Lesson notes | Lines, scales, and labels

Created by the GRAPH Courses team

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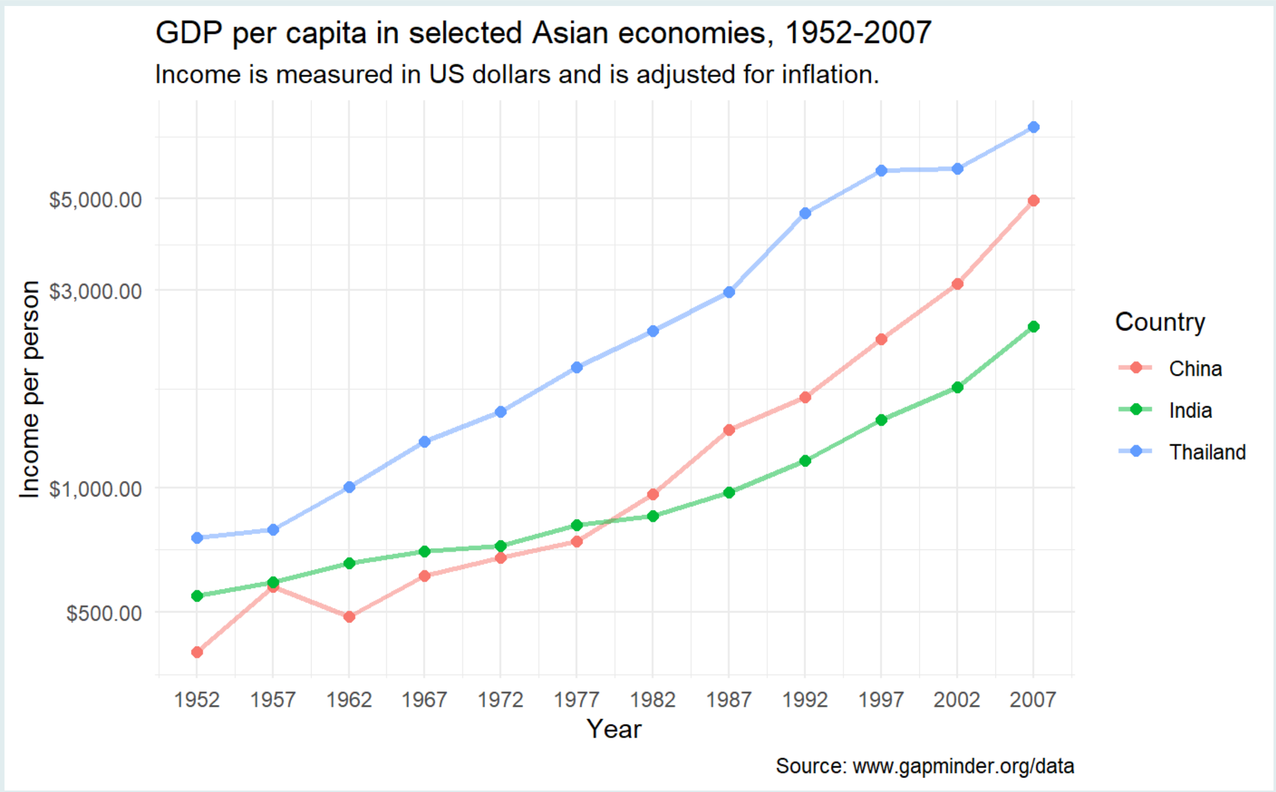
Learning Objectives

1. You can create **line graphs** to visualize relationships between two numerical variables with **`geom_line()`**.
2. You can **add points** to a line graph with `geom_point()`.
3. You can use aesthetics like `color`, **`size`**, **`color`**, and **`linetype`** to modify line graphs.
4. You can **manipulate axis scales** for continuous data with **`scale_*_continuous()`** and scale_*_log10().
5. You can **add labels** to a plot such as a **`title`**, **`subtitle`**, or **`caption`** with the **`labs()`** function.



Introduction

Line graphs are used to show **relationships** between two **numerical variables**, just like scatterplots. They are especially useful when the variable on the x-axis, also called the *explanatory* variable, is of a **sequential** nature. In other words, there is an inherent ordering to the variable.

