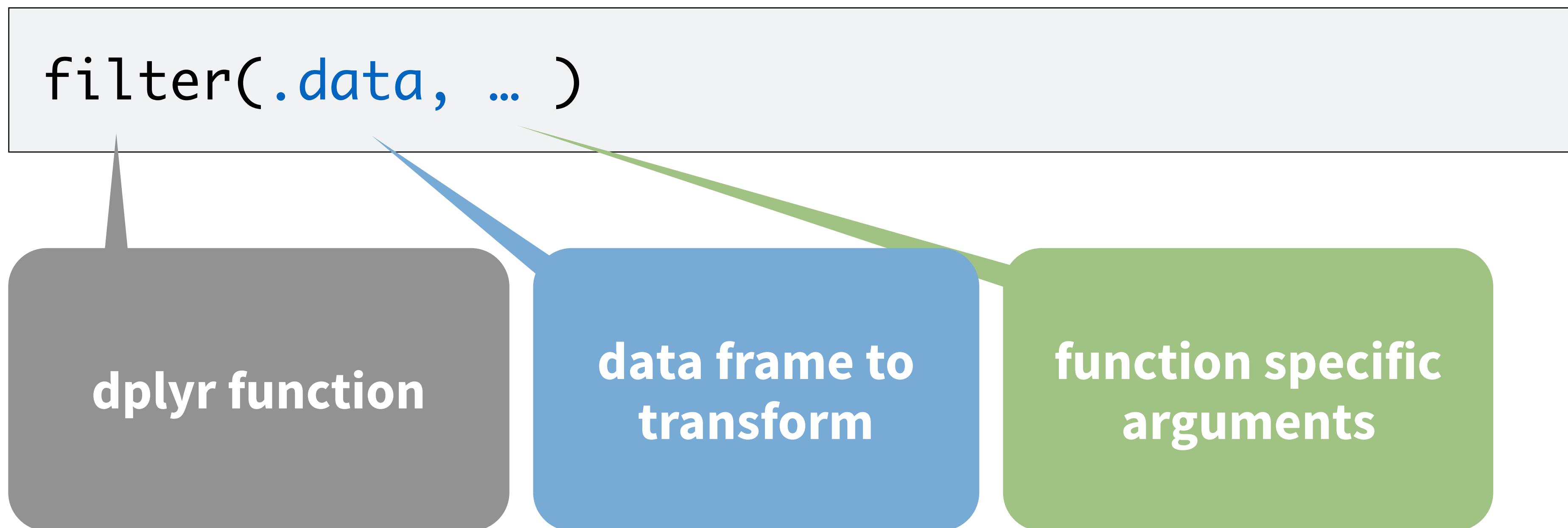
data frame to transform

one or more logical tests
(filter returns each row for which the test is TRUE)



common syntax

Each function takes a data frame / tibble as its first argument and returns a data frame / tibble.



filter()

Extract rows that meet logical criteria.

```
filter(babynames, name == "Amelia")
```

babynames				
year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135

→

year	sex	name	n	prop
1880	F	Amelia	221	0.00226
1881	F	Amelia	225	0.00238
...	...	Amelia



filter()

Extract rows that meet logical criteria.

```
filter(babynames, name == "Amelia")
```

year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135

= sets
(returns nothing)
== tests if equal
(returns TRUE or FALSE)



Logical tests

?Comparison

<code>x < y</code>	Less than
<code>x > y</code>	Greater than
<code>x == y</code>	Equal to
<code>x <= y</code>	Less than or equal to
<code>x >= y</code>	Greater than or equal to
<code>x != y</code>	Not equal to
<code>x %in% y</code>	Group membership
<code>is.na(x)</code>	Is NA
<code>!is.na(x)</code>	Is not NA



Your Turn 3

See if you can use the logical operators to manipulate our code below to show:

- All of the names where **prop** is greater than or equal to 0.08
- All of the children named “Sea”
- All of the names that have a missing value for **n**
(Hint: this should return an empty data set).



```
filter(babynames, prop >= 0.08)
```

```
#   year sex name    n      prop
# 1 1880 M  John 9655 0.08154630
# 2 1880 M William 9531 0.08049899
# 3 1881 M  John 8769 0.08098299
```

```
filter(babynames, name == "Sea")
```

```
#   year sex name    n      prop
# 1 1982 F  Sea     5 2.756771e-06
# 2 1985 M  Sea     6 3.119547e-06
# 3 1986 M  Sea     5 2.603512e-06
# 4 1998 F  Sea     5 2.580377e-06
```

```
filter(babynames, is.na(n))
```

```
# 0 rows
```

Two common mistakes

1. Using `=` instead of `==`

```
filter(babynames, name = "Sea")  
filter(babynames, name == "Sea")
```

2. Forgetting quotes

```
filter(babynames, name == Sea)  
filter(babynames, name == "Sea")
```



filter()

Extract rows that meet *every* logical criteria.

```
filter(babynames, name == "Amelia", year == 1880)
```

babynames				
year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135

→

year	sex	name	n	prop
1880	F	Amelia	221	0.00226



Boolean operators

?base::Logic

a & b	and
a b	or
xor(a, b)	exactly or
!a	not
a %in% c(a, b)	one of (in)



Your Turn 4

Use Boolean operators to alter the code below to return only the rows that contain:

- Girls named Sea
- Names that were used by exactly 5 or 6 children in 1880
- Names that are one of Acura, Lexus, or Yugo

```
filter(babynames, name == "Sea" | name == "Anemone")
```



```
filter(babynames, name == "Sea", sex == "F")
```

```
#   year  sex  name    n      prop
# 1 1982    F  Sea     5 2.756771e-06
# 2 1998    F  Sea     5 2.580377e-06
```

```
filter(babynames, n == 5 | n == 6, year == 1880)
```

```
#   year  sex  name    n      prop
# 1 1880    F  Abby    6 6.147289e-05
# 2 1880    F  Aileen  6 6.147289e-05
# ...    ...  ...    ...  ...  ...
```

```
filter(babynames, name == "Acura" | name == "Lexus" | name == "Yugo"))
```

```
#   year  sex  name    n      prop
# 1 1990    F  Lexus  36 1.752932e-05
# 2 1990    M  Lexus  12 5.579156e-06
# ...    ...  ...    ...  ...  ...
```

Two more common mistakes

3. Collapsing multiple tests into one

```
filter(babynames, 10 < n < 20)  
filter(babynames, 10 < n, n < 20)
```

4. Stringing together many tests (when you could use %in%)

```
filter(babynames, n == 5 | n == 6 | n == 7 | n == 8)  
filter(babynames, n %in% c(5, 6, 7, 8))
```



```
filter(babynames, name == "Sea", sex == "F")  
# # year sex name n prop  
# 1 1982 F Sea 5 2.756771e-06  
# 2 1998 F Sea 5 2.580377e-06
```

```
filter(babynames, n == 5 | n == 6, year == 1880)  
# # year sex name n prop  
# 1 1880 F Abby 6 6.147289e-05  
# 2 1880 F Aileen 6 6.147289e-05  
# ... ... ... ... ... ...
```

```
filter(babynames, name %in% c("Acura", "Lexus", "Yugo"))  
# # year sex name n prop  
# 1 1990 F Lexus 36 1.752932e-05  
# 2 1990 M Lexus 12 5.579156e-06  
# ... ... ... ... ... ...
```

arrange()



arrange()

Order rows from smallest to largest values.

```
arrange(.data, ...)
```

data frame to transform

one or more columns to order by
(additional columns will be used as tie breakers)



arrange()

Order rows from smallest to largest values.

```
arrange(babynames, n)
```

babynames				
year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135

→

year	sex	name	n	prop
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135
1880	F	Elizabeth	1939	0.0199
1880	F	Emma	2003	0.0205
1880	F	Anna	2604	0.0267
1880	F	Mary	7065	0.0724



Your Turn 5

Arrange babynames by n. Add prop as a second (tie breaking) variable to arrange by.

Can you tell what the smallest value of n is?



arrange(babynames, n, prop)

```
#   year   sex      name     n      prop
# 1 2007    M     Aaban  5 2.259872e-06
# 2 2007    M     Aareon  5 2.259872e-06
# 3 2007    M     Aaris  5 2.259872e-06
# 4 2007    M      Abd  5 2.259872e-06
# 5 2007    M  Abdulazeez  5 2.259872e-06
# 6 2007    M  Abdulhadi  5 2.259872e-06
# 7 2007    M  Abdulhamid  5 2.259872e-06
# 8 2007    M  Abdulkadir  5 2.259872e-06
# 9 2007    M  Abdulraheem 5 2.259872e-06
# 10 2007   M  Abdulrahim 5 2.259872e-06
# ... with 1,858,679 more rows
```



desc()

Changes ordering to largest to smallest.

```
arrange(babynames, desc(n))
```

babynames				
year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Amelia	221	0.00226
1880	F	Bertha	1320	0.0135

→

year	sex	name	n	prop
1880	F	Mary	7065	0.0724
1880	F	Anna	2604	0.0267
1880	F	Emma	2003	0.0205
1880	F	Elizabeth	1939	0.0199
1880	F	Bertha	1320	0.0135
1880	F	Amelia	221	0.00226



Your Turn 6

Use **desc()** to find the names with the highest prop.

Then, use **desc()** to find the names with the highest n.



```
arrange(babynames, desc(prop))
```

```
# #   year   sex   name    n      prop
# 1 1880     M   John  9655 0.08154630
# 2 1881     M   John  8769 0.08098299
# 3 1880     M William 9531 0.08049899
# 4 1883     M   John  8894 0.07907324
# 5 1881     M William 8524 0.07872038
# 6 1882     M   John  9557 0.07831617
# 7 1884     M   John  9388 0.07648751
# 8 1882     M William 9298 0.07619375
# 9 1886     M   John  9026 0.07582198
# 10 1885    M   John  8756 0.07551791
# ... with 1,858,679 more rows
```

```
arrange(babynames, desc(n))
```

```
# #   year   sex   name    n      prop
# 1 1947     F Linda 99680 0.05483609
# 2 1948     F Linda 96211 0.05521159
# 3 1947     M James 94763 0.05102057
# 4 1957     M Michael 92726 0.04238659
# 5 1947     M Robert 91646 0.04934237
# 6 1949     F Linda 91010 0.05184281
# 7 1956     M Michael 90623 0.04225479
# 8 1958     M Michael 90517 0.04203881
# 9 1948     M James 88588 0.04969679
# 10 1954    M Michael 88493 0.04279403
# ... with 1,858,679 more rows
```



%>%



Steps

```
boys_2015 <- filter(babynames, year == 2015, sex == "M")
boys_2015 <- select(boys_2015, name, n)
boys_2015 <- arrange(boys_2015, desc(n))
boys_2015
```

1. Filter babynames to just boys born in 2015
2. Select the name and n columns from the result
3. Arrange those columns so that the most popular names appear near the top.



