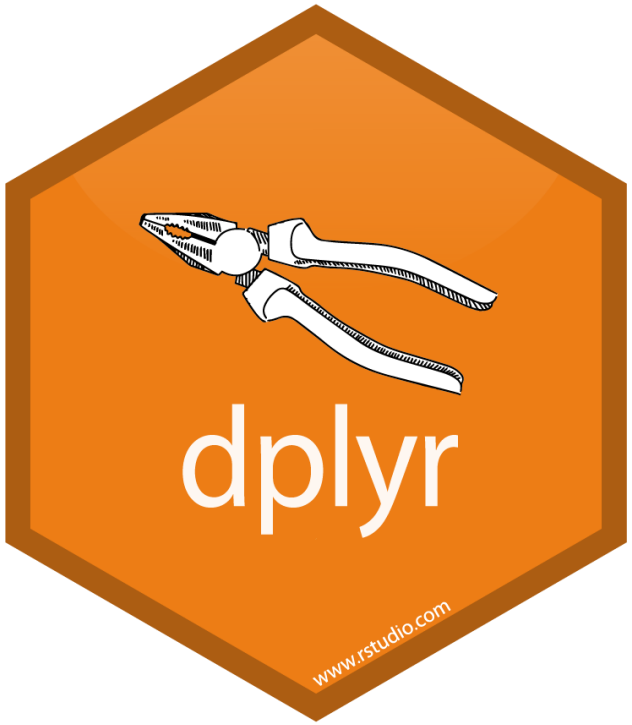
Manipulating Data with



Adapted from “Explore the Tidyverse” CC by Hadley Wickham

gapminder

A subset of Gapminder data: population, GDP per capita and life expectancy, for countries over time.

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

summary()

str()

?gapminder

Explore!

ggplot()

View()

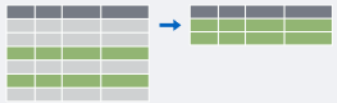
gapminder

country <fctr>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPercap <dbl>
Afghanistan	Asia	1952	28.80100	8425333	779.4453
Afghanistan	Asia	1957	30.33200	9240934	820.8530
Afghanistan	Asia	1962	31.99700	10267083	853.1007
Afghanistan	Asia	1967	34.02000	11537966	836.1971
Afghanistan	Asia	1972	36.08800	13079460	739.9811
Afghanistan	Asia	1977	38.43800	14880372	786.1134
Afghanistan	Asia	1982	39.85400	12881816	978.0114
Afghanistan	Asia	1987	40.82200	13867957	852.3959
Afghanistan	Asia	1992	41.67400	16317921	649.3414
Afghanistan	Asia	1997	41.76300	22227415	635.3414

1-10 of 1,704 rows

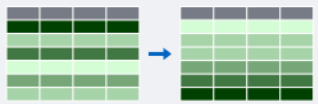
Previous 1 2 3 4 5 6 ... 100 Next

dplyr: Data manipulation

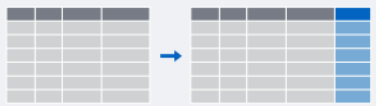


Extract cases with **filter()**

Extract variables with **select()**



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



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

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

along with **group_by()**

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)

filter()

Extract rows that meet logical criteria.

```
filter(gapminder, country == "New Zealand")
```

gapminder

country	continent	year	...
Afghanistan	Asia	1952	
Afghanistan	Asia	1957	
...	...	...	
Netherlands	Europe	2007	
New Zealand	Oceania	1952	
New Zealand	Oceania	1957	

country	continent	year	...
New Zealand	Oceania	1952	
New Zealand	Oceania	1957	
New Zealand	Oceania	1962	
New Zealand	Oceania	1967	
...	...	...	...

filter()

Extract rows that meet logical criteria.

```
filter(gapminder, country == "New Zealand")
```

= sets
(returns nothing)

== tests if equal
(returns TRUE or FALSE)

filter()

Extract rows that meet logical criteria.

```
filter(gapminder, country == "New Zealand")
```

= sets
(returns nothing)

== tests if equal
(returns TRUE or FALSE)

Base R Equivalent:

```
gapminder[gapminder$country == “New Zealand”,]
```


dplyr

Logical tests

?Comparison

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

Your Turn 1

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

1. The data for United States
2. All data for countries in Oceania
3. Rows where the life expectancy is greater than 82

```
filter(gapminder, country == "United States")
```

```
filter(gapminder, continent == "Oceania")
```

```
filter(gapminder, lifeExp > 82)
```

Two common mistakes

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

```
filter(gapminder, continent = "Oceania")
filter(gapminder, continent == "Oceania")
```

2. Forgetting quotes

```
filter(gapminder, continent == Oceania)
filter(gapminder, continent == "Oceania")
```

filter()

additional arguments must also be TRUE

Extract rows that meet *every* logical criteria.

```
filter(gapminder, country == "New Zealand", year > 2000)
```

gapminder

country	continent	year	...
...	...	...	
New Zealand	Oceania	1952	
...	...	...	
New Zealand	Oceania	2002	
New Zealand	Oceania	2007	

country	continent	year	...
New Zealand	Oceania	2002	
New Zealand	Oceania	2007	

Boolean operators

?base::Logic

a & b	and
a | b	or
!a	not

filter()

Extract rows that meet *every* logical criteria.

```
filter(gapminder, country == "New Zealand" & year > 2000)
```

gapminder

country	continent	year	...
...	...	...	
New Zealand	Oceania	1952	
...	...	...	
New Zealand	Oceania	2002	
New Zealand	Oceania	2007	

country	continent	year	...
New Zealand	Oceania	2002	
New Zealand	Oceania	2007	

Adapted from 'Ma

Your Turn 2

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

1. United States before 1970
2. Countries where life expectancy in 2007 is below 50
3. Records for any of "New Zealand", "Canada" or "United States"