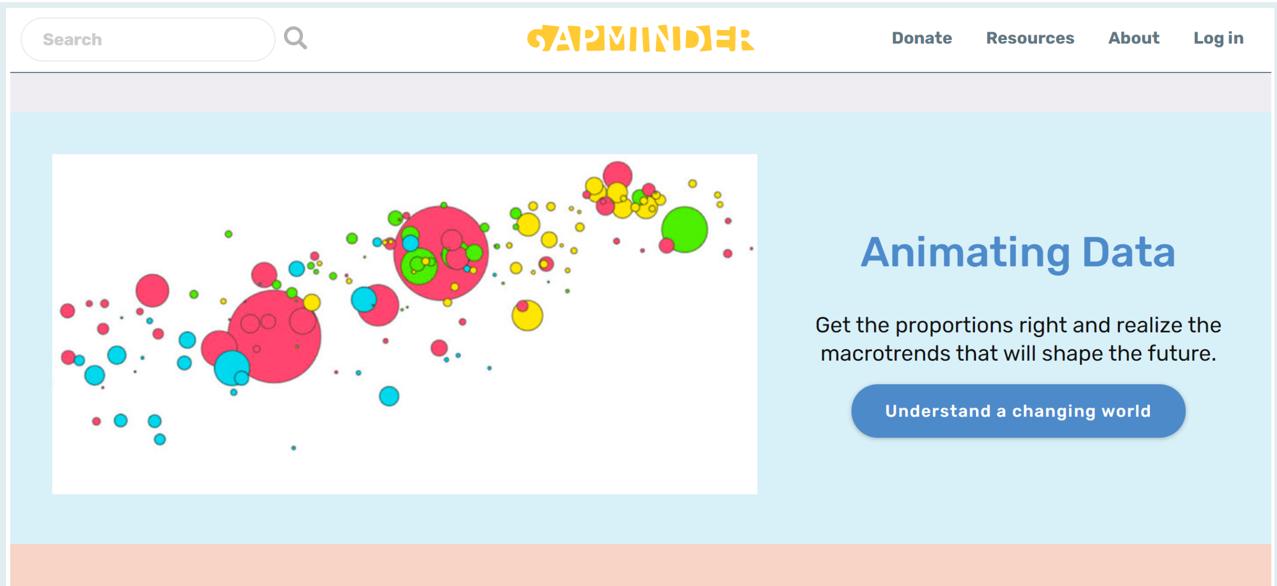
The most common examples of line graphs have some notion of **time on the x-axis**: hours, days, weeks, years, etc. Since time is sequential, we connect consecutive observations of the variable on the y-axis with a line. Line graphs that have some notion of time on the x-axis are also called **time series plots**.

Packages

```r
# Load packages
pacman::p_load(tidyverse,
               gapminder,
               here)
```

The `gapminder` data frame

In February 2006, a Swedish physician and data advocate named Hans Rosling gave a famous TED talk titled "The best stats you've ever seen" where he presented global economic, health, and development data complied by the Gapminder Foundation.



We can access a clean subset of this data with the R package {**gapminder**}, which we just loaded.

```r
# Load gapminder data frame from the gapminder package
data(gapminder, package="gapminder")

# Print dataframe
gapminder
```

Each row in this table corresponds to a country-year combination. For each row, we have 6 columns:

1. **`country`**: Country name

2. **`continent`**: Geographic region of the world

3. **`year`**: Calendar year

4. **`lifeExp`**: Average number of years a newborn child would live if current mortality patterns were to stay the same

5. **`pop`**: Total population

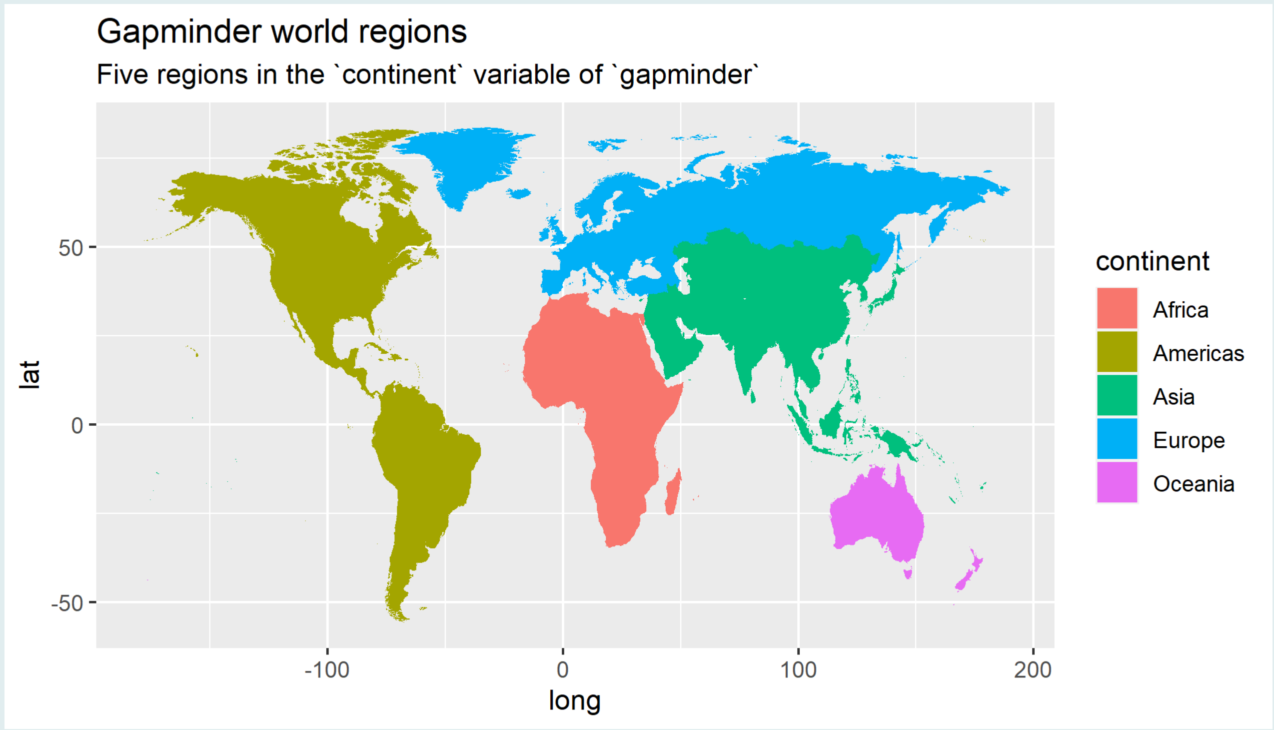
6. **`gdpPercap`**: Gross domestic product per person (inflation-adjusted US dollars)