Steps

```
boys_2015 <- filter(babynames, year == 2015, sex == "M")
boys_2015 <- select(boys_2015, name, n)
boys_2015 <- arrange(boys_2015, desc(n))
boys_2015
```

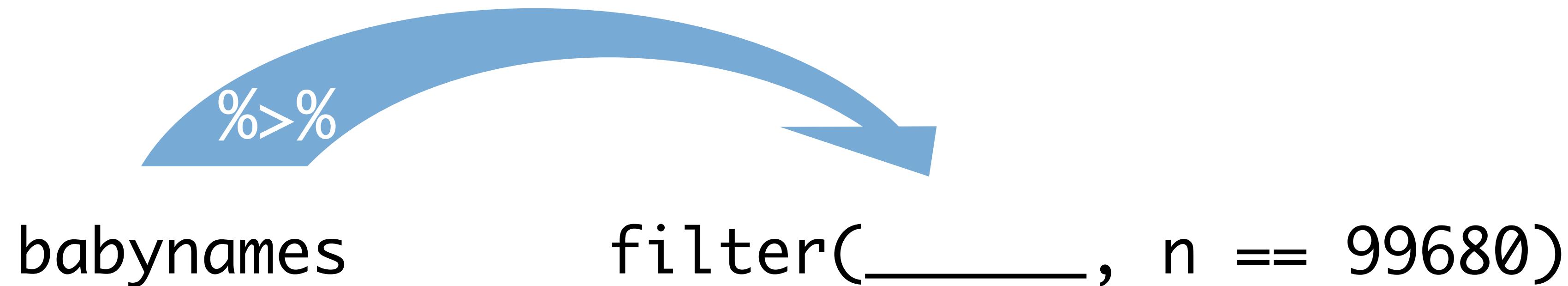


Steps

```
arrange(select(filter(babynames, year == 2015,  
sex == "M"), name, n), desc(n))
```



The pipe operator %>%



Passes result on left into first argument of function on right.
So, for example, these do the same thing. Try it.

```
filter(babynames, n == 99680)  
babynames %>% filter(n == 99680)
```



Pipes

```
babynames  
boys_2015 <- filter(babynames, year == 2015, sex == "M")  
boys_2015 <- select(boys_2015, name, n)  
boys_2015 <- arrange(boys_2015, desc(n))  
boys_2015
```

```
babynames %>%  
  filter(year == 2015, sex == "M") %>%  
  select(name, n) %>%  
  arrange(desc(n))
```

```
foo_foo <- little_bunny()
```

```
foo_foo %>%  
  hop_through(forest) %>%  
  scoop_up(field_mouse) %>%  
  bop_on(head)
```

vs.

```
foo_foo2 <- hop_through(foo_foo, forest)  
foo_foo3 <- scoop_up(foo_foo2, field_mouse)  
bop_on(foo_foo3, head)
```

Shortcut to type %>%

Cmd + Shift + M (Mac)

Ctrl + Shift + M (Windows)



Your Turn 7

Use %>% to write a sequence of functions that:

1. Filter babynames to just the girls that were born in 2015
2. Select the **name** and **n** columns
3. Arrange the results so that the most popular names are near the top.



```
babynames %>%  
  filter(year == 2015, sex == "F") %>%  
  select(name, n) %>%  
  arrange(desc(n))
```

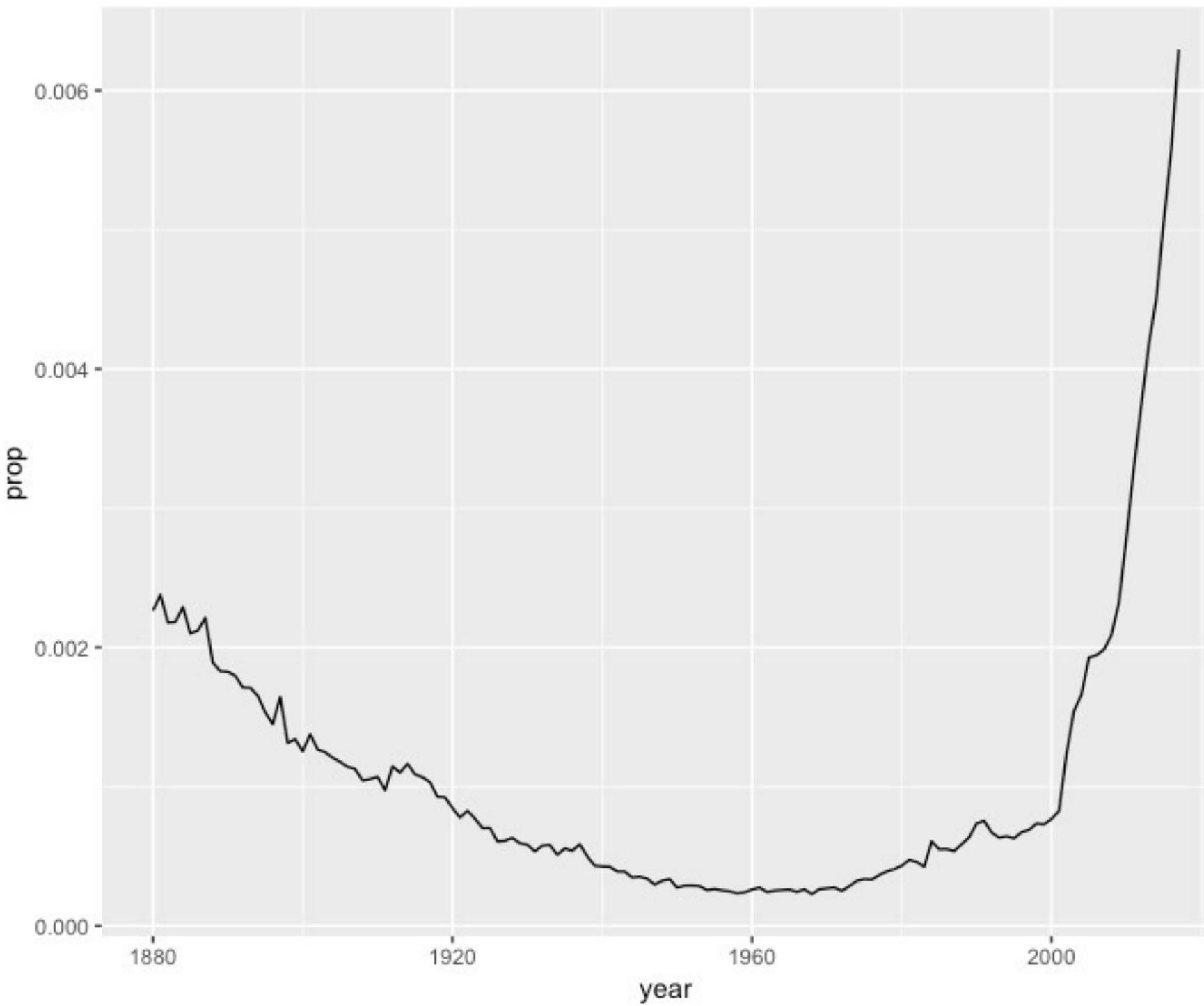
```
#          name     n  
# 1      Emma 20355  
# 2      Olivia 19553  
# 3      Sophia 17327  
# 4        Ava 16286  
# 5    Isabella 15504  
# 6        Mia 14820  
# 7    Abigail 12311  
# 8        Emily 11727  
# 9   Charlotte 11332  
# 10       Harper 10241  
# ... with 18,983 more rows
```

Your Turn 8

1. Trim babynames to just the rows that contain your **name** and your **sex**
2. Trim the result to just the columns that will appear in your graph (not strictly necessary, but useful practice)
3. Plot the results as a line graph with **year** on the x axis and **prop** on the y axis



```
babynames %>%  
  filter(name == "Amelia", sex == "F") %>%  
  select(year, prop) %>%  
  ggplot() +  
    geom_line(mapping = aes(year, prop))
```



What are the most
popular names?

How should we define popularity?

A name is popular if:



How should we define popularity?

A name is popular if:

1. **Sums** - a large number of children have the name when you sum across years



How should we define popularity?

A name is popular if:

1. **Sums** - a large number of children have the name when you sum across years
2. **Ranks** - it consistently ranks among the top names from year to year.

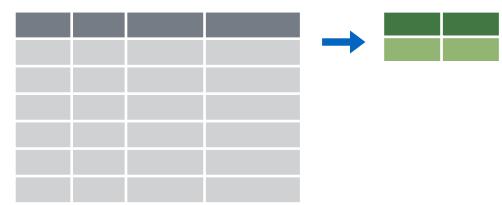


Consider

Do we have enough information to:

1. Calculate the total number of children with each name?
2. Rank names within each year?

Deriving information



Make tables of summaries with **summarise()**.



Make new variables, with **mutate()**.



summarise()



British and American spellings
recognized! Apologies for my
(inevitable) inconsistency

summarize()

summarise()

Compute table of summaries.

```
babynames %>% summarise(total = sum(n), max = max(n))
```

babynames

year	sex	name	n	prop	
1880	M	John	9655	0.0815	
1880	M	William	9532	0.0805	
1880	M	James	5927	0.0501	
1880	M	Charles	5348	0.0451	
1880	M	Garrett	13	0.0001	
1881	M	John	8769	0.081	

→

total	max
127538	99680



Your Turn 9

Use `summarise()` to compute three statistics *about the data*:

1. The first (minimum) year in the dataset
2. The last (maximum) year in the dataset
3. The total number of children represented in the data



```
babynames %>%  
  summarise(first = min(year),  
            last = max(year),  
            total = sum(n))
```

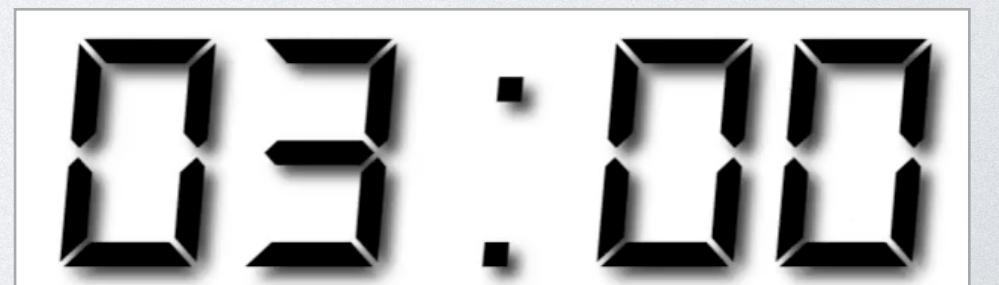
```
#     first  last      total  
# 1  1880  2015 340851912
```



Your Turn 10

Extract the rows where **name == "Khaleesi"**. Then use `summarise()` and a summary functions to find:

1. The total number of children named Khaleesi
2. The first year Khaleesi appeared in the data



```
babynames %>%  
  filter(name == "Khaleesi") %>%  
  summarise(total = sum(n), first = min(year))  
#   total first  
# 1  1127  2011
```



Summary functions

Take a vector as input.
Return a single value as output.

