Introduction to R Packages for Data Management

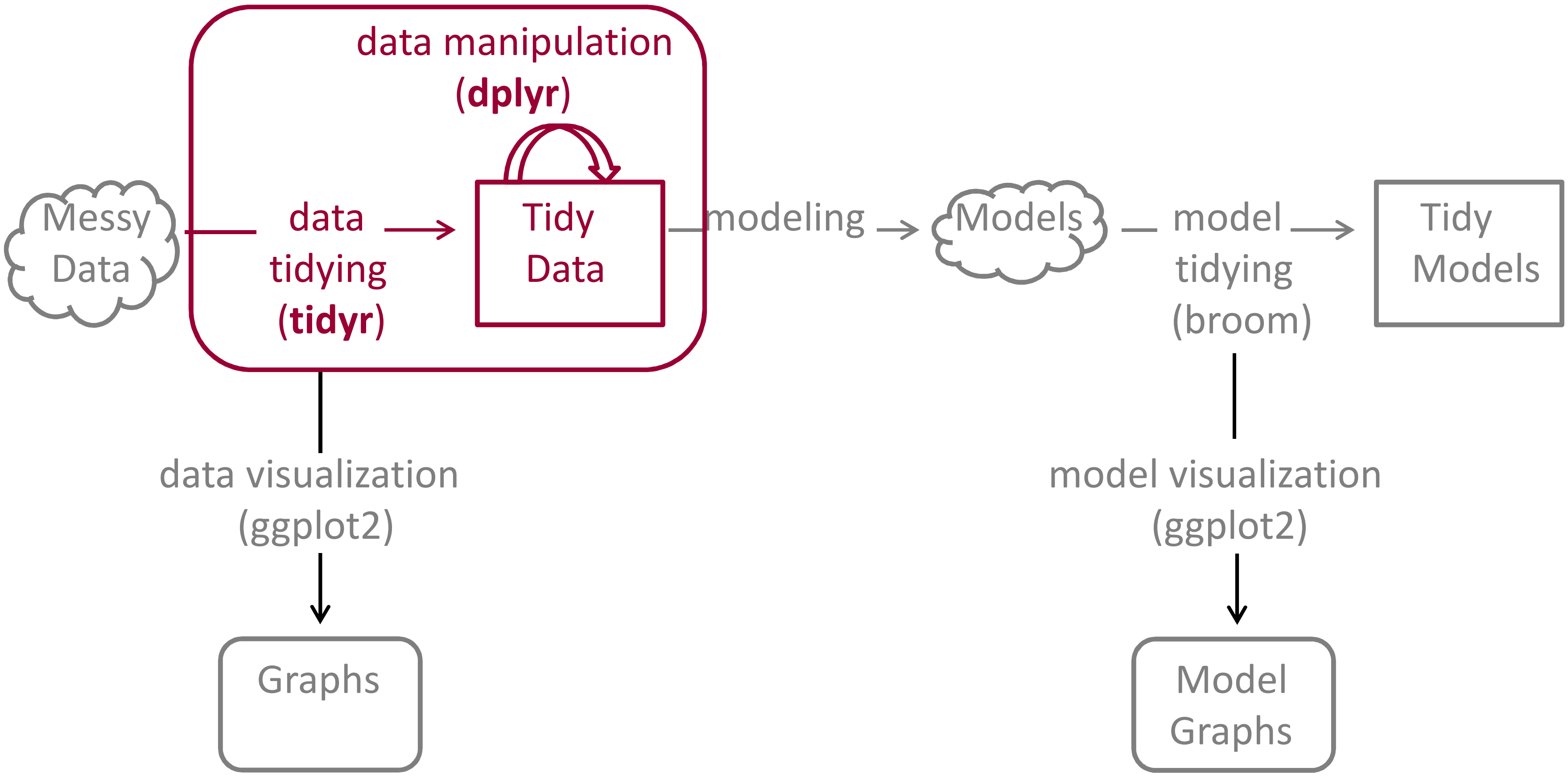

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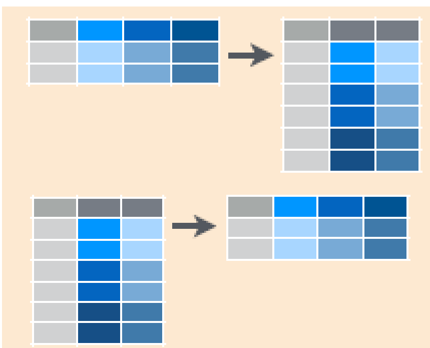
Diagram shown here based on David Robinson, 4/11/2015, "broom: an R Package to Convert Statistical Models into Tidy Data Frames"
http://opr.princeton.edu/workshops/Downloads/2016Jan_BroomRobinson.pdf

Tidy Data

Tidy data sets provide a **standardized** way to link physical layout of a data set with its meaning.

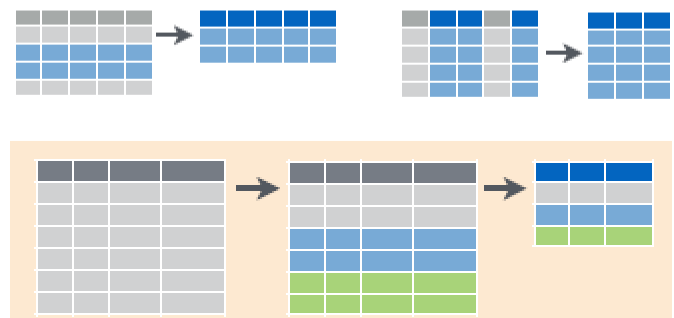
Data sets come in many formats …but many R tools work best with one format, a tidy data set.

tidyr



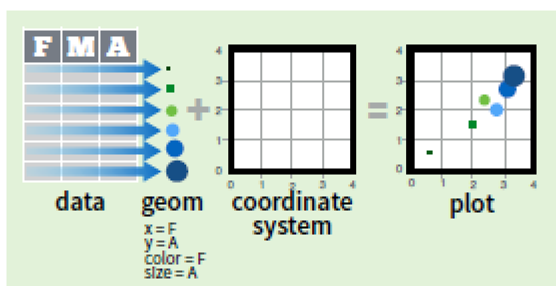
reshape data to be tidy

dplyr



manipulate and summarize tidy data

ggplot2



visualize tidy data

Source: RStudio Data Wrangling Cheatsheet
RStudio Data Visualization Cheatsheet

Tidy Format

Some terms:
- a data set is a collection of values
- many data sets are organized as rectangular tables made up of rows and columns

Values are organized in two ways:

every value belongs to a variable and an observation

- a variable contains all values that measure the same underlying attribute (for example, life expectancy or total fertility rate) across units
- an observation contains all values measured on the same unit (for example, country-year)

Each **variable** is saved in its own column and column headers are variable names, not values.
Each **observation** is saved in its own row.
Each “type” of observation is stored in a single table.

Principles of tidy data are very similar to principles of relational database design ... although terminology is a bit different.

Data Set Example 1

Tidy?

year	**le**	**le_male**	**le_female**	**le_w**	**le_wmale**	**le_wfemale**	**le_b**	**le_bmale**	**le_bfemale**
1900	47.3	46.3	48.3	47.6	46.6	48.7	33.0	32.5	33.5
1901	49.1	47.6	50.6	49.4	48.0	51.0	33.7	32.2	35.3
1902	51.5	49.8	53.4	51.9	50.2	53.8	34.6	32.9	36.4
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
1994	75.7	72.4	79.0	76.5	73.3	79.6	69.5	64.9	73.9
1995	75.8	72.5	78.9	76.5	73.4	79.6	69.6	65.2	73.9
1996	76.1	73.1	79.1	76.8	73.9	79.7	70.2	66.1	74.2
1997	76.5	73.6	79.4	77.2	74.3	79.9	71.1	67.2	74.7
1998	76.7	73.8	79.5	77.3	74.5	80.0	71.3	67.6	74.8
1999	76.7	73.9	79.4	77.3	74.6	79.9	71.4	67.8	74.7

Data Set Example 1

Tidy?

year	le	le_male	le_female	le_w	le_wmale	le_wfemale	le_b	le_bmale	le_bfemale
1900	47.3	46.3	48.3	47.6	46.6	48.7	33.0	32.5	33.5
1901	49.1	47.6	50.6	49.4	48.0	51.0	33.7	32.2	35.3
1902	51.5	49.8	53.4	51.9	50.2	53.8	34.6	32.9	36.4
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
1994	75.7	72.4	79.0	76.5	73.3	79.6	69.5	64.9	73.9
1995	75.8	72.5	78.9	76.5	73.4	79.6	69.6	65.2	73.9
1996	76.1	73.1	79.1	76.8	73.9	79.7	70.2	66.1	74.2
1997	76.5	73.6	79.4	77.2	74.3	79.9	71.1	67.2	74.7
1998	76.7	73.8	79.5	77.3	74.5	80.0	71.3	67.6	74.8
1999	76.7	73.9	79.4	77.3	74.6	79.9	71.4	67.8	74.7

Column headers contain **values**: male, female, b, w

Data Set Example 2

Tidy?