The `str()` function can tell us more about these variables.

```
# Data structure
str(gapminder)
```

```
## tibble [1,704 × 6] (S3: tbl_df/tbl/data.frame)
##  $ country  : Factor w/ 142 levels "Afghanistan",..: 1 1 1 1 1 1 1 1 1 1
...
##  $ continent: Factor w/ 5 levels "Africa","Americas",..: 3 3 3 3 3 3 3 3 3
3 ...
##  $ year     : int [1:1704] 1952 1957 1962 1967 1972 1977 1982 1987 1992
1997 ...
##  $ lifeExp  : num [1:1704] 28.8 30.3 32 34 36.1 ...
##  $ pop      : int [1:1704] 8425333 9240934 10267083 11537966 13079460
14880372 12881816 13867957 16317921 22227415 ...
##  $ gdpPercap: num [1:1704] 779 821 853 836 740 ...
```

This version of the **`gapminder`** dataset contains information for **142 countries**, divided in to **5 continents**.




```
# Data summary
summary(gapminder)
```

```
##          country        continent        year
##  Afghanistan:  12   Africa  :624   Min.   :1952
##  Albania    :  12   Americas:300   1st Qu.:1966
##  Algeria    :  12   Asia    :396   Median :1980
##  Angola     :  12   Europe  :360   Mean   :1980
##  Argentina  :  12   Oceania : 24   3rd Qu.:1993
##  Australia  :  12                  Max.   :2007
##  (Other)    :1632
##     lifeExp            pop               gdpPercap
##  Min.   :23.60   Min.   :6.001e+04   Min.   :   241.2
##  1st Qu.:48.20   1st Qu.:2.794e+06   1st Qu.:  1202.1
##  Median :60.71   Median :7.024e+06   Median :  3531.8
##  Mean   :59.47   Mean   :2.960e+07   Mean   :  7215.3
##  3rd Qu.:70.85   3rd Qu.:1.959e+07   3rd Qu.:  9325.5
##  Max.   :82.60   Max.   :1.319e+09   Max.   :113523.1
##
```

Data are recorded every 5 years from 1952 to 2007 (a total of 12 years).

Let's say we want to visualize the relationship between time (`year`) and life expectancy (`lifeExp`).

For now let's just focus on one country - United States. First, we need to create a new data frame with only the data from this country.

```r
# Select US cases
gap_US <- dplyr::filter(gapminder,
                        country == "United States")

gap_US
```