Summary Functions

TO USE WITH SUMMARISE ()

summarise() applies summary functions to columns to create a new table. Summary functions take vectors as input and return single values as output.

summary function →

COUNTS

dplyr::n() - number of values/rows
dplyr::n_distinct() - # of uniques
sum(!is.na()) - # of non-NA's

LOCATION

mean() - mean, also mean(!is.na())
median() - median

LOGICALS

mean() - Proportion of TRUE's
sum() - # of TRUE's

POSITION/ORDER

dplyr::first() - first value
dplyr::last() - last value
dplyr::nth() - value in nth location of vector

RANK

quantile() - nth quantile
min() - minimum value
max() - maximum value

SPREAD

IQR() - Inter-Quartile Range
mad() - median absolute deviation
sd() - standard deviation
var() - variance

Vector Functions

TO USE WITH MUTATE ()

mutate() and **transmute()** apply vectorized functions to columns to create new columns. Vectorized functions take vectors as input and return vectors of the same length as output.

vectorized function →

OFFSETS

dplyr::lag() - Offset elements by 1
dplyr::lead() - Offset elements by -1

CUMULATIVE AGGREGATES

dplyr::cumall() - Cumulative all()
dplyr::cumany() - Cumulative any()
cummax() - Cumulative max()
dplyr::cummean() - Cumulative mean()
cummin() - Cumulative min()
cumprod() - Cumulative prod()
cumsum() - Cumulative sum()

RANKINGS

dplyr::cume_dist() - Proportion of all values <=
dplyr::dense_rank() - rank with ties = min, no gaps
dplyr::min_rank() - rank with ties = min
dplyr::ntile() - bins into n bins
dplyr::percent_rank() - min_rank scaled to [0,1]
dplyr::row_number() - rank with ties = "first"

MATH

+, -, *, /, ^, %/%, %% - arithmetic ops
log(), log2(), log10() - logs
<, <=, >, >=, !=, == - logical comparisons

MISC

dplyr::between() - x >= left & x <= right
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dplyr::coalesce() - first non-NA values by element across a set of vectors
dplyr::if_else() - element-wise if() + else()
dplyr::na_if() - replace specific values with NA
pmax() - element-wise max()
pmin() - element-wise min()
dplyr::recode() - Vectorized switch()
dplyr::recode_factor() - Vectorized switch() for factors

Summary Functions

TO USE WITH SUMMARISE ()

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summary function →

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LOCATION

mean() - mean, also mean(!is.na())
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LOGICALS

mean() - Proportion of TRUE's
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POSITION/ORDER

dplyr::first() - first value
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quantile() - nth quantile
min() - minimum value
max() - maximum value

SPREAD

IQR() - Inter-Quartile Range
mad() - median absolute deviation
sd() - standard deviation
var() - variance

Row Names

Tidy data does not use rownames, which store a variable outside of the columns. To work with the rownames, first move them into a column.

rownames_to_column()
Move row names into col.
a <- rownames_to_column(iris, var = "C")

column_to_rownames()
Move col in row names.
column_to_rownames(a, var = "C")

Also **has_rownames()**, **remove_rownames()**

Combine Tables

COMBINE VARIABLES

X Y
 =

Use bind_cols() to paste tables beside each other as they are.

COMBINE CASES

X Y
 +

Use bind_rows() to paste tables below each other as they are.

bind_rows(..., .id = NULL)

Returns tables one on top of the other as a single table. Set.id to a column name to add a column of the original table names (as pictured)

intersect(x, y, ...)

Rows that appear in both x and y.

setdiff(x, y, ...)

Rows that appear in x but not y.

union(x, y, ...)

Rows that appear in x or y. (Duplicates removed). union_all() retains duplicates.

setequal()

Use setequal() to test whether two data sets contain the exact same rows (in any order).

EXTRACT ROWS

X Y
 =

Use a "Filtering Join" to filter one table against the rows of another.

semi_join(x, y, by = NULL, ...)

Return rows of x that have a match in y. USEFUL TO SEE WHAT WILL BE JOINED.

anti_join(x, y, by = NULL, ...)

Return rows of x that do not have a match in y. USEFUL TO SEE WHAT WILL NOT BE JOINED.



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n()

The number of rows in a dataset/group

```
babynames %>% summarise(n = n())
```

babynames

year	sex	name	n	prop	
1880	M	John	9655	0.0815	
1880	M	William	9532	0.0805	
1880	M	James	5927	0.0501	
1880	M	Charles	5348	0.0451	
1880	M	Garrett	13	0.0001	
1881	M	John	8769	0.081	

→

n
1858689



n_distinct()

The number of distinct values in a variable

```
babynames %>% summarise(n = n(), nname = n_distinct(name))
```

babynames

year	sex	name	n	prop		n	nname
1880	M	John	9655	0.0815		1858689	95025
1880	M	William	9532	0.0805			
1880	M	James	5927	0.0501			
1880	M	Charles	5348	0.0451			
1880	M	Garrett	13	0.0001			
1881	M	John	8769	0.081			



Grouping cases



group_by()

Groups cases by common values of one or more columns.

```
babynames %>%  
  group_by(sex)
```

Source: local data frame [1,825,433 x 5]

Groups: sex [2]

	year	sex	name	n	prop
	<dbl>	<chr>	<chr>	<int>	<dbl>
1	1880	F	Mary	7065	0.07238359



group_by()

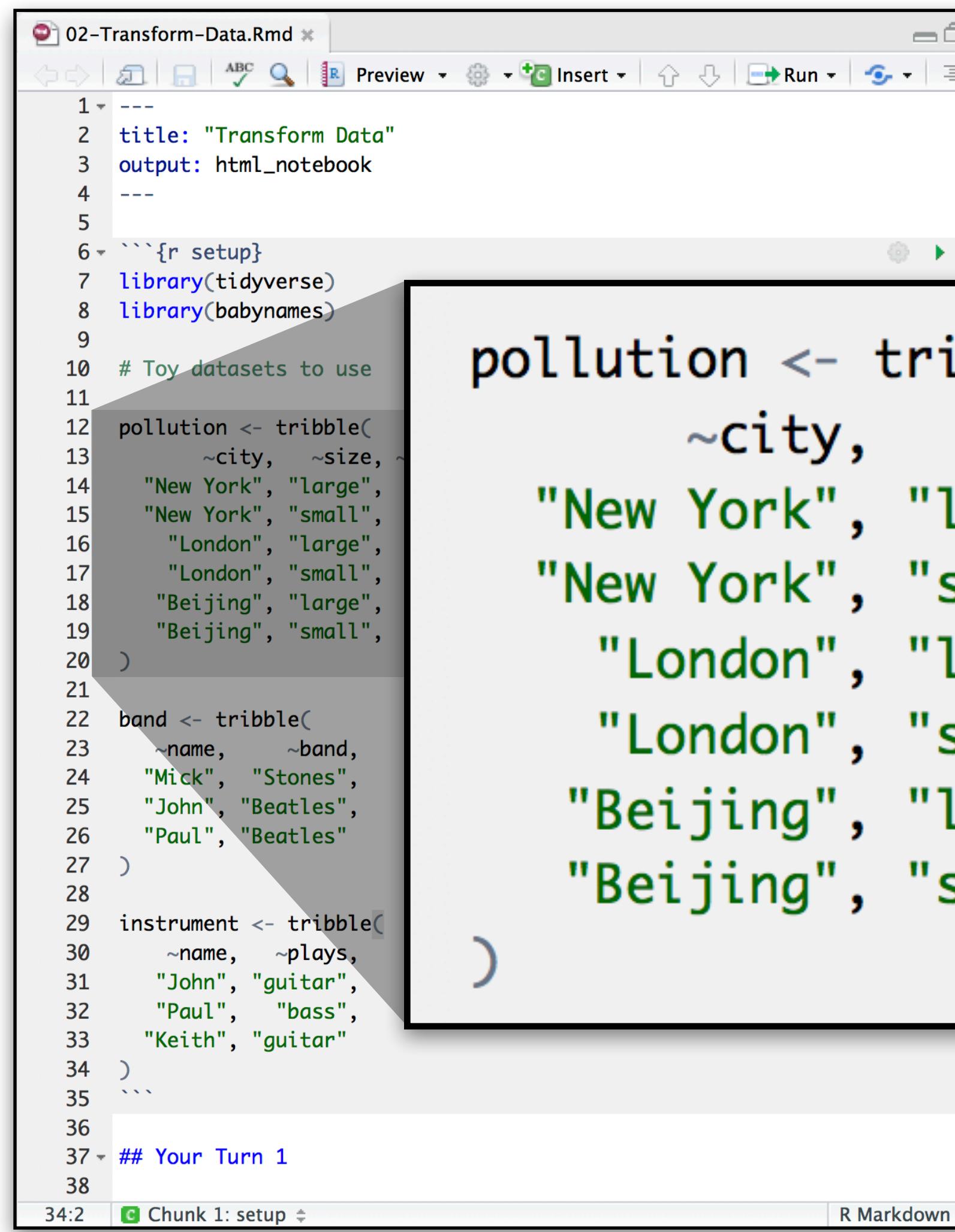
Groups cases by common values.

```
babynames %>%  
  group_by(sex) %>%  
  summarise(total = sum(n))
```

sex	total
F	167070477
M	170064949



Transform Data Notebook



```
1 ---  
2 title: "Transform Data"  
3 output: html_notebook  
4 ---  
5  
6 ```{r setup}  
7 library(tidyverse)  
8 library(babynames)  
9  
10 # Toy datasets to use  
11  
12 pollution <- tribble(  
13   ~city, ~size, ~amount,  
14   "New York", "large", 23,  
15   "New York", "small", 14,  
16   "London", "large", 22,  
17   "London", "small", 16,  
18   "Beijing", "large", 121,  
19   "Beijing", "small", 56  
20 )  
21  
22 band <- tribble(  
23   ~name, ~band,  
24   "Mick", "Stones",  
25   "John", "Beatles",  
26   "Paul", "Beatles"  
27 )  
28  
29 instrument <- tribble(  
30   ~name, ~plays,  
31   "John", "guitar",  
32   "Paul", "bass",  
33   "Keith", "guitar"  
34 )  
35  
36  
37 ## Your Turn 1  
38
```

```
pollution <- tribble(  
  ~city, ~size, ~amount,  
  "New York", "large", 23,  
  "New York", "small", 14,  
  "London", "large", 22,  
  "London", "small", 16,  
  "Beijing", "large", 121,  
  "Beijing", "small", 56
```

Toy data sets to practice with



pollution

```
pollution <- tribble(  
  ~city, ~size, ~amount,  
  "New York", "large", 23,  
  "New York", "small", 14,  
  "London", "large", 22,  
  "London", "small", 16,  
  "Beijing", "large", 121,  
  "Beijing", "small", 56  
)
```

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56



city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56



mean	sum	n
42	252	6

```
pollution %>%  
  summarise(mean = mean(amount), sum = sum(amount), n = n())
```

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6



city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6



city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14



mean	sum	n
18.5	37	2

London	large	22
London	small	16



19.0	38	2
------	----	---

Beijing	large	121
Beijing	small	56



88.5	177	2
------	-----	---

group_by() + summarise()



group_by()

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14

London	large	22
London	small	16

Beijing	large	121
Beijing	small	56

city	mean	sum	n
New York	18.5	37	2
London	19.0	38	2
Beijing	88.5	177	2

```
pollution %>%  
  group_by(city) %>%  
  summarise(mean = mean(amount), sum = sum(amount), n = n())
```

group_by()

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

city	particle size	amount ($\mu\text{g}/\text{m}^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

city	particle size	mean	sum	n
New York	large	23	23	1
New York	small	14	14	1
London	large	22	22	1
London	small	16	16	1
Beijing	large	121	121	1
Beijing	small	56	56	1

```
pollution %>%  
  group_by(city, size) %>%  
  summarise(mean = mean(amount), sum = sum(amount), n = n())
```