country	continent	year	lifeExp	pop	gdpPercap
Afghanistan	Asia	1992	41.674	16317921	649.3414
Afghanistan	Asia	1997	41.763	22227415	635.3414
Afghanistan	Asia	2002	42.129	25268405	726.7341
Afghanistan	Asia	2007	43.828	31889923	974.5803
Albania	Europe	1992	71.581	3326498	2497.4379
Albania	Europe	1997	72.950	3428038	3193.0546
Albania	Europe	2002	75.651	3508512	4604.2117
Albania	Europe	2007	76.423	3600523	5937.0295
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Zambia	Africa	1992	46.100	8381163	1210.8846
Zambia	Africa	1997	40.238	9417789	1071.3538
Zambia	Africa	2002	39.193	10595811	1071.6139
Zambia	Africa	2007	42.384	11746035	1271.2116
Zimbabwe	Africa	1992	60.377	10704340	693.4208
Zimbabwe	Africa	1997	46.809	11404948	792.4500
Zimbabwe	Africa	2002	39.989	11926563	672.0386
Zimbabwe	Africa	2007	43.487	12311143	469.7093

Data Set Example 2

Tidy?

country	continent	year	lifeExp	pop	gdpPercap
Afghanistan	Asia	1992	41.674	16317921	649.3414
Afghanistan	Asia	1997	41.763	22227415	635.3414
Afghanistan	Asia	2002	42.129	25268405	726.7341
Afghanistan	Asia	2007	43.828	31889923	974.5803
Albania	Europe	1992	71.581	3326498	2497.4379
Albania	Europe	1997	72.950	3428038	3193.0546
Albania	Europe	2002	75.651	3508512	4604.2117
Albania	Europe	2007	76.423	3600523	5937.0295
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Zambia	Africa	1992	46.100	8381163	1210.8846
Zambia	Africa	1997	40.238	9417789	1071.3538
Zambia	Africa	2002	39.193	10595811	1071.6139
Zambia	Africa	2007	42.384	11746035	1271.2116
Zimbabwe	Africa	1992	60.377	10704340	693.4208
Zimbabwe	Africa	1997	46.809	11404948	792.4500
Zimbabwe	Africa	2002	39.989	11926563	672.0386
Zimbabwe	Africa	2007	43.487	12311143	469.7093

Data about two different types of observations are stored in the same table:

continent is an attribute of country

lifeExp, pop and gdpPercap are attributes of country-year

Storing variable continent in a table where unit of observation is country-year is redundant and therefore wastes space and is prone to error.

Data Set Example 3

Tidy?

country	**pop2012**	**imr**	**tfr**	**le**	**leM**	**leF**	**region**	**area**
Algeria	37.4	24	2.9	73	72	75	Northern Africa	Africa
Egypt	82.3	24	2.9	72	70	74	Northern Africa	Africa
Libya	6.5	14	2.6	75	72	77	Northern Africa	Africa
Morocco	32.6	30	2.3	72	70	74	Northern Africa	Africa
Sth Sudan	9.4	101	5.4	52	50	53	Northern Africa	Africa
Sudan	33.5	67	4.2	60	58	62	Northern Africa	Africa
Tunisia	10.8	20	2.1	75	73	77	Northern Africa	Africa
Benin	9.4	81	5.4	56	54	58	Western Africa	Africa
Gambia	1.8	70	4.9	58	57	59	Western Africa	Africa
Ghana	25.5	47	4.2	64	63	65	Western Africa	Africa
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
Serbia	7.1	7	1.3	74	71	77	Southern Europe	Europe
Slovenia	2.1	3	1.5	80	76	83	Southern Europe	Europe
Spain	46.2	3	1.4	82	79	85	Southern Europe	Europe
Australia	22.0	4	1.9	82	80	84	Oceania	Oceania
ew Zeal.	4.4	5	2.1	81	79	83	Oceania	Oceania

Data Set Example 3

Tidy?

country	pop2012	imr	tfr	le	leM	leF	region	area
Algeria	37.4	24	2.9	73	72	75	Northern Africa	Africa
Egypt	82.3	24	2.9	72	70	74	Northern Africa	Africa
Libya	6.5	14	2.6	75	72	77	Northern Africa	Africa
Morocco	32.6	30	2.3	72	70	74	Northern Africa	Africa
Sth Sudan	9.4	101	5.4	52	50	53	Northern Africa	Africa
Sudan	33.5	67	4.2	60	58	62	Northern Africa	Africa
Tunisia	10.8	20	2.1	75	73	77	Northern Africa	Africa
Benin	9.4	81	5.4	56	54	58	Western Africa	Africa
Gambia	1.8	70	4.9	58	57	59	Western Africa	Africa
Ghana	25.5	47	4.2	64	63	65	Western Africa	Africa
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
Serbia	7.1	7	1.3	74	71	77	Southern Europe	Europe
Slovenia	2.1	3	1.5	80	76	83	Southern Europe	Europe
Spain	46.2	3	1.4	82	79	85	Southern Europe	Europe
Australia	22.0	4	1.9	82	80	84	Oceania	Oceania
New Zeal.	4.4	5	2.1	81	79	83	Oceania	Oceania

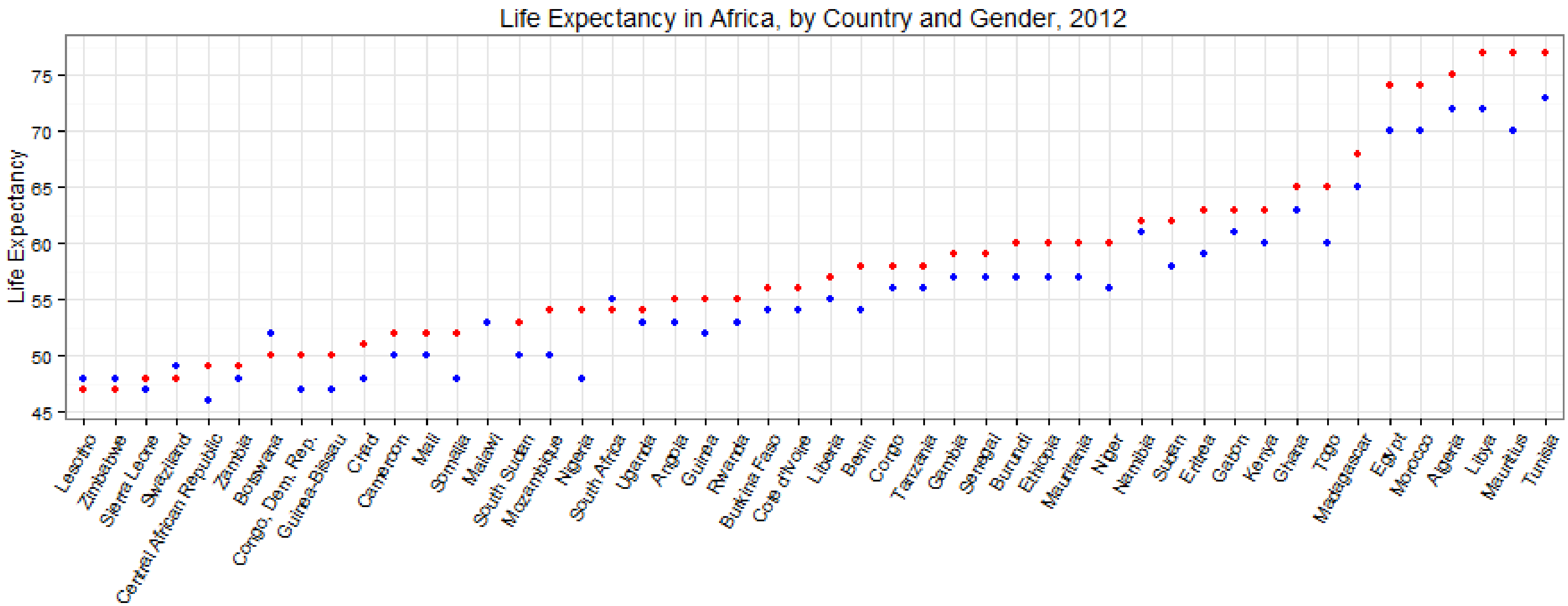
Column header contains **value**: 2012 ... simple remedy

Column header contains **values**: M, F ... use 2nd table with unit of observation country-year-sex

Data Set Example 3

Using ggplot2 to display gender-specific life-expectancy

```
p <- ggplot(data=subset(w,area=="Africa"),
     aes(x=reorder(factor(country),leF),y=leF))
p + geom_point(color="red") +
    geom_point(aes(y=leM), color="blue")
```