Bonus:

4. Countries outside of Africa that had an average life expectancy between 30-35 years in 1952.

```
filter(gapminder, country == "Canada", year < 1970)
```

```
filter(gapminder, year == 2007, lifeExp < 50)
```

```
filter(gapminder,
  country %in% c("Canada", "New Zealand", "United States"))
```

Bonus:

```
filter(gapminder,
       continent != ‘Africa’, between(lifeExp,30,35),
       year == 1952)

OR

filter(gapminder,
       continent != ‘Africa’, lifeExp > 30 & lifeExp < 35,
       year==1952)
```

Two more common mistakes

3. Collapsing multiple tests into one

```
filter(gapminder, 1960 < year < 1980)
filter(gapminder, 1960 < year, year < 1980)
```

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

```
filter(gapminder, country == "New Zealand" |
  country == "Canada" | country == "United States")
filter(gapminder,
  country %in% c("New Zealand", "Canada", "United States"))
```

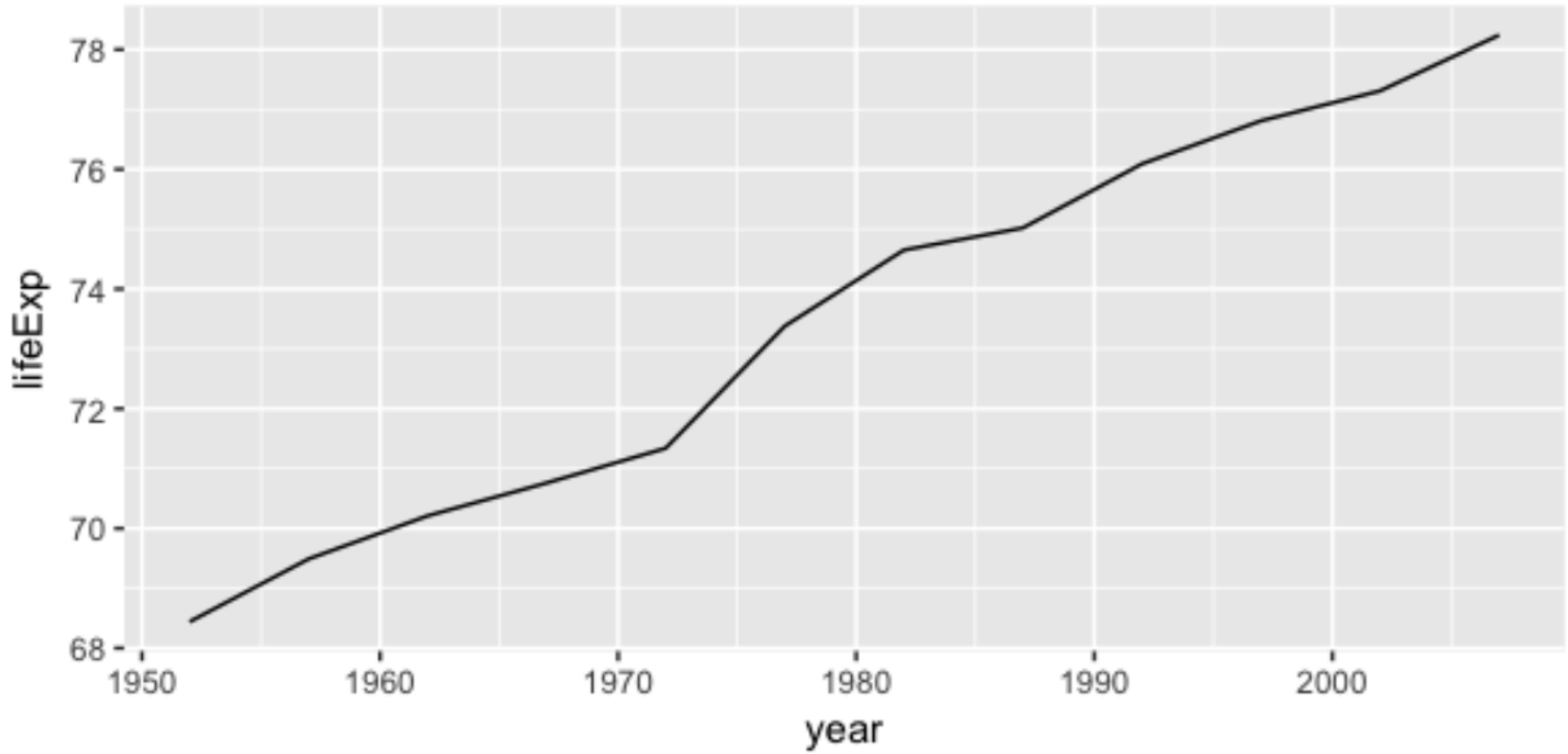
Your Turn 3

Use `filter()` to get the records for the US, then plot the life expectancy over time.

```
filter(gapminder, country == "United States")
```

```r
us <- filter(gapminder, country == "United States")

ggplot(us, aes(x = year, y = lifeExp)) +
  geom_line()
```



dplyr common syntax

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

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

select()

select()

Extract rows that meet logical criteria.

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

data frame to transform

One or more column names (select returns each column that you name)

Base R Equivalent:

```
gapminder[,c("country", "continent")]
```

select()

Extract rows that meet logical criteria.