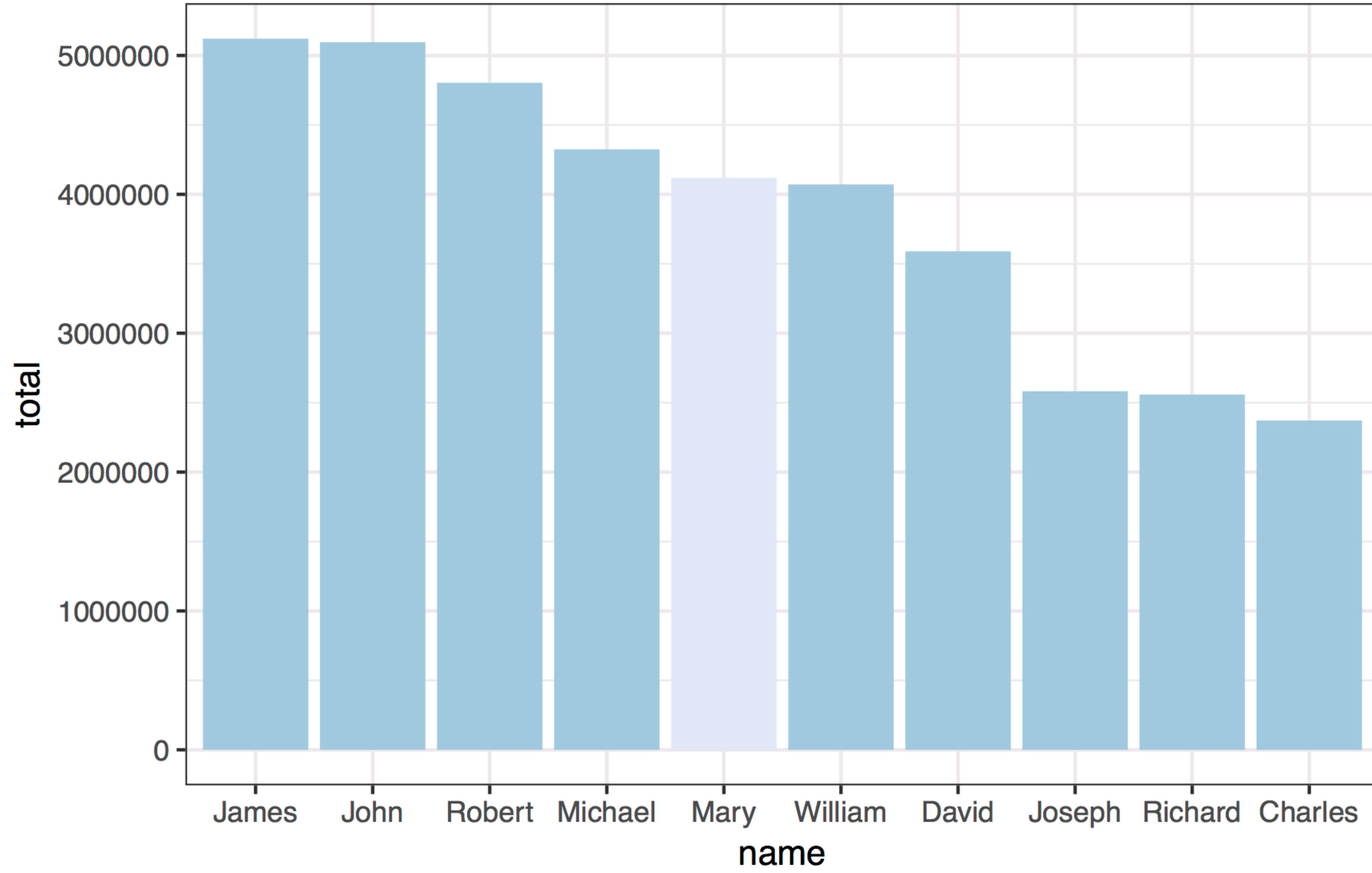
Your Turn 11

Use `group_by()`, `summarise()`, and `arrange()` to display the ten most popular baby names. Compute popularity as the total number of children of a single gender given a name.



```
babynames %>%  
  group_by(name, sex) %>%  
  summarise(total = sum(n)) %>%  
  arrange(desc(total))
```

```
#          name sex total  
# 1      James   M 5120990  
# 2      John   M 5095674  
# 3    Robert   M 4803068  
# 4  Michael   M 4323928  
# 5      Mary   F 4118058  
# 6  William   M 4071645  
# 7     David   M 3589754  
# 8    Joseph   M 2581785  
# 9  Richard   M 2558165  
# 10   Charles   M 2371621  
# ... with 105,376 more rows
```



```
babynames %>%  
  group_by(name, sex) %>%  
  summarise(total = sum(n)) %>%  
  arrange(desc(total)) %>%  
  ungroup() %>%  
  slice(1:10) %>%  
  ggplot() +  
    geom_col(mapping = aes(x = fct_reorder(name,  
      desc(total)), y = total, fill = sex)) +  
    theme_bw() +  
    scale_fill_brewer() +  
    labs(x = "name")
```

Your Turn 12

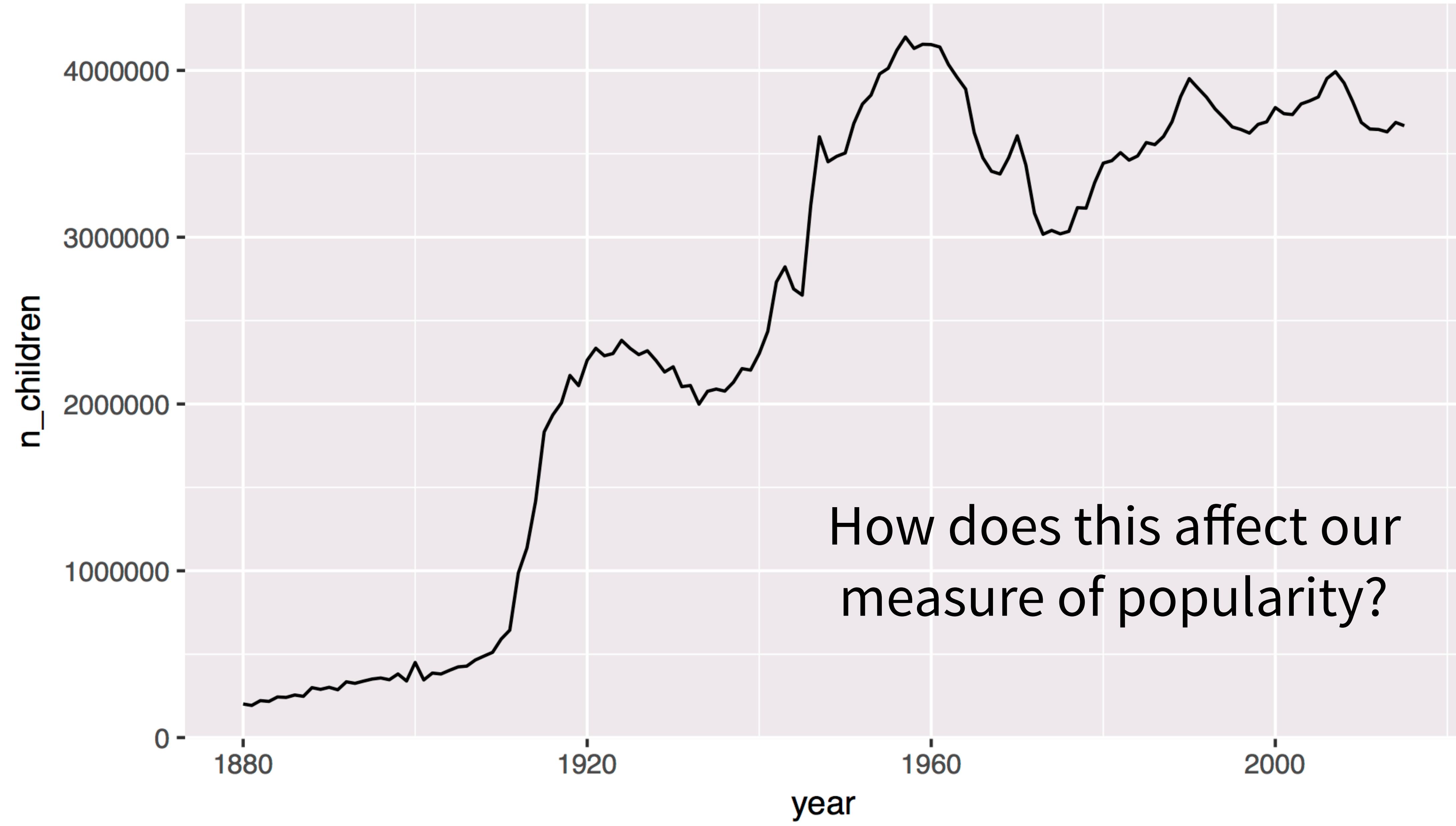
Use grouping to calculate number of children born each year.

Plot the results as a line graph.



```
babynames %>%  
  group_by(year) %>%  
  summarise(n_children = sum(n)) %>%  
  ggplot() +  
    geom_line(mapping = aes(x = year, y = n_children))
```





ungroup()

Removes grouping criteria from a data frame.

```
babynames %>%  
  group_by(name, sex) %>%  
  summarise(total = sum(n)) %>%  
  arrange(desc(total))
```

#	name	sex	total
# 1	James	M	5120990
# 2	John	M	5095674
# 3	Robert	M	4803068
# 4	Michael	M	4323928
# 5	Mary	F	4118058



ungroup()

Removes grouping criteria from a data frame.

```
babynames %>%  
  group_by(name, sex) %>%  
  ungroup() %>%  
  summarise(total = sum(n)) %>%  
  arrange(desc(total))  
  
#       total  
# 1 340851912
```



mutate()



mutate()

Create new columns.

```
babynames %>%  
  mutate(percent = round(prop*100, 2))
```

year	sex	name	n	prop
1880	M	John	9655	0.0815
1880	M	William	9532	0.0805
1880	M	James	5927	0.0501
1880	M	Charles	5348	0.0451
1880	M	Garrett	13	0.0001
1881	M	John	8769	0.081



year	sex	name	n	prop	percent
1880	M	John	9655	0.0815	8.15
1880	M	William	9532	0.0805	8.05
1880	M	James	5927	0.0501	5.01
1880	M	Charles	5348	0.0451	4.51
1880	M	Garrett	13	0.0001	0.01
1881	M	John	8769	0.081	8.1



mutate()

Create new columns.

```
babynames %>%  
  mutate(percent = round(prop*100, 2), nper = round(percent))
```

babynames

year	sex	name	n	prop	percent	nper
1880	M	John	9655	0.0815	8.15	8
1880	M	William	9532	0.0805	8.05	8
1880	M	James	5927	0.0501	5.01	5
1880	M	Charles	5348	0.0451	4.51	5
1880	M	Garrett	13	0.0001	0.01	0
1881	M	John	8769	0.081	8.1	8

Vector Functions

TO USE WITH MUTATE ()

mutate() and **transmute()** apply vectorized functions to columns to create new columns. Vectorized functions take vectors as input and return vectors of the same length as output.

vectorized function 

OFFSETS

dplyr::lag() - Offset elements by 1
dplyr::lead() - Offset elements by -1

CUMULATIVE AGGREGATES

dplyr::cumall() - Cumulative all()
dplyr::cumany() - Cumulative any()
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cummin() - Cumulative min()
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cumsum() - Cumulative sum()

RANKINGS

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dplyr::min_rank() - rank with ties = min
dplyr::ntile() - bins into n bins
dplyr::percent_rank() - min_rank scaled to [0,1]
dplyr::row_number() - rank with ties = "first"

MATH

+, -, *, /, ^, %/%, %% - arithmetic ops
log(), log2(), log10() - logs
<, <=, >, >=, !=, == - logical comparisons

MISC

dplyr::between() - x >= left & x <= right
dplyr::case_when() - multi-case if_else()
dplyr::coalesce() - first non-NA values by element across a set of vectors
dplyr::if_else() - element-wise if() + else()
dplyr::na_if() - replace specific values with NA
pmax() - element-wise max()
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dplyr::recode() - Vectorized switch()
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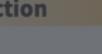
Vector functions

Take a vector as input.
Return a vector of the same length as output.