REMINDER

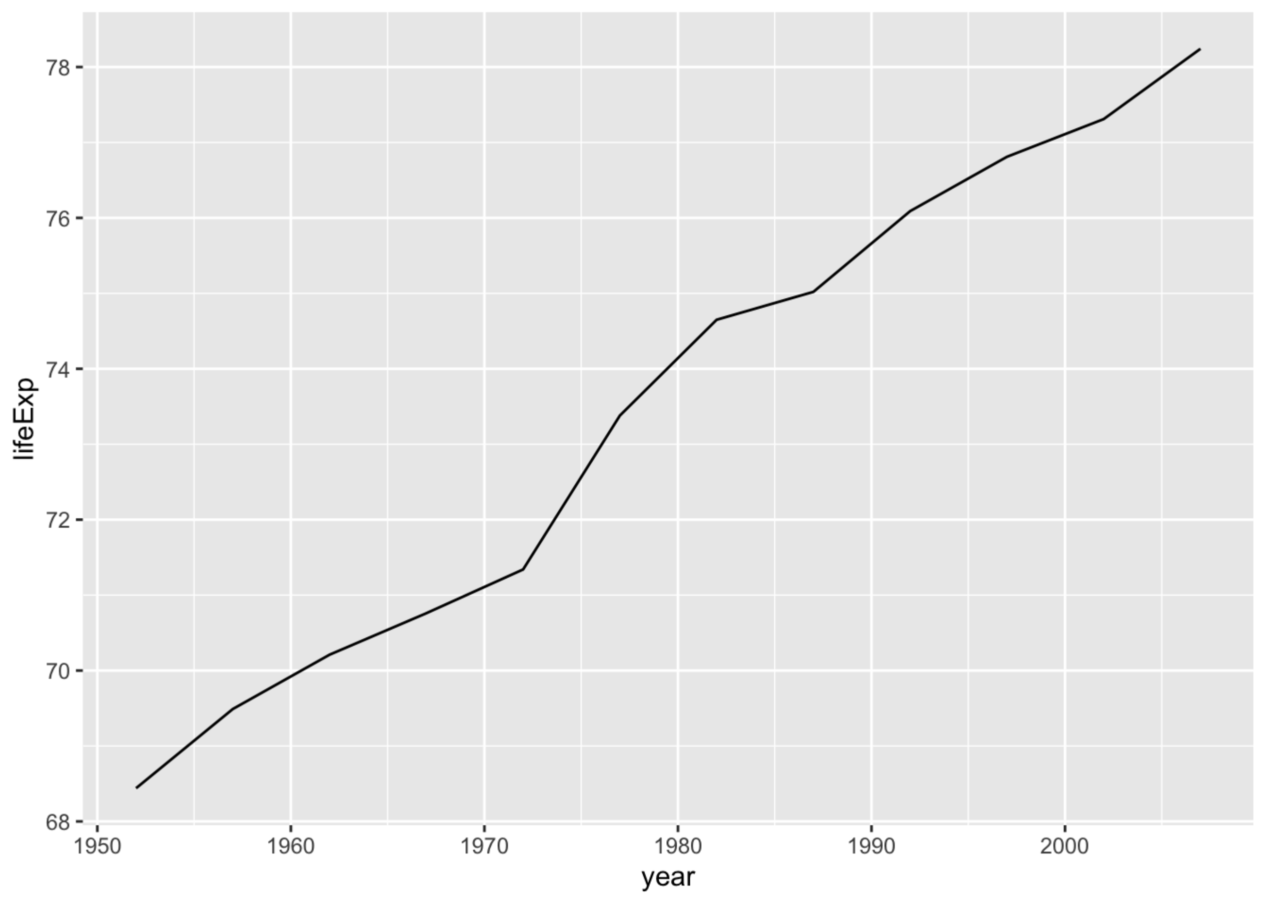
The code above is a covered in our course on Data Wrangling using the {dplyr} package. Data wrangling is the process of transforming and modifying existing data with the intent of making it more appropriate for analysis purposes. For example, this code segments used the `filter()` function to create a new data frame (gap_US) by choosing only a subset of rows of original `gapminder` data frame (only those that have "United States" in the `country` column).

Line graphs via `geom_line()`

Now we're ready to feed the gap_US data frame to `ggplot()`, mapping **time** in years on the horizontal x axis and **life expectancy** on the vertical y axis.

We can visualize this time series data by using `geom_line()` to create a line graph, instead of using `geom_point()` like we used previously to create scatterplots:

```r
# Simple line graph
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line()
```



Much as with the `ggplot()` code that created the scatterplot of age and viral load with `geom_point()`, let's break down this code piece-by-piece in terms of the grammar of graphics:

Within the `ggplot()` function call, we specify two of the components of the grammar of graphics as arguments:

1. The `data` to be the gap_US data frame by setting `data = gap_US`.
2. The `aesthetic mapping` by setting `mapping = aes(x = year, y = lifeExp)`. Specifically, the variable `year` maps to the x position aesthetic, while the variable `lifeExp` maps to the y position aesthetic.

After telling R which data and aesthetic mappings we wanted to plot we then added the third essential component, the geometric object using the + sign, In this case, the geometric object was set to lines using `geom_line()`.

PRACTICE

(in RMD)

Create a time series plot of the GPD per capita (`gdpPercap`) recorded in the gap_US data frame by using `geom_line()` to create a line graph.

