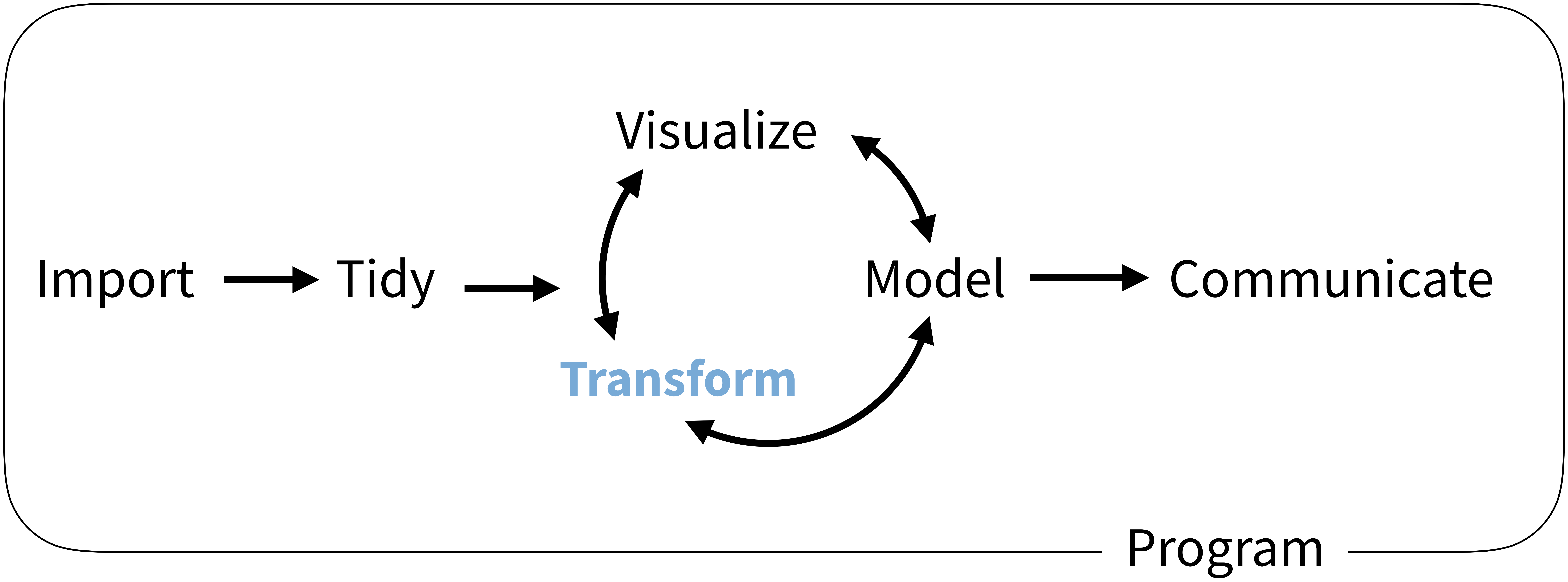
Data Transformation with

dplyr

(Applied) Data Science



babynames

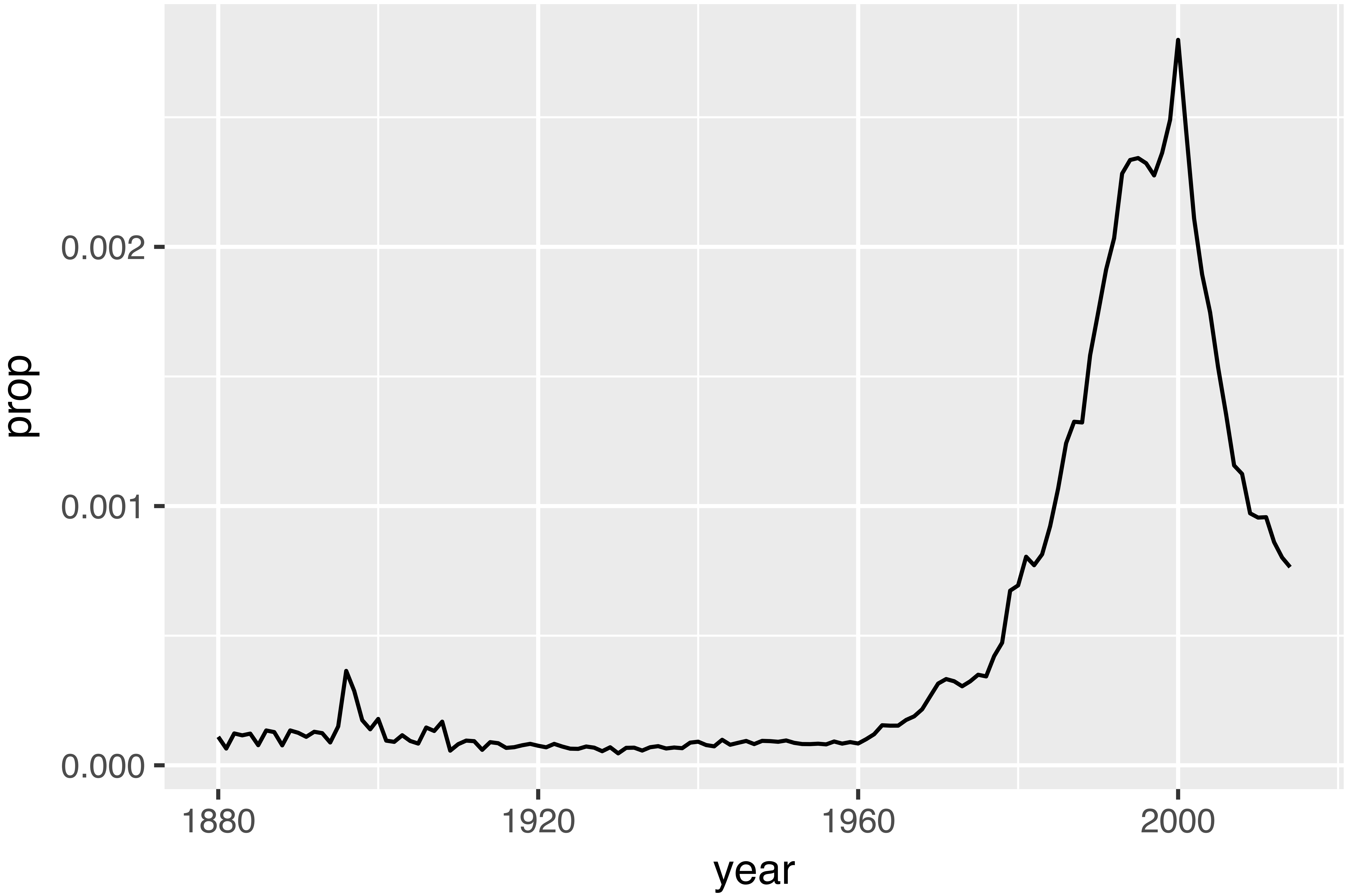
Names of male and female babies born in the US from 1880 to 2008. 1.8M rows.

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

```
View(babynames)
```

	year	sex	name	n	prop
1	1880	F	Mary	7065	0.0723835869
2	1880	F	Anna	2604	0.0266789611
3	1880	F	Emma	2003	0.0205214897
4	1880	F	Elizabeth	1939	0.0198657856
5	1880	F	Minnie	1746	0.0178884278
6	1880	F	Margaret	1578	0.0161672045
7	1880	F	Ida	1472	0.0150811946
8	1880	F	Alice	1414	0.0144869628
9	1880	F	Bertha	1320	0.0135238973
10	1880	F	Sarah	1288	0.0131960453
11	1880	F	Annie	1258	0.0128886840

Proportion of boys with the name Garrett

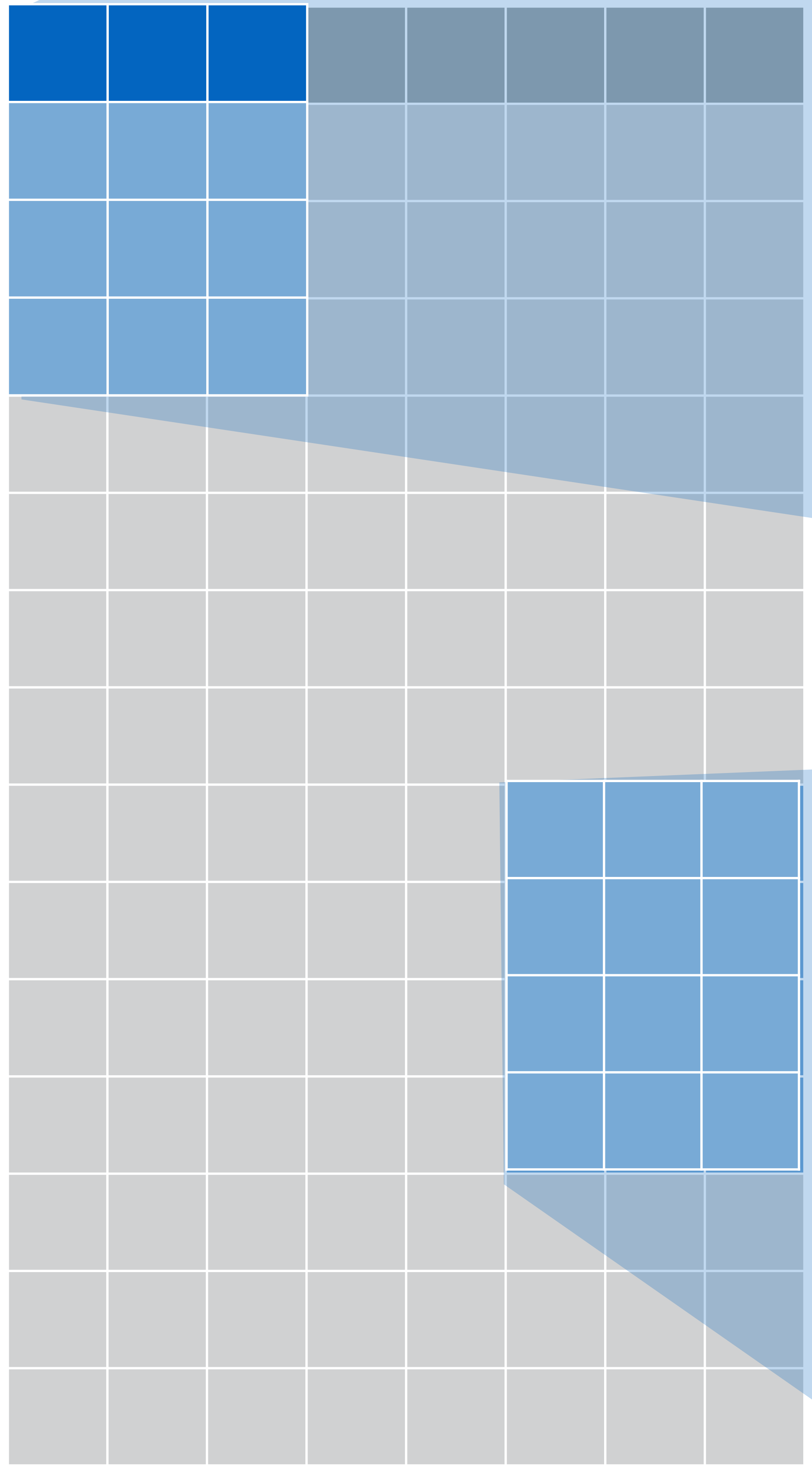


tibbles

tibbles

A type of data frame common throughout tidyverse packages. Tibbles enhance data frames in three ways:

1. **Subsetting** - [always returns a new tibble, [[and $ always return a new vector
2. **No partial matching** - You must use full column names when subsetting
3. **Display** - When you print a tibble, R provides a concise view of the data that fits on one screen



A large table to display

```
# A tibble: 234 × 6
   manufacturer      model displ
          <chr>      <chr> <dbl>
1          audi         a4   1.8
2          audi         a4   1.8
3          audi         a4   2.0
4          audi         a4   2.0
5          audi         a4   2.8
6          audi         a4   2.8
7          audi         a4   3.1
8          audi a4 quattro   1.8
9          audi a4 quattro   1.8
10         audi a4 quattro   2.0
# ... with 224 more rows, and 3
#   more variables: year <int>,
#   cyl <int>, trans <chr>
```

tibble display

```
156 1999   6   auto(l4)
157 1999   6   auto(l4)
158 2008   6   auto(l4)
159 2008   8   auto(s4)
160 1999   4 manual(m5)
161 1999   4   auto(l4)
162 2008   4 manual(m5)
163 2008   4 manual(m5)
164 2008   4   auto(l4)
165 2008   4   auto(l4)
166 1999   4   auto(l4)
 [ reached getOption("max.print") --
omitted 68 rows ]
```

data frame display

R package

tibble

A package with several helper functions for tibbles:

- **as_tibble()** - convert a data frame to a tibble
- **as.data.frame()** - convert a tibble to a data frame
- **tribble()** - make a tibble (transversed)

```
tribble(
    ~x,  ~y,
     1, "a",
     2, "b",
     3, "c")
```

x	y
1	a
2	b
3	c

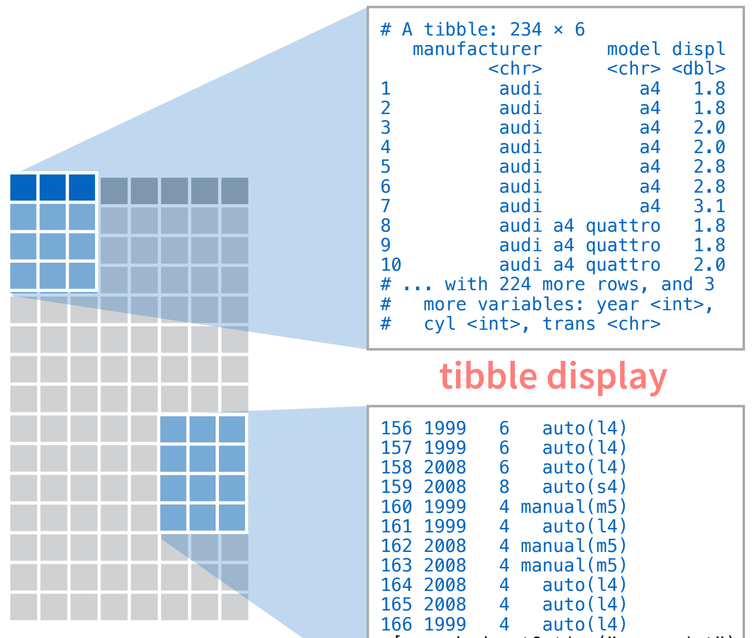
dplyr

tibbles

Tibbles - an enhanced data frame

The **tibble** package provides a new S3 class for storing tabular data, the tibble. Tibbles inherit the data frame class, but improve two behaviors:

- **Display** - When you print a tibble, R provides a concise view of the data that fits on one screen.
- **Subsetting** - [always returns a new tibble, [[and $ always return a vector.
- **No partial matching** - You must use full column names when subsetting



A large table to display

```
# A tibble: 234 × 6
   manufacturer       model displ
          <chr>       <chr> <dbl>
1          audi          a4   1.8
2          audi          a4   1.8
3          audi          a4   2.0
4          audi          a4   2.0
5          audi          a4   2.8
6          audi          a4   2.8
7          audi          a4   3.1
8          audi  a4 quattro   1.8
9          audi  a4 quattro   1.8
10         audi  a4 quattro   2.0
# ... with 224 more rows, and 3
#   more variables: year <int>,
#   cyl <int>, trans <chr>
```

tibble display

```
156 1999    6   auto(l4)
157 1999    6   auto(l4)
158 2008    6   auto(l4)
159 2008    8   auto(s4)
160 1999    4 manual(m5)
161 1999    4   auto(l4)
162 2008    4 manual(m5)
163 2008    4 manual(m5)
164 2008    4   auto(l4)
165 2008    4   auto(l4)
166 1999    4   auto(l4)
 [ reached getOption("max.print")
-- omitted 68 rows ]
```

data frame display

- Control the default appearance with options:

  options(tibble.print_max = n, tibble.print_min = m, tibble.width = Inf)

- View entire data set with **View**(x, title) or **glimpse**(x, width = NULL, …)
- Revert to data frame with **as.data.frame()** (required for some older packages)

Construct a tibble in two ways

tibble(…)
Construct by columns.
tibble(x = 1:3, y = c("a", "b", "c"))

Both make this tibble

tribble(…)
Construct by rows.
tribble(~x, ~y, 1, "a", 2, "b", 3, "c")