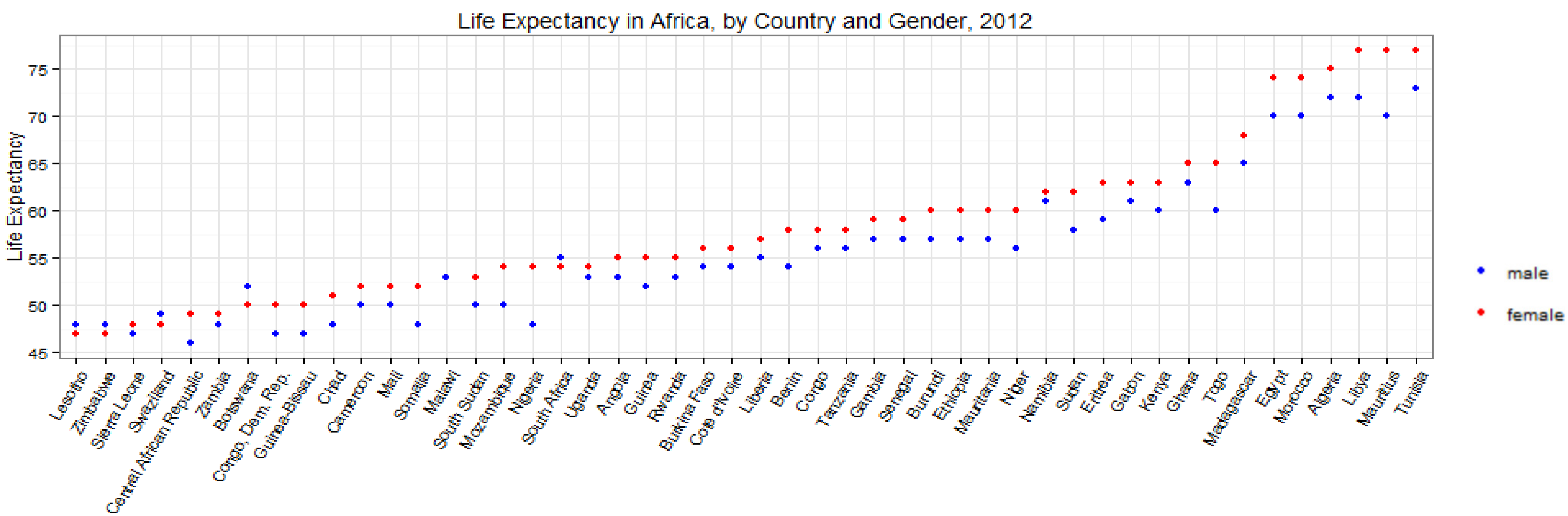


Data Set Example 3

country	year	sex	le
Algeria	2012	male	72
Algeria	2012	female	75
.	.	.	.
.	.	.	.
Zambia	2012	male	48
Zambia	2012	female	49
Zimbabwe	2012	male	48
Zimbabwe	2012	female	47

Using ggplot2 to display gender-specific life-expectancy

```
p <- ggplot(data=subset(w,area=="Africa"),
     aes(x=reorder(factor(country),le), y=le,
     color=sex))
p + geom_point()
```



Data Set Example 4

Tidy?

country	measure	value
Algeria	imr	24
Algeria	tfr	2.9
Algeria	le	73
Egypt	imr	24
Egypt	tfr	2.9
Egypt	le	72
Libya	imr	14
Libya	tfr	2.6
Libya	le	75
Morocco	imr	30
Morocco	tfr	2.3
Morocco	le	72
South Sudan	imr	101
South Sudan	tfr	5.4
South Sudan	le	52
.	.	.
.	.	.
.	.	.

Data Set Example 4

Tidy?

country	measure	value
Algeria	imr	24
Algeria	tfr	2.9
Algeria	le	73
Egypt	imr	24
Egypt	tfr	2.9
Egypt	le	72
Libya	imr	14
Libya	tfr	2.6
Libya	le	75
Morocco	imr	30
Morocco	tfr	2.3
Morocco	le	72
South Sudan	imr	101
South Sudan	tfr	5.4
South Sudan	le	52
.	.	.
.	.	.
.	.	.

Each variable is not saved in its own column.

Data Set Example 5

Tidy?

country	**imr**	**tfr**	**le**	**region**
Algeria	24	2.9	73	Northern Africa
Egypt	24	2.9	72	Northern Africa
Benin	81	5.4	56	Western Africa
Burkina Faso	65	6.0	55	Western Africa
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Albania	18	1.4	75	Southern Europe
Bosnia-Herz.	5	1.2	76	Southern Europe
Croatia	4	1.5	77	Southern Europe
Greece	4	1.5	80	Southern Europe
Italy	3	1.4	82	Southern Europe

Data Set Example 5

Tidy?

country	imr	tfr	le	region
Algeria	24	2.9	73	Northern Africa
Egypt	24	2.9	72	Northern Africa
Benin	81	5.4	56	Western Africa
Burkina Faso	65	6.0	55	Western Africa
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Albania	18	1.4	75	Southern Europe
Bosnia-Herz.	5	1.2	76	Southern Europe
Croatia	4	1.5	77	Southern Europe
Greece	4	1.5	80	Southern Europe
Italy	3	1.4	82	Southern Europe

Are **multiple** variables stored in **one column**?

Should there be a region column (Northern, Western, Southern, ...) and a separate continent column (Africa, Europe, ...)?

Data Set Example 6

Tidy?

country	continent	lifeExp	pop	gdpPercap
Afghanistan	Asia	41.674	16317921	649.3414
Albania	Europe	71.581	3326498	2497.4379
Algeria	Africa	67.744	26298373	5023.2166
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Yemen, Rep.	Asia	55.599	13367997	1879.4967
Zambia	Africa	46.100	8381163	1210.8846
Zimbabwe	Africa	60.377	10704340	693.4208

file: world_data_1992.csv

country	continent	lifeExp	pop	gdpPercap
Afghanistan	Asia	42.129	25268405	726.7341
Albania	Europe	75.651	3508512	4604.2117
Algeria	Africa	70.994	31287142	5288.0404
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Yemen, Rep.	Asia	60.308	18701257	2234.8208
Zambia	Africa	39.193	10595811	1071.6139
Zimbabwe	Africa	39.989	11926563	672.0386

file: world_data_2002.csv

Data Set Example 6

Tidy?

country	continent	lifeExp	pop	gdpPercap
Afghanistan	Asia	41.674	16317921	649.3414
Albania	Europe	71.581	3326498	2497.4379
Algeria	Africa	67.744	26298373	5023.2166
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Yemen, Rep.	Asia	55.599	13367997	1879.4967
Zambia	Africa	46.100	8381163	1210.8846
Zimbabwe	Africa	60.377	10704340	693.4208

file: world_data_1992.csv

country	continent	lifeExp	pop	gdpPercap
Afghanistan	Asia	42.129	25268405	726.7341
Albania	Europe	75.651	3508512	4604.2117
Algeria	Africa	70.994	31287142	5288.0404
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
Yemen, Rep.	Asia	60.308	18701257	2234.8208
Zambia	Africa	39.193	10595811	1071.6139
Zimbabwe	Africa	39.989	11926563	672.0386

file: world_data_2002.csv

The same observational unit (country-year) is stored in multiple files ...
and within the data set ... there is a hidden variable value stored in files names.

Tidy Data Summary

Tidy data sets

- Each variable is stored in its own column.

  and

- Column headers do not contain values.

  and

- Each observation is stored in its own row.

  and

- Each "type" of observation is stored in a single table.

Messy data sets

- Multiple variables are stored in one column.
- Column headers contain values.
- Variables are stored in both rows and columns
- Multiple types of observational units are stored in the same table
- Single observational unit is stored in multiple tables

Install and Load Packages, Read Data

```
install.packages("tidyr")
install.packages("dplyr")
install.packages("ggplot2")
install.packages("gapminder")

library("tidyr")
library("dplyr")
library("ggplot2")
library("gapminder")

usle <- read.csv(file="uslifeexp.csv", head=TRUE, sep=",")
usle
```

	year	le	le_male	le_female	le_w	le_wmale	le_wfemale	le_b	le_bmale	le_bfemale
1	1900	47.3	46.3	48.3	47.6	46.6	48.7	33.0	32.5	33.5
2	1901	49.1	47.6	50.6	49.4	48.0	51.0	33.7	32.2	35.3
3	1902	51.5	49.8	53.4	51.9	50.2	53.8	34.6	32.9	36.4
4	1903	50.5	49.1	52.0	50.9	49.5	52.5	33.1	31.7	34.6
.	.	.	.	.	.	.	.	.	.	.
97	1996	76.1	73.1	79.1	76.8	73.9	79.7	70.2	66.1	74.2
98	1997	76.5	73.6	79.4	77.2	74.3	79.9	71.1	67.2	74.7
99	1998	76.7	73.8	79.5	77.3	74.5	80.0	71.3	67.6	74.8
100	1999	76.7	73.9	79.4	77.3	74.6	79.9	71.4	67.8	74.7

Source: National Vital Statistics Report, Vol. 50, No. 6, 21mar2000

Reshape Data

gather(usle, key="sex", value="lifeexp", le_male, le_female)

	year	le	le_w	le_wmale	le_wfemale	le_b	le_bmale	le_bfemale	sex	lifeexp
1	1900	47.3	47.6	46.6	48.7	33.0	32.5	33.5	le_male	46.3
2	1901	49.1	49.4	48.0	51.0	33.7	32.2	35.3	le_male	47.6
3	1902	51.5	51.9	50.2	53.8	34.6	32.9	36.4	le_male	49.8
4	1903	50.5	50.9	49.5	52.5	33.1	31.7	34.6	le_male	49.1
.	.	.	.	.	.	.	.	.	.	.
197	1996	76.1	76.8	73.9	79.7	70.2	66.1	74.2	le_female	79.1
198	1997	76.5	77.2	74.3	79.9	71.1	67.2	74.7	le_female	79.4
199	1998	76.7	77.3	74.5	80.0	71.3	67.6	74.8	le_female	79.5
200	1999	76.7	77.3	74.6	79.9	71.4	67.8	74.7	le_female	79.4

"pipe operator" ... think of "then"

select(usle, year, le_male, le_female) %>%
gather(key="sex", value="lifeexp", le_male, le_female) %>% arrange(year)

	year	sex	lifeexp
1	1900	le_male	46.3
2	1900	le_female	48.3
3	1901	le_male	47.6
4	1901	le_female	50.6
.	.	.	.
197	1998	le_male	73.8
198	1998	le_female	79.5
199	1999	le_male	73.9
200	1999	le_female	79.4