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

data frame to transform

One or more column names (select returns each column that you name)

```
select(-country)
```

```
select(country:year)
```

```
select(contains('c')
```

You can also 'unselect', 'range' select, 'match' select, etc – see `?select`

```
select(starts_with('c')
```

arrange()

arrange()

Order cases 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 cases from smallest to largest values.

```
arrange(gapminder, lifeExp)
```

country	continent	year	lifeExp	...
Afghanista	Afghanistan	1952	28.8	
Afghanista	Afghanistan	1957	30.3	
Angola	Angola	1952	30.0	
Gambia	Gambia	1952	30.0	
Rwanda	Rwanda	1992	23.6	
Sierra	Sierra	1952	30.3	

country	continent	year	lifeExp	...
Rwanda	Rwanda	1992	23.6	
Afghanista	Afghanistan	1952	28.8	
Gambia	Gambia	1952	30.0	
Angola	Angola	1952	30.0	
Sierra	Sierra	1952	30.3	
Afghanista	Afghanistan	1957	30.3	

desc()

Changes order to largest to smallest values.

```
arrange(gapminder, desc(lifeExp))
```

country	continent	year	lifeExp	...
Afghanista	Afghanistan	1952	28.8	
Afghanista	Afghanistan	1957	30.3	
Angola	Angola	1952	30.0	
Gambia	Gambia	1952	30.0	
Rwanda	Rwanda	1992	23.6	
Sierra	Sierra	1952	30.3	

country	continent	year	lifeExp	...
Afghanista	Afghanistan	1957	30.3	
Sierra	Sierra	1952	30.3	
Angola	Angola	1952	30.0	
Gambia	Gambia	1952	30.0	
Afghanista	Afghanistan	1952	28.8	
Rwanda	Rwanda	1992	23.6	

Your Turn 4

Find the records with the smallest population.

Find the records with the largest GDP per capita.

```
arrange(gapminder, desc(gdpPercap))
```

```
## A tibble: 1,704 x 6
#   country   continent  year lifeExp     pop gdpPercap
#   <fctr>    <fctr>    <int>   <dbl>   <int>     <dbl>
# 1 Kuwait    Asia       1957    58.0  212846    113523
# 2 Kuwait    Asia       1972    67.7  841934    109348
# 3 Kuwait    Asia       1952    55.6  160000    108382
# 4 Kuwait    Asia       1962    60.5  358266     95458
# 5 Kuwait    Asia       1967    64.6  575003     80895
```

Pipe: %>%

Multistep Operations

Consider the following:
Extract rows with year equal to 2007, then
Arrange by decreasing life expectancy

Option 1: Use intermediate variables

```
gapminder_2007 <- filter(gapminder, year == 2007)
arrange(gapminder_2007, desc(lifeExp))
```

Multistep Operations

Consider the following:
Extract rows with year equal to 2007, then
Arrange by decreasing life expectancy

Option 2: Do it all in one line

```
arrange(filter(gapminder, year == 2007), desc(lifeExp))
```

Multistep Operations

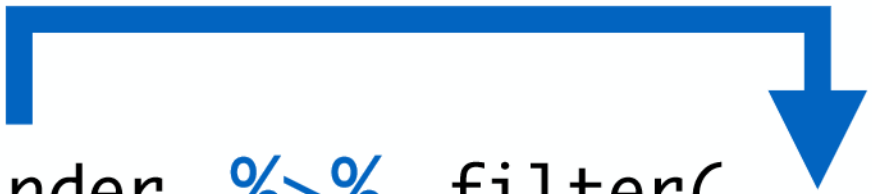
Consider the following:
Extract rows with year equal to 2007, then
Arrange by decreasing life expectancy

Option 2: Do it all in one line

```
arrange(filter(gapminder, year == 2007), desc(lifeExp))
```

The pipe operator %>%

Passes result on left into first argument of function on right.



```
gapminder %>% filter(_____, country == "Canada")
```

These do the same thing. Try it.

```
filter(gapminder, country == "Canada")
gapminder %>% filter(country == "Canada")
```

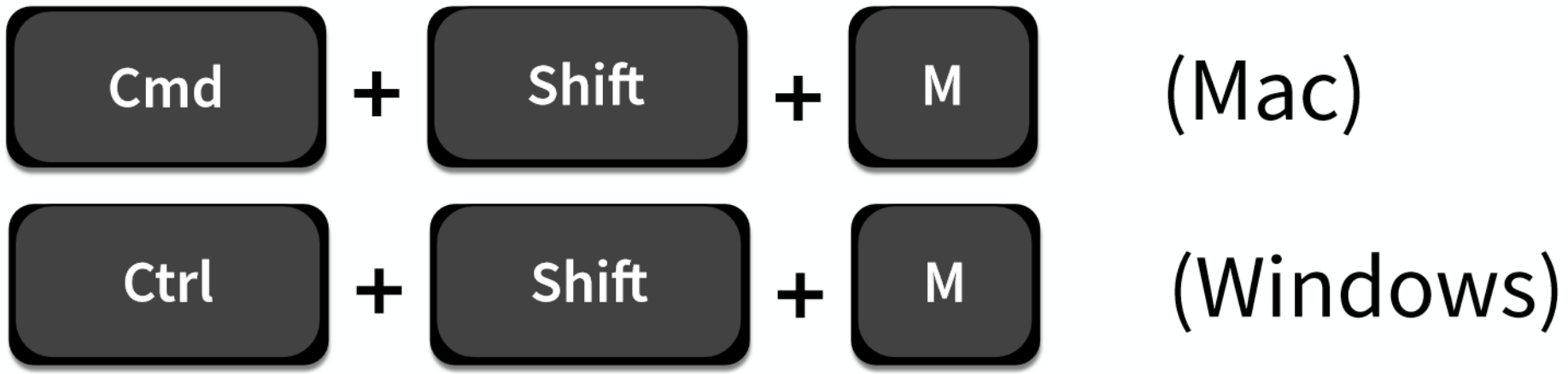
Multistep Operations

Consider the following:
Extract rows with year equal to 2007, then
Arrange by decreasing life expectancy