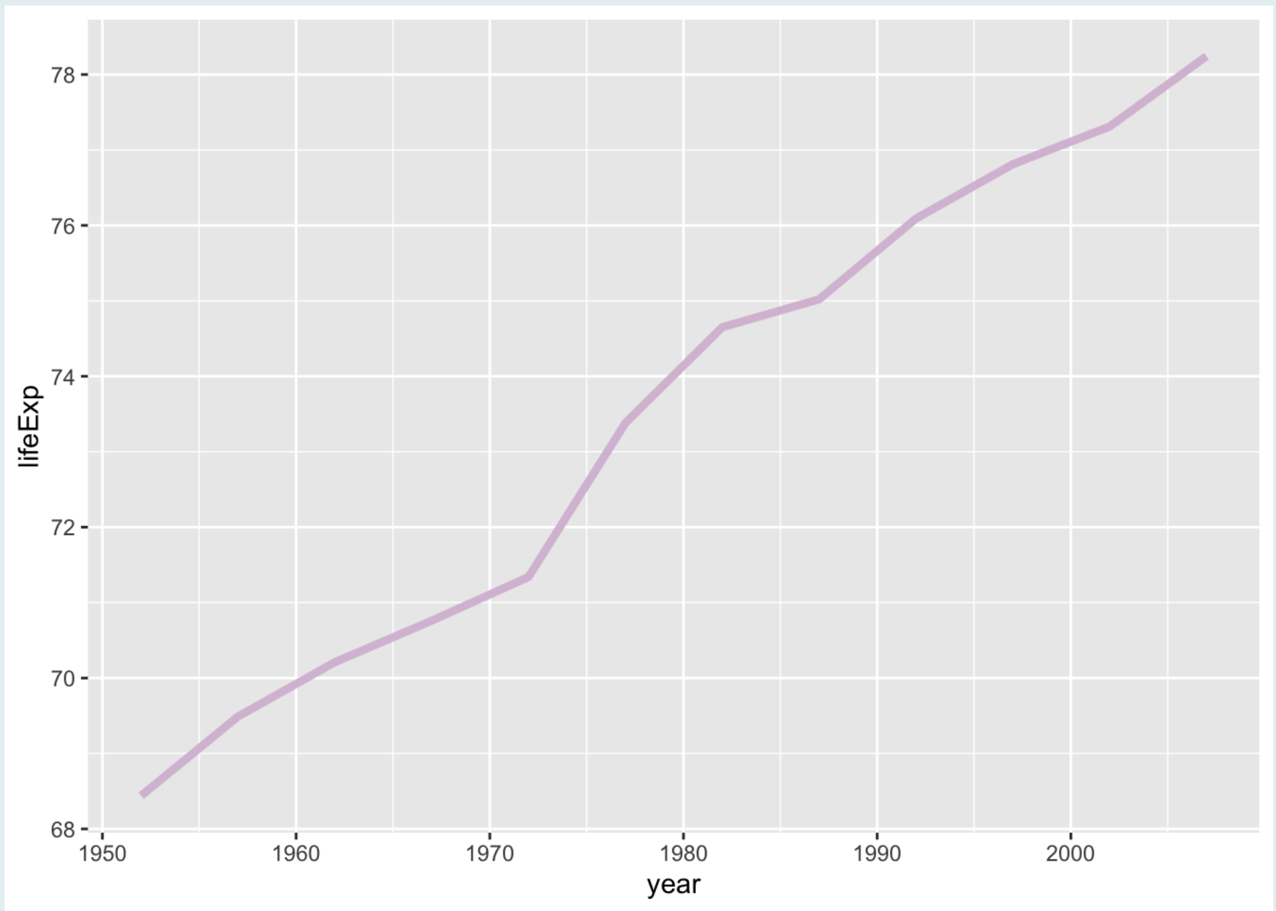
Fixed aesthetics in geom_line()

The color, line width and line type of the line graph can be customized making use of `color`, `size` and `linetype` arguments, respectively.