Rename and Reshape Data

```
select(usle, year, le_male, le_female) %>%
  rename(male = le_male, female = le_female) %>%
  gather(key="sex", value="lifeexp", male, female) %>%
  arrange(year)
```

```
    year    sex lifeexp
1   1900   male    46.3
2   1900 female    48.3
3   1901   male    47.6
4   1901 female    50.6
.      .      .       .
.      .      .       .
.      .      .       .
197 1998   male    73.8
198 1998 female    79.5
199 1999   male    73.9
200 1999 female    79.4
```

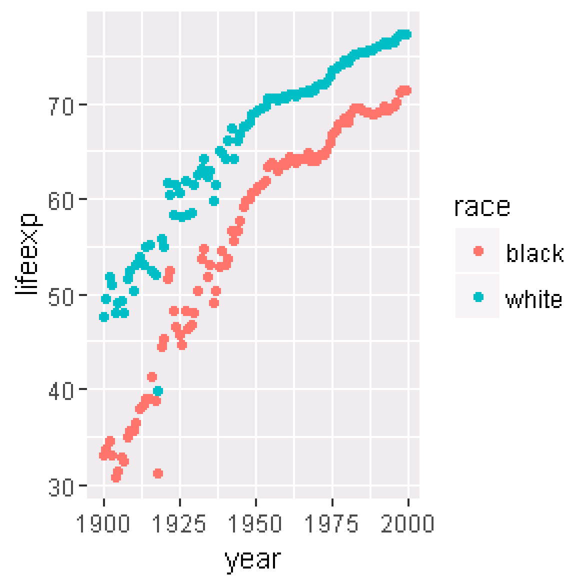
Exercises

```
# EXERCISE:
# Display tidy data that shows
# life expectancy by race (black, white)
```

```
# EXTRA CREDIT EXERCISE:
# Using your tidy data along with additional "piping" ...
# display a ggplot2 graph that shows life expectancy by race (black, white)
```

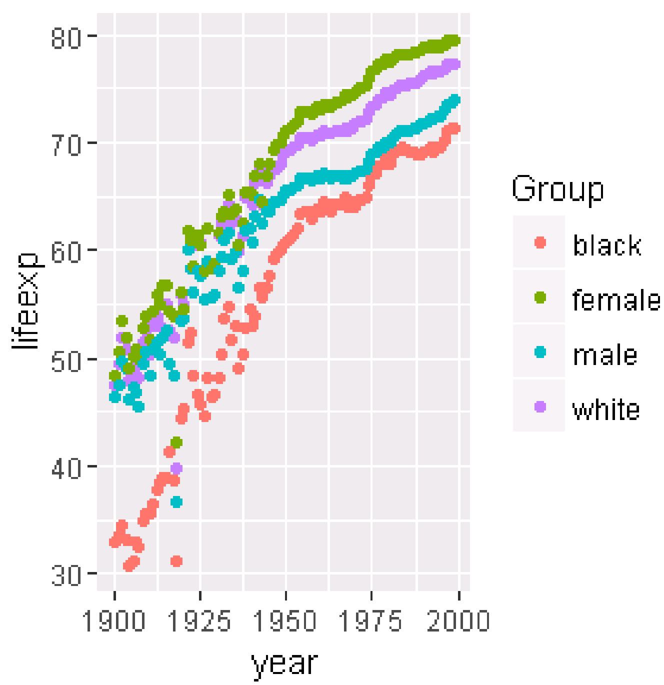
Exercise Solutions

```
# EXERCISE:
# Display tidy data that shows
# life expectancy by race (black, white)
select(usle, year, le_b, le_w) %>%
  rename(black = le_b, white = le_w) %>%
  gather(key="race", value="lifeexp", black, white) %>%
  arrange(year)

# EXTRA CREDIT EXERCISE:
# Using your tidy data along with additional "piping" ...
# display a ggplot2 graph that shows life expectancy by race (black, white)
select(usle, year, le_b, le_w) %>%
  rename(black = le_b, white = le_w) %>%
  gather(key="race", value="lifeexp", black, white) %>%
  arrange(year) %>%
  ggplot(aes(year, lifeexp, color= race)) + geom_point()
```



Reshape Data

```
# show life expectancy for black, white, male, female on same graph
mfle <- select(usle, year, le_male, le_female) %>%
  rename(male = le_male, female = le_female) %>%
  gather(key="sex", value="lifeexp", male, female) %>%
  arrange(year)

select(usle, year, le_b, le_w) %>%
  rename(black = le_b, white = le_w) %>%
  gather(key="race", value="lifeexp", black, white) %>%
  arrange(year) %>%
  ggplot(aes(year, lifeexp, color= race)) +
  geom_point() +
  geom_point(data = mfle, aes(color = sex )) +
  scale_color_discrete(name="Group")
```



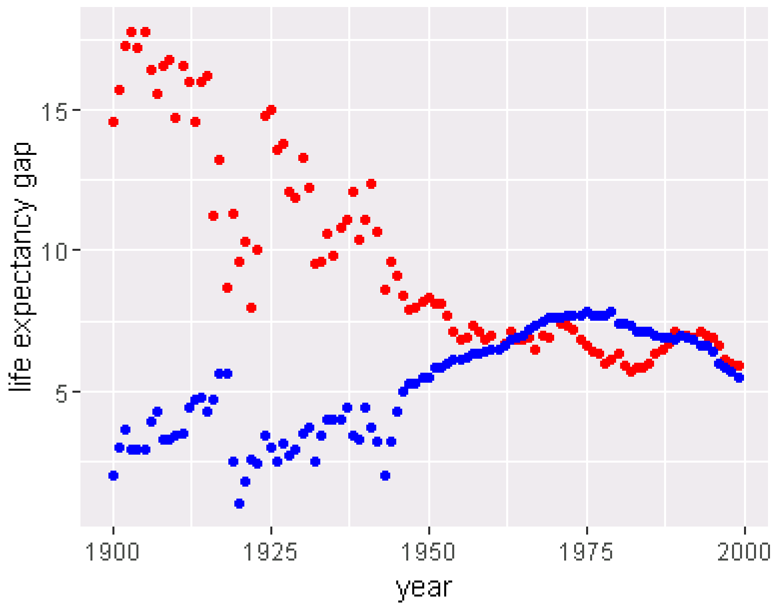
Add New Columns

use mutate to store life expectancy gap between male and female,
and between black and white

```
mutate(usle, race_le_gap = le_w - le_b, sex_le_gap = le_female - le_male) %>%
  select(year, race_le_gap, sex_le_gap)
```

is above data tidy?

```
mutate(usle, race_le_gap = le_w - le_b, sex_le_gap = le_female - le_male) %>%
  select(year, race_le_gap, sex_le_gap) %>%
  ggplot(aes(year, race_le_gap)) +
  geom_point(color="red") +
  geom_point(aes(y=sex_le_gap), color="blue")  +
  ylab("life expectancy gap")
```



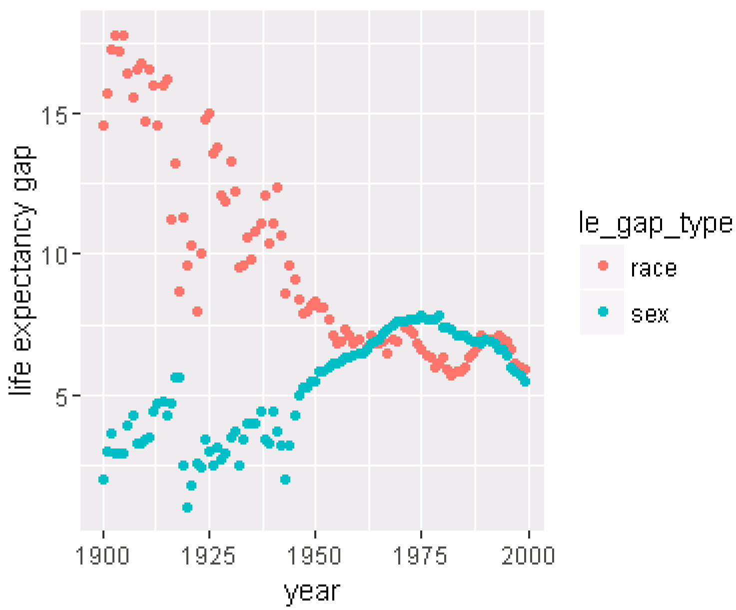
Reshape Data

how to tidy this data?

```
mutate(usle, race = le_w - le_b, sex = le_female - le_male) %>%
  select(year, race, sex) %>%
  gather(key="le_gap_type", value="le_gap_years", race, sex)
```

and then use tidy data to draw graph?

```
mutate(usle, race = le_w - le_b, sex = le_female - le_male) %>%
  select(year, race, sex) %>%
  gather(key="le_gap_type", value="le_gap_years", race, sex) %>%
  ggplot(aes(year, le_gap_years, color = le_gap_type)) +
  geom_point()+
  ylab("life expectancy gap")
```