Option 3: Use the pipe

```
gapminder %>%
  filter(year == 2007) %>%
  arrange(desc(lifeExp))
```

Shortcut to type %>%



mutate()

mutate()

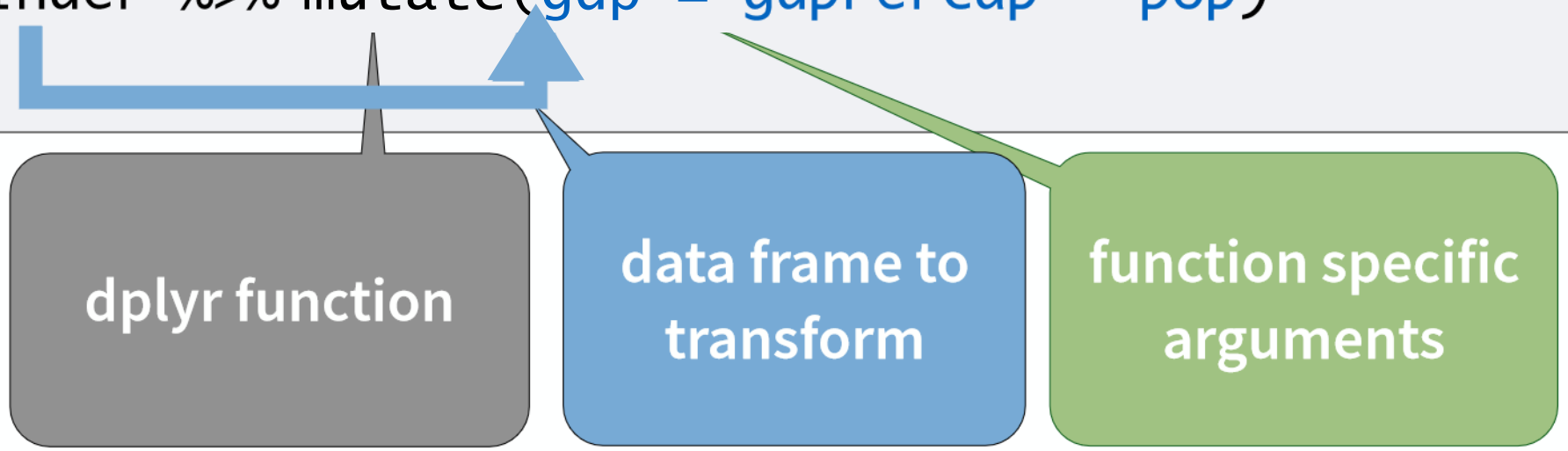
Create new columns.

```
gapminder %>% mutate(gdp = gdpPercap * pop)
```

mutate()

Create new columns.

```
gapminder %>% mutate(gdp = gdpPercap * pop)
```



mutate()

Create new columns.

```
gapminder %>% mutate(gdp = gdpPercap * pop)
```

argument name is new column name

argument value is how to calculate, based on existing columns

mutate()

Create new columns.

```
gapminder %>% mutate(gdp = gdpPercap * pop)
```

gapminder

country	continent	year	...
Afghanistan	Asia	1952	
Afghanistan	Asia	1957	
Afghanistan	Asia	1962	
Afghanistan	Asia	1967	
Afghanistan	Asia	1972	
Afghanistan	Asia	1977	

country	continent	year	...	gdp
Afghanistan	Asia	1952		6567086330
Afghanistan	Asia	1957		7585448670
Afghanistan	Asia	1962		8758855797
Afghanistan	Asia	1967		9648014150
Afghanistan	Asia	1972		9678553274
Afghanistan	Asia	1977		11697659231

mutate()

Create new columns.

```
gapminder %>% mutate(gpd = gdpPercap * pop,
                     pop_mill = round(pop/1000000))
```

gapminder

country	continent	year	...
Afghanistan	Asia	1952	
Afghanistan	Asia	1957	
Afghanistan	Asia	1962	
Afghanistan	Asia	1967	
Afghanistan	Asia	1972	
Afghanistan	Asia	1977	

country	continent	year	...	gdp	pop_mill
Afghanistan	Asia	1952		6567086330	8
Afghanistan	Asia	1957		7585448670	9
Afghanistan	Asia	1962		8758855797	10
Afghanistan	Asia	1967		9648014150	12
Afghanistan	Asia	1972		9678553274	13
Afghanistan	Asia	1977		11697659231	15

transmute()

Create new columns.

```
gapminder %>% transmute(gdp = gdpPercap * pop,
                        pop_mill = round(pop/1000000))
```

gapminder

country	continent	year	...
Afghanistan	Asia	1952	
Afghanistan	Asia	1957	
Afghanistan	Asia	1962	
Afghanistan	Asia	1967	
Afghanistan	Asia	1972	
Afghanistan	Asia	1977	

country	continent	year	...	gdp	pop_mill
Afghanistan	Asia	1952		6567086330	8
Afghanistan	Asia	1957		7585448670	9
Afghanistan	Asia	1962		8758855797	10
Afghanistan	Asia	1967		9648014150	12
Afghanistan	Asia	1972		9678553274	13
Afghanistan	Asia	1977		11697659231	15

Quiz

A function that returns a vector the same length as the input is called **vectorized**.