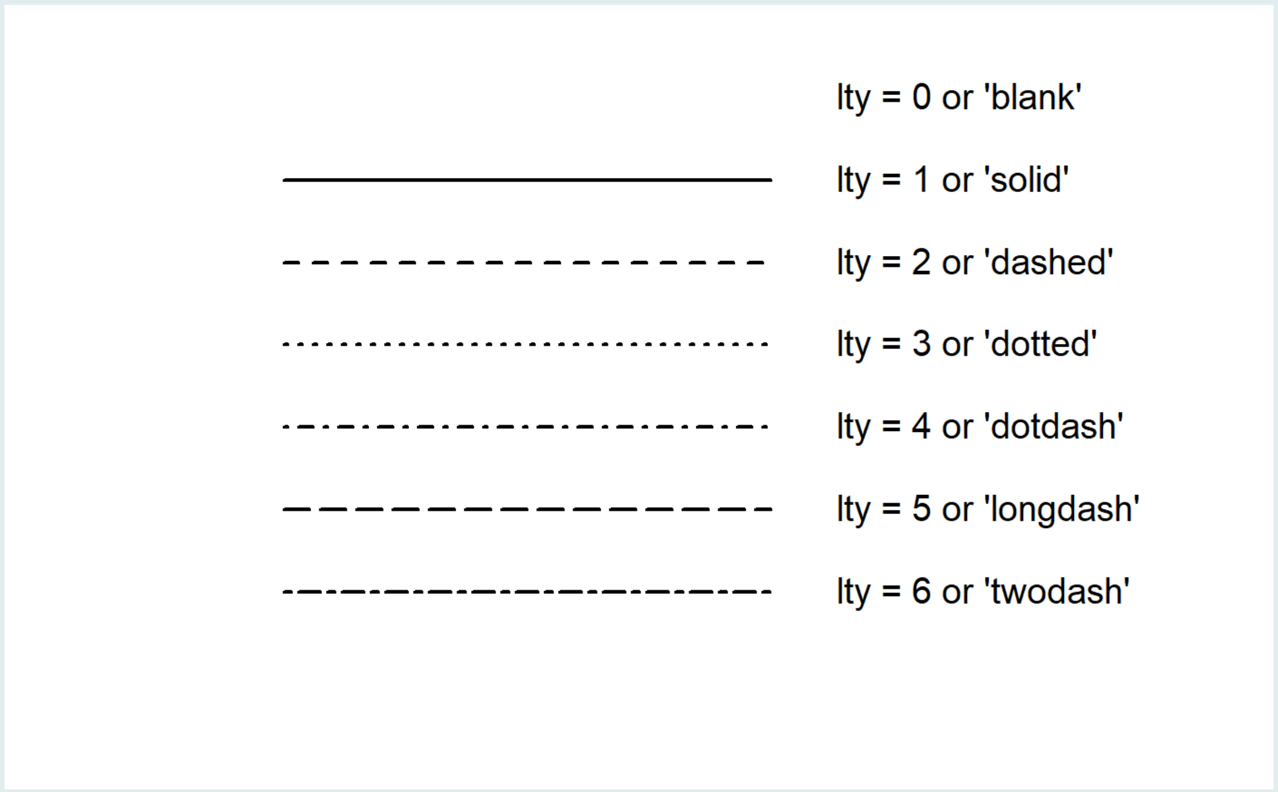
We've changed the color and size of geoms in previous lessons.

Here we will add these as fixed aesthetics:

```
# enhanced line graph with color and size as fixed aesthetics
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(color = "thistle",
            size = 1.5)
```