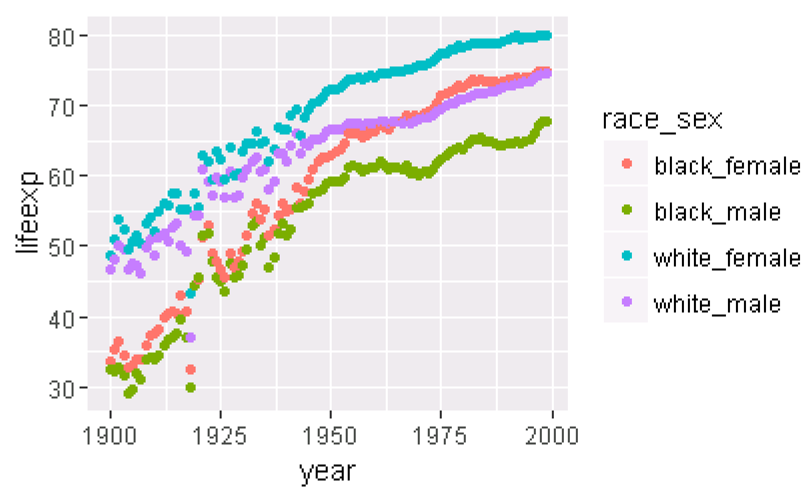


Reshape Data

Display tidy data where unit of observation is year-race-sex

```
select(usle, year, le_wmale, le_wfemale, le_bmale, le_bfemale) %>%
rename(white_male = le_wmale, white_female = le_wfemale, black_male = le_bmale,
        black_female = le_bfemale) %>%
gather(key="race_sex", value="lifeexp", white_male, white_female, black_male, black_female)
%>%  arrange(year, race_sex)
```

```
select(usle, year, le_wmale, le_wfemale, le_bmale, le_bfemale) %>%
rename(white_male = le_wmale, white_female = le_wfemale, black_male = le_bmale,
        black_female = le_bfemale) %>%
gather(key="race_sex", value="lifeexp", white_male, white_female, black_male, black_female)
%>%  arrange(year, race_sex) %>%
ggplot(aes(year, lifeexp, color = race_sex)) +
geom_point()
```



Store Each Variable in its Own Column

Reminder - tidy data: each variable is saved in ITS OWN column

```
select(usle, year, le_wmale, le_wfemale, le_bmale, le_bfemale) %>%
rename(white_male = le_wmale, white_female = le_wfemale, black_male = le_bmale,
        black_female = le_bfemale) %>%
gather(key="racesex", value="lifeexp", white_male, white_female, black_male, black_female)
%>%  arrange(year, racesex) %>%
separate(racesex, c("race", "sex"), sep = "_")
```

```
    year  race    sex lifeexp
 1   1900 black female    33.5
 2   1900 black   male    32.5
 3   1900 white female    48.7
 4   1900 white   male    46.6
 .     .    .       .       .
 .     .    .       .       .
 397 1999 black female    74.7
 398 1999 black   male    67.8
 399 1999 white female    79.9
 400 1999 white   male    74.6
```

Combine Multiple Columns

tidyr function that goes in reverse direction: unite

```
tidy_le <- select(usle, year, le_wmale, le_wfemale, le_bmale, le_bfemale) %>%
rename(white_male = le_wmale, white_female = le_wfemale, black_male = le_bmale,
        black_female = le_bfemale) %>%
gather(key="racesex", value="lifeexp", white_male, white_female, black_male, black_female)
%>% arrange(year, racesex) %>%
separate(racesex, c("race", "sex"), sep = "_")

unite(tidy_le, "racesex", c(race, sex), sep = "_")
```

```
    year      racesex lifeexp
1   1900 black_female    33.5
2   1900   black_male    32.5
3   1900 white_female    48.7
4   1900   white_male    46.6
.     .          .          .
.     .          .          .
397 1999 black_female    74.7
398 1999   black_male    67.8
399 1999 white_female    79.9
400 1999   white_male    74.6
```

Reverse of gather(): spread()

tidyr function that goes in reverse direction: spread (rows -> columns; "long" to "wide")

```
unite(tidy_le, "racesex", c(race, sex), sep = "_") %>%
  spread(key="racesex", value="lifeexp")
```

	year	black_female	black_male	white_female	white_male
1	1900	33.5	32.5	48.7	46.6
2	1901	35.3	32.2	51.0	48.0
3	1902	36.4	32.9	53.8	50.2
4	1903	34.6	31.7	52.5	49.5
.	.	.	.	.	.
.	.	.	.	.	.
97	1996	74.2	66.1	79.7	73.9
98	1997	74.7	67.2	79.9	74.3
99	1998	74.8	67.6	80.0	74.5
100	1999	74.7	67.8	79.9	74.6

```
unite(tidy_le, "race_sex", c(race, sex), sep = "_") %>%
spread(key="race_sex", value="lifeexp") %>%
rename(le_bfemale = black_female, le_bmale = black_male, le_wfemale = white_female,
        le_wmale = white_male)
```

Exercise

EXERCISE:
list data in tidy format with group as one variable
(taking values:
all, male, female, black, white, white_male, white_female, black_male, black_female),
and life_expectancy as the other variable.

```
    year        group life_expectancy
1   1900          all            47.3
2   1900        black            33.0
3   1900 black_female            33.5
4   1900   black_male            32.5
5   1900       female            48.3
6   1900         male            46.3
7   1900        white            47.6
8   1900 white_female            48.7
9   1900   white_male            46.6
10  1901          all            49.1
11  1901        black            33.7
12  1901 black_female            35.3
13  1901   black_male            32.2
14  1901       female            50.6
15  1901         male            47.6
16  1901        white            49.4
17  1901 white_female            51.0
18  1901   white_male            48.0
 .    ..          .                .
```

Exercise Solution

```
# EXERCISE:
# list data in tidy format with group as one variable
# (taking values:
# all, male, female, black, white, white_male, white_female, black_male, black_female),
# and life_expectancy as the other variable.

rename(usle, all=le, male=le_male, female=le_female, black=le_b, white=le_w,
              white_male=le_wmale, white_female=le_wfemale, black_male=le_bmale,
              black_female=le_bfemale) %>%
gather(key = "group", value = "life_expectancy", 2:10) %>%
arrange(year, group)
```

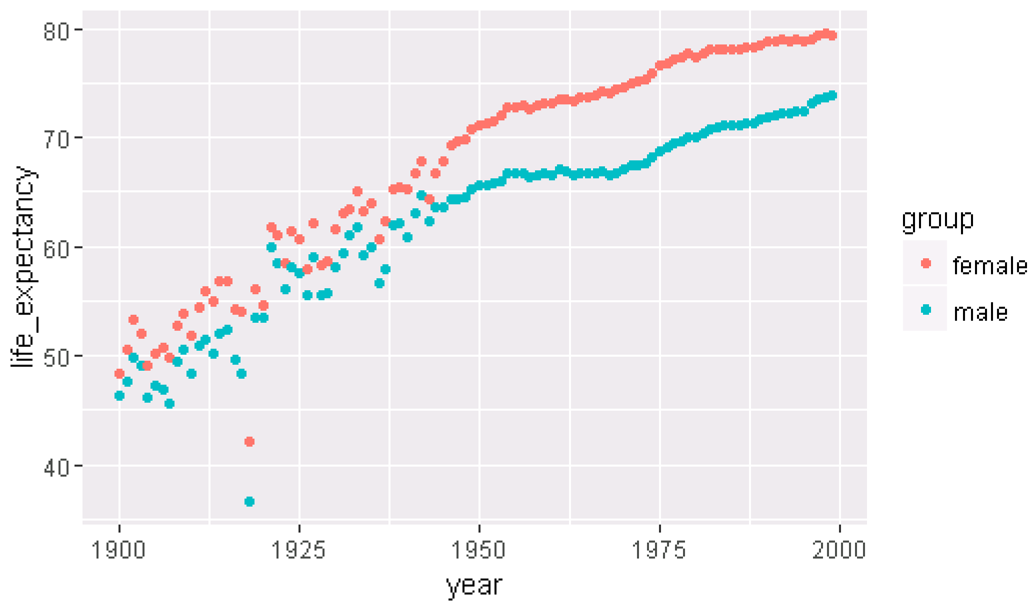
Filter Rows

```
# preview a bit more dplyr
rename(usle, all=le, male=le_male, female=le_female, black=le_b, white=le_w,
                   white_male=le_wmale, white_female=le_wfemale, black_male=le_bmale,
                  black_female=le_bfemale) %>%
 gather(key = "group", value = "life_expectancy", 2:10) %>%
 arrange(year, group) %>%
 filter(group == "black" | group == "white")
```

```
    year group life_expectancy
1   1900 black            33.0
2   1900 white            47.6
3   1901 black            33.7
4   1901 white            49.4
5   1902 black            34.6
6   1902 white            51.9
7   1903 black            33.1
8   1903 white            50.9
9   1904 black            30.8
10  1904 white            48.0
.     .                    .
.     .                    .
.     .                    .
```