Which of the following functions are vectorized?

- `ifelse()`
- `diff()`
- `sum()`

```
gapminder %>%
  mutate(size = ifelse(pop < 10e06, "small", "large"))
```

OK, **`ifelse()` is** vectorized

```
gapminder %>%
  mutate(diff_pop = diff(pop))
```

```
Error in mutate_impl(.data, dots) :
  Column `diff_pop` must be length 1704
  (the number of rows) or one, not 1703
```

Not OK, **`diff()` is not** vectorized

```
gapminder %>%
  mutate(total_pop = sum(as.numeric(pop)))
```

```
# A tibble: 1,704 x 7
   country     continent  year lifeExp      pop gdpPercap   total_pop
   <fctr>      <fctr>    <int>   <dbl>    <int>     <dbl>       <dbl>
 1 Afghanistan Asia       1952    28.8  8425333       779 50440465801
 2 Afghanistan Asia       1957    30.3  9240934       821 50440465801
 3 Afghanistan Asia       1962    32.0 10267083       853 50440465801
```

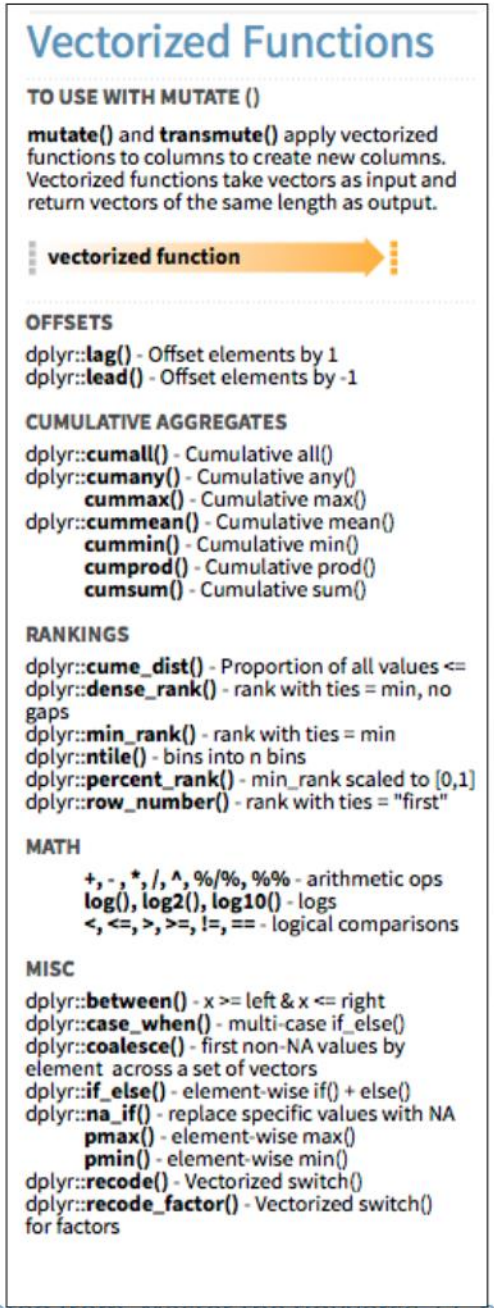
OK, `sum()` **is not** vectorized,

but `mutate()` just repeats the single returned values to fill the rows.

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.

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

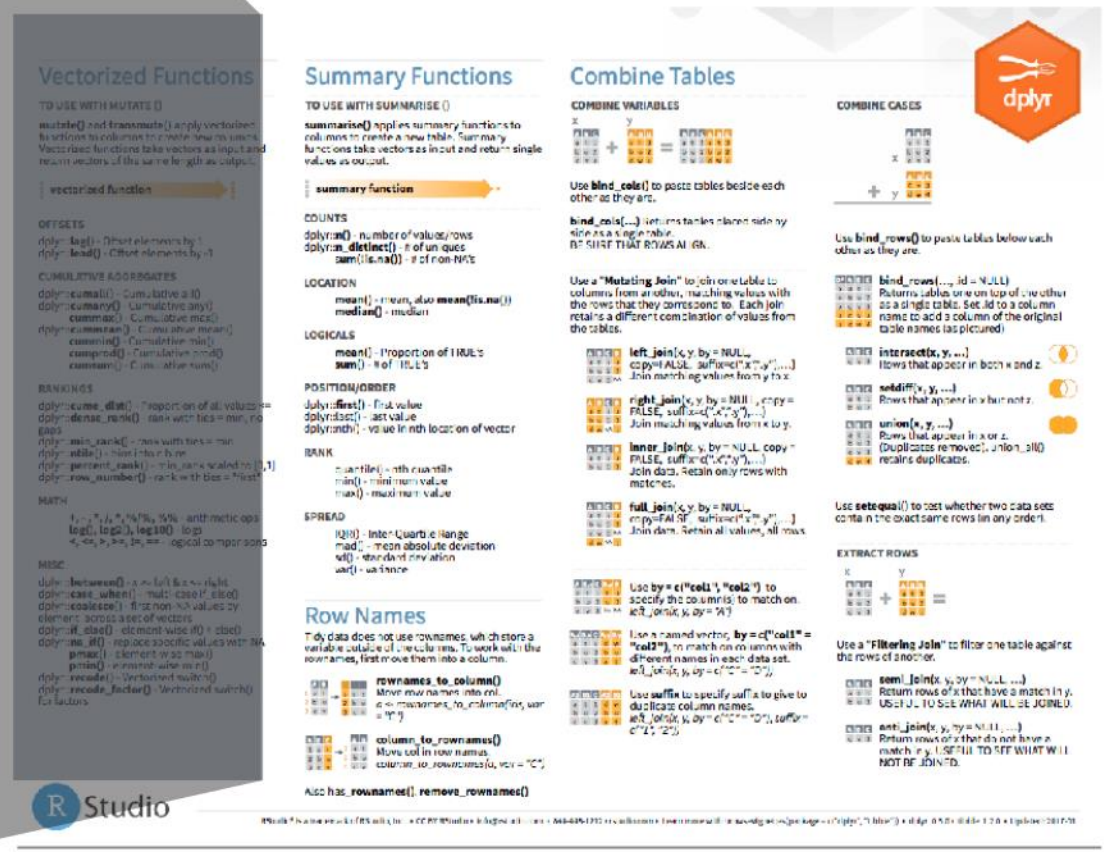
dplyr::**cume_dist()** - Proportion of all values <=
dplyr::**dense_rank()** - rank with ties = min, no gaps
dplyr::**min_rank()** - rank with ties = min
dplyr::**ntile()** - bins into n bins
dplyr::**percent_rank()** - min_rank scaled to [0,1]
dplyr::**row_number()** - rank with ties = "first"