Vector Functions

TO USE WITH MUTATE ()

mutate() and **transmute()** apply vectorized functions to columns to create new columns. Vectorized functions take vectors as input and return vectors of the same length as output.

vectorized function 

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pmin() - element-wise min()
dplyr::recode() - Vectorized switch()
dplyr::recode_factor() - Vectorized switch() for factors

Summary Functions

TO USE WITH SUMMARISE ()

summarise() applies summary functions to columns to create a new table. Summary functions take vectors as input and return single values as output.

summary function 

COUNTS

dplyr::n() - number of values/rows
dplyr::n_distinct() - # of uniques
sum(is.na()) - # of non-NA's

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mean() - mean, also mean(is.na())
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dplyr::last() - last value
dplyr::nth() - value in nth location of vector

RANK

quantile() - nth quantile
min() - minimum value
max() - maximum value

SPREAD

IQR() - Inter-Quartile Range
mad() - median absolute deviation
sd() - standard deviation
var() - variance

Row Names

Tidy data does not use rownames, which store a variable outside of the columns. To work with the rownames, first move them into a column.

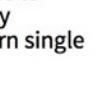
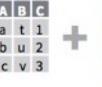
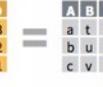
rownames_to_column()
Move row names into col.
a <- rownames_to_column(iris, var = "C")

column_to_rownames()
Move col in row names.
column_to_rownames(a, var = "C")

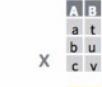
Also has_rownames(), remove_rownames()

Combine Tables

COMBINE VARIABLES

x y
 +  = 
Use bind_cols() to paste tables beside each other as they are.

COMBINE CASES

x y
 +  = 
Use bind_rows() to paste tables below each other as they are.

dplyr

COMBINE VARIABLES

x y
 +  = 
Use bind_cols() to paste tables beside each other as they are.

COMBINE CASES

x y
 +  = 
Use bind_rows() to paste tables below each other as they are.

dplyr

bind_rows(..., id = NULL)

Returns tables one on top of the other as a single table. Set .id to a column name to add a column of the original table names (as pictured)

intersect(x, y, ...)

Rows that appear in both x and y.

setdiff(x, y, ...)

Rows that appear in x but not y.

union(x, y, ...)

Rows that appear in x or y. (Duplicates removed). union_all() retains duplicates.

full_join(x, y, by = NULL, copy = FALSE, suffix = c("x", "y"), ...)

Join matching values from y to x.

right_join(x, y, by = NULL, copy = FALSE, suffix = c("x", "y"), ...)

Join matching values from x to y.

inner_join(x, y, by = NULL, copy = FALSE, suffix = c("x", "y"), ...)

Join data. Retain only rows with matches.

semi_join(x, y, by = NULL, ...)

Return rows of x that have a match in y. USEFUL TO SEE WHAT WILL BE JOINED.

anti_join(x, y, by = NULL, ...)

Return rows of x that do not have a match in y. USEFUL TO SEE WHAT WILL NOT BE JOINED.

setequal()

Use setequal() to test whether two data sets contain the exact same rows (in any order).

EXTRACT ROWS

x y
 +  = 
Use by = c("col1", "col2") to specify the column(s) to match on.

left_join(x, y, by = "A")

Use a named vector, by = c("col1" = "col2"), to match on columns with different names in each data set.

left_join(x, y, by = c("C" = "D"))

Use suffix to specify suffix to give to duplicate column names.

left_join(x, y, by = c("C" = "D"), suffix = c("1", "2"))

Also has_rownames(), remove_rownames()

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min_rank()

A go to ranking function (ties share the lowest rank)

```
min_rank(c(50, 100, 1000))  
# [1] 1 2 3
```

```
min_rank(desc(c(50, 100, 1000)))  
# [1] 3 2 1
```



Your Turn 13

Use `min_rank()` and `mutate()` to rank each row in `babynames` from largest `n` to lowest `n`.



```
babynames %>%
  mutate(rank = min_rank(desc(prop)))
```

#	year	sex	name	n	prop	rank
# 1	1880	F	Mary	7065	0.07238433	14
# 2	1880	F	Anna	2604	0.02667923	709
# 3	1880	F	Emma	2003	0.02052170	1131
# 4	1880	F	Elizabeth	1939	0.01986599	1192
# 5	1880	F	Minnie	1746	0.01788861	1427
# 6	1880	F	Margaret	1578	0.01616737	1683
# 7	1880	F	Ida	1472	0.01508135	1897
# 8	1880	F	Alice	1414	0.01448711	2040
# 9	1880	F	Bertha	1320	0.01352404	2279
# 10	1880	F	Sarah	1288	0.01319618	2387
# ...	with 1,858,679 more rows					

```
babynames %>%  
  group_by(year, sex) %>%  
  mutate(rank = min_rank(desc(prop)))
```



```
babynames %>%  
  group_by(year, sex) %>%  
  mutate(rank = min_rank(desc(prop)))
```

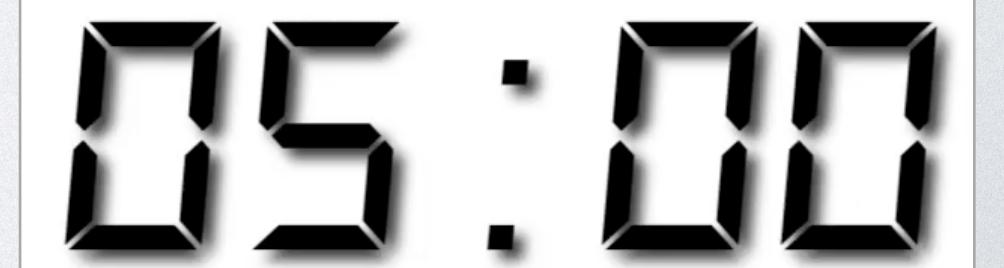
#	year	sex	name	n	prop	rank
# 1	1880	F	Mary	7065	0.0724	1
# 2	1880	F	Anna	2604	0.0267	2
# 3	1880	F	Emma	2003	0.0205	3
# 4	1880	F	Elizabeth	1939	0.0199	4
# 5	1880	F	Minnie	1746	0.0179	5
# 6	1880	F	Margaret	1578	0.0162	6
# 7	1880	F	Ida	1472	0.0151	7
# 8	1880	F	Alice	1414	0.0145	8
# ...			with 1,858,681 more rows			

Your Turn 14

What was each name's median rank?

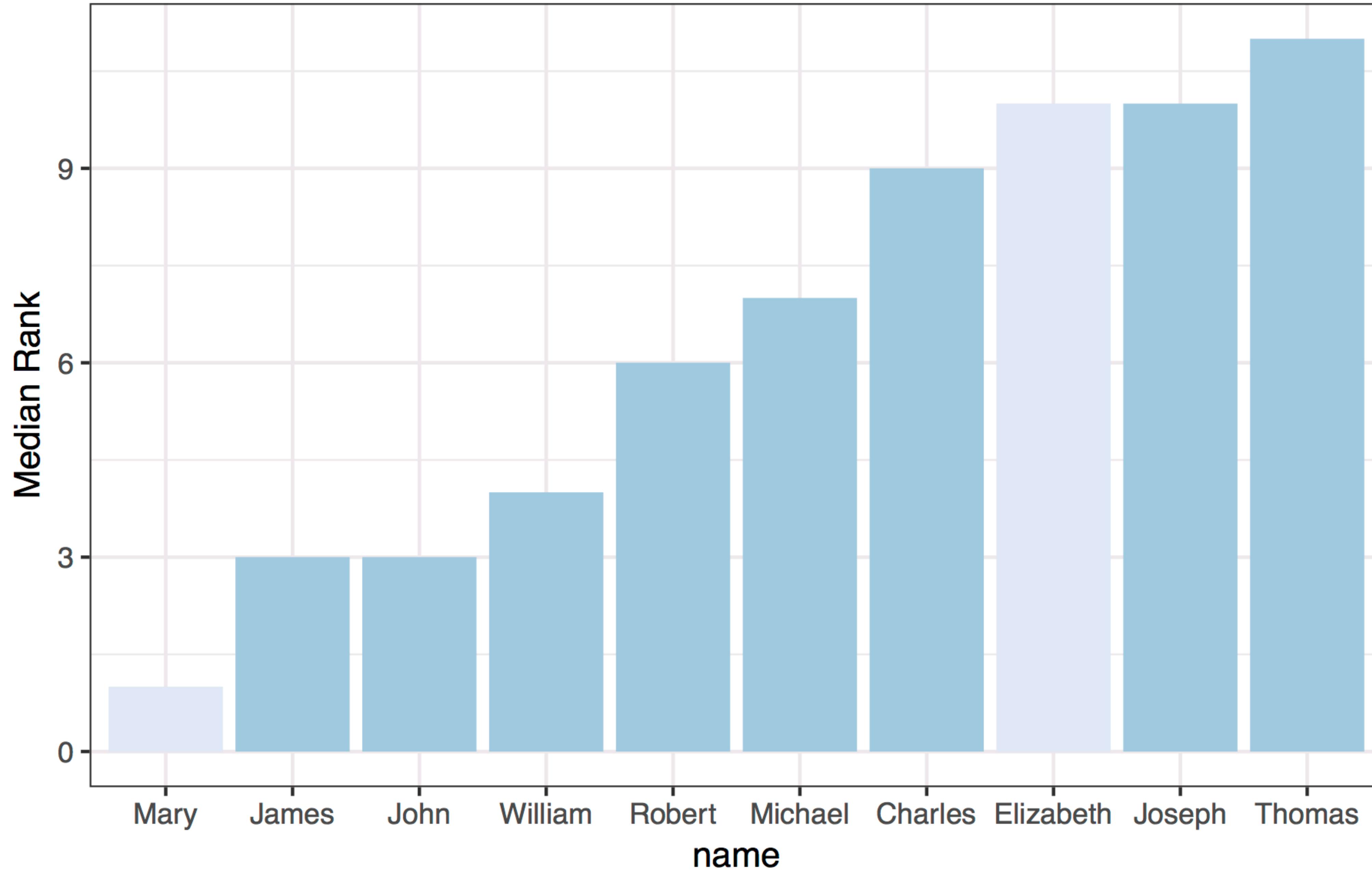
i.e., compute each name's rank *within its year and sex.*

Then compute the median rank for each combination of *name and sex*, and arrange the results from highest median rank to lowest.



```
babynames %>%  
  group_by(year, sex) %>%  
  mutate(rank = min_rank(desc(prop))) %>%  
  group_by(name, sex) %>%  
  summarise(score = median(rank)) %>%  
  arrange(score)
```

```
#          name sex score  
# 1      Mary   F     1  
# 2    James   M     3  
# 3    John   M     3  
# 4  William   M     4  
# 5   Robert   M     6  
# ... with 105,381 more rows
```

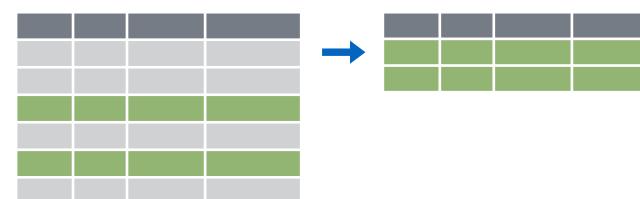


```
babynames %>%  
  group_by(year, sex) %>%  
  mutate(rank = min_rank(desc(prop))) %>%  
  group_by(name, sex) %>%  
  summarise(score = median(rank)) %>%  
  ungroup() %>%  
  arrange(score) %>%  
  slice(1:10) %>%  
  ggplot() +  
    geom_col(mapping = aes(x = fct_reorder(name, score), y = score,  
                           fill = sex)) +  
    theme_bw() +  
    scale_fill_brewer() +  
    labs(x = "name", y = "Median Rank")
```

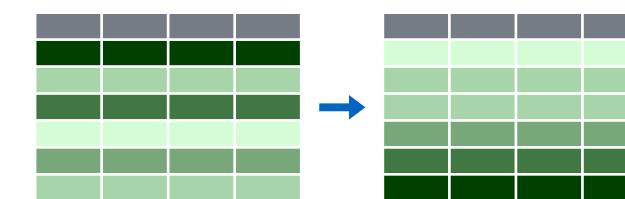
Recap: Single table verbs



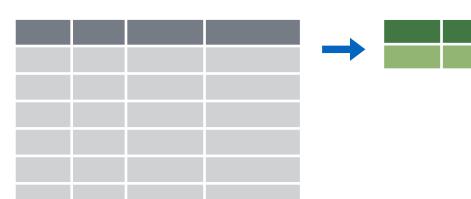
Extract variables with **select()**



Extract cases with **filter()**



Arrange cases, with **arrange()**.