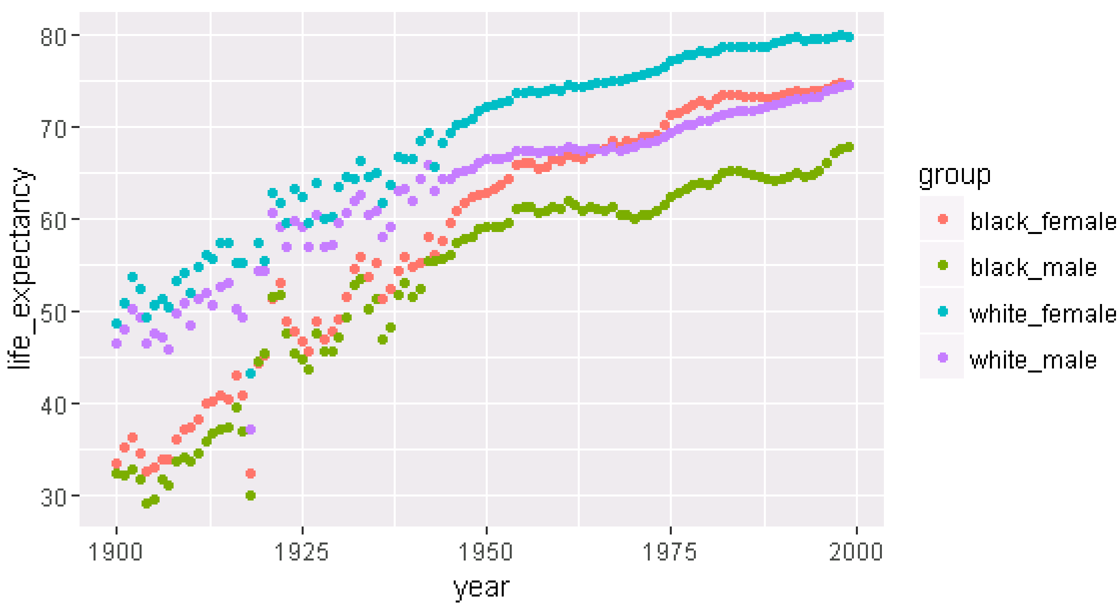
Tidy Data, Filter Rows, then Graph

```
rename(usle, all=le, male=le_male, female=le_female, black=le_b, white=le_w,
                        white_male=le_wmale, white_female=le_wfemale,
                        black_male=le_bmale,  black_female=le_bfemale) %>%
gather(key = "group", value = "life_expectancy", 2:10) %>%
arrange(year, group) %>%
filter(group == "male" | group == "female") %>%
ggplot(aes(year, life_expectancy, color = group)) + geom_point()
```



Again … Tidy Data, Filter Rows, then Graph

```
rename(usle, all=le, male=le_male, female=le_female, black=le_b, white=le_w,
                white_male=le_wmale, white_female=le_wfemale,
                black_male=le_bmale, black_female=le_bfemale) %>%
  gather(key = "group", value = "life_expectancy", 2:10) %>%
  arrange(year, group) %>%
  filter(group %in% c("white_male", "white_female", "black_male", "black_female")) %>%
  ggplot(aes(year, life_expectancy, color = group)) + geom_point()
```



Basic dplyr Principles

consistent with tidyr philosophy

input: data frame
output: data frame

first argument to dplyr commands is a data frame

input data frame is never modified in place ...
may want to save results in a new data frame

commands are optimized for
- clairty (clean, clear syntax)
- computaion time (written in C++)

dplyr Commands: Verbs

filter() subset observations (rows)

arrange() order observations (rows)

select() subset variables (columns)

rename() change name of variables (column headers)

mutate() add new variables (columns)

group_by() partition observations into groups based on variable values

summarise() collapse each group into a single row of values

Load gapminder tbl_df

```
# check structure of gapminder data
str(gapminder)

# tbl_df: improved data.frame for which dplyr provides nice methods for high-level inspection
# these methods do something sensible for datasets with many observations and/or variables

gdf <- as.data.frame(gapminder)
str(gdf)

gtdf <- tbl_df(gdf)
str(gtdf)

# high-level inspection of tbl_df
glimpse(gapminder)
Observations: 1,704
Variables: 6
$ country   (fctr) Afghanistan, Afghanistan, Afghanistan, Afghanistan, Afghanistan,...
$ continent (fctr) Asia, Asia, Asia, Asia, Asia, Asia, Asia, Asia, Asia, Asia, Asia...
$ year      (int)  1952, 1957, 1962, 1967, 1972, 1977, 1982, 1987, 1992, 1997, 2002,...
$ lifeExp   (dbl)  28.801, 30.332, 31.997, 34.020, 36.088, 38.438, 39.854, 40.822, 4...
$ pop       (int)  8425333, 9240934, 10267083, 11537966, 13079460, 14880372, 1288181...
$ gdpPercap (dbl)  779.4453, 820.8530, 853.1007, 836.1971, 739.9811, 786.1134, 978.0...

View(gapminder) # note capital V
```

gapminder Data

	country	continent	year	lifeExp	pop	gdpPercap
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
4	Afghanistan	Asia	1967	34.020	11537966	836.1971
5	Afghanistan	Asia	1972	36.088	13079460	739.9811
6	Afghanistan	Asia	1977	38.438	14880372	786.1134
7	Afghanistan	Asia	1982	39.854	12881816	978.0114
8	Afghanistan	Asia	1987	40.822	13867957	852.3959
9	Afghanistan	Asia	1992	41.674	16317921	649.3414
10	Afghanistan	Asia	1997	41.763	22227415	635.3414
11	Afghanistan	Asia	2002	42.129	25268405	726.7341
12	Afghanistan	Asia	2007	43.828	31889923	974.5803
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
1693	Zimbabwe	Africa	1952	48.451	3080907	406.8841
1694	Zimbabwe	Africa	1957	50.469	3646340	518.7643
1695	Zimbabwe	Africa	1962	52.358	4277736	527.2722
1696	Zimbabwe	Africa	1967	53.995	4995432	569.7951
1697	Zimbabwe	Africa	1972	55.635	5861135	799.3622
1698	Zimbabwe	Africa	1977	57.674	6642107	685.5877
1699	Zimbabwe	Africa	1982	60.363	7636524	788.8550
1700	Zimbabwe	Africa	1987	62.351	9216418	706.1573
1701	Zimbabwe	Africa	1992	60.377	10704340	693.4208
1702	Zimbabwe	Africa	1997	46.809	11404948	792.4500
1703	Zimbabwe	Africa	2002	39.989	11926563	672.0386
1704	Zimbabwe	Africa	2007	43.487	12311143	469.7093

Subset Observations

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

filter(gapminder, lifeExp < 30)

filter(gapminder, pop < 1000000 )

filter(gapminder, pop < 1000000, year == 2007)

filter(gapminder, pop < 1000000 & year == 2007)

filter(gapminder, country == "United States" | country == "Canada", year > 2000)

filter(gapminder, country %in% c("United States", "Canada"),  year > 2000)

distinct(gapminder, country)
View(distinct(gapminder, country))
distinct(gapminder, country) %>% View()

distinct(as.data.frame(gapminder), country)
```

Subset Columns

```
select(gapminder, country, continent)

country_continent <- select(gapminder, country, continent) %>% distinct()
country_continent

select(gapminder, -continent) # "-" means not ... gives TIDIER data set
tgap <- select(gapminder, -continent)

# But how to combine tgap and country_continent when want
# to summarize values by continent???
# Will later use a "join" function to combine

select(gapminder, year, country, continent, lifeExp)  # select and re-order columns

select(gapminder, starts_with("co"))

select(gapminder, country:lifeExp)  # range
```

Exercises

```
# EXERCISE:
# list all countries showing only life expectancy for 2007
```

```
# EXTRA CREDIT EXERCISE:
# list all countries showing only life expectancy for 2007
# with life expectancy variable named le (rather than lifeExp)
```

Exercise Solutions

```
# EXERCISE:
# list all countries showing only life expectancy for 2007

filter(gapminder, year == 2007) %>% select(country, year, lifeExp)

# EXTRA CREDIT EXERCISE:
# list all countries showing only life expectancy for 2007
# with life expectancy variable named le (rather than lifeExp)

filter(gapminder, year == 2007) %>%
select(country, year, lifeExp) %>%
rename(le = lifeExp)
```

Order Rows

```
arrange(gapminder, year)

rename(gapminder, le = lifeExp) %>% filter(year == 2007) %>%
  select(country, year, le) %>% arrange(le)

rename(gapminder, le = lifeExp) %>% filter(year == 2007) %>%
  select(country, year, le) %>% arrange(desc(le))  # order by descending le

# to list all rows, can use gapminder as a data frame
rename(as.data.frame(gapminder), le = lifeExp) %>%
  filter(year == 2007) %>%
  select(country, year, le) %>% arrange(desc(le))

# list 5 countries with highest life expectancy in 2007
# show country, year, and le
rename(gapminder, le = lifeExp) %>%
  filter(year == 2007) %>%
  top_n(5, le) %>%  # filter rows again
  select(country, year, le) %>%
  arrange(desc(le))  # sort top 5
```

Exercise

EXERCISE:

list 10 lowest life expectancies, with lowest at the top

HINT: use a second filter command

Exercise Solution

```
# EXERCISE:
# list 10 lowest life expectancies, with lowest at the top
# HINT: use a second filter command

rename(gapminder, le=lifeExp) %>%
  filter(year == 2007) %>%
  select(country, year, le) %>%
  arrange(le) %>% # low to high
  slice(1:10) # filter rows a second time, by position
```

Construct New Columns

mutate(gapminder, popMil = round(pop / 1000000, 1), le = round(lifeExp, 1))