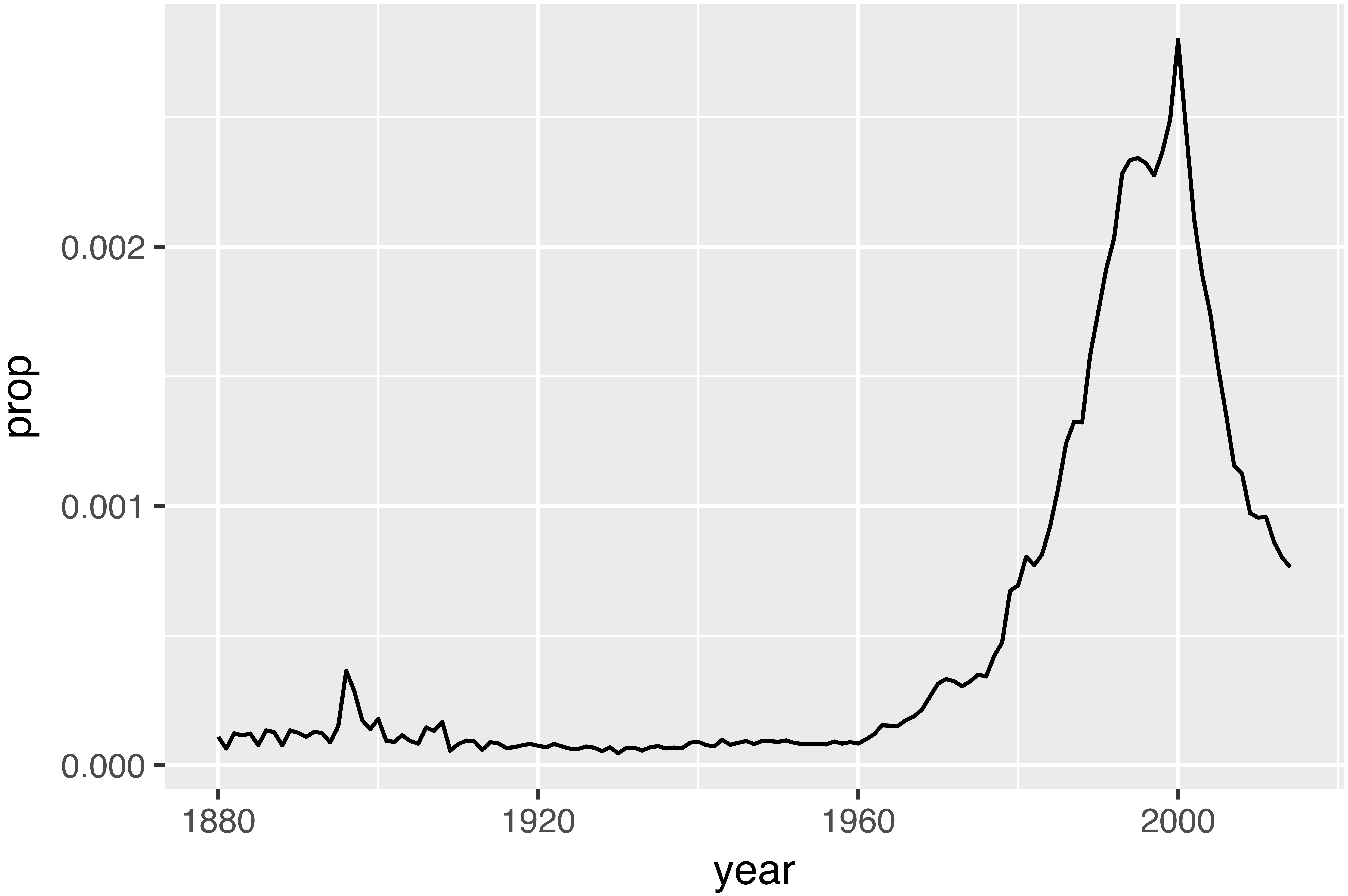
```
A tibble: 3 × 2
      x     y
  <int> <dbl>
1     1     a
2     2     b
3     3     c
```

as_tibble(x, …) Convert data frame to tibble.

enframe(x, name = "name", value = "value") Converts named vector to a tibble with a names column and a values column.

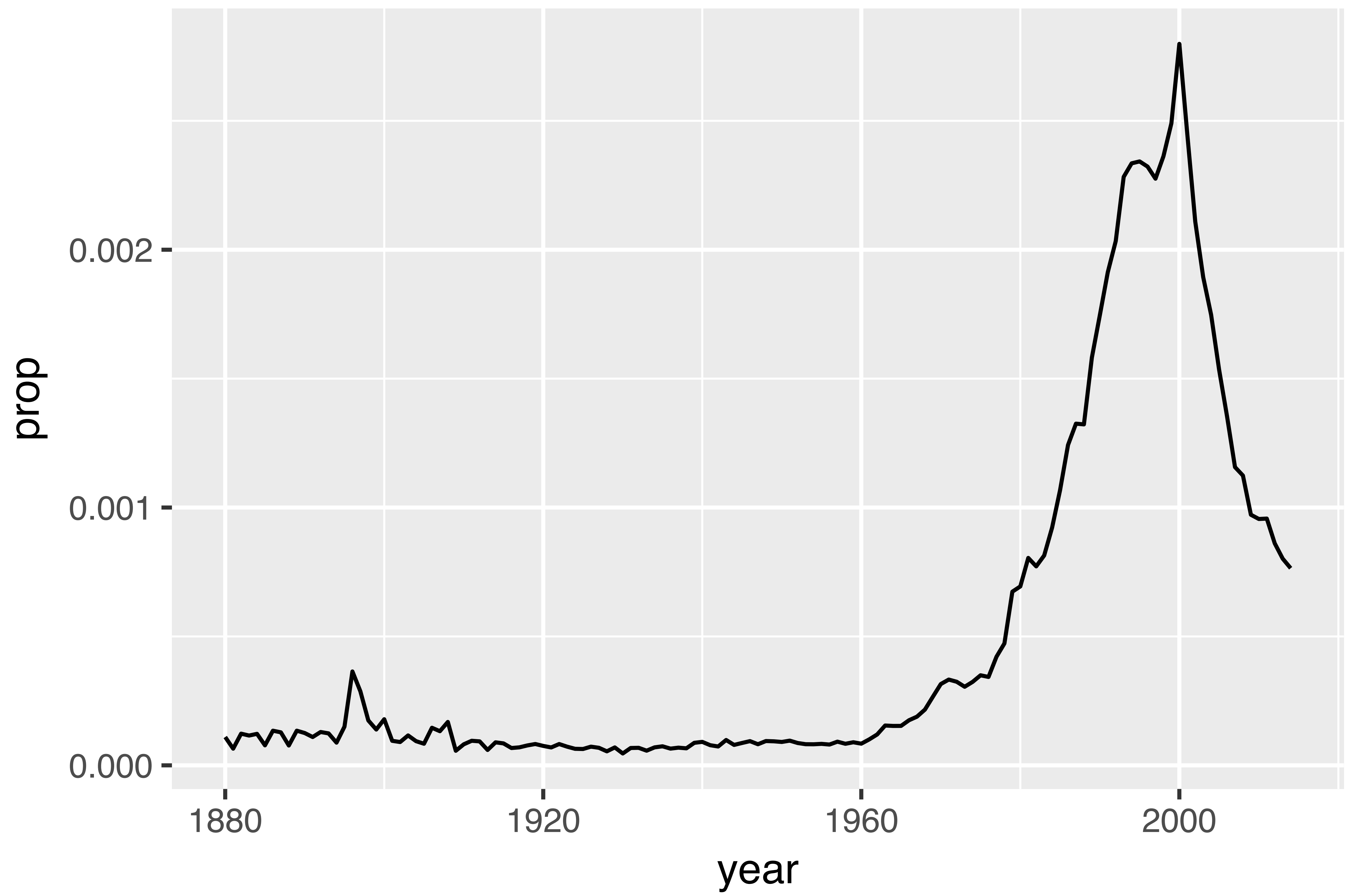
is_tibble(x) Test whether x is a tibble.

Proportion of boys with the name Garrett



What variables do we need?

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
1881	M	William	8524	0.0787
1881	M	James	5442	0.0503
1881	M	Charles	4664	0.0431
1881	M	Garrett	7	0.0001
1881	M	Gideon	7	0.0001



What variables do we need?

year	sex	name	n	prop
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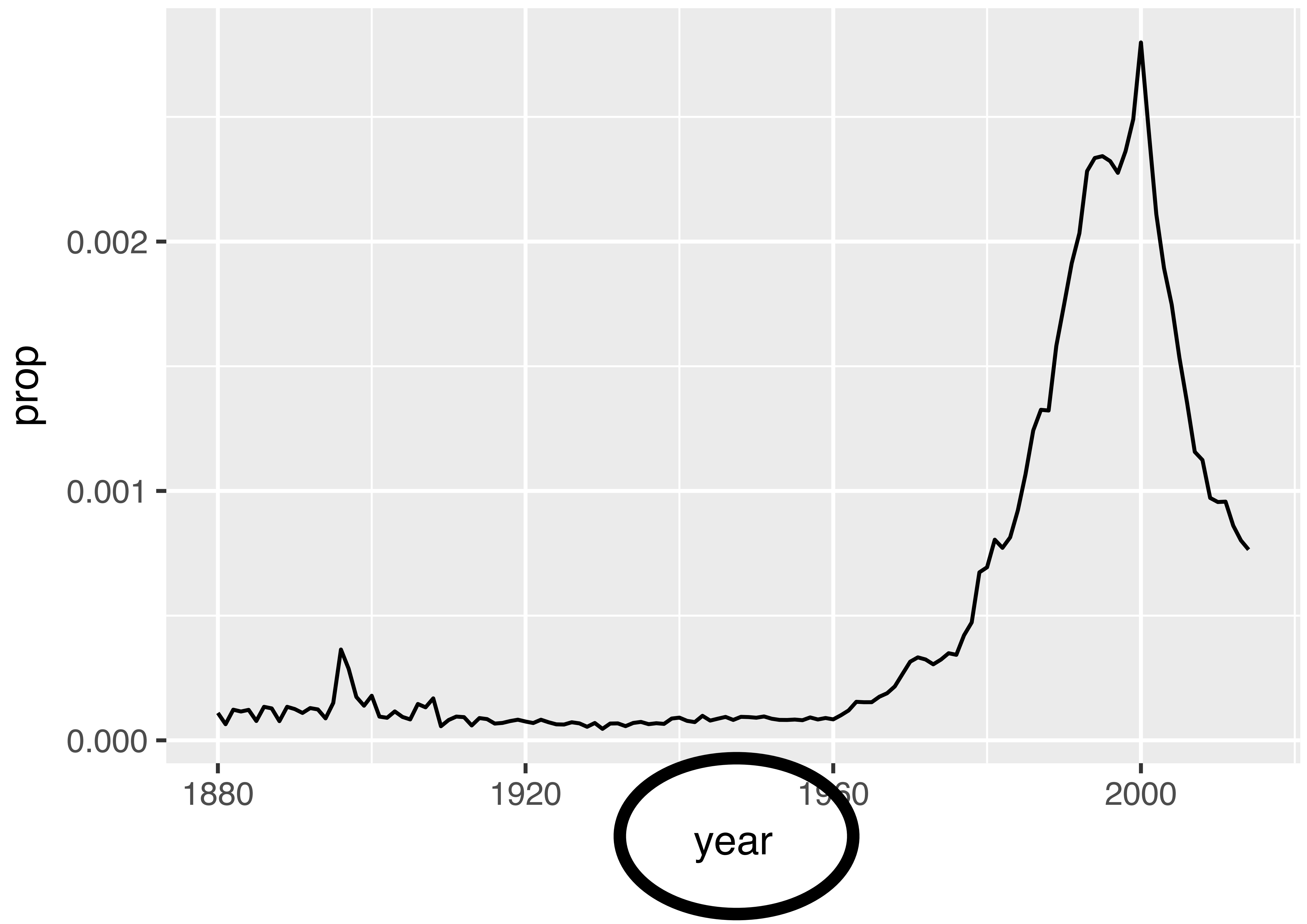
1881	M	William	8524	0.0787
1881	M	James	5442	0.0503
1881	M	Charles	4664	0.0431
1881	M	Garrett	7	0.0001
1881	M	Gideon	7	0.0001



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1880	M	Charles	5348	0.0451
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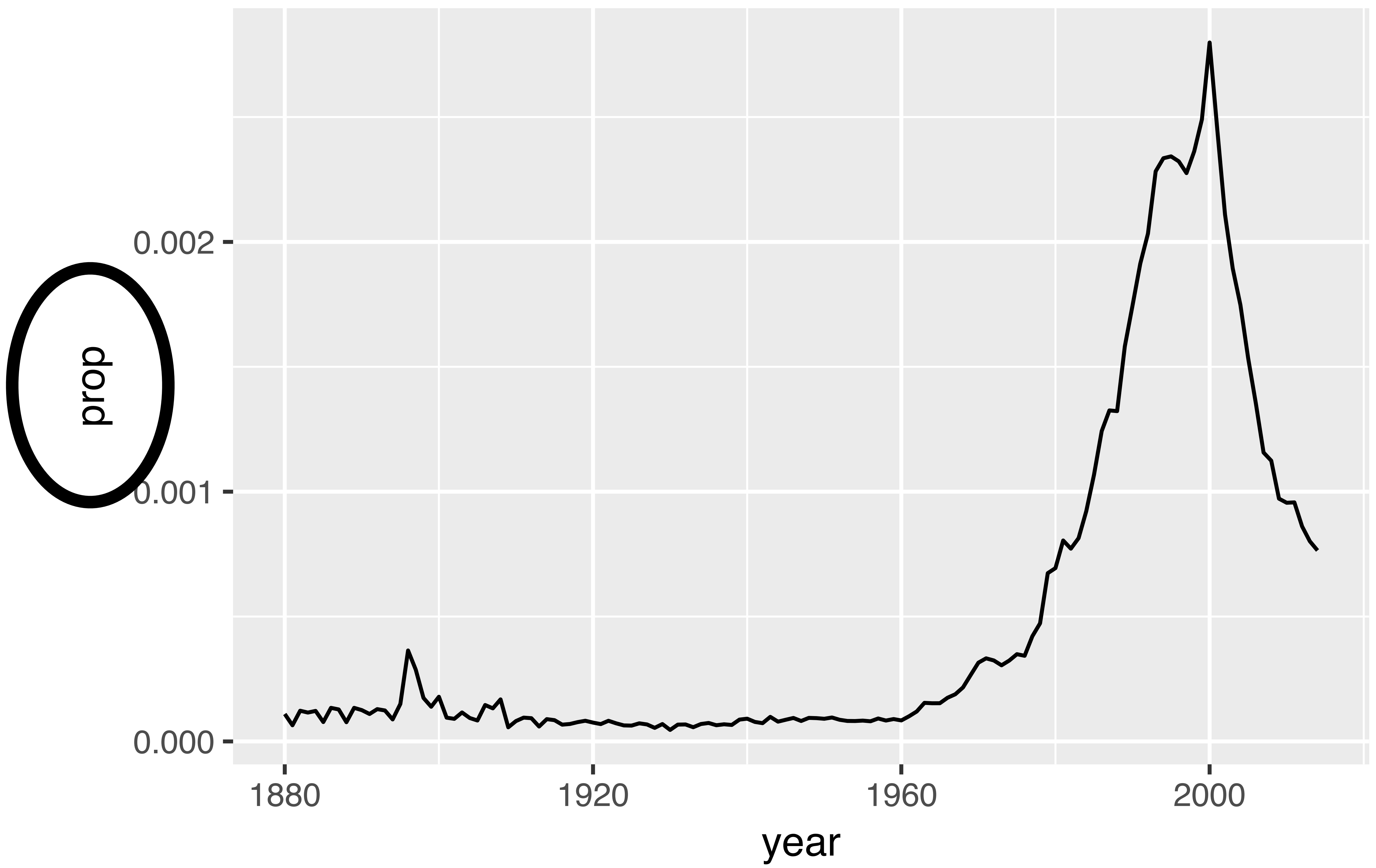

What cases do we need?

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
1881	M	William	8524	0.0787
1881	M	James	5442	0.0503
1881	M	Charles	4664	0.0431
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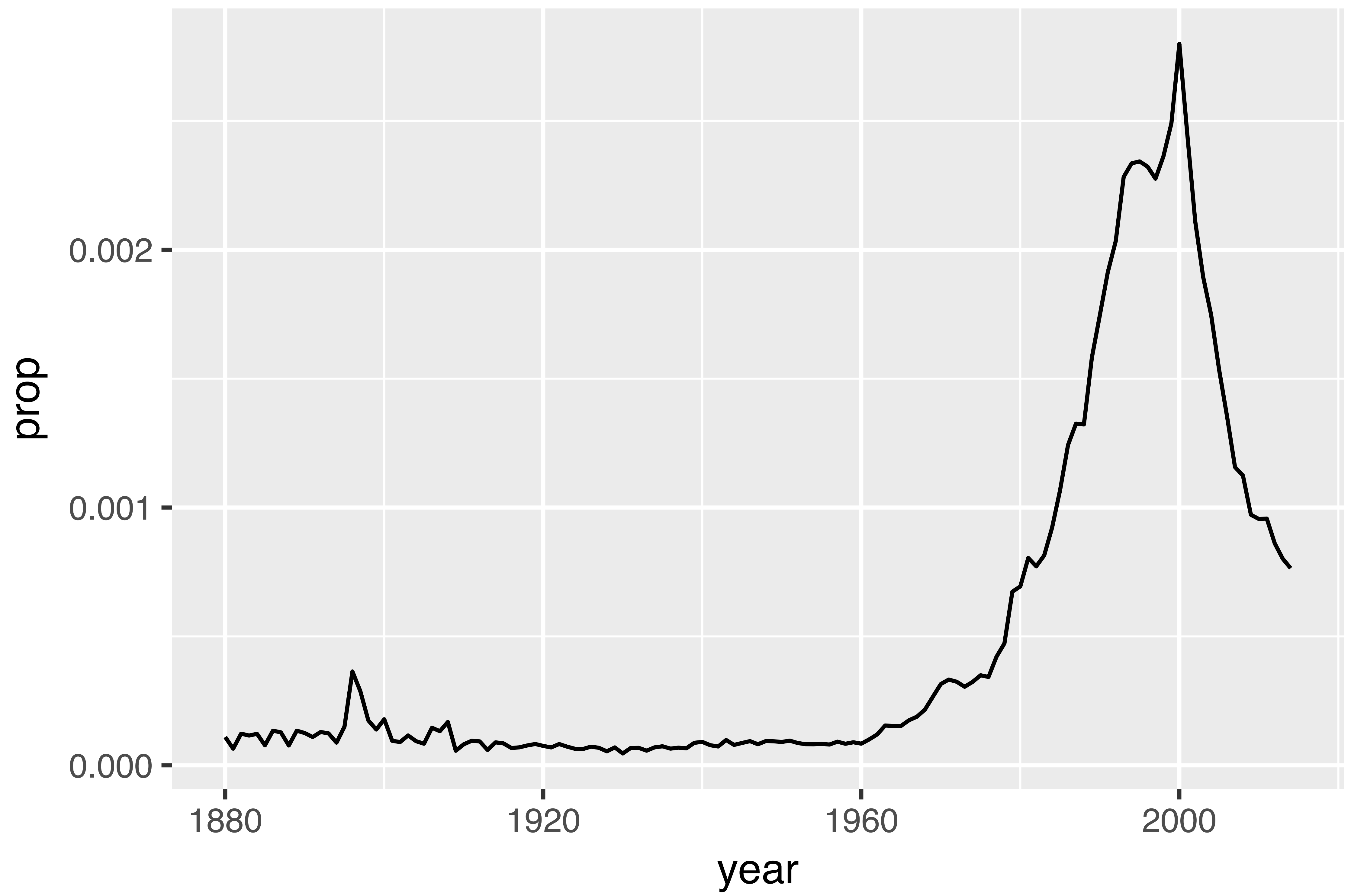
1881	M	Gideon	7	0.0001