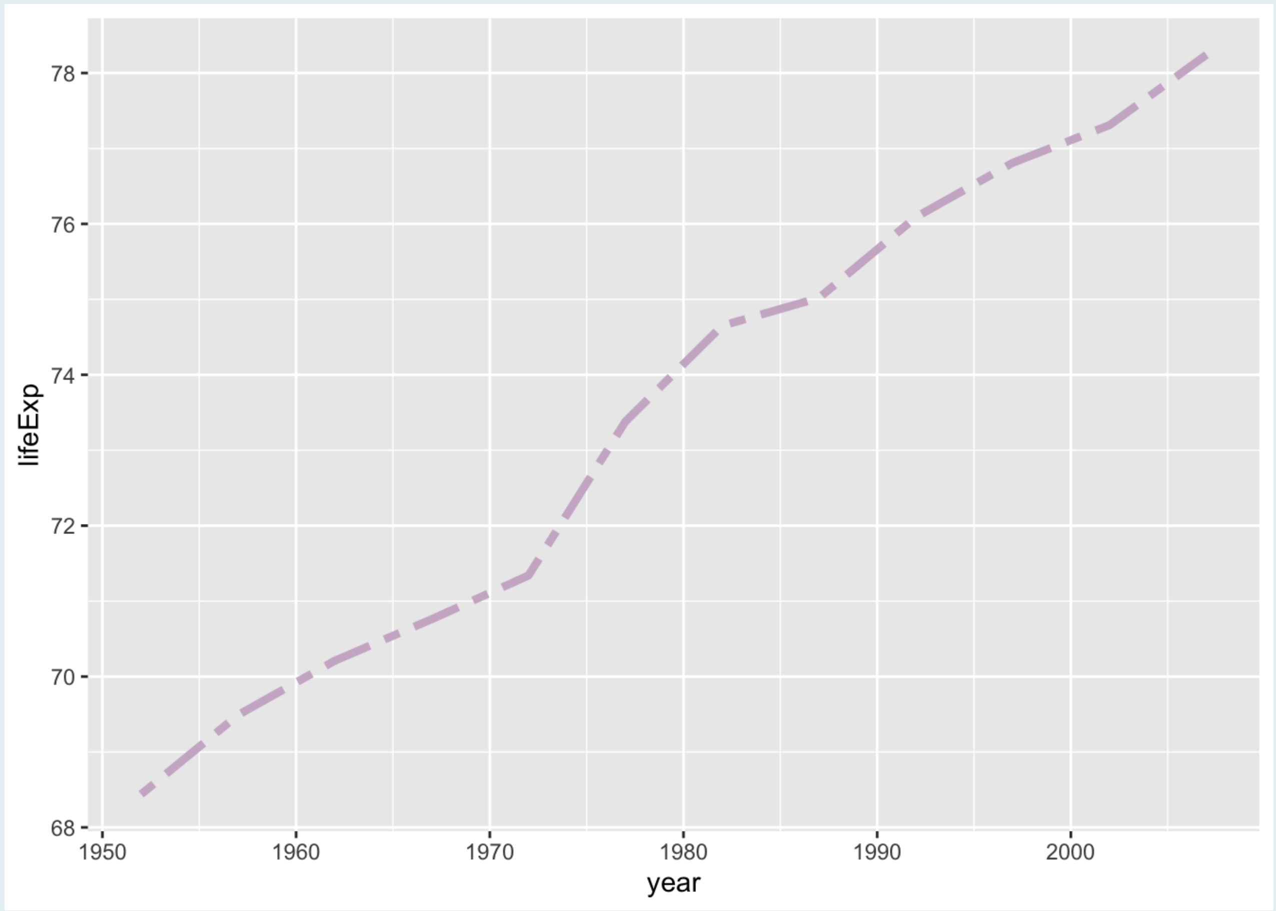


In this lesson we introduce a new fixed aesthetic that is specific to line graphs: `linetype` (or `lty` for short).



Line type can be specified using a name or with an integer. Valid line types can be set using a human readable character string: `"blank"`, `"solid"`, `"dashed"`, `"dotted"`, `"dotdash"`, `"longdash"`, and `"twodash"` are all understood by `linetype` or `lty`.

```
        # Enhanced line graph with color, size, and line type as fixed
aesthetics
        ggplot(data = gap_US,
               mapping = aes(x = year,
                             y = lifeExp)) +
          geom_line(color = "thistle3",
                    size = 1.5,
                    linetype = "twodash")
```



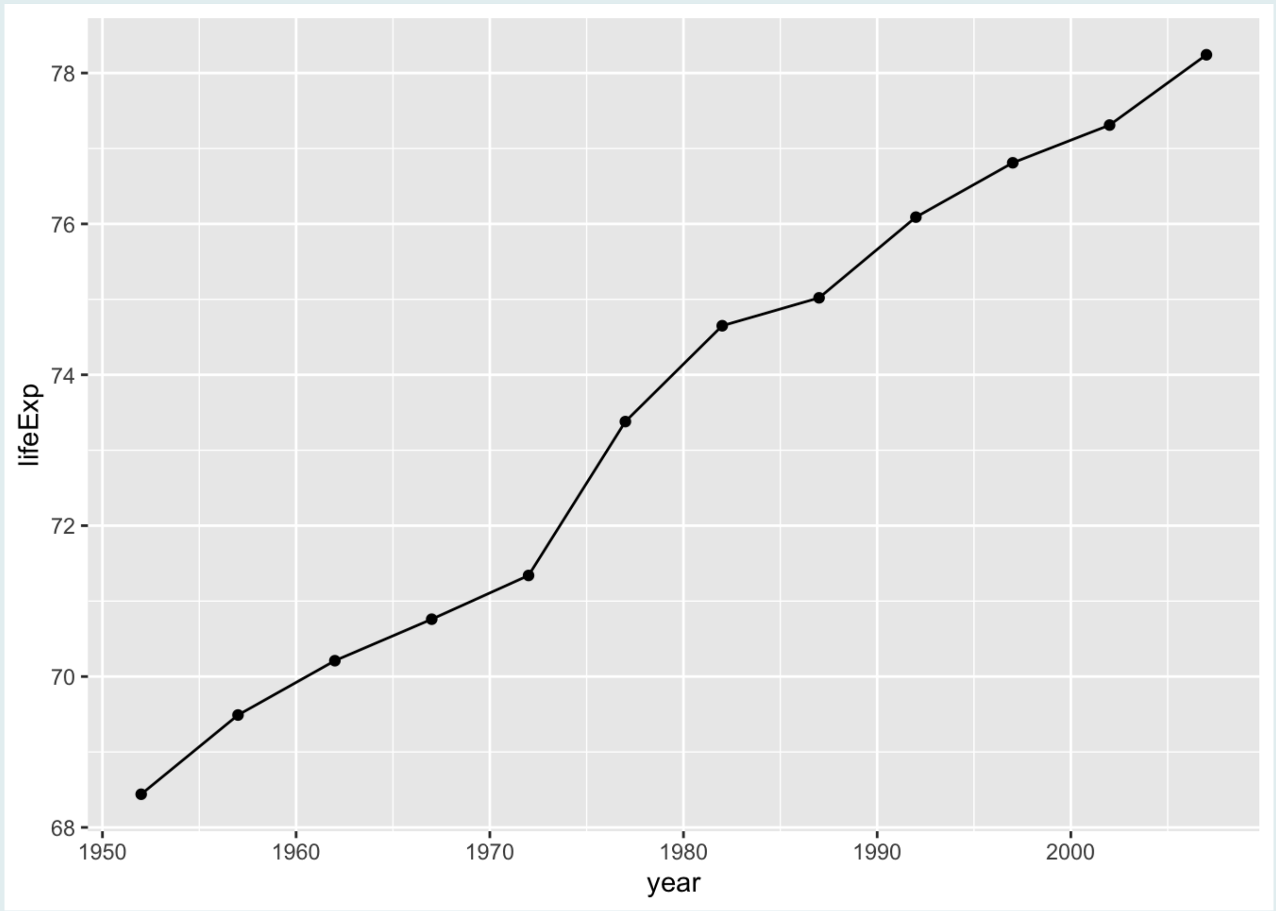
In these line graphs, it can be hard to tell where exactly there data points are. In the next plot, we'll add points to make this clearer.