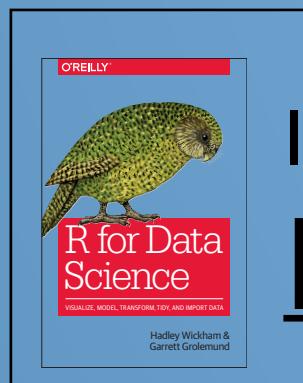
Make tables of summaries with **summarise()**.



Make new variables, with **mutate()**.



Joining Datasets



In R4DS
Relational Data

nycflights13



Data about every flight that departed La
Guardia, JFK, or Newark airports in 2013

```
# install.packages("nycflights13")
library(nycflights13)
```



Flights

[View\(flights\)](#)

year	month	day	dep_time	sched_dep_time	dep_delay	arr_time	sched_arr_time	arr_delay	carrier	flight	tailnum	origin	dest	air_time	distance	hour	minute	time_hour
2013	1	1	517	515	2	830	819	11	UA	1545	N14228	EWR	IAH	227	1400	5	15	2013-01-01 05:00:00
2013	1	1	533	529	4	850	830	20	UA	1714	N24211	LGA	IAH	227	1416	5	29	2013-01-01 05:00:00
2013	1	1	542	540	2	923	850	33	AA	1141	N619AA	JFK	MIA	160	1089	5	40	2013-01-01 05:00:00
2013	1	1	544	545	-1	1004	1022	-18	B6	725	N804JB	JFK	BQN	183	1576	5	45	2013-01-01 05:00:00
2013	1	1	554	600	-6	812	837	-25	DL	461	N668DN	LGA	ATL	116	762	6	0	2013-01-01 06:00:00
2013	1	1	554	558	-4	740	728	12	UA	1696	N39463	EWR	ORD	150	719	5	58	2013-01-01 05:00:00
2013	1	1	555	600	-5	913	854	19	B6	507	N516JB	EWR	FLL	158	1065	6	0	2013-01-01 06:00:00
2013	1	1	557	600	-3	709	723	-14	EV	5708	N829AS	LGA	IAD	53	229	6	0	2013-01-01 06:00:00
2013	1	1	557	600	-3	838	846	-8	B6	79	N593JB	JFK	MCO	140	944	6	0	2013-01-01 06:00:00
2013	1	1	558	600	-2	753	745	8	AA	301	N3ALAA	LGA	ORD	138	733	6	0	2013-01-01 06:00:00
2013	1	1	558	600	-2	849	851	-2	B6	49	N793JB	JFK	PBI	149	1028	6	0	2013-01-01 06:00:00
2013	1	1	558	600	-2	853	856	-3	B6	71	N657JB	JFK	TPA	158	1005	6	0	2013-01-01 06:00:00
2013	1	1	558	600	-2	924	917	7	UA	194	N29129	JFK	LAX	345	2475	6	0	2013-01-01 06:00:00
2013	1	1	558	600	-2	923	937	-14	UA	1124	N53441	EWR	SFO	361	2565	6	0	2013-01-01 06:00:00
2013	1	1	559	600	-1	941	910	31	AA	707	N3DUAA	LGA	DFW	257	1389	6	0	2013-01-01 06:00:00
2013	1	1	559	559	0	702	706	-4	B6	1806	N708JB	JFK	BOS	44	187	5	59	2013-01-01 05:00:00
2013	1	1	559	600	-1	854	902	-8	UA	1187	N76515	EWR	LAS	337	2227	6	0	2013-01-01 06:00:00
2013	1	1	600	600	0	851	858	-7	B6	371	N595JB	LGA	FLL	152	1076	6	0	2013-01-01 06:00:00

skim(flights)

Skim summary statistics

n obs: 336776

n variables: 19

— Variable type:character

	variable	missing	complete	n	min	max	empty	n_unique
	carrier	0	336776	336776	2	2	0	16
	dest	0	336776	336776	3	3	0	105
	origin	0	336776	336776	3	3	0	3
	tailnum	2512	334264	336776	5	6	0	4043

— Variable type:integer

	variable	missing	complete	n	mean	sd	p0	p25	p50	p75	p100	hist
	arr_time	8713	328063	336776	1502.05	533.26	1	1104	1535	1940	2400	
	day	0	336776	336776	15.71	8.77	1	8	16	23	31	
	dep_time	8255	328521	336776	1349.11	488.28	1	907	1401	1744	2400	
	flight	0	336776	336776	1971.92	1632.47	1	553	1496	3465	8500	
	month	0	336776	336776	6.55	3.41	1	4	7	10	12	
	sched_arr_time	0	336776	336776	1536.38	497.46	1	1124	1556	1945	2359	
	sched_dep_time	0	336776	336776	1344.25	467.34	106	906	1359	1729	2359	
	year	0	336776	336776	2013	0	2013	2013	2013	2013	2013	

— Variable type:numeric

	variable	missing	complete	n	mean	sd	p0	p25	p50	p75	p100	hist
	air_time	9430	327346	336776	150.69	93.69	20	82	129	192	695	
	arr_delay	9430	327346	336776	6.9	44.63	-86	-17	-5	14	1272	
	dep_delay	8255	328521	336776	12.64	40.21	-43	-5	-2	11	1301	



Details



⚠ The class of service you searched may not be available on one or more flights

BNA - ORD

Flight 1 of 2

ORD - YVR

Flight 2 of 2

Nashville, TN to Chicago, IL

Thursday, July 26, 2018

4:10 PM → 6:03 PM

AA 3246 ■ CRJ-Canadair RJ 700
Operated by SkyWest Airlines As American Eagle

Travel info

Travel time: 1h 53m
Connection time: 2h 33m

Performance

On time: 52%
Late: 43%

Performance*

On time: 52%**
Late: 43%

Main Cabin

Meals: Beverage service
Booking code: V
Class: Economy

Business

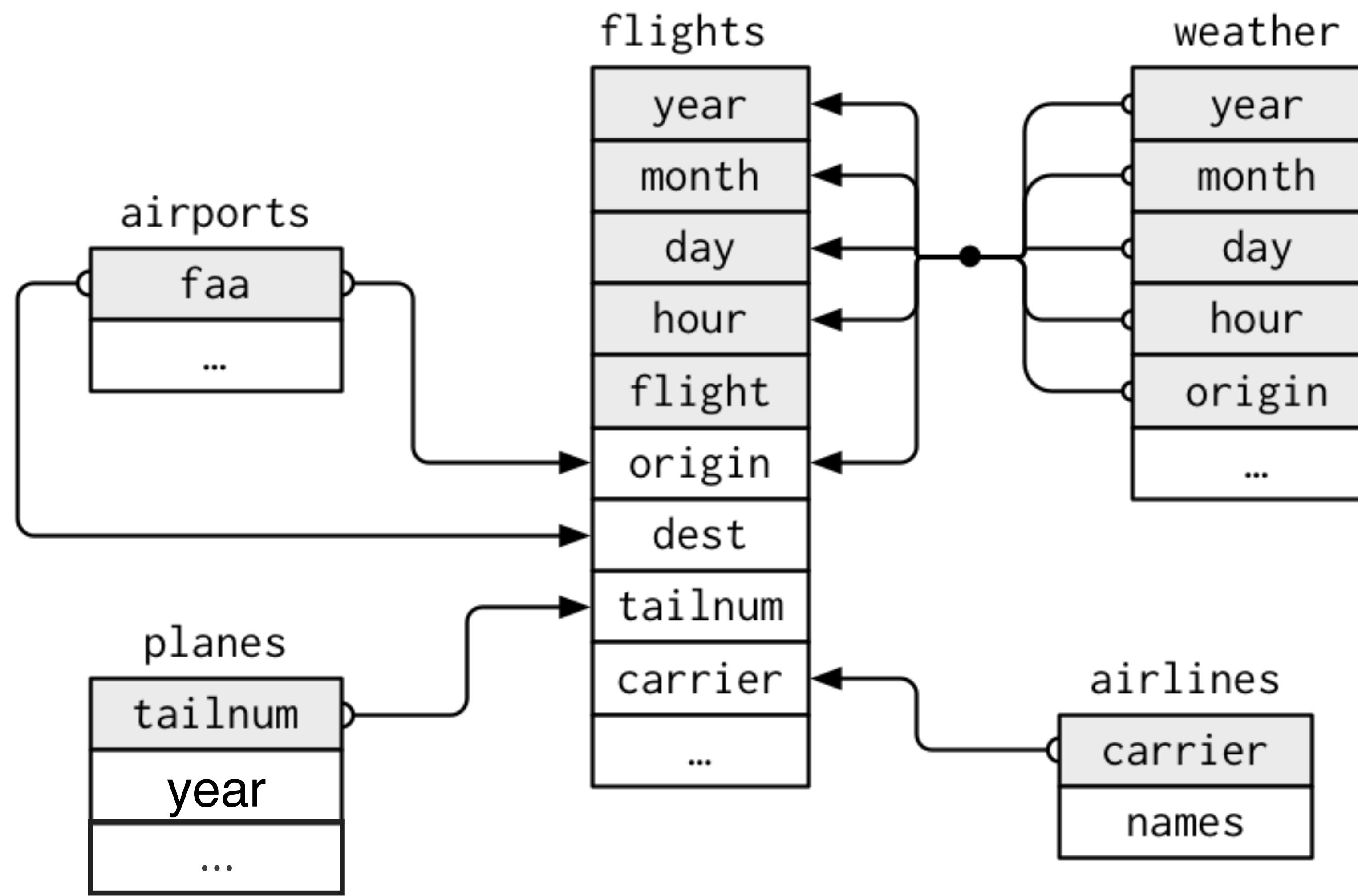
Meals: Beverage service
Booking code: I
Class: First