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year	sex	name	n	prop
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1881	M	James	5442	0.0503
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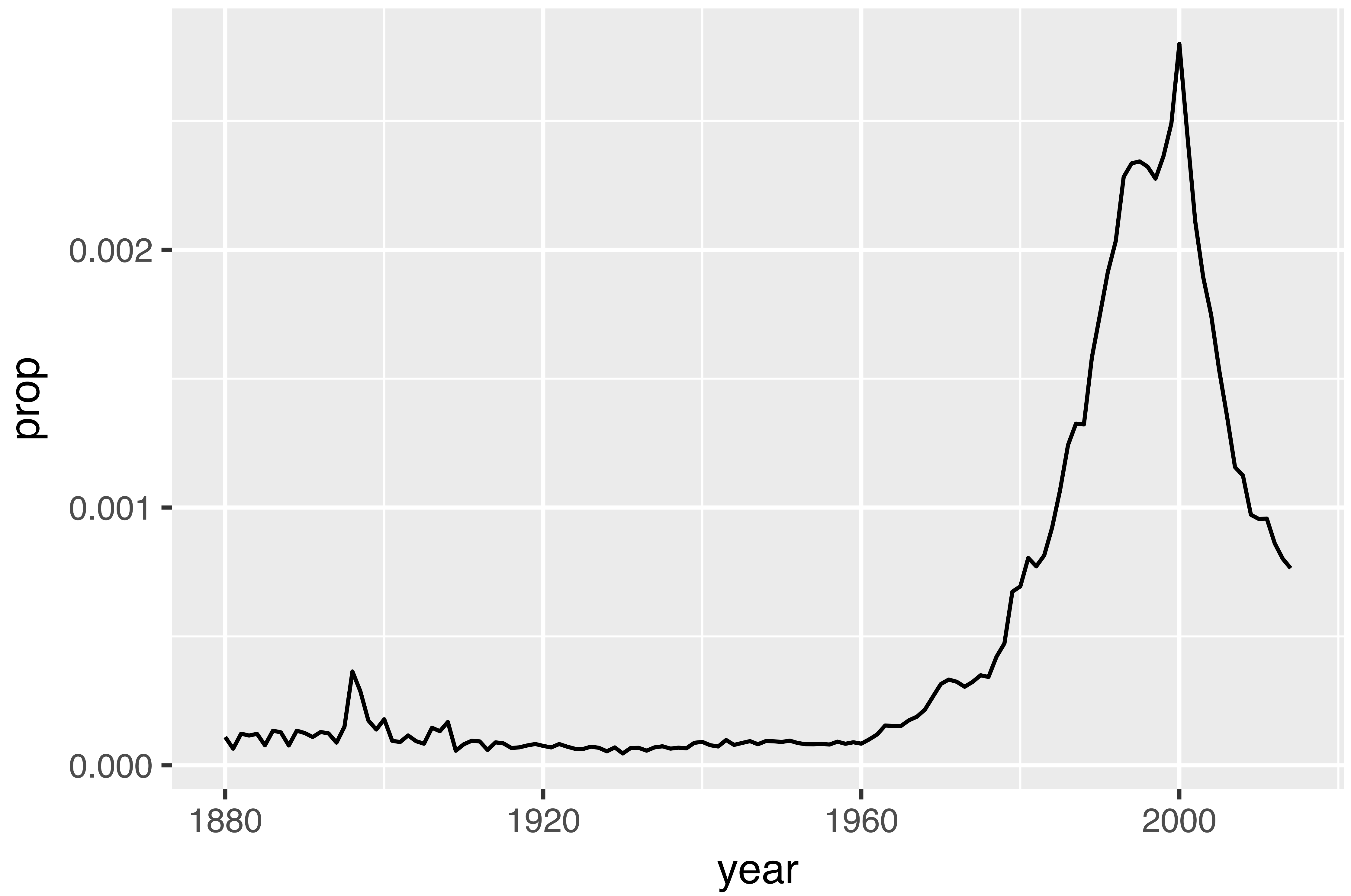
1881	M	Garrett	7	0.0001
1881	M	Gideon	7	0.0001



What cases do we need?

year	sex	name	n	prop
1880	M	John	9655	0.0815
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1880	M	James	5927	0.0501
1880	M	Charles	5348	0.0451
1880	M	Garrett	13	0.0001
1881	M	John	8769	0.081
1881	M	William	8524	0.0787
1881	M	James	5442	0.0503
1881	M	Charles	4664	0.0431
1881	M	Garrett	7	0.0001
1881	M	Gideon	7	0.0001

→

year	sex	name	n	prop
1880	M	Garrett	13	0.0001
1881	M	Garrett	7	0.0001
…	…	Garrett	…	…

dplyr

dplyr

A package that transforms data.

dplyr implements a *grammar* for transforming tabular data.

single table verbs

filter() - extract **cases**
arrange() - reorder **cases**
group_by() - group **cases**
select() - extract **variables**
mutate() - create new **variables**
summarise() - summarise **variables** / create **cases**

two table verbs

bind_rows() - adds one table to another as new **cases**

union(), **intersect()**, **setdiff()** - set operations for **cases**

semi_join(), **anti_join()** - filters **cases** in one table against another

bind_cols() - adds one table to another as new **variables**

left_join(), **right_join()**, **full_join()**, **inner_join()** - mutates one table by matching values from another as new **variables**

Toy data

```
storms <- tribble(
     ~storm, ~wind, ~pressure,        ~date,
  "Alberto",   110,      1007, "2000-08-12",
     "Alex",    45,      1009, "1998-07-30",
  "Allison",    65,      1005, "1995-06-04",
      "Ana",    40,      1013, "1997-07-01",
   "Arlene",    50,      1010, "1999-06-13",
   "Arthur",    45,      1010, "1996-06-21"
)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

dplyr

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)

dplyr

filter()

Extract rows that meet logical criteria.

```
filter(storms, wind == 45)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21

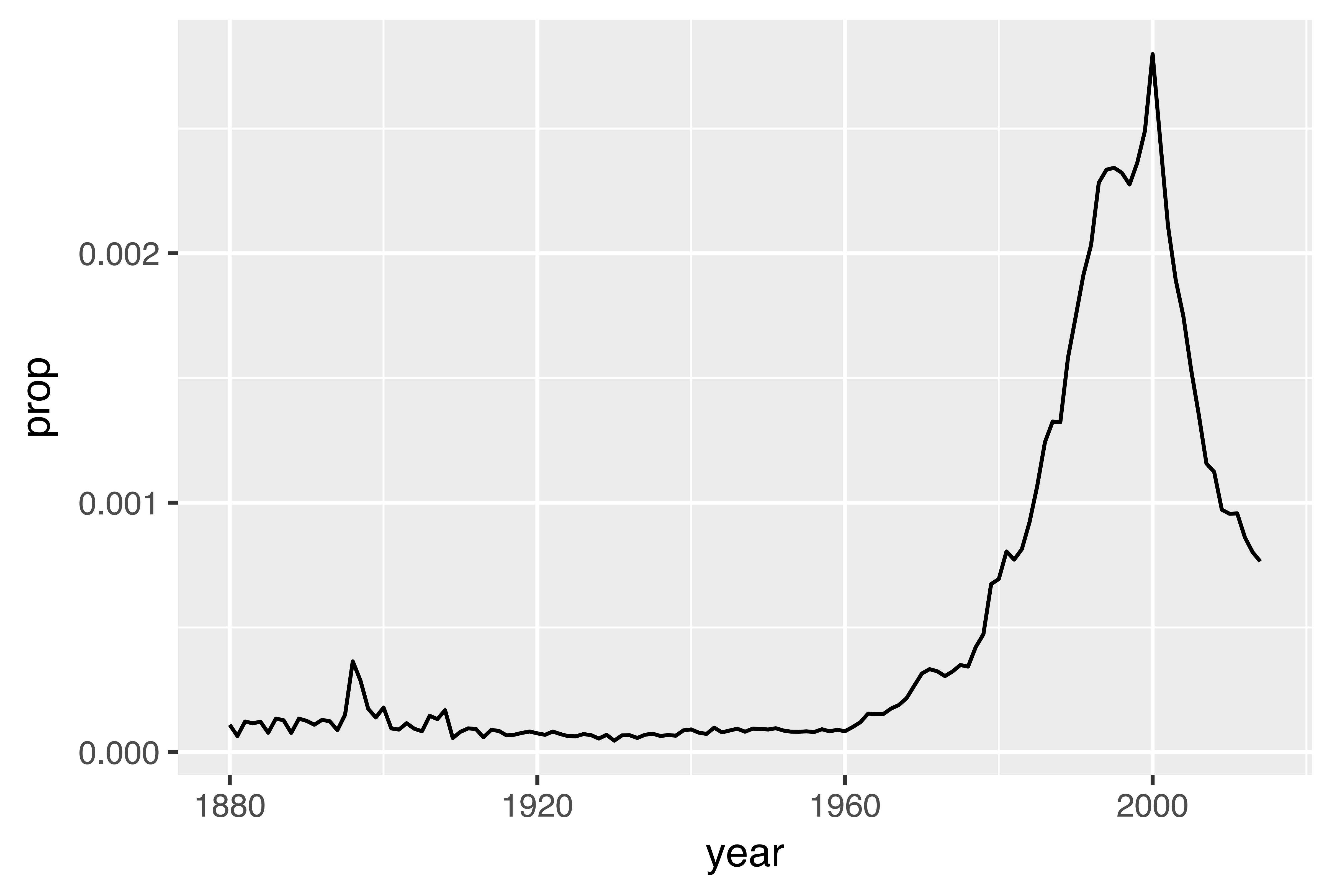
= sets
(returns nothing)

== tests if equal
(returns TRUE or FALSE)

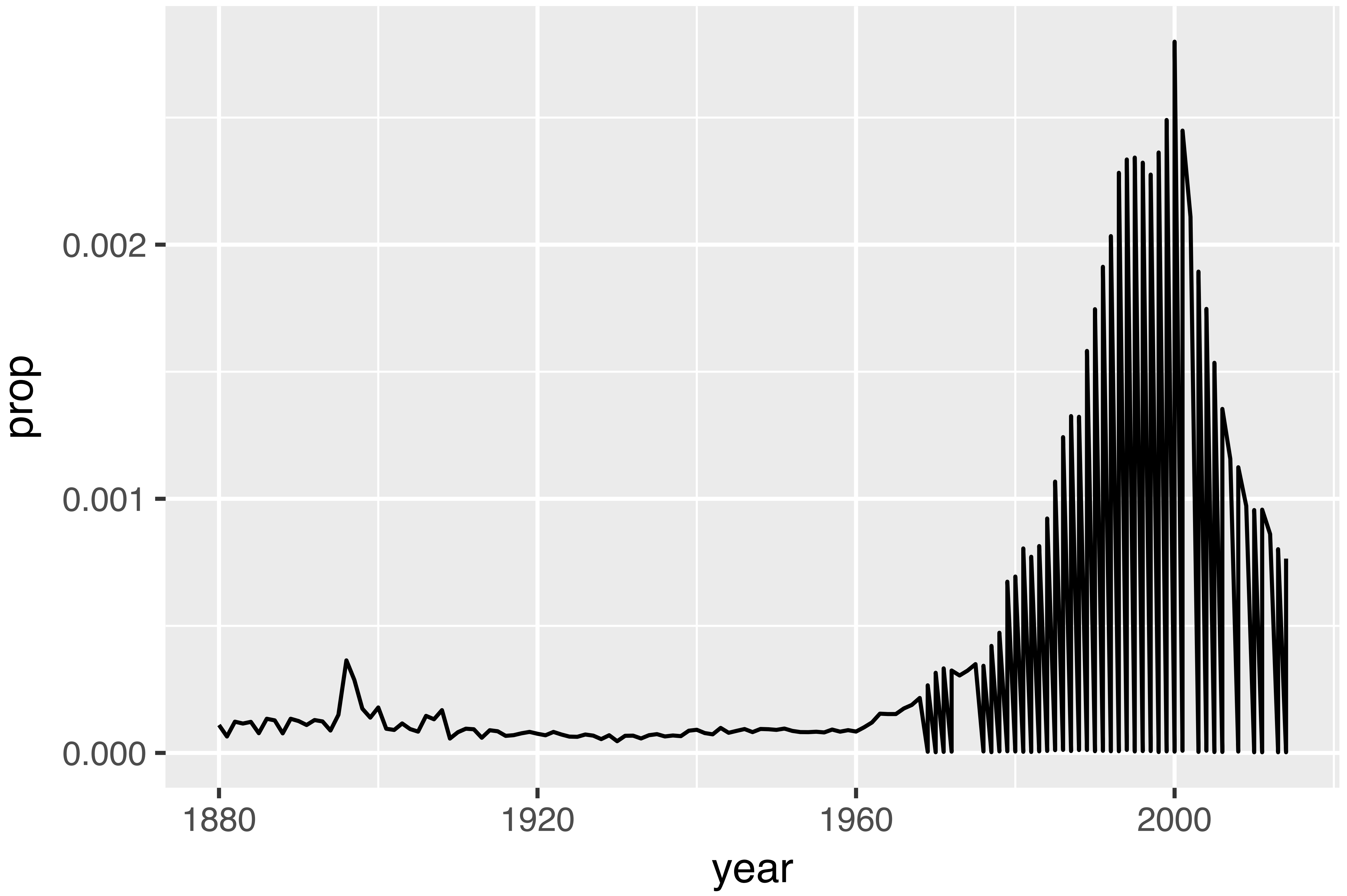
dplyr

Your Turn

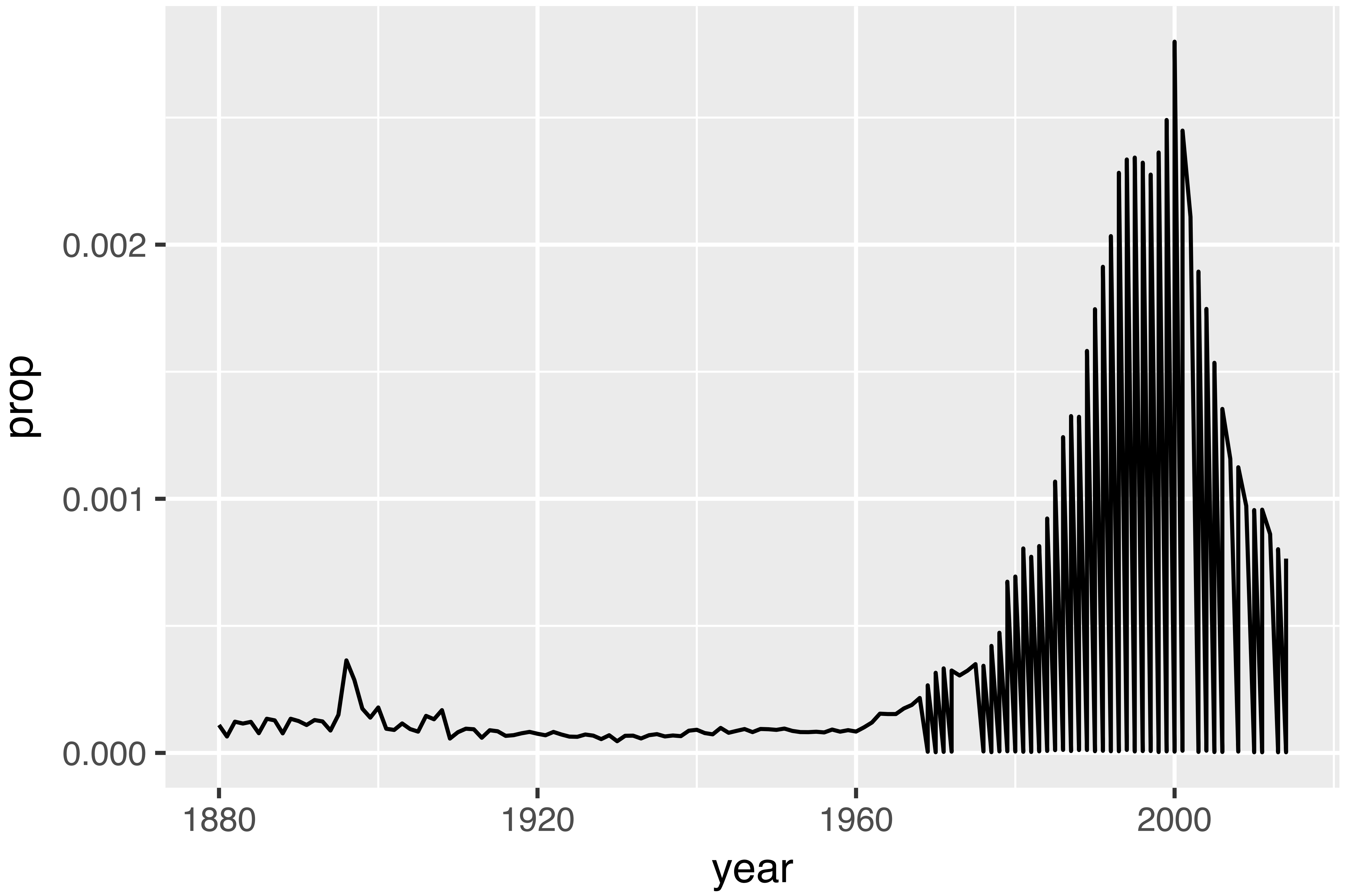
Use filter() to extract all of the rows in babynames that feature your name. Then use the result to recreate the plot below for your name:

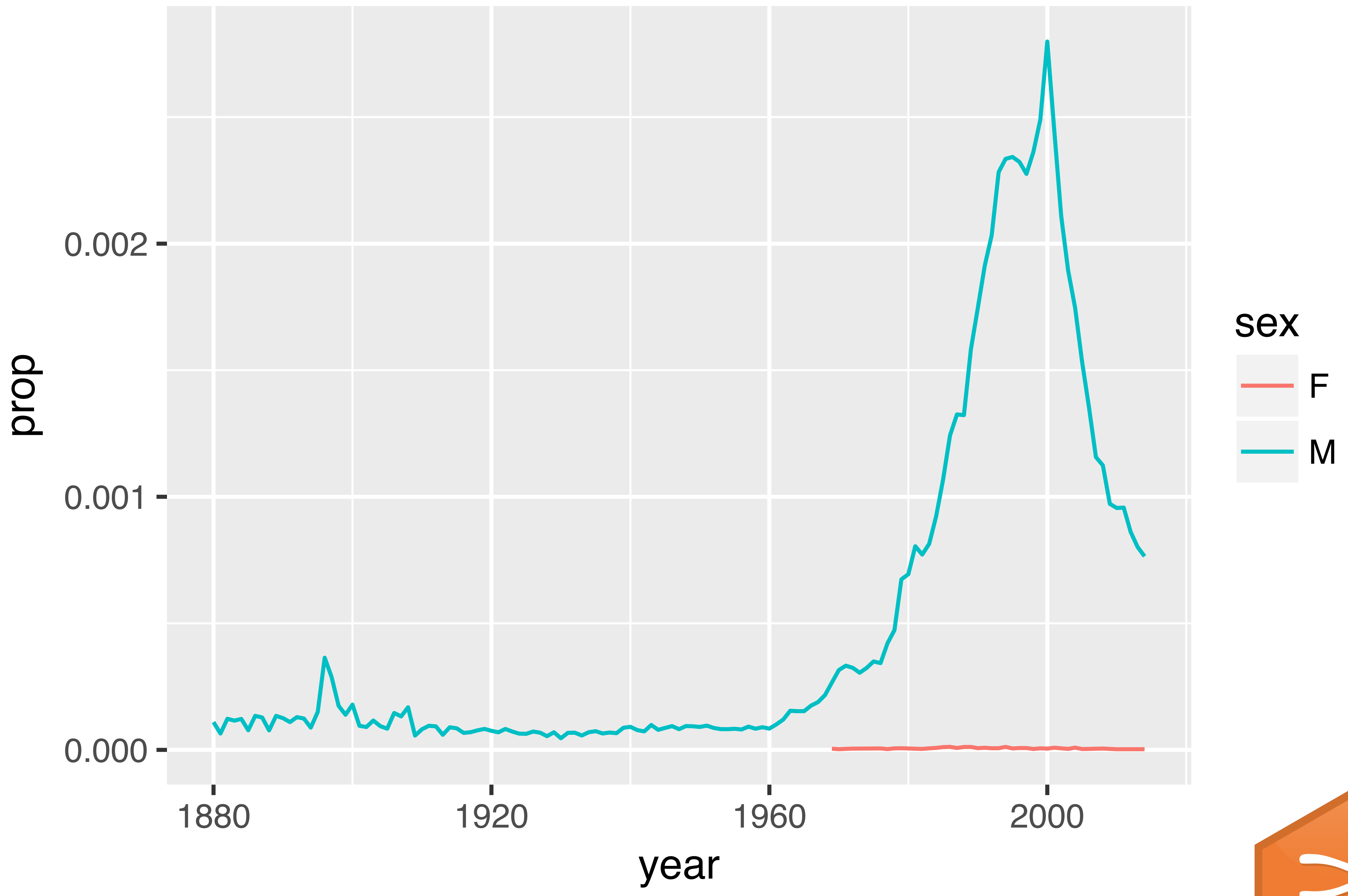


```
garrett <- filter(babynames, name == "Garrett")
ggplot(data = garrett, mapping = aes(year, prop)) +
  geom_line()
```



"Whipsawing" suggests that you are trying to plot two groups with a single line.





filter()

Extract rows that meet logical criteria.

```
filter(storms, wind == 45)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21

dplyr

filter()

Extract rows that meet logical criteria.

```
filter(storms, wind == 45, pressure == 1009)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

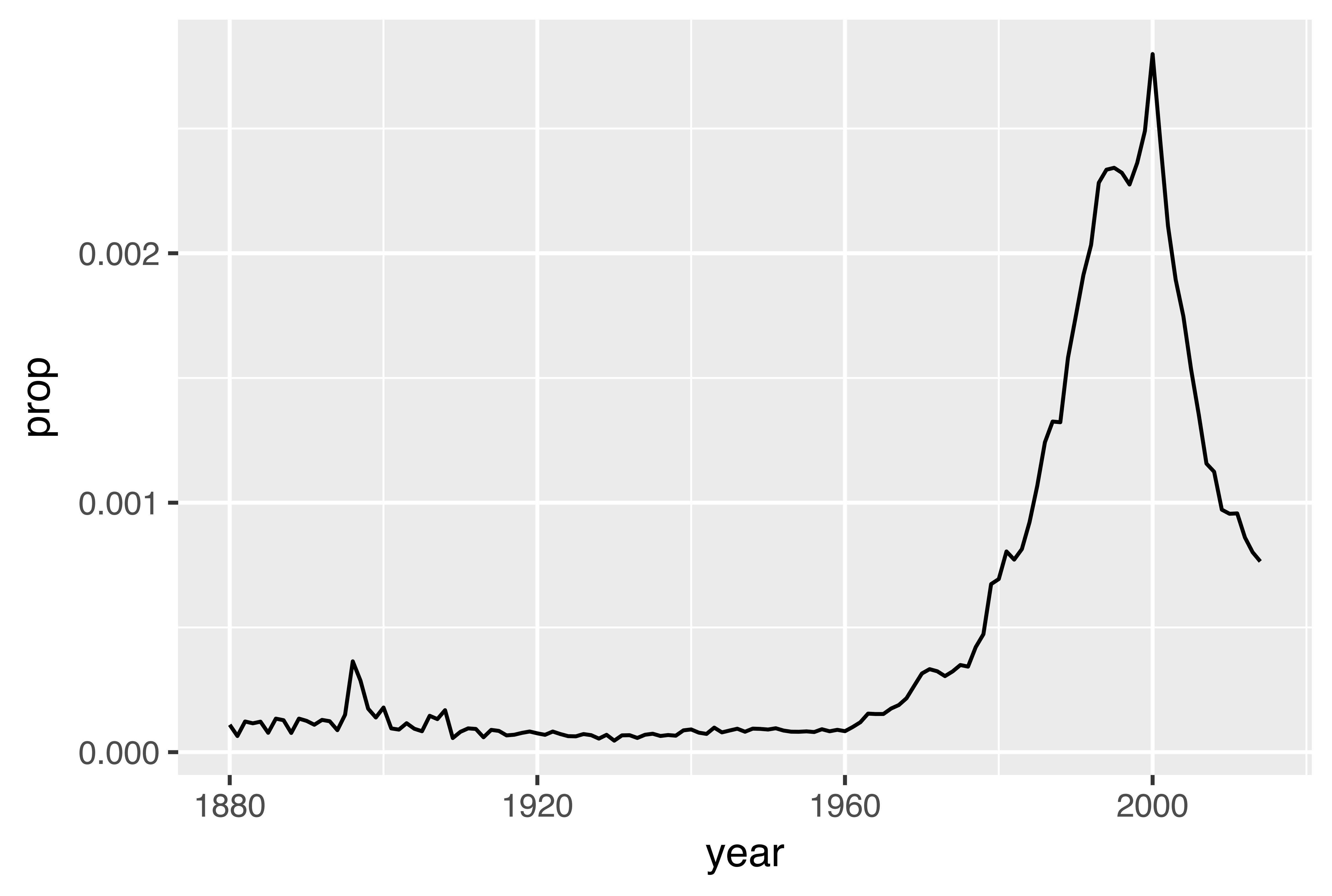
→

storm	wind	pressure	date
Alex	45	1009	1998-07-30

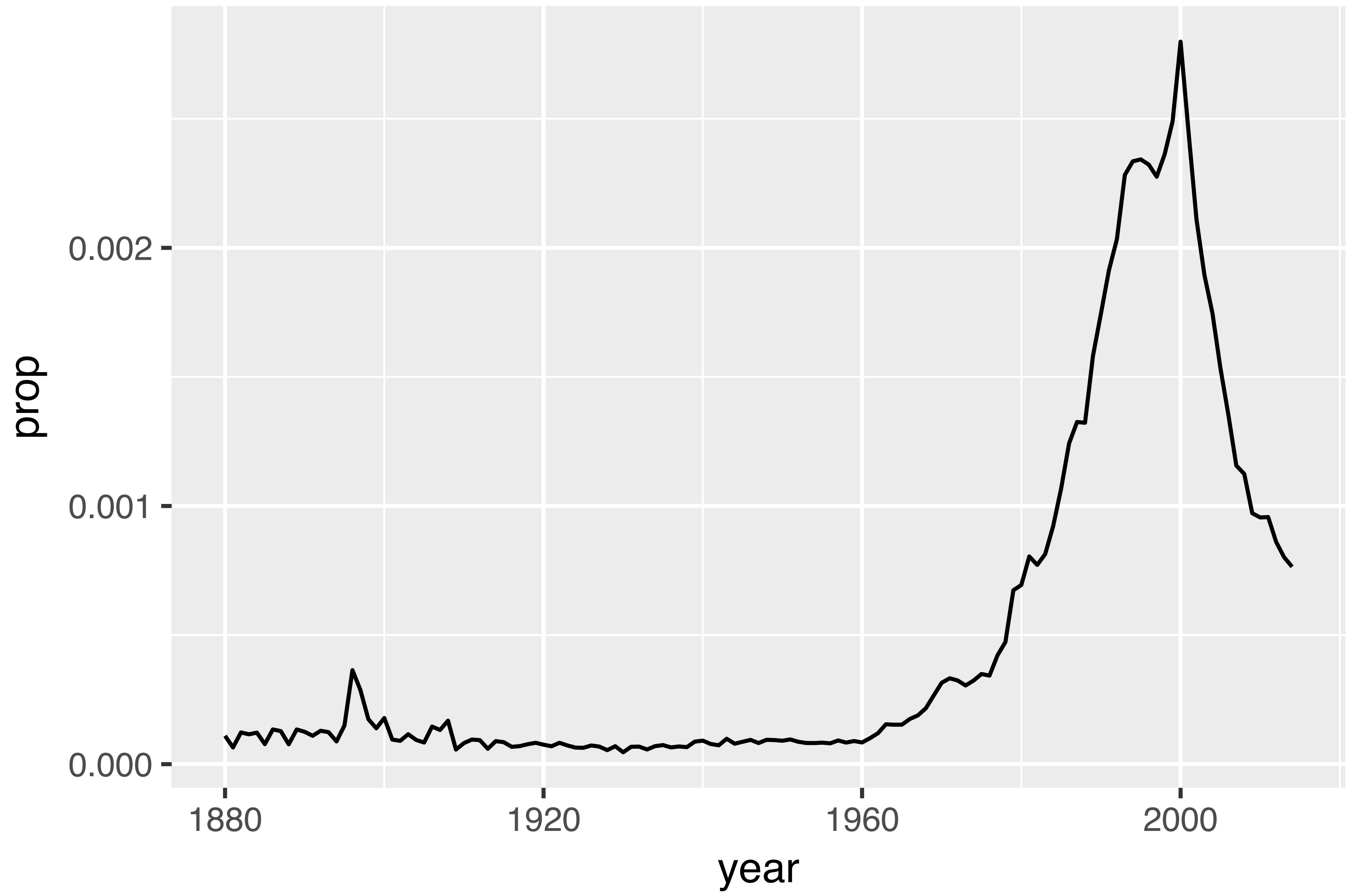
dplyr

Your Turn

Use filter() to extract rows with your name *and sex* then recreate your plot.



```
garrett <- filter(babynames, name == "Garrett", sex == "M")
ggplot(data = garrett, mapping = aes(year, prop)) +
  geom_line()
```