MATH

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

MISC

dplyr::**between()** - x >= left & x <= right
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



Vectorized Functions

Summary Functions

Combine Tables

Row Names

RStudio

dplyr

Most useful:

- Math
- Misc

Your Turn 5

Alter the code to add a `prev_lifeExp` column that contains the life expectancy from the previous record. (**Hint:** use the cheatsheet, you want to offset elements by one)

Extra challenge: Why isn't this quite '*life expectancy five years ago*'?

```
gapminder %>%
  mutate(prev_lifeExp = lag(lifeExp))
```

country <fctr>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPercap <dbl>	prev_lifeExp <dbl>
Afghanistan	Asia	1952	28.80100	8425333	779.4453	*NA*
Afghanistan	Asia	1957	30.33200	9240934	820.8530	28.80100
Afghanistan	Asia	1962	31.99700	10267083	853.1007	30.33200
Afghanistan	Asia	1967	34.02000	11537966	836.1971	31.99700
Afghanistan	Asia	1972	36.08800	13079460	739.9811	34.02000
Afghanistan	Asia	1977	38.43800	14880372	786.1134	36.08800
Afghanistan	Asia	1982	39.85400	12881816	978.0114	38.43800
Afghanistan	Asia	1987	40.82200	13867957	852.3959	39.85400
Afghanistan	Asia	1992	41.67400	16317921	649.3414	40.82200
Afghanistan	Asia	1997	41.76300	22227415	635.3414	41.67400

1-10 of 1,704 rows

This is the life expectancy for Afghanistan 55 years in the future

country <fctr>	continent <fctr>	year <int>	lifeExp <dbl>	pop <int>	gdpPercap <dbl>	
Afghanistan	Asia	2002	42.12900	25268405	726.7341	
Afghanistan	Asia	2007	43.82800	31889923	974.5803	42.12900
Albania	Europe	1952	55.23000	1282697	1601.0561	43.82800
Albania	Europe	1957	59.28000	1476505	1942.2842	55.23000
Albania	Europe	1962	64.82000	1728137	2312.8890	59.28000
Albania	Europe	1967	66.22000	1984060	2760.1969	64.82000
Albania	Europe	1972	67.69000	2263554	3313.4222	66.22000
Albania	Europe	1977	68.93000	2509048	3533.0039	67.69000
Albania	Europe	1982	70.42000	2780097	3630.8807	68.93000
Albania	Europe	1987	72.00000	3075321	3738.9327	70.42000

11-20 of 1,704 rows

summarise()

summarise()

Compute table of summaries.

```
gapminder %>% summarise(mean_life = mean(lifeExp))
```

gapminder

country	continent	year	lifeExp	...
Afghanistan	Asia	1952	28.801	
Afghanistan	Asia	1957	30.332	
Afghanistan	Asia	1962	31.997	
Afghanistan	Asia	1967	34.020	
Afghanistan	Asia	1972	36.088	

mean_life
59.47444

summarise()

Compute table of summaries.

```
gapminder %>% summarise(mean_life = mean(lifeExp),
                        min_life = min(lifeExp))
```

gapminder

country	continent	year	lifeExp	...
Afghanistan	Asia	1952	28.801	
Afghanistan	Asia	1957	30.332	
Afghanistan	Asia	1962	31.997	
Afghanistan	Asia	1967	34.020	
Afghanistan	Asia	1972	36.088	