* This is based on information from the month of May 2018

** The on-time arrival percentage for the selected flight is based on arrival within 14 minutes after

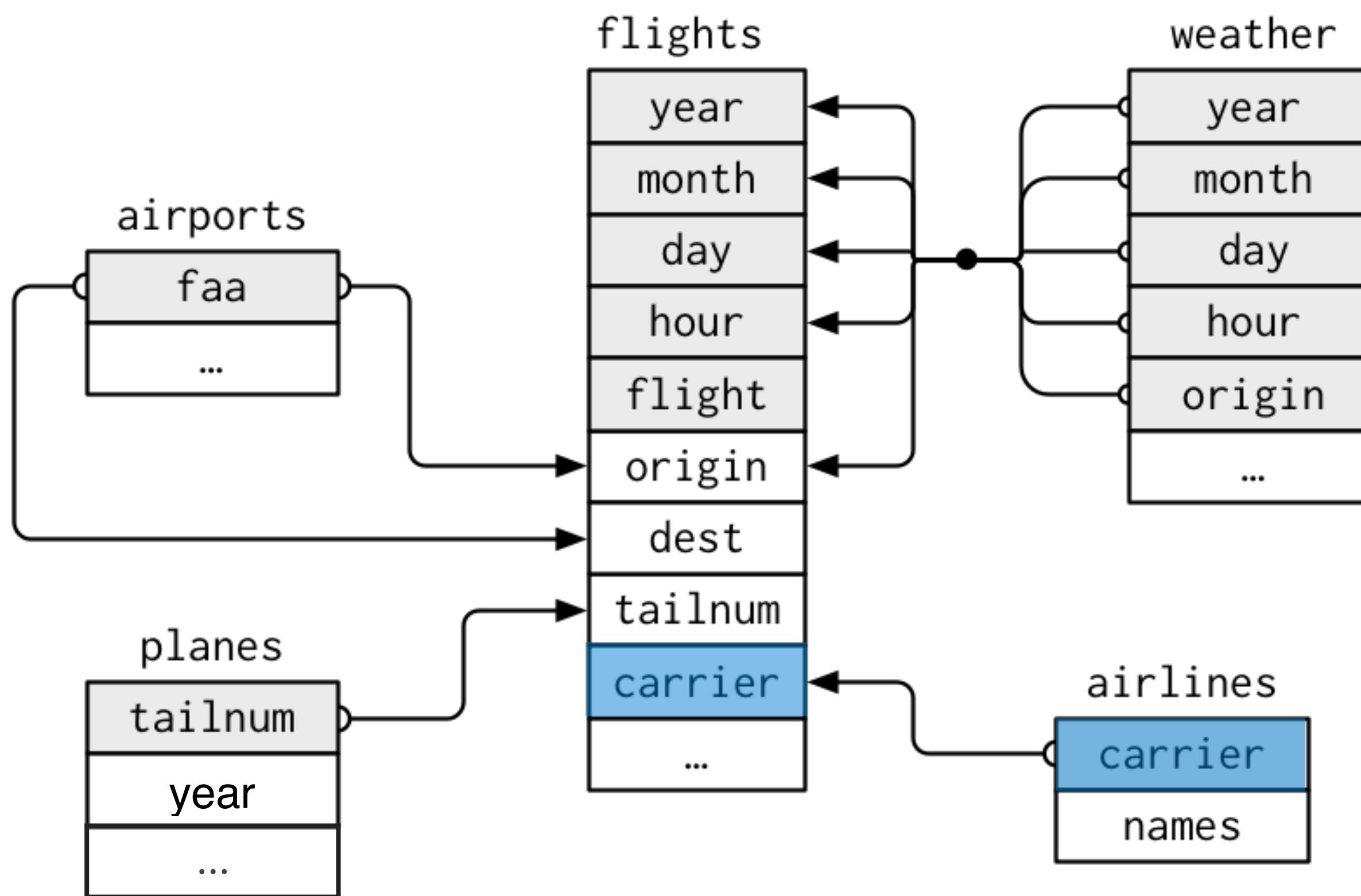
**** The on-time arrival percentage for the selected flight is based on arrival within 14 minutes after the scheduled arrival as reported monthly to the U.S. Department of Transportation.**

nycflights13



nycflights13

What airline had the longest delays?



Airline names

`View(flights["carrier"])`

	carrier
1	UA
2	UA
3	AA
4	B6
5	DL
6	UA
7	B6

`View(airlines)`

	carrier	name
1	9E	Endeavor Air Inc.
2	AA	American Airlines Inc.
3	AS	Alaska Airlines Inc.
4	B6	JetBlue Airways
5	DL	Delta Air Lines Inc.
6	EV	ExpressJet Airlines Inc.
7	F9	Frontier Airlines Inc.

types of joins

Mutating joins use information from one data set **to add variables** to another data set (like **mutate()**)

Filtering joins use information from one data set **to extract cases** from another data set (like **filter()**)



mutating joins

A large, semi-transparent watermark of the R logo is positioned in the bottom right corner. The logo consists of a bold, italicized capital letter 'R' enclosed within a circular arrow.

common syntax

Each join function returns a data frame / tibble.

```
left_join(x, y, by = NULL, ...)
```

join function

data frames
to join

names of columns
to join on



Toy data

```
band <- tribble(  
  ~name,      ~band,  
  "Mick",    "Stones",  
  "John",    "Beatles",  
  "Paul",    "Beatles"  
)
```

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

```
instrument <- tribble(  
  ~name,    ~plays,  
  "John",   "guitar",  
  "Paul",   "bass",  
  "Keith",  "guitar"  
)
```

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar



Toy data

band		instrument	
name	band	name	plays
Mick	Stones	John	guitar
John	Beatles	Paul	bass
Paul	Beatles	Keith	guitar



left

```
band %>% left_join(instrument, by = "name")
```

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass

=

name	band	plays
Mick	Stones	<NA>
John	Beatles	guitar
Paul	Beatles	bass



right

```
band %>% right_join(instrument, by = "name")
```

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	plays
John	Beatles	guitar
Paul	Beatles	bass
Keith	<NA>	guitar



full

```
band %>% full_join(instrument, by = "name")
```

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band	plays
Mick	Stones	<NA>
John	Beatles	guitar
Paul	Beatles	bass
Keith	<NA>	guitar



inner

```
band %>% inner_join(instrument, by = "name")
```

The diagram illustrates the addition of two tables: **band** and **instrument**, resulting in a combined table.

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

+

=

name	band	plays
John	Beatles	guitar
Paul	Beatles	bass



Airline names

`View(flights["carrier"])`

	carrier
1	UA
2	UA
3	AA
4	B6
5	DL
6	UA
7	B6

`View(airlines)`

	carrier	name
1	9E	Endeavor Air Inc.
2	AA	American Airlines Inc.
3	AS	Alaska Airlines Inc.
4	B6	JetBlue Airways
5	DL	Delta Air Lines Inc.
6	EV	ExpressJet Airlines Inc.
7	F9	Frontier Airlines Inc.

Your Turn 15

Which airlines had the largest arrival delays? Work in groups to complete the code below.

```
flights %>%
```

```
drop_na(arr_delay) %>%
```

```
_____ %>%
```

```
group_by(_____) %>%
```

```
_____ %>%
```

```
arrange(____)
```

1. Join airlines to flights

2. Compute and order the average arrival delays by airline. Display full names, no codes.



```
flights %>%  
  drop_na(arr_delay) %>%  
  left_join(airlines, by = "carrier") %>%  
  group_by(name) %>%  
  summarise(delay = mean(arr_delay)) %>%  
  arrange(delay)  
  
## # A tibble: 16 × 2  
##   name          delay  
##   <chr>        <dbl>  
## 1 Alaska Airlines Inc. -9.9308886  
## 2 Hawaiian Airlines Inc. -6.9152047  
## 3 American Airlines Inc.  0.3642909  
## 4 Delta Air Lines Inc.   1.6443409  
## 5 Virgin America          1.7644644
```



Toy data

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

```
band <- tribble(  
  ~name,      ~band,  
  "Mick",    "Stones",  
  "John",    "Beatles",  
  "Paul",    "Beatles"  
)
```

instrument2

artist	plays
John	guitar
Paul	bass
Keith	guitar

```
instrument2 <- tribble(  
  ~artist,    ~plays,  
  "John",    "guitar",  
  "Paul",    "bass",  
  "Keith",   "guitar"  
)
```



What if the names do not match?

Use a named vector to match on variables with different names.

```
band %>% left_join(instrument2, by = c("name" = "artist"))
```

A named vector

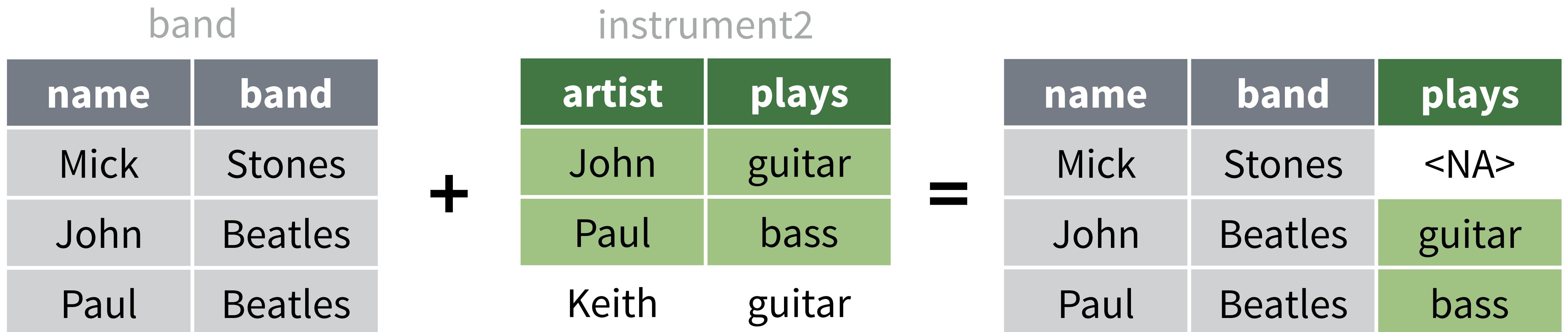
The name of the
element = the column
name in the first data
set

The value of the
element = the column
name in the second
data set



common syntax - matching names

```
band %>% left_join(instrument2, by = c("name" = "artist"))
```



Airport names

`View(flights["dest"])`

	dest
1	IAH
2	IAH
3	MIA
4	BQN
5	ATL
6	ORD
7	FIA

`View(airports)`

faa	name
04G	Lansdowne Airport
06A	Moton Field Municipal Airport
06C	Schaumburg Regional
06N	Randall Airport
09J	Jekyll Island Airport
0A9	Elizabethton Municipal Airport
0CC	Willow Creek Airport

Airport names

```
airports %>% select(1:3)
```

	faa	name
	<chr>	<chr>
04G	Lansdowne Airport	
06A	Moton Field Municipal Airport	
06C	Schaumburg Regional	
06N	Randall Airport	
09J	Jekyll Island Airport	
0A9	Elizabethton Municipal Airport	
0G6	Williams County Airport	
0G7	Finger Lakes Regional Airport	

```
flights %>% select(14:15)
```

	dest	air_time
	<chr>	<dbl>
	IAH	227
	IAH	227
	MIA	160
	BQN	183
	ATL	116
	ORD	150
	FLL	158
	IAD	53



common syntax - matching names

```
airports %>% left_join(flights, by = c("faa" = "dest"))
```

	faa <chr>	name <chr>		dest <chr>	air_time <dbl>
04G	Lansdowne Airport			IAH	227
06A	Moton Field Municipal Airport			IAH	227
06C	Schaumburg Regional			MIA	160
06N	Randall Airport			BQN	183
09J	Jekyll Island Airport			ATL	116
0A9	Elizabethton Municipal Airport			ORD	150
0G6	Williams County Airport			FLL	158
0G7	Finger Lakes Regional Airport			IAD	53



filtering joins

A faint watermark of the R logo is visible in the bottom right corner, consisting of two interlocking curved arrows forming a circular shape.