Logical tests

?Comparison

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

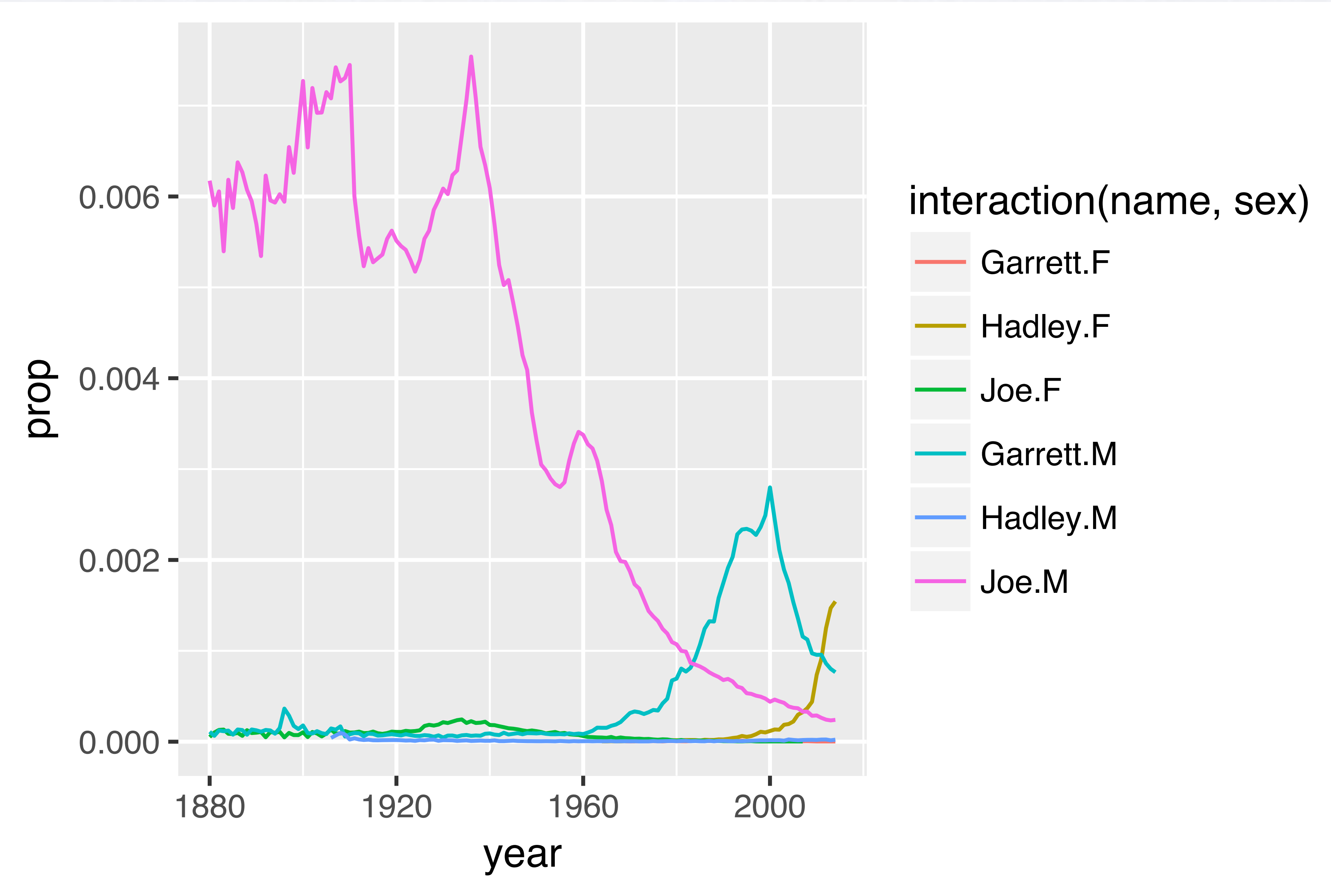
?base::Logic

`&`	and
`|`	or
`xor()`	exactly or
`!`	not
`any()`	any true
`all()`	all true

Your Turn

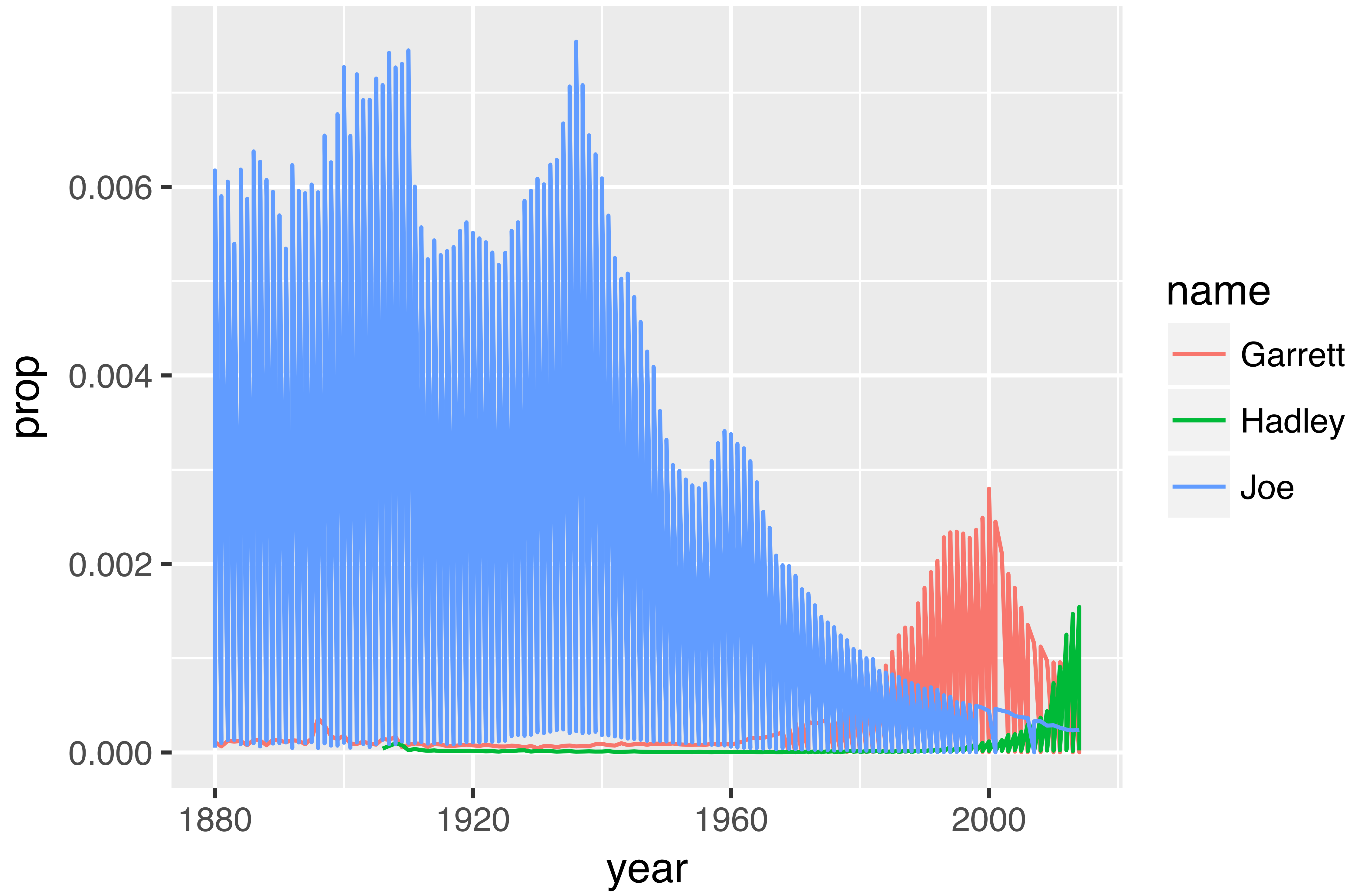
Compare the popularity of names within your group:

1. Create a vector that contains the name of each of your group members.
2. Extract all rows whose name value appears in the vector
3. Recreate the plot. Choose an aesthetic to distinguish different names

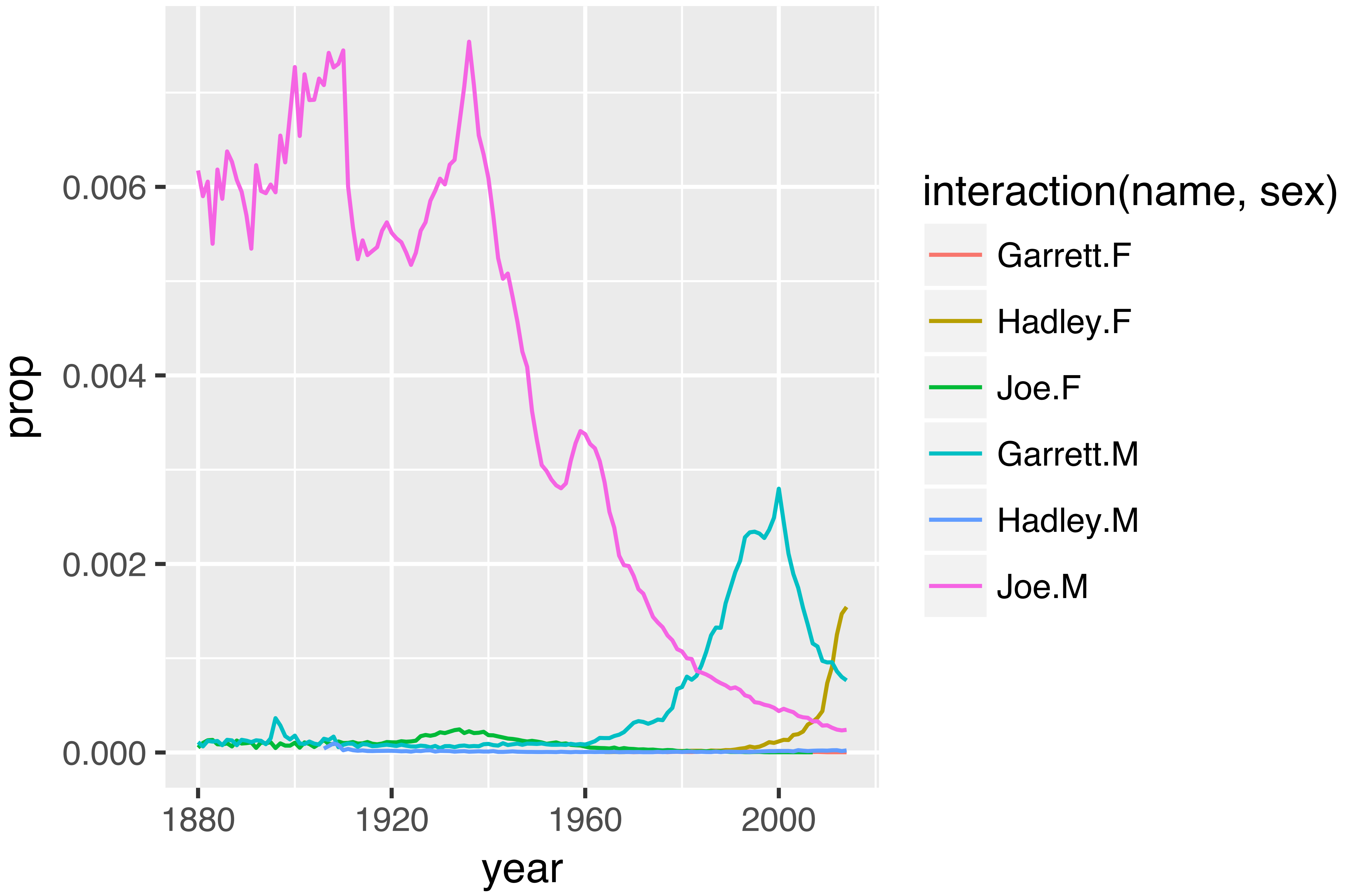


05:00

```
gnames <- c("Garrett", "Hadley", "Joe")
group_names <- filter(babynames, name %in% gnames)
ggplot(group_names, aes(year, prop, color = name)) +
  geom_line()
```



```
gnames <- c("Garrett", "Hadley", "Joe")
group_names <- filter(babynames, name %in% gnames)
ggplot(group_names, aes(year, prop, color = interaction(name, sex))) +
  geom_line()
```



interaction() to separate combinations of variables

single table verbs

filter() - extract **cases**

arrange() - reorder **cases**

select() - extract **variables**

mutate() - create new **variables**

summarise() - summarise **variables** / create **cases**

common syntax

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

```
filter(.data, … )
```

dplyr function

data frame to transform

function specific arguments

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)

dplyr

arrange()

Order rows from smallest to largest values.

```
arrange(storms, wind)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

storm	wind	pressure	date
Ana	40	1013	1997-07-01
Alex	45	1009	1998-07-30
Arthur	45	1010	1996-06-21
Arlene	50	1010	1999-06-13
Allison	65	1005	1995-06-04
Alberto	110	1007	2000-08-12

desc()

Changes ordering to largest to smallest.

```
arrange(storms, desc(wind))
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Allison	65	1005	1995-06-04
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21
Alex	45	1009	1998-07-30
Ana	40	1013	1997-07-01

Your Turn

Use arrange() (and perhaps desc()) to discover:

1. Which name was the most popular in a single year?
2. In what year was your name the most popular (hint: use the data set with just your name)

03:00

```
arrange(babynames, desc(prop))
# 1   1880      M     John  9655 0.08154561


arrange(garrett, desc(prop))
# 1   2000      M Garrett  5840 0.002798524
```

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(storms, storm, pressure)
```

storms

storm	wind	pressure	date
Albert	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

storm	pressure
Alberto	1007
Alex	1009
Allison	1005
Ana	1013
Arlene	1010
Arthur	1010

dplyr

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}$"))
```

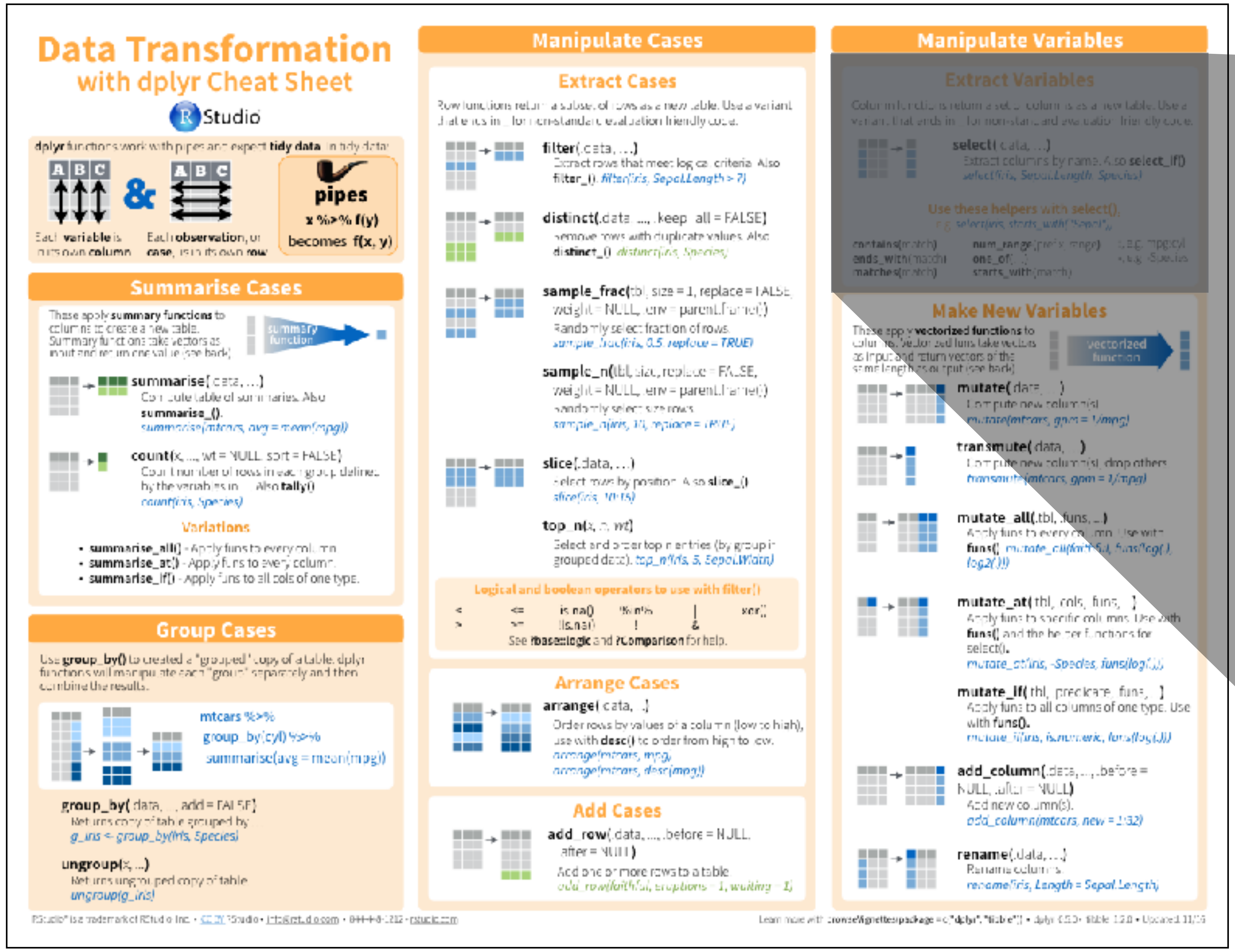
one_of() - Select columns whose names are one of a set

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

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

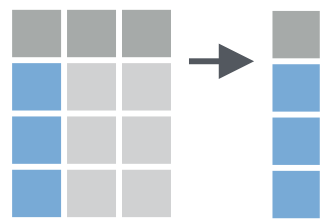
```
select(storms, num_range("x", 1:5))
```

select() helpers



Extract Variables

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)	

Your Turn

Write down as many ways as you can think of to select storms$storm with select(). Use each helper no more than once.

```
select(storms, storm)
select(storms, -c(wind, pressure, date))
select(storms, starts_with("s"))
select(storms, ends_with("m"))
select(storms, contains("st"))
select(storms, matches("storm"))
select(storms, one_of("storm"))
```

mutate()

mutate()

Create new columns.

```
mutate(.data, …)
```

data frame to transform

named argument
(that consists of the name of column to create set equal to an expression that creates it)

dplyr

mutate()

Create new columns.

```
mutate(storm, ratio = pressure / wind)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

storm	wind	pressure	date	ratio
Alberto	110	1007	2000-08-12	9.15
Alex	45	1009	1998-07-30	22.42
Allison	65	1005	1995-06-04	15.46
Ana	40	1013	1997-07-01	25.32
Arlene	50	1010	1999-06-13	20.20
Arthur	45	1010	1996-06-21	22.44

mutate()

Create new columns.

```
mutate(ratio = pressure / wind, inverse = ratio^-1)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

storm	wind	pressure	date	ratio	inverse
Alberto	110	1007	2000-08-12	9.15	0.11
Alex	45	1009	1998-07-30	22.42	0.04
Allison	65	1005	1995-06-04	15.46	0.06
Ana	40	1013	1997-07-01	25.32	0.04
Arlene	50	1010	1999-06-13	20.20	0.05
Arthur	45	1010	1996-06-21	22.44	0.0

transmute()

Create new columns. Drop the old.

```
transmute(ratio = pressure / wind, inverse = ratio^-1)
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

ratio	inverse
9.15	0.11
22.42	0.04
15.46	0.06
25.32	0.04
20.20	0.05
22.44	0.04

dplyr

Vectorized functions

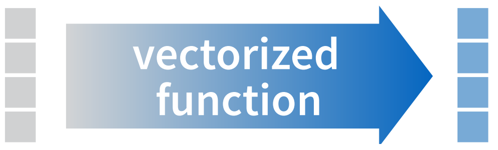
Take a vector as input.

Return a vector of the same length as output.

Vectorized 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.



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

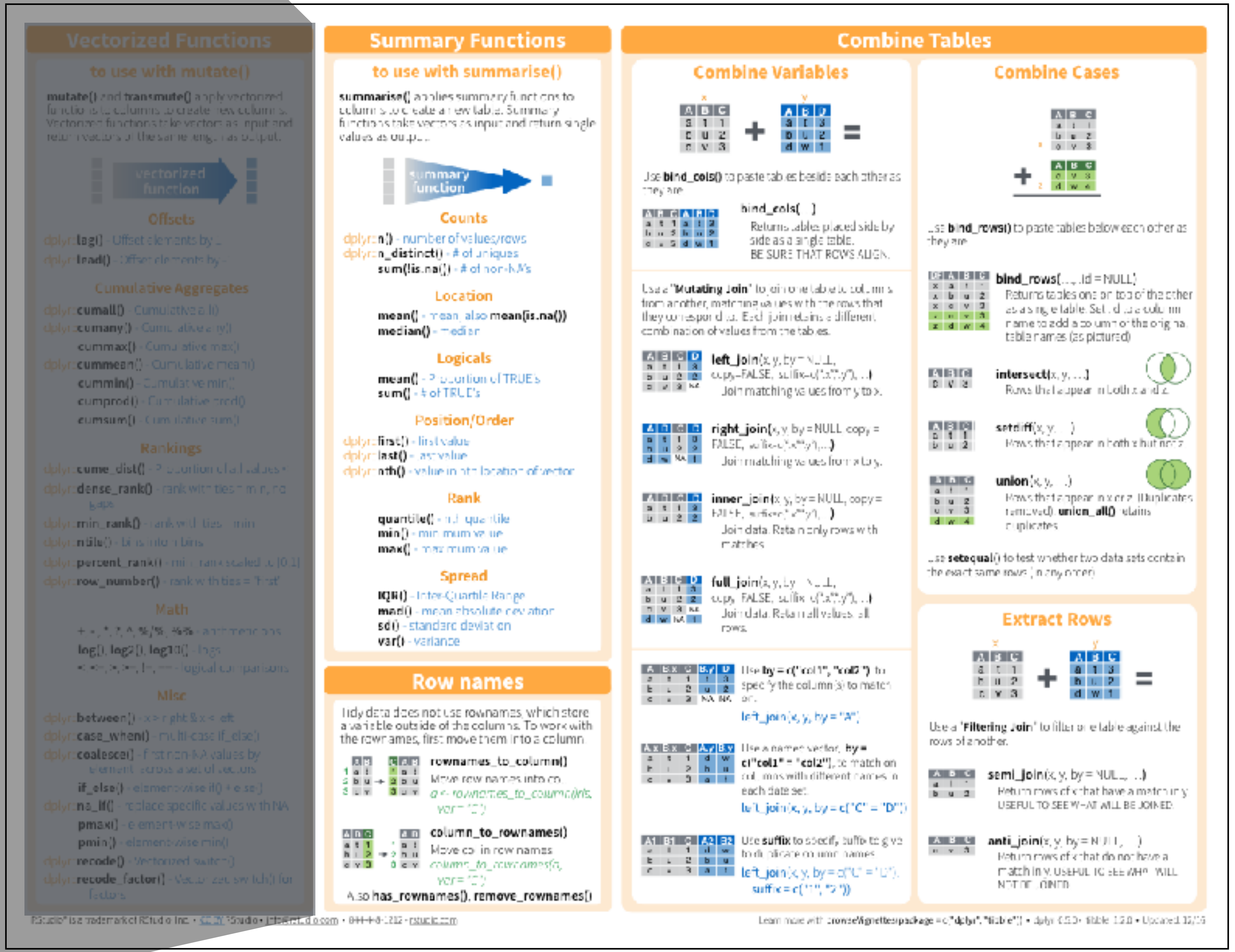
dplyr::**cume_dist()** - Proportion of all values <=
dplyr::**dense_rank()** - rank with ties = min, no gaps
dplyr::**min_rank()** - rank with ties = min
dplyr::**ntile()** - bins into n bins
dplyr::**percent_rank()** - min_rank scaled to [0,1]
dplyr::**row_number()** - rank with ties = "first"

Math

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

Misc

dplyr::**between()** - x > right & x < left
dplyr::**case_when()** - multi-case if_else()
dplyr::**coalesce()** - first non-NA values by element across a set of vectors
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



summarise()

summarise()

Compute table of summaries.