```
Source: local data frame [1,704 x 8]

       country continent  year lifeExp      pop gdpPercap popMil    le
        (fctr)    (fctr) (int)   (dbl)    (int)     (dbl)  (dbl) (dbl)
1  Afghanistan      Asia  1952  28.801  8425333  779.4453    8.4  28.8
2  Afghanistan      Asia  1957  30.332  9240934  820.8530    9.2  30.3
3  Afghanistan      Asia  1962  31.997 10267083  853.1007   10.3  32.0
4  Afghanistan      Asia  1967  34.020 11537966  836.1971   11.5  34.0
..         ...       ...   ...     ...      ...       ...    ...   ...
```

transmute(gapminder, country = country, y = year,
popMil = round(pop / 1000000, 1), le = round(lifeExp, 1)) %>%
arrange(y, country)

```
Source: local data frame [1,704 x 4]

       country     y popMil    le
        (fctr) (int)  (dbl) (dbl)
1  Afghanistan  1952    8.4  28.8
2      Albania  1952    1.3  55.2
3      Algeria  1952    9.3  43.1
4       Angola  1952    4.2  30.0
```

Window Functions

```
# window functions take a vector of n values and return n values
# types of window functions:
#   - ranking and ordering functions
#   - cumulative aggregates
#   - access to previous and next values

filter(gapminder, year == 2007) %>%
  mutate(le_rank = dense_rank(lifeExp)) %>%
  select(country, continent, year, lifeExp, le_rank) %>%
  arrange(le_rank)

# how to assign lowest rank to highest life expectancy?
filter(gapminder, year == 2007) %>%
  mutate(le_rank = dense_rank(-lifeExp)) %>%
  select(country, continent, year, lifeExp, le_rank) %>%
  arrange(le_rank)
```

Window Functions: Cumulative Sum

```
filter(as.data.frame(gapminder), year == 1952) %>%
  arrange(continent, country) %>%
  mutate(popMil = round(pop / 1000000, 1)) %>%
  mutate(cumpopMil = cumsum(popMil))
```

	country	continent	year	lifeExp	pop	gdpPercap	popMil	cumpopMil
1	Algeria	Africa	1952	43.077	9279525	2449.0082	9.3	9.3
2	Angola	Africa	1952	30.015	4232095	3520.6103	4.2	13.5
3	Benin	Africa	1952	38.223	1738315	1062.7522	1.7	15.2
4	Botswana	Africa	1952	47.622	442308	851.2411	0.4	15.6
.	...	...	...	...	...	...	...	...
142	New Zealand	Oceania	1952	69.390	1994794	10556.5757	2.0	2406.6

```
filter(as.data.frame(gapminder), year == 2007) %>%
  arrange(continent, country) %>%
  mutate(popMil = round(pop / 1000000, 1)) %>%
  mutate(cumpopMil = cumsum(popMil))
```

	country	continent	year	lifeExp	pop	gdpPercap	popMil	cumpopMil
1	Algeria	Africa	2007	72.301	33333216	6223.3675	33.3	33.3
2	Angola	Africa	2007	42.731	12420476	4797.2313	12.4	45.7
.	...	...	...	...	...	...	...	...
142	New Zealand	Oceania	2007	80.204	4115771	25185.0091	4.1	6251.1

Group Data: Construct New Column Values By Group

```
filter(gapminder, year == 2007) %>%
  mutate(popMil = round(pop / 1000000, 1)) %>%
  arrange(continent, popMil) %>%
  group_by(continent) %>%
  mutate(cumpopMil = cumsum(popMil)) %>% View()
```

	country	continent	year	lifeExp	pop	gdpPercap	popMil	cumpopMil
	(fctr)	(fctr)	(int)	(dbl)	(int)	(dbl)	(dbl)	(dbl)
1	Sao Tome and Principe	Africa	2007	65.528	199579	1598.4351	0.2	0.2
2	Djibouti	Africa	2007	54.791	496374	2082.4816	0.5	0.7
3	Equatorial Guinea	Africa	2007	51.579	551201	12154.0897	0.6	1.3
4	Comoros	Africa	2007	65.152	710960	986.1479	0.7	2.0
5	Reunion	Africa	2007	76.442	798094	7670.1226	0.8	2.8
6	Swaziland	Africa	2007	39.613	1133066	4513.4806	1.1	3.9
.	...	...	...	...	...	...	...	....
52	**Nigeria**	**Africa**	**2007**	**46.869**	**135031164**	**2013.9773**	**135.0**	**929.6**
53	**Trinidad and Tobago**	**Americas**	**2007**	**69.819**	**1056608**	**18008.5092**	**1.1**	**1.1**
.	…	…	…	…	…	...	...	....

```
select(gapminder, country, year, pop) %>%
  group_by(country) %>%
  mutate(pop_lag = lag(pop), pop_chg = pop - pop_lag,
      pop_pctchg = round(pop_chg/pop_lag * 100, 1)) %>% View()
```

Exercise

list only rows that experienced a population decline during the previous 5 years

show country, year, pop, pop_chg, pop_pctchg

Exercise Solution

```
# list only rows that experienced a population decline during the previous 5 years
# show country, year, pop, pop_chg, pop_pctchg

select(gapminder, country, year, pop) %>%
  group_by(country) %>%
  mutate(pop_lag = lag(pop), pop_chg = pop - pop_lag,
        pop_pctchg = round(pop_chg/pop_lag * 100, 1)) %>%
  filter(pop_chg < 0) %>% View()
```

Summarise Data

```
# use summarise() with a summary function to change the unit of observation
# summary functions take a vector of values and return a single value
# very often used with group_by()

filter(gapminder, year == 2007) %>%
  summarise(year = mean(year), ncountries = n(),
  avg_country_le = mean(lifeExp), sd_country_le = sd(lifeExp))  # not used with group_by()

filter(gapminder, year == 2007) %>%
  group_by(continent) %>%
  summarise(avg_country_le = mean(lifeExp))

filter(gapminder, year == 2007) %>%
  group_by(continent) %>%
  summarise(year = mean(year), ncountries = n(),
  avg_country_le = mean(lifeExp), sd_country_le = sd(lifeExp))

filter(gapminder, year == 1952) %>%
  group_by(continent) %>%
  summarise(year = mean(year), ncountries = n(),
  avg_country_le = mean(lifeExp), sd_country_le = sd(lifeExp))
```

Exercises

EXERCISE 1:

show data by continent and years 1952 AND 2007

list number of countries, avg_country_le, and sd_country_le

EXERCISE 2:

By continent and year, show ncountries, avg_country_le, sd_country_le for ALL years of data

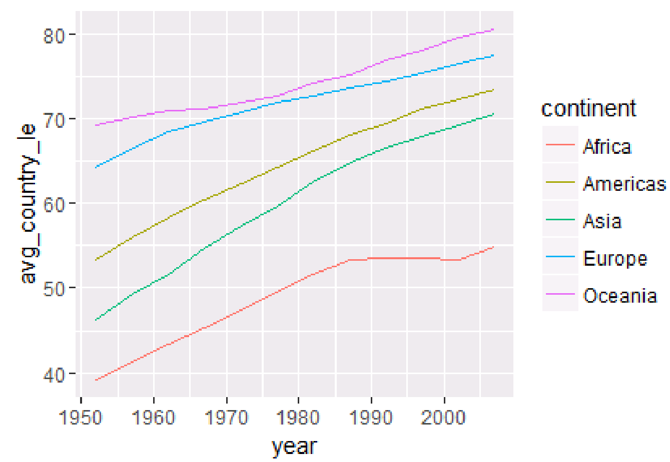
EXTRA CREDIT EXERCISE:

Make a simple graph that shows avg_country_le over time,

for each continent

Exercise Solutions

```
# EXERCISE 1:
# show data by continent and years 1952 AND 2007
# list number of countries, avg_country_le, and sd_country_le
filter(gapminder, year == 1952 | year == 2007) %>%
  group_by(continent, year) %>%
  summarise(ncountries = n(), avg_country_le = mean(lifeExp), sd_country_le = sd(lifeExp))

# EXERCISE 2:
# By continent and year, show ncountries, avg_country_le, sd_country_le for ALL years of data
group_by(gapminder, continent, year) %>%
summarise(ncountries = n(), avg_country_le = mean(lifeExp), sd_country_le = sd(lifeExp)) %>%
View()

# EXTRA CREDIT EXERCISE:
# Make a simple graph that shows avg_country_le over time,
# for each continent
group_by(gapminder, continent, year) %>%
  summarise(avg_country_le = mean(lifeExp)) %>%
 ggplot(aes(x = year, y = avg_country_le, color = continent)) +
 geom_line()
```



summarise() "Peels Off" group_by()

```
# how many continents each country
# has belonged to over time
group_by(gapminder, country) %>%
  summarise(n_continents = n_distinct(continent))
```

	country	n_continents
	(fctr)	(int)
1	Afghanistan	1
2	Albania	1
3	Algeria	1
4	Angola	1
5	Argentina	1
6	Australia	1
7	Austria	1
8	Bahrain	1
9	Bangladesh	1
10	Belgium	1
..	...	...

```
# each summarise() "peels off" one level of group_by()
group_by(gapminder, country) %>%
  summarise(n_continents = n_distinct(continent)) %>%
  summarise(avg_n_continents = mean(n_continents))
```

	avg_n_continents
	(dbl)
1	1

summarise() "Peels Off" group_by()

```
group_by(gapminder, continent, country) %>%
  summarise(avg_le_cc = mean(lifeExp))
```

	continent (fctr)	country (fctr)	avg_le_cc (dbl)
1	Africa	Algeria	59.03017
2	Africa	Angola	37.88350
3	Africa	Benin	48.77992
4	Africa	Botswana	54.59750
5	Africa	Burkina Faso	44.69400
6	Africa	Burundi	44.81733
7	Africa	Cameroon	48.12850
..	...	...	...