mean_life	min_life
59.47444	23.599

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

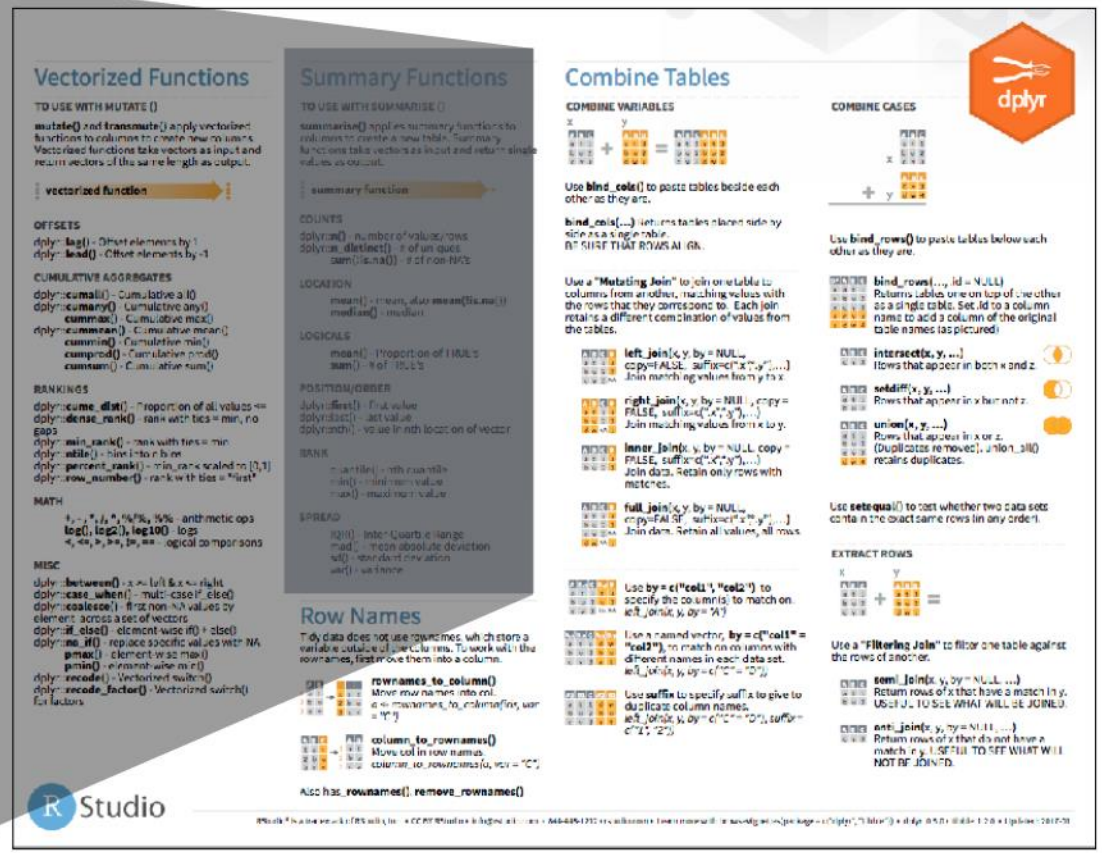
dplyr::**first()** - first value
dplyr::last() - last value
dplyr::nth() - value in nth location of vector

RANK

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

SPREAD

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



Your Turn 6

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 number of countries represented in the data (Hint: use cheatsheet)

```
gapminder %>%
  summarise(first = min(year),
            last = max(year),
            n_countries = n_distinct(country))

# A tibble: 1 x 3
#   first  last n_countries
#   <dbl> <dbl>       <int>
# 1  1952  2007         142
```

Grouping Cases

group_by()

Groups cases by common values of one or more columns.

```
gapminder %>%
  group_by(continent)
```

In console

```
# A tibble: 1,704 x 6
# Groups:   continent [5]
       country continent  year lifeExp      pop gdpPercap
        <fctr>    <fctr> <int>   <dbl>    <int>     <dbl>
 1 Afghanistan      Asia  1952  28.801  8425333  779.4453
 2 Afghanistan      Asia  1957  30.332  9240934  820.8530
 3 Afghanistan      Asia  1962  31.997 10267083  853.1007
```

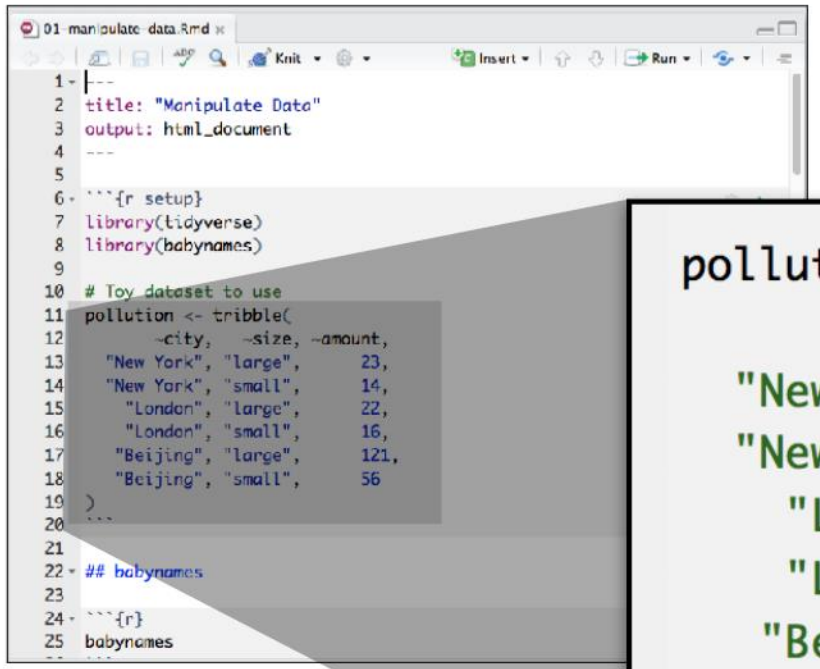
group_by()

Groups cases by common values, then summarise acts by group

```
gapminder %>%
  group_by(continent) %>%
  summarise(n_countries = n_distinct(country))
```

continent	n_countries
Africa	52
Americas	25
Asia	33
Europe	30
Oceania	2

Transform Data Notebook




```
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 set to practice with