```
summarise(.data, …)
```

data frame to transform

named argument
(that consists of the name of column to create set equal to an expression that creates it)

dplyr

summarise()

Compute table of summaries.

```
summarise(storms, avg_wind = mean(wind), n = n())
```

storms

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

avg_wind	n
59.17	6

Returns the number of cases (rows) Very useful!

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.

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

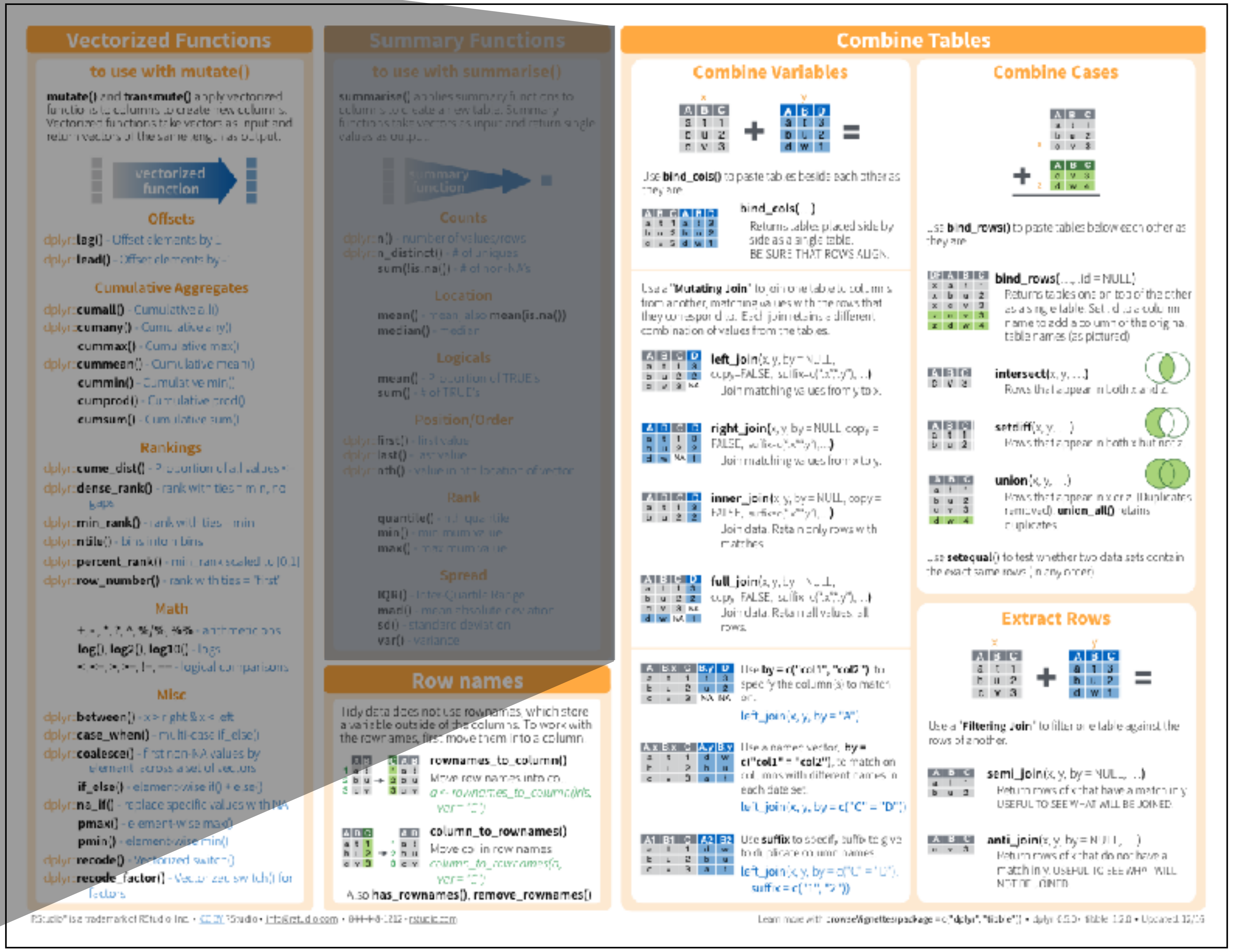
dplyr::**first()** - first value
dplyr::**last()** - last value
dplyr::**nth()** - value in nth location of vector

Rank

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

Spread

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



dplyr

n() and n_distinct()

Two helper functions for summarise.

```
summarise(storms,
  n = n(), # Number of cases / rows
  n_wind = n_distinct(wind) # number of unique values
)
```

storm	wind	pressure	date
Alberto	110	1007	2000-08-12
Alex	45	1009	1998-07-30
Allison	65	1005	1995-06-04
Ana	40	1013	1997-07-01
Arlene	50	1010	1999-06-13
Arthur	45	1010	1996-06-21

→

n	n_wind
6	5

Your Turn

1. Add a new column to the data that changes the prop to a percentage
2. Determine how many unique names appear in the data set.
3. Create a summary that displays the min, mean, and max prop for your name.
4. Use three dplyr verbs plus n() to determine how many times a single name was given to more than 1% of the boys or girls in a year.

07:00

```
mutate(babynames, percent = prop * 100)
```

```
summarize(babynames, n = n_distinct(name))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
babynames2 <- mutate(babynames, percent = prop * 100)
babynames3 <- filter(babynames2, percent > 1)
summarise(babynames3, nn = n())
```

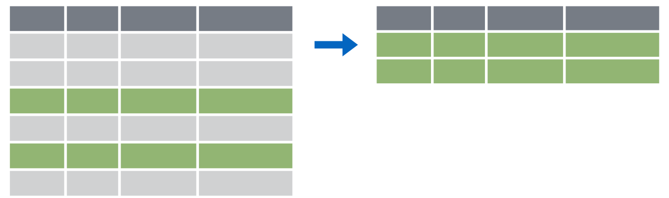
```
mutate(babynames, percent = prop * 100)
```

```
summarize(babynames, n = n_distinct(name))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

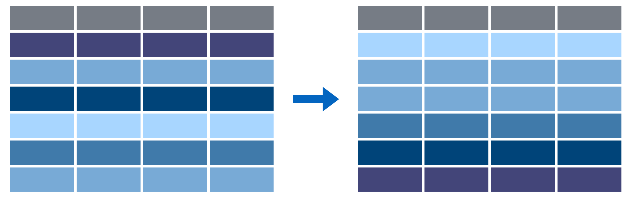
```
babynames2 <- mutate(babynames, percent = prop * 100)
babynames3 <- filter(babynames2, percent > 1)
count(babynames3)
```

Recap: Single table verbs

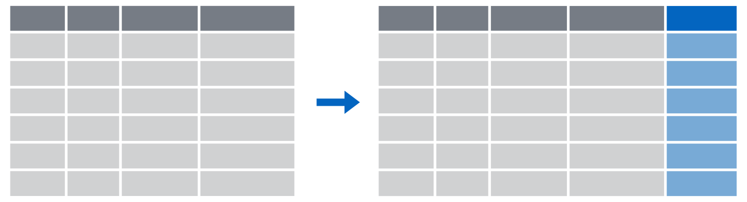


Extract cases with **filter()**

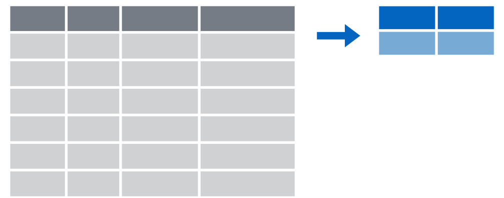
Extract variables with **select()**



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



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



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

%>%

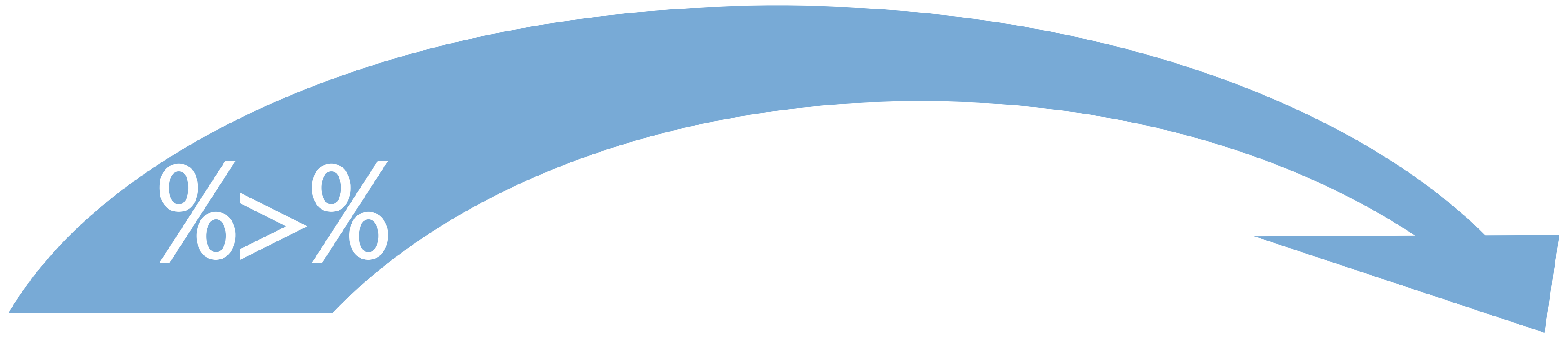
```
mutate(babynames, percent = prop * 100)
```

```
summarize(babynames, n = n_distinct(name))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
babynames2 <- mutate(babynames, percent = prop * 100)
babynames3 <- filter(babynames2, percent > 1)
summarise(babynames3, nn = n())
```

The pipe operator %>%




```
babynames          mutate(______, percent = prop * 100)
```

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

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

```r
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```r
filter(babynames, name == "Garrett", sex == "M") %>%
  summarise(min = min(prop), mean = mean(prop),
    max = max(prop))
```

```
garrett <- filter(babynames, name == "Garrett", sex == "M")
summarise(garrett, min = min(prop), mean = mean(prop),
  max = max(prop))
```

```
babynames %>%
  filter(name == "Garrett", sex == "M") %>%
  summarise(min = min(prop), mean = mean(prop),
    max = max(prop))
```

Shortcut to type %>%

Cmd + Shift + M (Mac)

Ctrl + Shift + M (Windows)

dplyr

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

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

vs.

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

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

```
bop_on(
  scoop_up(
    hop_through(foo_foo, forest),
    field_mouse
  ),
  head
)
```

Your Turn

Rewrite the code below to use the pipe operator. Then run it to ensure that it works.

```
babynames
babynames2 <- mutate(babynames, percent = prop * 100)
babynames3 <- filter(babynames2, percent > 1)
summarise(babynames3, nn = n())
```

```
babynames %>%
  mutate(percent = prop * 100) %>%
  filter(percent >= 1) %>%
  summarize(nn = n())
```

Grouping cases

Your Turn

Are there more boys in the data set or girls?

Outline a strategy with your group and then find out.

05:00

```r
girls <- babynames %>%
  filter(sex == "F") %>%
  summarise(total = sum(n))
# 167070477

boys <- babynames %>%
  filter(sex == "M") %>%
  summarise(total = sum(n))
# 170064949
```

Toy data

```
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
)
```

pollution

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

city	particle size	amount (μg/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 ($\mu g/m^3$)
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

dplyr

city	particle size	amount (μg/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 ($\mu g/m^3$)
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()

dplyr

group_by()

city	particle size	amount (μg/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 (μg/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()

Groups cases by common values.

```
group_by(.data, …)
```

data frame to transform

column(s) to group by
(will group by combinations of values if more than one column is specified)

group_by()

Groups cases by common values.

```
.data %>% group_by(…)
```

data frame to transform

column(s) to group by
(will group by combinations of values if more than one column is specified)

group_by()

Groups cases by common values.

```
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.

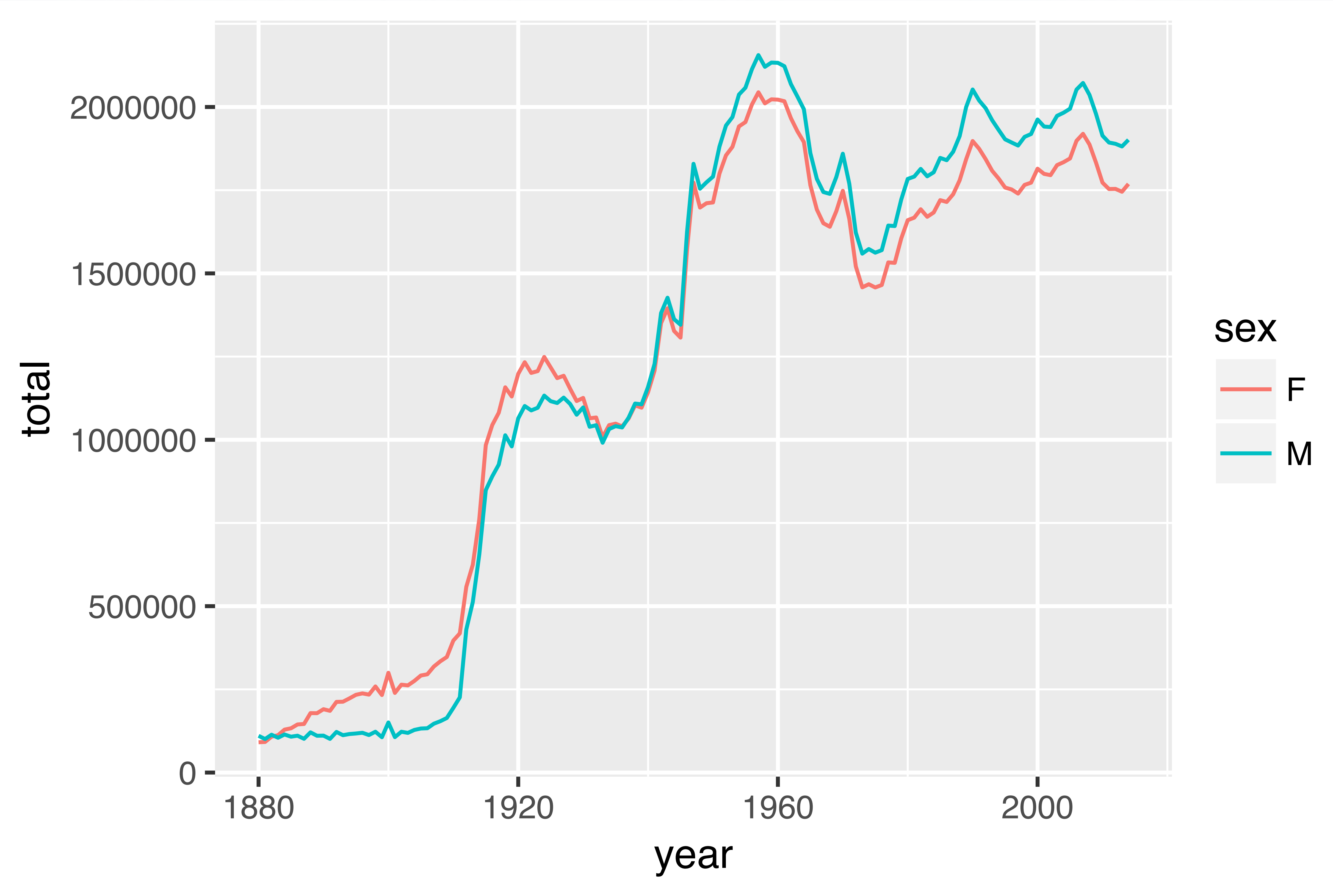
```
babynames %>%
  group_by(sex) %>%
  summarise(total = sum(n))
```

sex	total
F	167070477
M	170064949

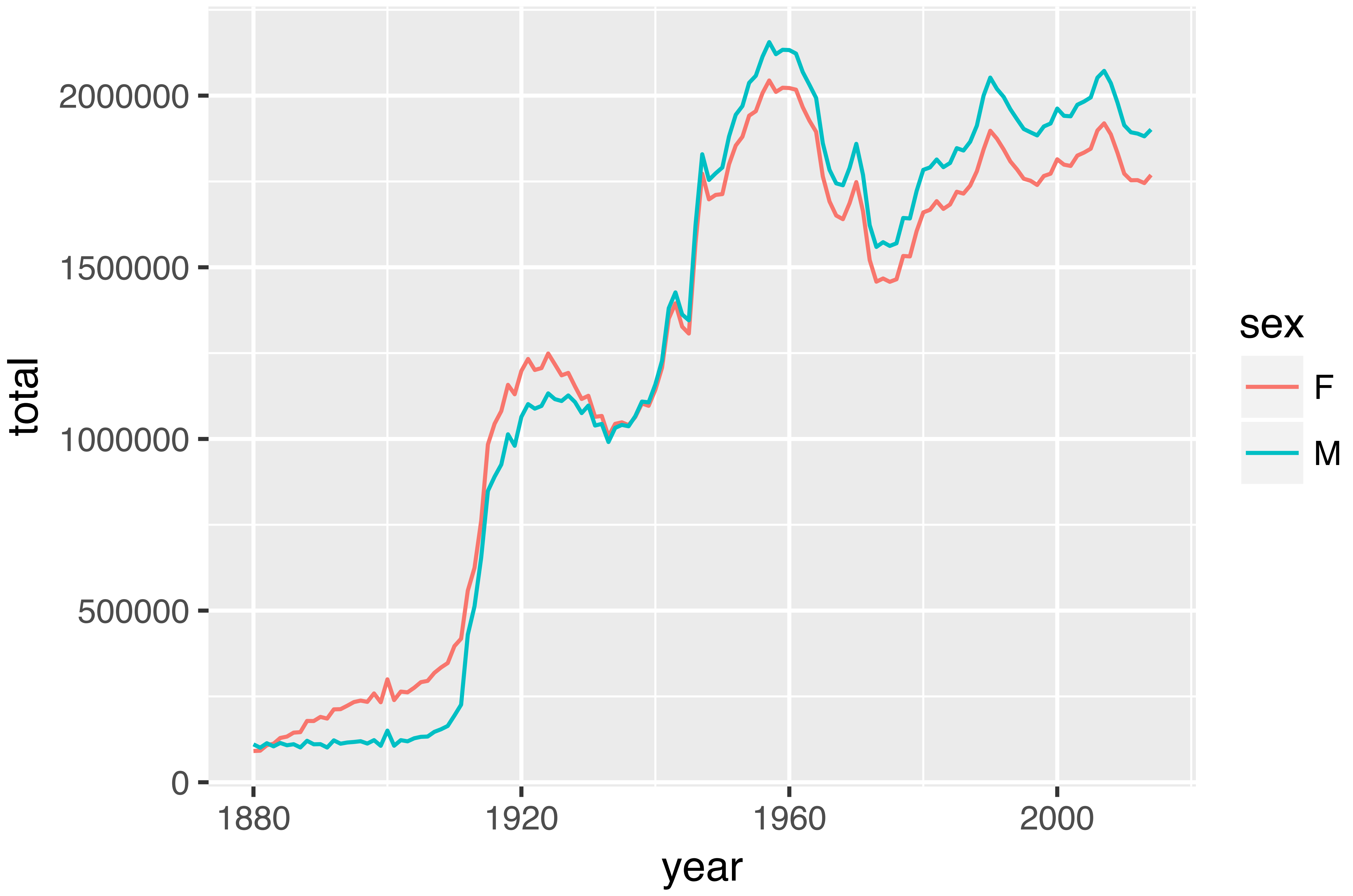
Your Turn

Does the ratio of boys and girls change over time?

Use group_by() to group by *year and sex*. Then use the result to make this plot:



```
babynames %>%
  group_by(year, sex) %>%
  summarise(total = sum(n)) %>%
  ggplot(aes(x = year, y = total, color = sex)) +
    geom_line()
```



ungrouping

summarise() removes **one** grouping variable each time you call it.

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

```
Source: local data frame [1,825,433 x 5]
Groups: year, sex [270]

   year   sex      name     n       prop
  <dbl> <chr>     <chr> <int>      <dbl>
1  1880     F      Mary  7065 0.07238359
2  1880     F      Anna  2604 0.02667896
```

ungrouping

summarise() removes **one** grouping variable each time you call it.

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

```
Source: local data frame [270 x 3]
Groups: year [?]

   year   sex  total
  <dbl> <chr>  <int>
1  1880     F  90993
```

ungrouping

summarise() removes **one** grouping variable each time you call it.

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

```
# A tibble: 135 × 2
   year total
  <dbl> <int>
1  1880     2
2  1881     2
```

ungroup()

Removes grouping criteria from a data frame.

```
babynames %>%
  group_by(year, sex) %>%
  ungroup()
```

```
# A tibble: 1,825,433 × 5
   year   sex      name     n       prop
  <dbl> <chr>     <chr> <int>      <dbl>
1  1880     F      Mary  7065 0.07238359
2  1880     F      Anna  2604 0.02667896
3  1880     F      Emma  2003 0.02052149
```

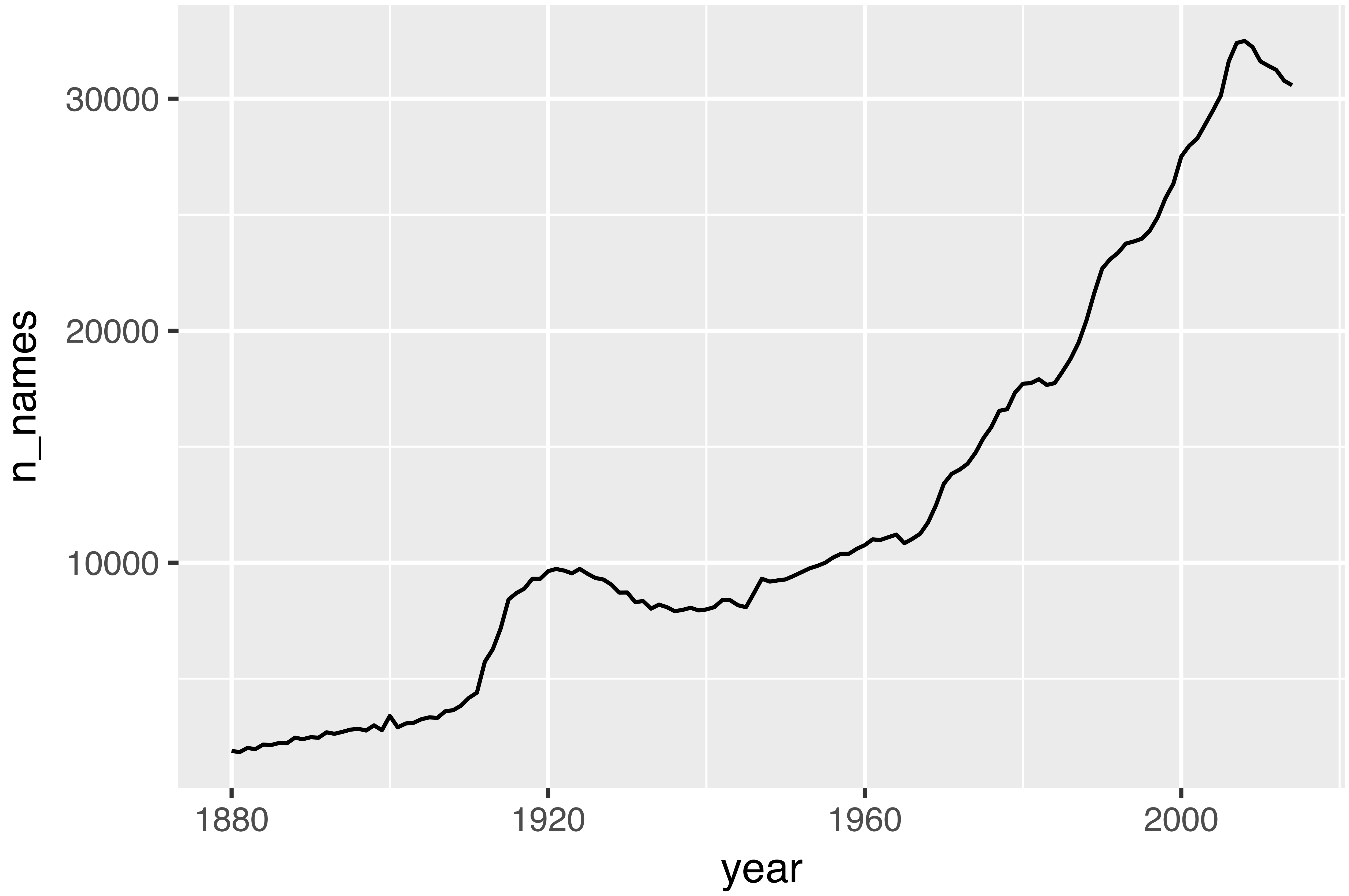
Your Turn

For both exercises, use the %>% operator whenever possible:

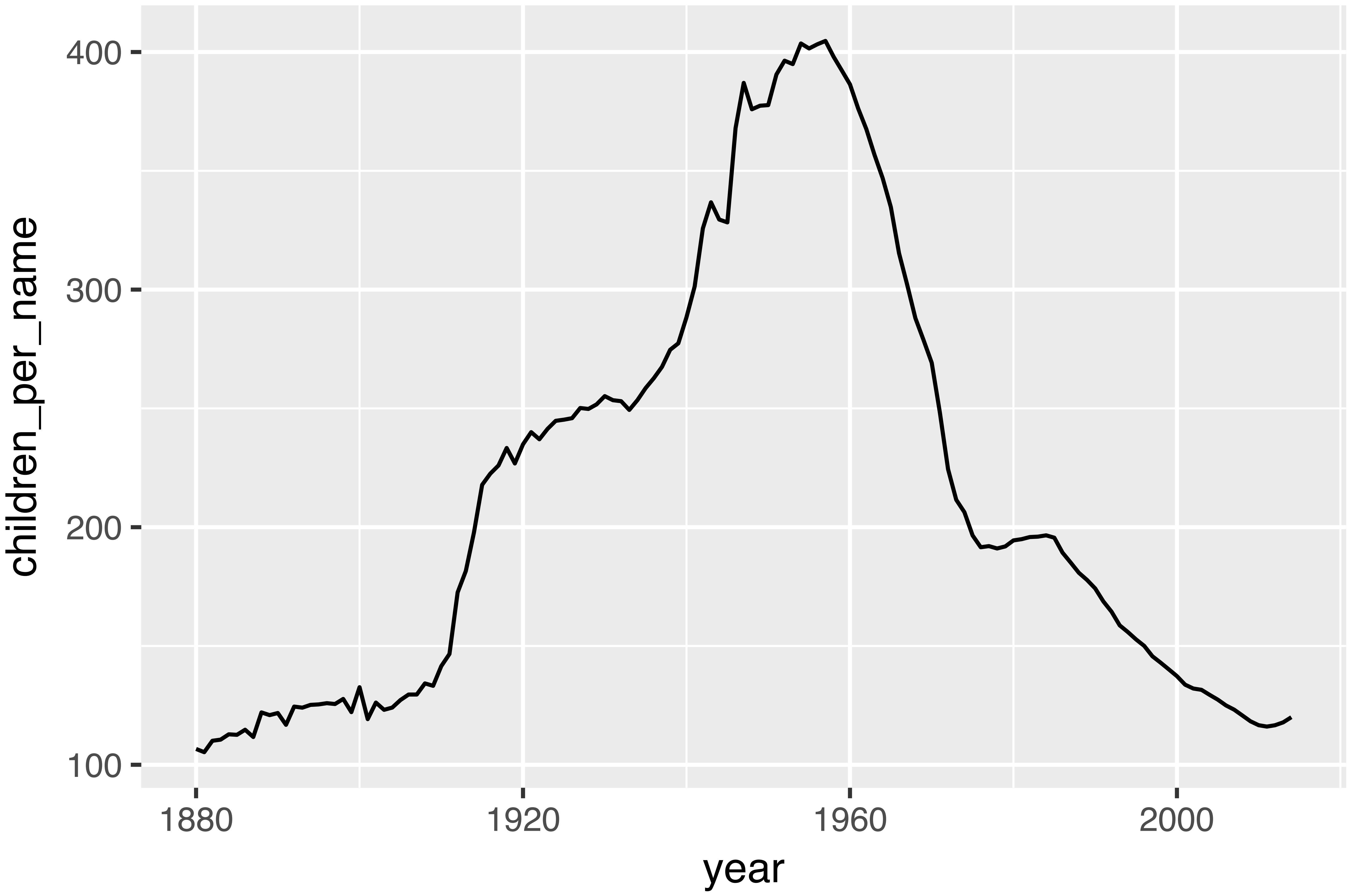
1. Plot the number of unique names by year over time. Does it change?
2. Plot the average number of children per name by year over time (total number of children / number of unique names). Does the plot tell a different story? Why?

08:00

```r
babynames %>%
  group_by(year) %>%
  summarise(n_names = n_distinct(name)) %>%
  ggplot(aes(year, n_names)) + geom_line()
```



```
babynames %>%
  group_by(year) %>%
  summarise(n_names = n_distinct(name), n_children = sum(n)) %>%
  mutate(children_per_name = n_children / n_names) %>%
  ggplot(aes(year, children_per_name)) + geom_line()
```



Quiz

For a given year, what does the difference between n() and n_distinct(name) reveal?

```
babynames %>%
  filter(year == 1930, n > 500) %>%
  summarise(n = n(),
    n_name = n_distinct(name)) %>%
  mutate(diff = n - n_name)
# A tibble: 1 × 3
      n n_name  diff
  <int>  <int> <int>
1   549    541     8
```

Quiz

For a given year, what does the difference between n() and n_distinct(name) reveal?

```
babynames %>%
  filter(year == 1930, n >= 500) %>%
  summarise(n = n(),
    n_name = n_distinct(name)) %>%
  mutate(diff = n - n_name)
# A tibble: 1 × 3
      n n_name  diff
  <int>  <int> <int>
1   549    541     8
```

name
Billie
Bobbie
Jackie
Jessie
Jimmie
Johnnie
Marion
Willie

Your Turn

Remove all cases where n < 500 (to minimize data entry errors).

Then, for each year, calculate the percent of names that are used for both sexes.

Then plot how the percent of dual sex names changes over time.

05:00