```
group_by(gapminder, continent, country) %>%
  summarise(avg_le_cc = mean(lifeExp)) %>%
  summarise(avg_le_c =  mean(avg_le_cc))
```

	continent (fctr)	avg_le_c (dbl)
1	Africa	48.86533
2	Americas	64.65874
3	Asia	60.06490
4	Europe	71.90369
5	Oceania	74.32621

```
group_by(gapminder, continent, country)  %>%
  summarise(avg_le_cc = mean(lifeExp))   %>%
  summarise(avg_le_c  = mean(avg_le_cc)) %>%
  summarise(avg_le    = mean(avg_le_c))
```

	avg_le (dbl)
1	63.96377

More Summary Functions

```
group_by(gapminder, country) %>%
  summarise(year = first(year), le = first(lifeExp))
```

```
    country       year         le
     (fctr)      (int)      (dbl)
1 Afghanistan   1952     28.801
2     Albania   1952     55.230
3     Algeria   1952     43.077
..       ...      ...       ...
```

```
group_by(gapminder, country) %>%
  summarise(year = last(year), le = last(lifeExp))
```

```
group_by(gapminder, country) %>%
  summarise(year = nth(year, 3), le = nth(lifeExp, 3))
```

```
       country  year         le
        (fctr) (int)      (dbl)
1  Afghanistan  1962     31.997
2      Albania  1962     64.820
3      Algeria  1962     48.303
..         ...   ...        ...
```

summarise_each()

Apply one or more functions to one or more columns.
Grouping variables are always excluded from modification.
Variables to include or exclude ...
can be specified in same way as variables are specified for select().
If variable list is not specified, variable list defaults to all non-grouping variables.

```
group_by(gapminder, continent, year) %>%  summarise_each(funs(min, median, max), lifeExp, pop)
```

... and to re-order columns ... can use select:

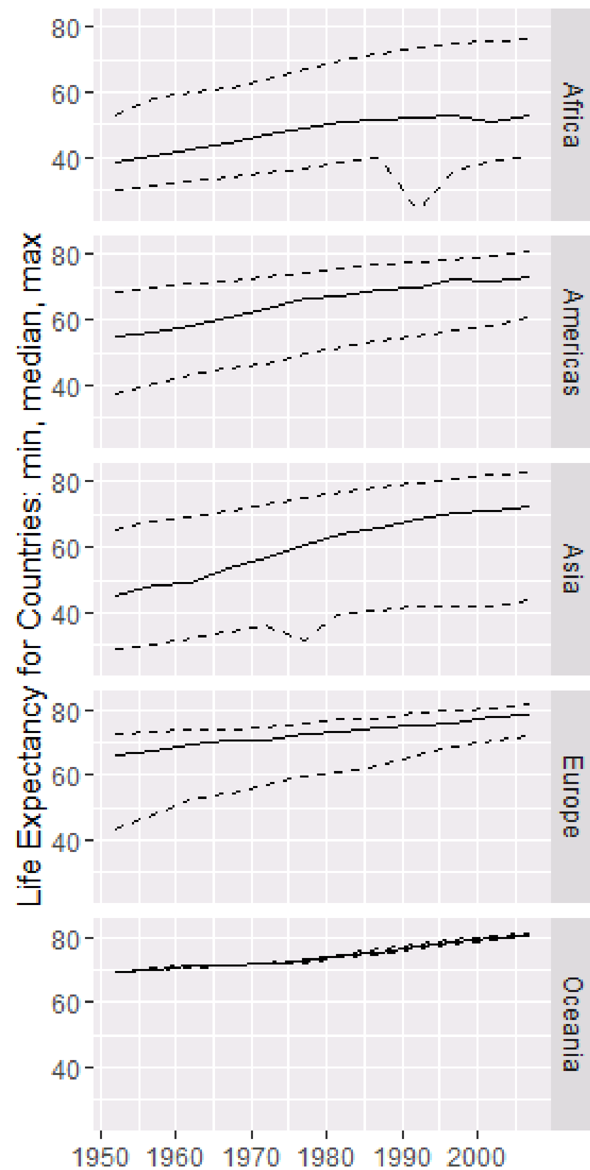
```
group_by(gapminder, continent, year) %>%
summarise_each(funs(min, median, max), lifeExp, pop) %>%
select(continent, year, lifeExp_min, lifeExp_median, lifeExp_max, pop_min, pop_median, pop_max)
```

	continent	year	lifeExp_min	lifeExp_median	lifeExp_max	pop_min	pop_median	pop_max
	(fctr)	(int)	(dbl)	(dbl)	(dbl)	(int)	(dbl)	(int)
1	Africa	1952	30.000	38.8330	52.724	60011	2668125	33119096
2	Africa	1957	31.570	40.5925	58.089	61325	2885791	37173340
3	Africa	1962	32.767	42.6305	60.246	65345	3145210	41871351
4	Africa	1967	34.113	44.6985	61.557	70787	3473693	47287752
.	...	...	...	...	...	...	...	...

Graphing Results of summarise_each() Functions

graph min, median, max country life expectancy, by continent

```
group_by(gapminder, continent, year) %>%
summarise_each(funs(min, median, max), lifeExp, pop) %>%

ggplot(aes(x=year, y = lifeExp_median)) + geom_line() +
geom_line(aes(y = lifeExp_min), linetype = "dashed") +
geom_line(aes(y = lifeExp_max), linetype = "dashed") +
facet_grid(continent ~ .) +
labs(y="Life Expectancy for Countries: min, median, max",
x="")
```



count() function

```
# count() function wraps up the
# common combination of group_by() and summarise()

# How many rows for each value of continent?
count(gapminder, continent)
```

	continent	n
	(fctr)	(int)
1	Africa	624
2	Americas	300
3	Asia	396
4	Europe	360
5	Oceania	24

```
# How many rows for each value of continent and year
count(gapminder, continent, year) %>% View()

filter(gapminder, year == 2002 | year == 2007) %>%
  count(continent)  # How many rows for each continent,
                      for only years 2002 and 2007
```

	continent	n
	(fctr)	(int)
1	Africa	104
2	Americas	50
3	Asia	66
4	Europe	60
5	Oceania	4

```
filter(gapminder, year == 2002 | year == 2007) %>%
  count(continent, wt = year-2000) # wt is a multiplier
# Here, values for 2002 are multiplied by 2;
# and values for 2007 are multiplied by 5
# (example: 4 Oceania rows ... (2 * 2) + (2 * 7)
```

dplyr Commands to Combine/Compare Data Sets

left_join()

right_join()

inner_join()

full_join()

potentially add variables (columns) to data sets, making them wider

bind_rows() adds observations (rows) to data sets, making them longer

semi_join()

anti_join()

potentially remove observations (rows) from data sets, making them shorter

Combining Data Sets: left_join()

```
# saw above that every country has been associated with just one continent during time period
# so ...
# continent belongs in a table where unit of observation is country
# other variables belong in a table where unit of observation is country-year:

country_continent <- select(gapminder, country, continent) %>% distinct()
country_continent
tgap <- select(gapminder, -continent)
tgap

# BUT descriptive exploration has required
# continent be included in data set for grouping
# HOW TO COMBINE ("join" or "merge") tgap and country_continent?

# join matching rows from second data set to first
left_join(tgap, country_continent, by = "country") %>% View()
```

Combining Data Sets: left_join() and right_join()

```
country_continent_inc <- slice(country_continent, 6:142) # cut out rows 1-5
View(country_continent_inc)

tgap_inc <- slice(tgap, 49:144) # cut out rows 1-48 and rows 145-1704
View(tgap_inc)

# join matching rows from 2nd data set to first
left_join(tgap, country_continent_inc, by = "country") %>% View()

# join matching rows from first data set to 2nd
right_join(tgap, country_continent, by = "country") %>% View()

right_join(tgap, country_continent_inc, by = "country") %>% View()
# country_continent_inc is the driver!
```

Combining Data Sets
inner_join(), full_join(), semi_join(), anti_join()

```
# join and retain only rows in both data sets
inner_join(tgap_inc, country_continent_inc, by = "country") %>% View()

# join and retain all values, all rows
full_join(tgap_inc, country_continent_inc, by = "country") %>% View()

# retain all rows in first data set that have a match in second data set
# (but don't add columns)
semi_join(tgap_inc, country_continent_inc, by = "country") %>% View()

# retain all rows in first data set that do not have a match in second data set
# (but don't add columns)
anti_join(tgap_inc, country_continent_inc, by = "country") %>% View()
```

Appending Data Sets

```
# TO APPEND ROWS use bind_rows() ... more efficient than rbind()

tgap1992 <- filter(tgap, year == 1992) %>% select(-year)
tgap1997 <- filter(tgap, year == 1997) %>% select(-year)
tgap2002 <- filter(tgap, year == 2002) %>% select(-year)
tgap2007 <- filter(tgap, year == 2007) %>% select(-year)

tgap1992
tgap2007

bind_rows(tgap1992, tgap1997, tgap2002, tgap2007) %>% View() # ... OOPS .. not quite right!

bind_rows(list(tgap1992, tgap1997, tgap2002, tgap2007), .id="id") %>% View()  # ... a bit better!

bind_rows("1992" = tgap1992, "1997" = tgap1997, "2002" = tgap2002, "2007" = tgap2007,
.id="year") %>% View()
```