```
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

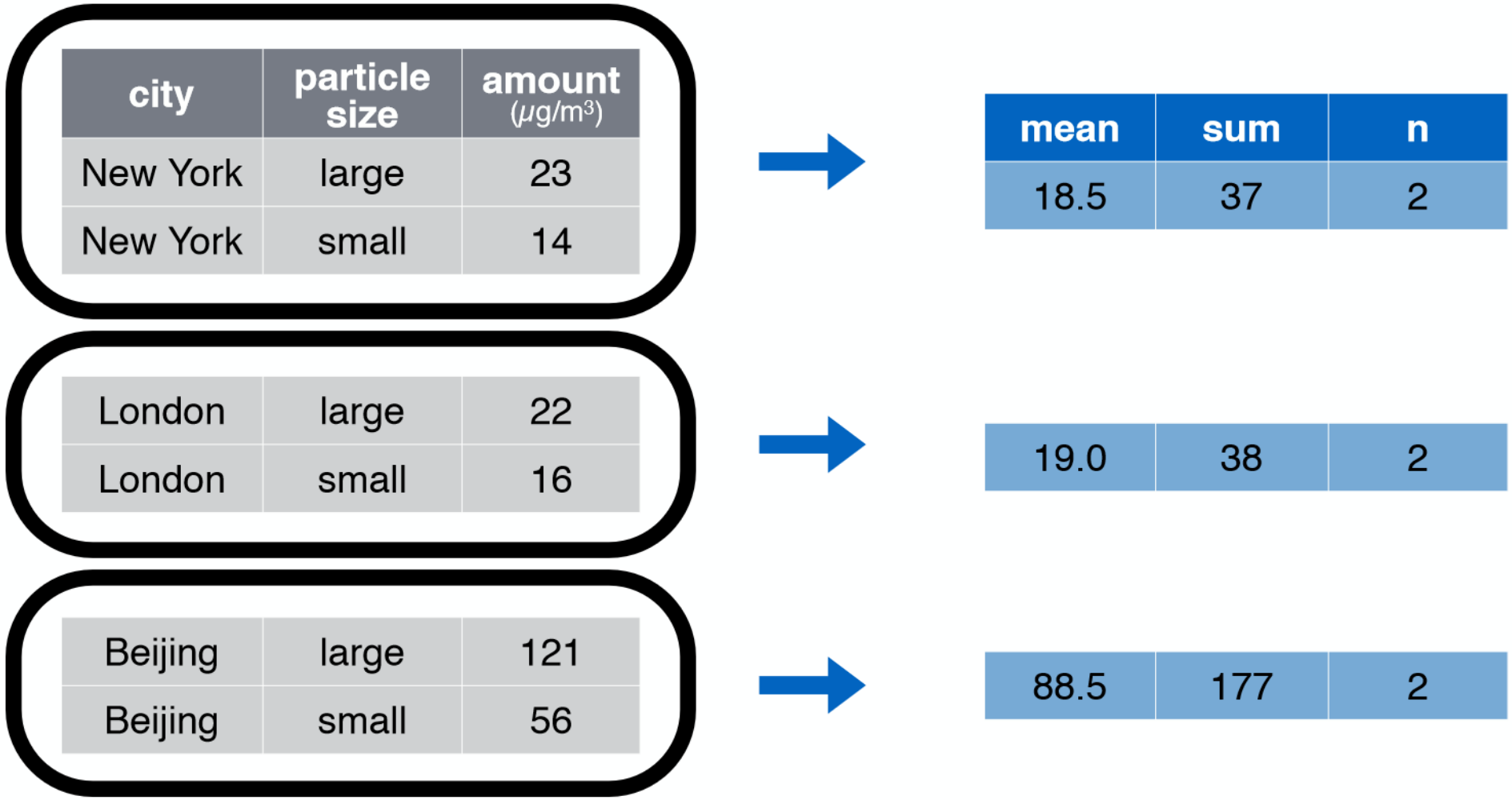
city	particle size	amount ($\mu g/m^3$)
New York	large	23
New York	small	14
London	large	22
London	small	16
Beijing	large	121
Beijing	small	56

mean	sum	n
42	252	6

```
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



group_by() + summarise()

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 ($\mu g/m^3$)
New York	large	23
New York	small	14

city	particle size	amount ($\mu g/m^3$)
London	large	22
London	small	16

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

Your Turn 8

Find the median life expectancy by continent in 2007.

```
gapminder %>%
  filter(year == 2007) %>%
  group_by(continent) %>%
  summarise(med_life_exp = median(lifeExp))
```

continent <fctr>	med_life_exp <dbl>
Africa	52.9265
Americas	72.8990
Asia	72.3960
Europe	78.6085
Oceania	80.7195

5 rows

Challenge

Task

I want to find the countries with **biggest jump** in life expectancy (between any two consecutive records).

Your Turn 9

Brainstorm with your neighbour

What sequence of operations would you need to do?

(**Hint:** `mutate()` will respect groups too)

I want to find the countries with **biggest jump** in life expectancy (between any two consecutive records).

Your Turn 10

Putting it all together

Find the country with biggest jump in life expectancy (between any two consecutive records).

```
# One of many solutions
gapminder %>%
  group_by(country) %>%
  mutate(prev_lifeExp = lag(lifeExp),
         jump = lifeExp - prev_lifeExp) %>%
  arrange(desc(jump))
```

```
# One of many solutions
gapminder %>%
  group_by(country) %>%
  mutate(jump = lifeExp - lag(lifeExp)) %>%
  summarise(jump = max(jump, na.rm = TRUE)) %>%
  arrange(desc(jump))
```