```
babynames %>%
  filter(n > 500) %>%
  group_by(year) %>%
  summarise(nn = n(), n_names = n_distinct(name)) %>%
  mutate(per_dual = (nn - n_names) / n_names * 100) %>%
  ggplot(aes(x = year, y = per_dual)) +
    geom_line()
```

Two table verbs

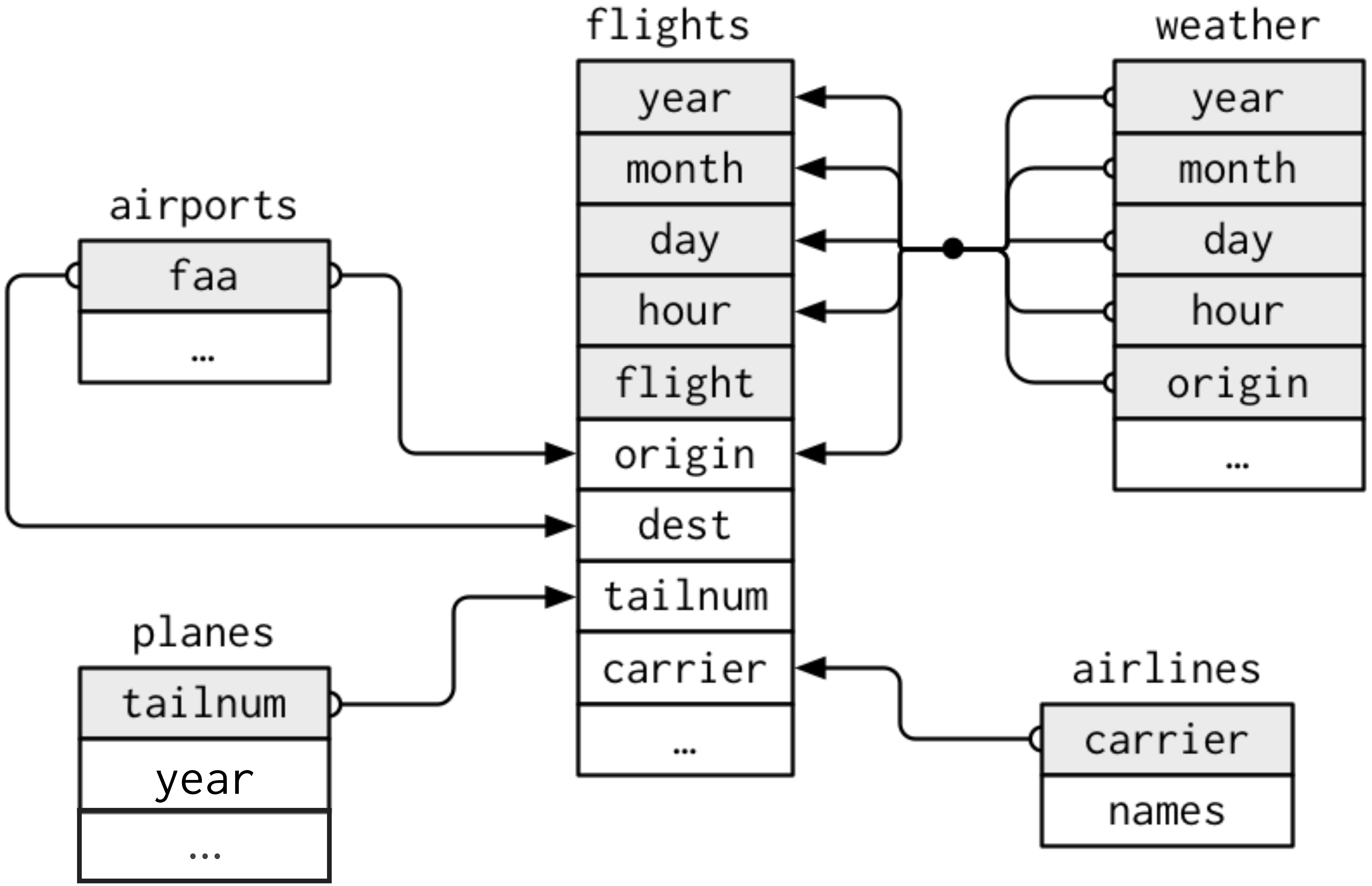
(joining data sets)

nycflights13

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

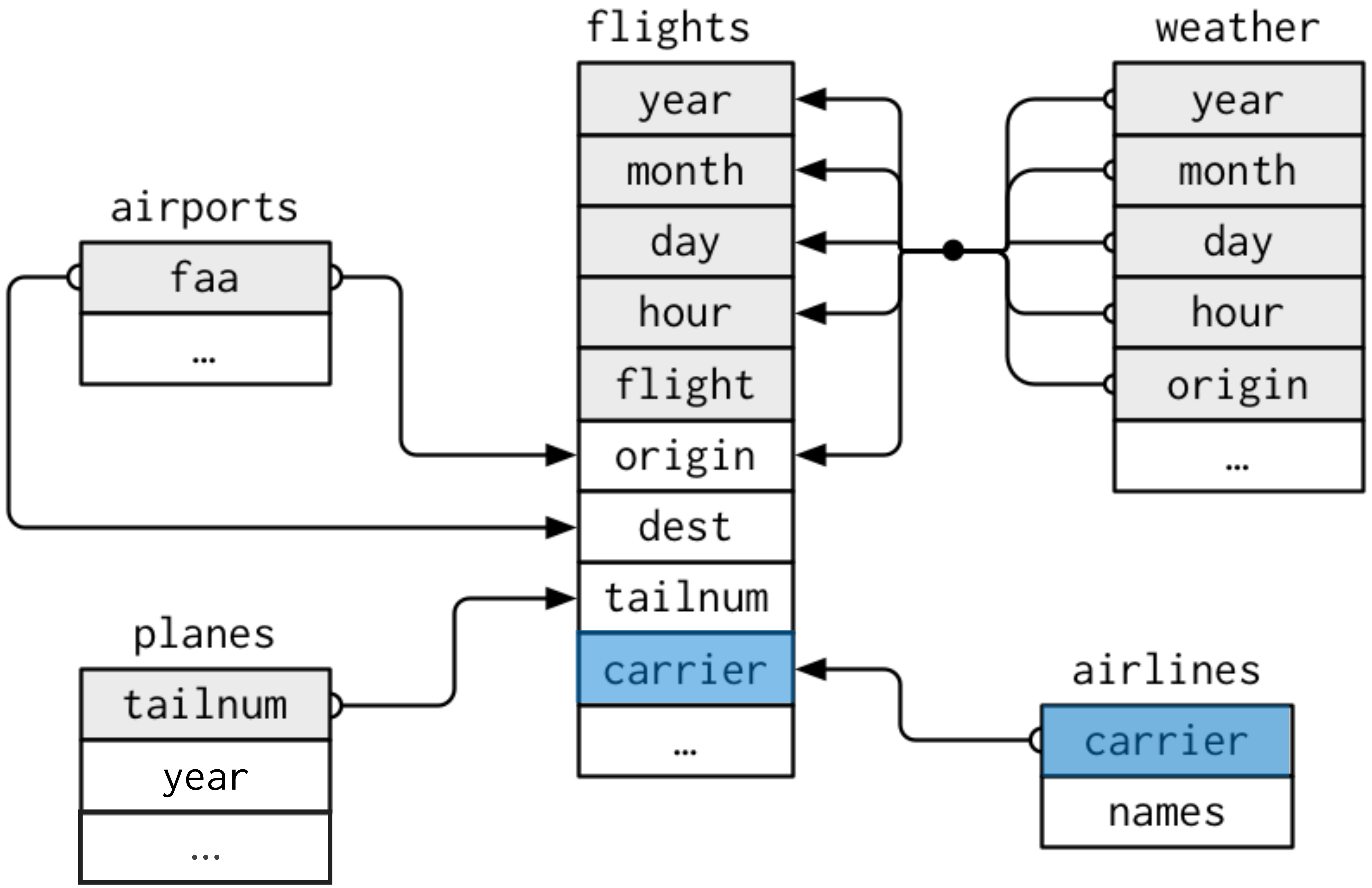
```
# install.packages("nycflights13")
library(nycflights13)
```

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.

mutating joins

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"
)
```

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

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

Toy data

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

left

```
left_join(band, 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

right

```
right_join(band, 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

```
full_join(band, 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

```
inner_join(band, 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

Airline names

```
View(flights["carrier"])
```

```
View(airlines)
```

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

	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

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.

06:00

```
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

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.

```
left_join(band, 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

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

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

\+

instrument2

artist	plays
John	guitar
Paul	bass
Keith	guitar

=

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

Airport names

```r
View(flights["dest"])
```

```r
View(airports)
```

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

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

Your Turn

Use flights and airports to compute the distance and average arr_delay by destination airport (names only, not codes). Order by average delay, worst to best.

Hint: use first() to get distance.

```
flights %>%
  drop_na(arr_delay) %>%
  left_join(airports, by = c("dest" = "faa")) %>%
  group_by(name) %>%
  summarise(distance = first(distance),
    delay = mean(arr_delay)) %>%
  arrange(desc(delay))
## # A tibble: 101 × 3
##                            name  distance     delay
##                           <chr>     <dbl>     <dbl>
## 1          Columbia Metropolitan       602 41.76415
## 2                     Tulsa Intl      1215 33.65986
## 3              Will Rogers World      1325 30.61905
```

filtering joins

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

```
semi_join(band, 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

dplyr

anti

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

band

name	band
Mick	Stones
John	Beatles
Paul	Beatles

+

instrument

name	plays
John	guitar
Paul	bass
Keith	guitar

=

name	band
Mick	Stones

dplyr

Airport names

```
View(flights["dest"])
```

```
View(airports)
```

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

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

Your Turn

1. How many airports in airports are serviced by flights originating in New York (i.e. flights in our data set)?
2. How many flights in flights flew to an airport not listed in airports?

06:00

```r
airports %>%
  semi_join(flights, by = c("faa" = "dest"))
## # A tibble: 101 × 7
```

```r
flights %>%
  anti_join(airports, by = c("dest" = "faa"))
## # A tibble: 7,602 × 19
```

```
flights %>%
  anti_join(airports, by = c("dest" = "faa")) %>%
  distinct(dest)
# A tibble: 4 × 1
   dest
  <chr>
1   PSE
2   STT
3   SJU
4   BQN
```

distinct()

Removes rows with duplicate values (in a column).

```
distinct(df, name)
```

df

name	band
Mick	Stones
John	Beatles
John	Zeppelin

name
Mick
John

Recap: Two table verbs


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


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

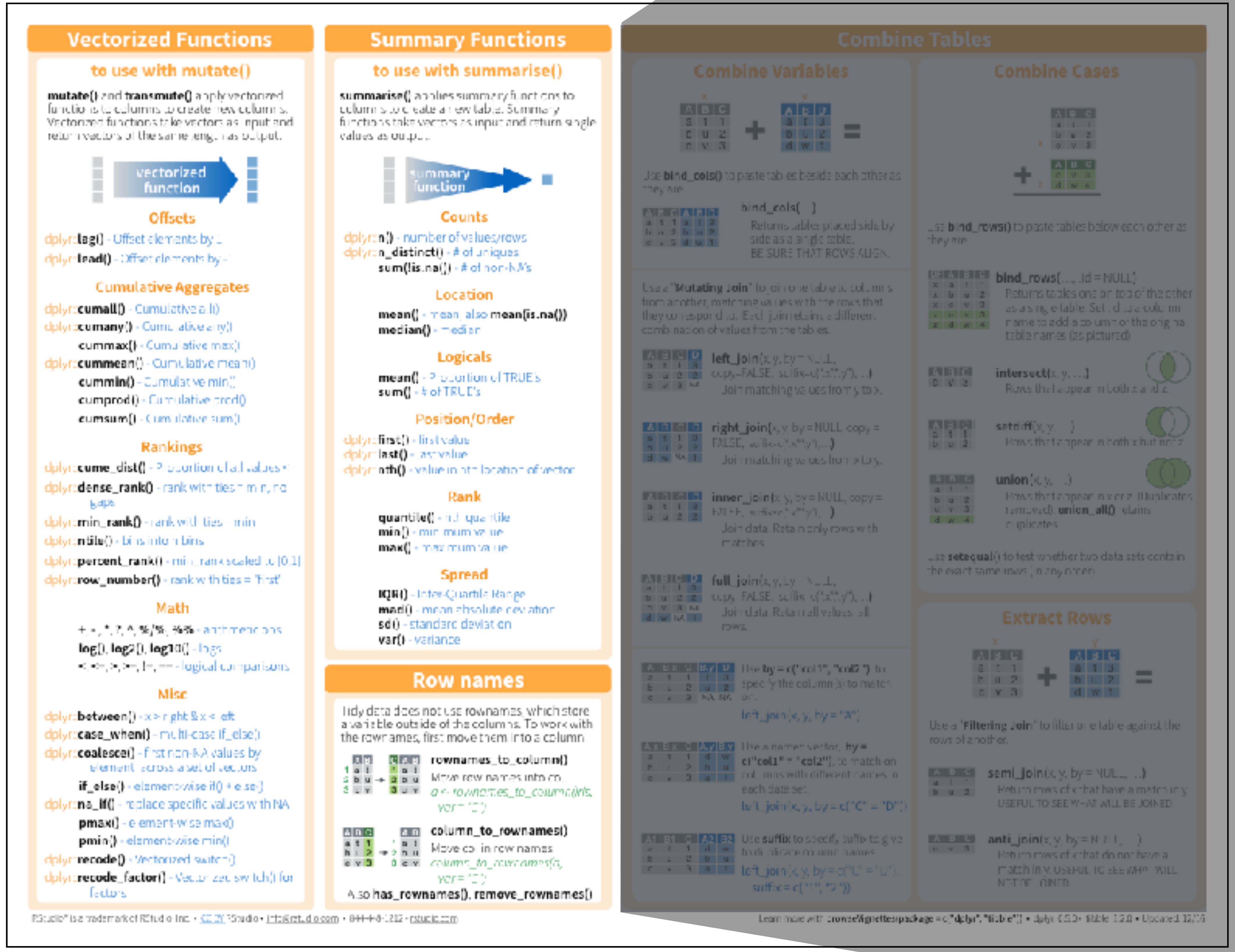

full_join() retains all cases in **either** data set

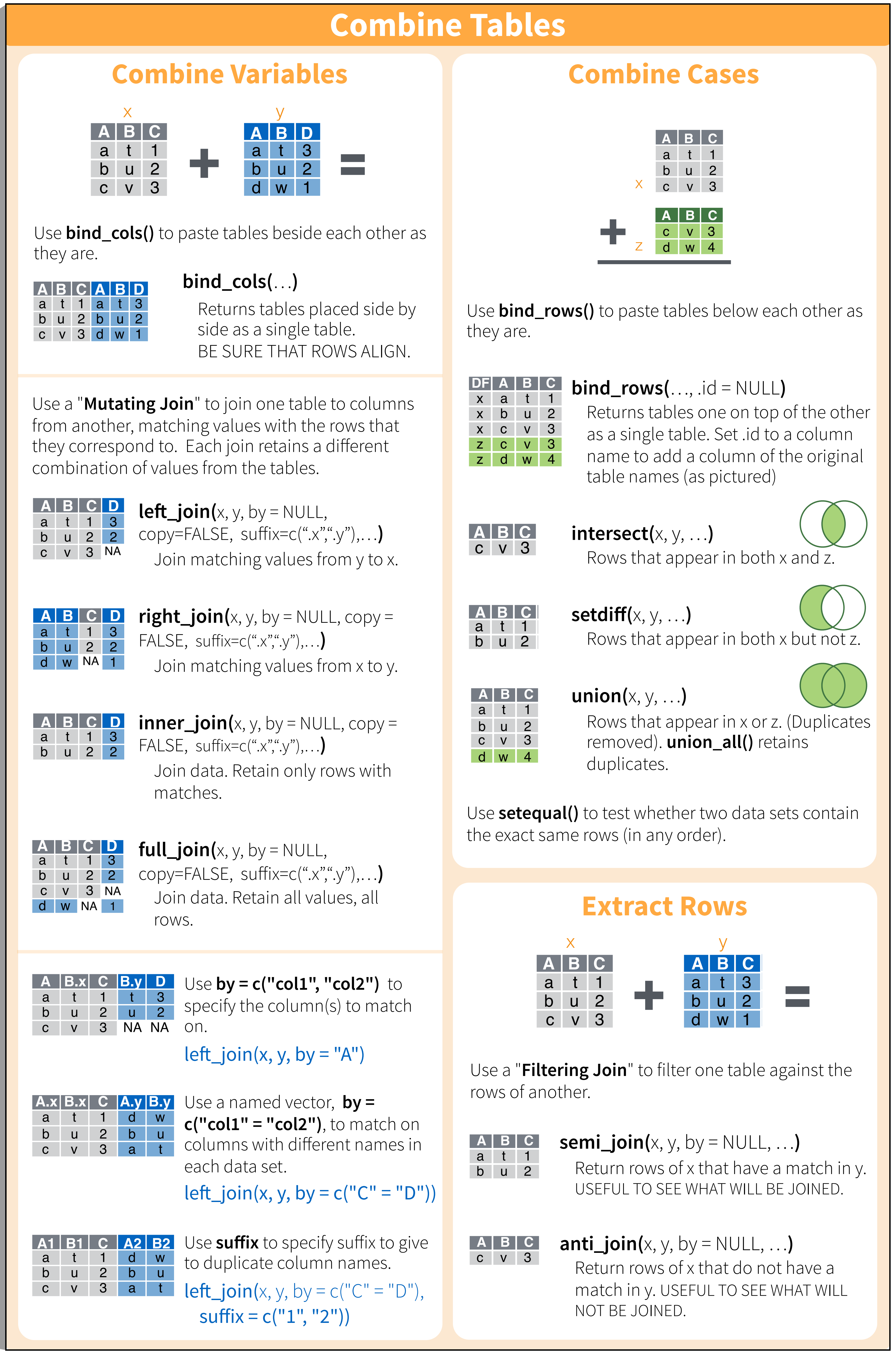

inner_join() retains only cases in **both** data sets


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


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

Two table verbs





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.

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.

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

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

Combine Cases

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 z.

setdiff(x, y, …**)**
Rows that appear in both x but not z.

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

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

Extract Rows

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.

Tidy tools

Tidy tools

Functions are easiest to use when they are:

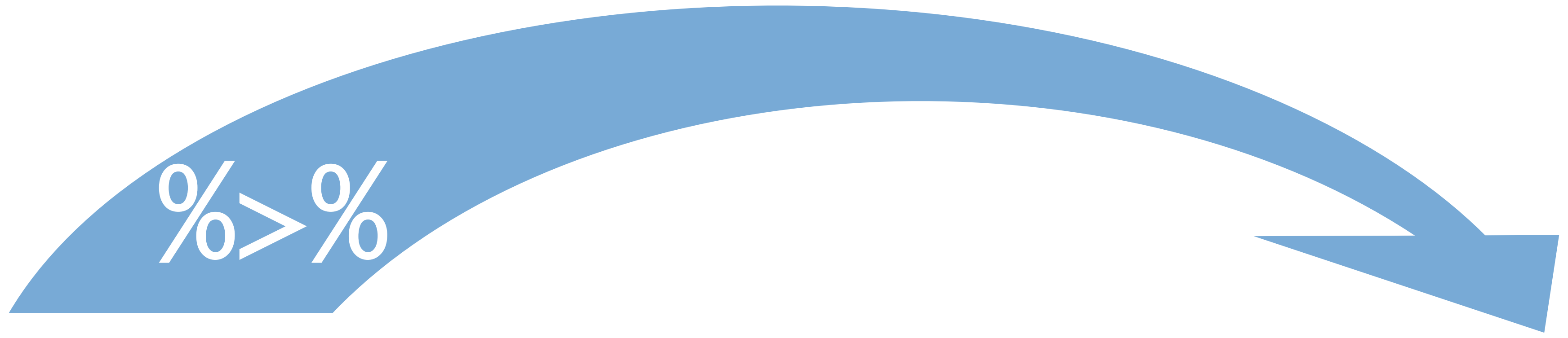
1. **Simple** - They do one thing, and they do it well
2. **Composable** - They can be combined with other functions for multi-step operations
3. **Smart** - They can use R objects as input.

Tidy functions do these things in a specific way.

1. Simple - They do one thing, and they do it well

filter() - extract **cases**
arrange() - reorder **cases**
group_by() - group **cases**
select() - extract **variables**
mutate() - create new **variables**
summarise() - summarise **variables** / create **cases**

2. **Composable** - They can be combined with other functions for multi-step operations




```
babynames        mutate(______, percent = prop * 100)
```

Each dplyr function takes a data frame as its first argument and returns a data frame. As a result, you can directly pipe the output of one function into the next.

3. Smart - They can use R objects as input.

TODO: Dplyr functions use non-standard evaluation, which means that you cannot simply pass an R object.

```r
babynames %>% filter(n > 500)
```

These objects are looked up in the scope of x

These objects are looked up in babynames

```r
x <- n > 500
babynames %>% filter(x) # ERROR!
```

_ functions

Every major dplyr function comes with a programming friendly version that accepts formulas. The version has an _ at the end of its name.

~ saves the expression as a formula

filter_()

```
x <- ~n > 500
babynames %>% filter_(x) # Works :)
```

Data Transformation with

dplyr