filtering joins

Mutating joins use information from one data set **to add variables** to another data set (like **mutate()**)

Filtering joins use information from one data set **to extract cases** from another data set (like **filter()**)



semi

```
band %>% semi_join(instrument, by = "name")
```

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass

Keith guitar

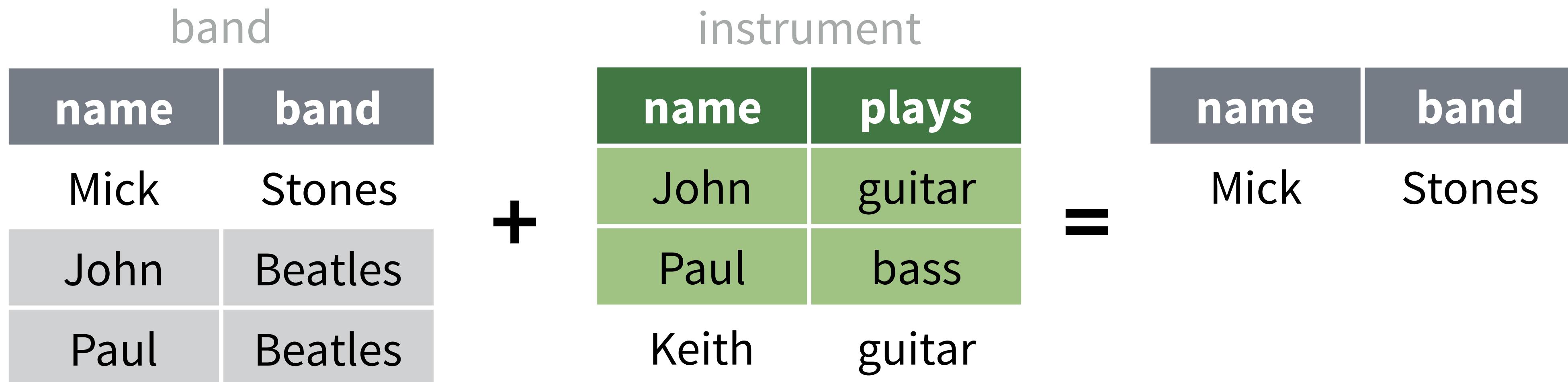
=

name	band
John	Beatles
Paul	Beatles



anti

```
band %>% anti_join(instrument, by = "name")
```



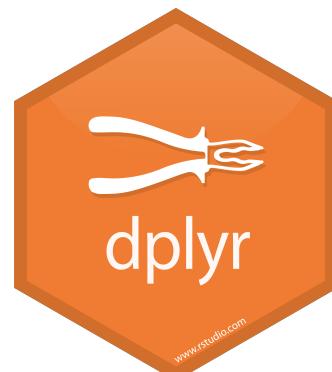
Airport names

```
airports %>% select(1:3)
```

	faa	name
	<chr>	<chr>
04G	Lansdowne Airport	
06A	Moton Field Municipal Airport	
06C	Schaumburg Regional	
06N	Randall Airport	
09J	Jekyll Island Airport	
0A9	Elizabethton Municipal Airport	
0G6	Williams County Airport	
0G7	Finger Lakes Regional Airport	

```
flights %>% select(14:15)
```

	dest	air_time
	<chr>	<dbl>
	IAH	227
	IAH	227
	MIA	160
	BQN	183
	ATL	116
	ORD	150
	FLL	158
	IAD	53



Your Turn 16

How many airports in **airports** are serviced by flights originating in New York (i.e. flights in our dataset?)

Notice that the column to join on is named **faa** in the **airports** dataset and **dest** in the **flights** dataset.



```
airports %>%  
  semi_join(flights, by = c("faa" = "dest")) %>%  
  distinct(faa)
```

faa
<chr>
IAH
MIA
ATL
ORD
FLL
IAD
MCO
PBI
TPA
LAX

1-10 of 101 rows

Previous 1 2 3 4 5 6 ... 11 Next



distinct()

Removes rows with duplicate values (in a column).

```
distinct(instrument, plays)
```

instrument

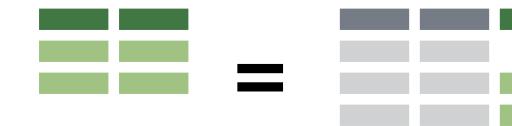
name	plays
John	guitar
Paul	bass
Keith	guitar

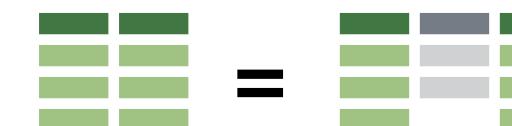
→

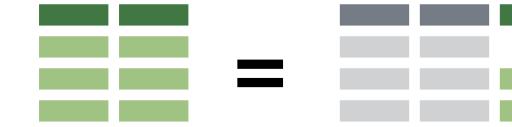
plays
guitar
bass

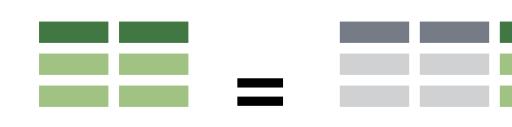


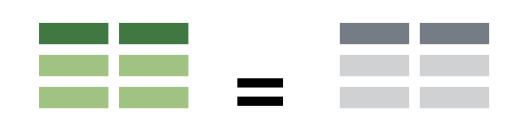
Recap: Two table verbs

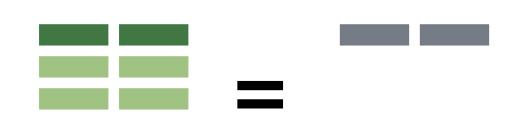
 +  =  **left_join()** retains all cases in **left** data set

 +  =  **right_join()** retains all cases in **right** data set

 +  =  **full_join()** retains all cases in **either** data set

 +  =  **inner_join()** retains only cases in **both** data sets

 +  =  **semi_join()** extracts cases that **have a match**

 +  =  **anti_join()** extracts cases that **do not have a match**



Two table verbs

Vector Functions

TO USE WITH MUTATE()

mutate() and **transmute()** apply vectorized functions to columns to create new columns. Vectorized functions take vectors as input and return vectors of the same length as output.

- vectorized function**

OFFSETS

dplyr::lag() - Offset elements by 1
dplyr::lead() - Offset elements by -1

CUMULATIVE AGGREGATES

dplyr::cumall() - Cumulative all()
dplyr::cumany() - Cumulative any()
dplyr::cummax() - Cumulative max()
dplyr::cummean() - Cumulative mean()
dplyr::cummin() - Cumulative min()
dplyr::cumprod() - Cumulative prod()
dplyr::cumsum() - Cumulative sum()

RANKINGS

dplyr::cume_dist() - Proportion of all values <=
dplyr::dense_rank() - rank with ties = min, no gaps
dplyr::min_rank() - rank with ties = min
dplyr::ntile() - bins into n bins
dplyr::percent_rank() - min_rank scaled to [0,1]
dplyr::row_number() - rank with ties = "first"

MATH

+, -, *, /, ^, %/%, %% - arithmetic ops
log(), log2(), log10() - logs
<, <=, >, >=, !=, == - logical comparisons

MISC

dplyr::between() - x >= left & x <= right
dplyr::case_when() - multi-case if_else()
dplyr::coalesce() - first non-NA values by element across a set of vectors
dplyr::if_else() - element-wise if() + else()
dplyr::na_if() - replace specific values with NA
pmax() - element-wise max()
pmin() - element-wise min()
dplyr::recode() - Vectorized switch()
dplyr::recode_factor() - Vectorized switch() for factors

Row Names

Tidy data does not use rownames, which store a variable outside of the columns. To work with the rownames, first move them into a column.

- rownames_to_column()**
Move row names into col.
a <- rownames_to_column(iris, var = "C")
- column_to_rownames()**
Move col in row names.
b <- column_to_rownames(a, var = "C")

Also has **rownames()**, **remove_rownames()**

Summary Functions

TO USE WITH SUMMARISE()

summarise() applies summary functions to columns to create a new table. Summary functions take vectors as input and return single values as output.

- summary function**

COUNTS

dplyr::n() - number of values/rows
dplyr::n_distinct() - # of uniques
sum(!is.na()) - # of non-NAs

LOCATION

mean() - mean, also mean(is.na())
median() - median

LOGICALS

mean() - Proportion of TRUE's
sum() - # of TRUE's

POSITION/ORDER

dplyr::first() - first value
dplyr::last() - last value
dplyr::nth() - value in nth location of vector

RANK

quantile() - nth quantile
min() - minimum value
max() - maximum value

SPREAD

IQR() - Inter-Quartile Range
mad() - median absolute deviation
sd() - standard deviation
var() - variance

Combine Tables

COMBINE VARIABLES

Use **bind_cols()** to paste tables beside each other as they are.

bind_cols(...) Returns tables placed side by side as a single table.
BE SURE THAT ROWS ALIGN.

COMBINE CASES

Use **bind_rows(..., .id = NULL)** to paste tables below each other as they are.

bind_rows(..., .id = NULL) Returns tables one on top of the other as a single table. Set **.id** to a column name to add a column of the original table names (as pictured)

COMBINE CASES

Use a "Mutating Join" to join one table to columns from another, matching values with the rows that they correspond to. Each join retains a different combination of values from the tables.

left_join(x, y, by = NULL, copy = FALSE, suffix=c("x","y"),...)
Join matching values from y to x.

right_join(x, y, by = NULL, copy = FALSE, suffix=c("x","y"),...)
Join matching values from x to y.

bind_rows(..., .id = NULL)
Returns tables one on top of the other as a single table. Set **.id** to a column name to add a column of the original table names (as pictured)

inner_join(x, y, by = NULL, copy = FALSE, suffix=c("x","y"),...)
Join data. Retain only rows with matches.

intersect(x, y, ...)
Rows that appear in both x and y.

setdiff(x, y, ...)
Rows that appear in x but not y.

union(x, y, ...)
Rows that appear in x or y. (Duplicates removed). **union_all()** retains duplicates.

full_join(x, y, by = NULL, copy = FALSE, suffix=c("x","y"),...)
Join data. Retain all values, all rows.

use_sequal() to test whether two data sets contain the exact same rows (in any order).

EXTRACT ROWS

Use **by = c("col1", "col2")** to specify the column(s) to match on.
left_join(x, y, by = "A")

Use a named vector, **by = c("col1" = "col2")**, to match on columns with different names in each data set.
left_join(x, y, by = c("C" = "D"))

Use **suffix** to specify suffix to give to duplicate column names.
left_join(x, y, by = c("C" = "D"), suffix = c("1", "2"))

Use a "Filtering Join" to filter one table against the rows of another.

semi_join(x, y, by = NULL, ...)
Return rows of x that have a match in y. USEFUL TO SEE WHAT WILL BE JOINED.

anti_join(x, y, by = NULL, ...)
Return rows of x that do not have a match in y. USEFUL TO SEE WHAT WILL NOT BE JOINED.

use_sequal() to test whether two data sets contain the exact same rows (in any order).

semi_join(x, y, by = NULL, ...)
Return rows of x that have a match in y. USEFUL TO SEE WHAT WILL BE JOINED.

anti_join(x, y, by = NULL, ...)
Return rows of x that do not have a match in y. USEFUL TO SEE WHAT WILL NOT BE JOINED.



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Transform Data with