Combining compatible geoms

As long as the geoms are compatible, we can layer them on top of one another to further customize a graph.

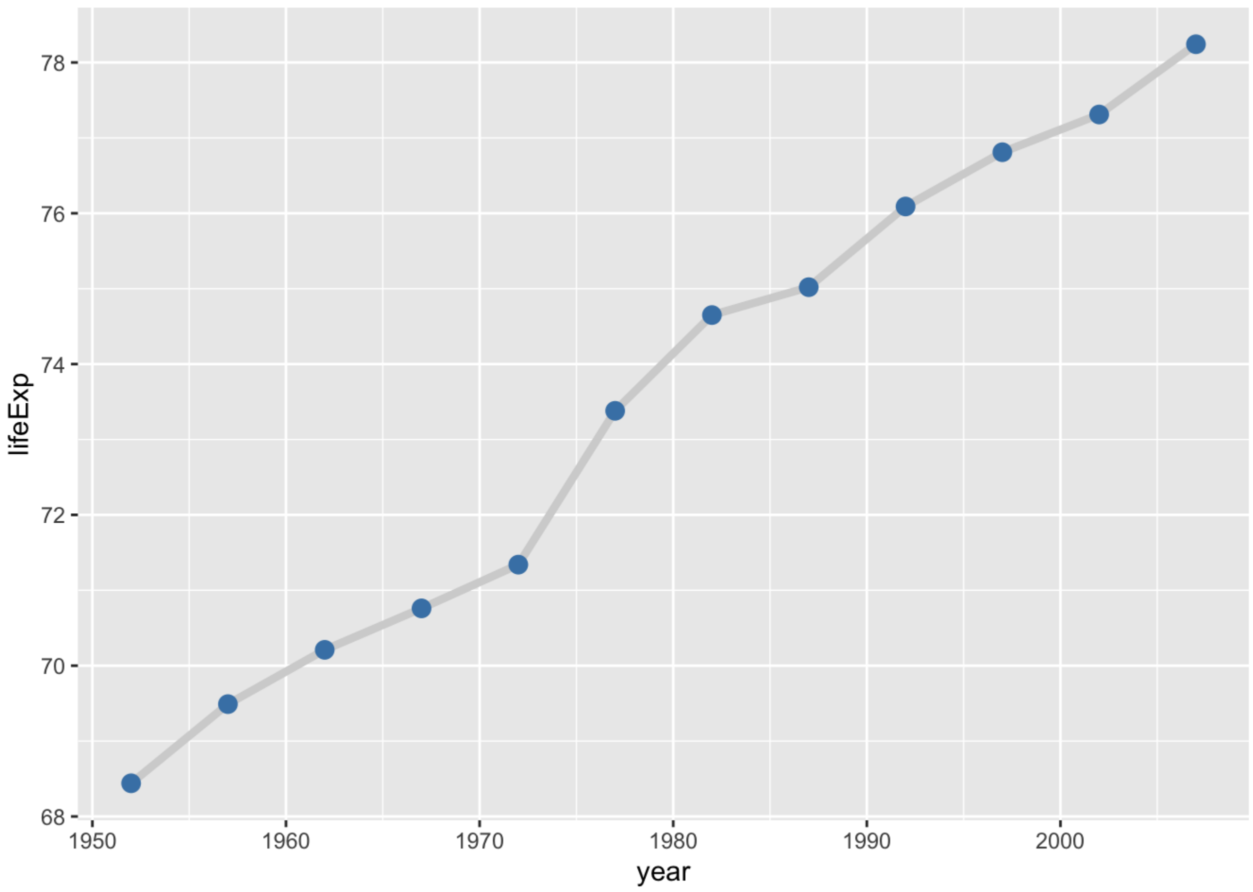
For example, we can add points to our line graph using the + sign to add a second `geom` layer with `geom_point()`:

```
# Simple line graph with points
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line() +
  geom_point()
```



We can create a more attractive plot by customizing the size and color of our geoms.

```
# Line graph with points and fixed aesthetics
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1.5,
            color = "lightgrey") +
  geom_point(size = 3,
             color = "steelblue")
```



Building on the code above, visualize the relationship between time and **GPD per capita** from the gap_US data frame.

Use both points and lines to represent the data.

Change the line type of the line and the color of the points to any valid values of your choice.

Mapping data to multiple lines

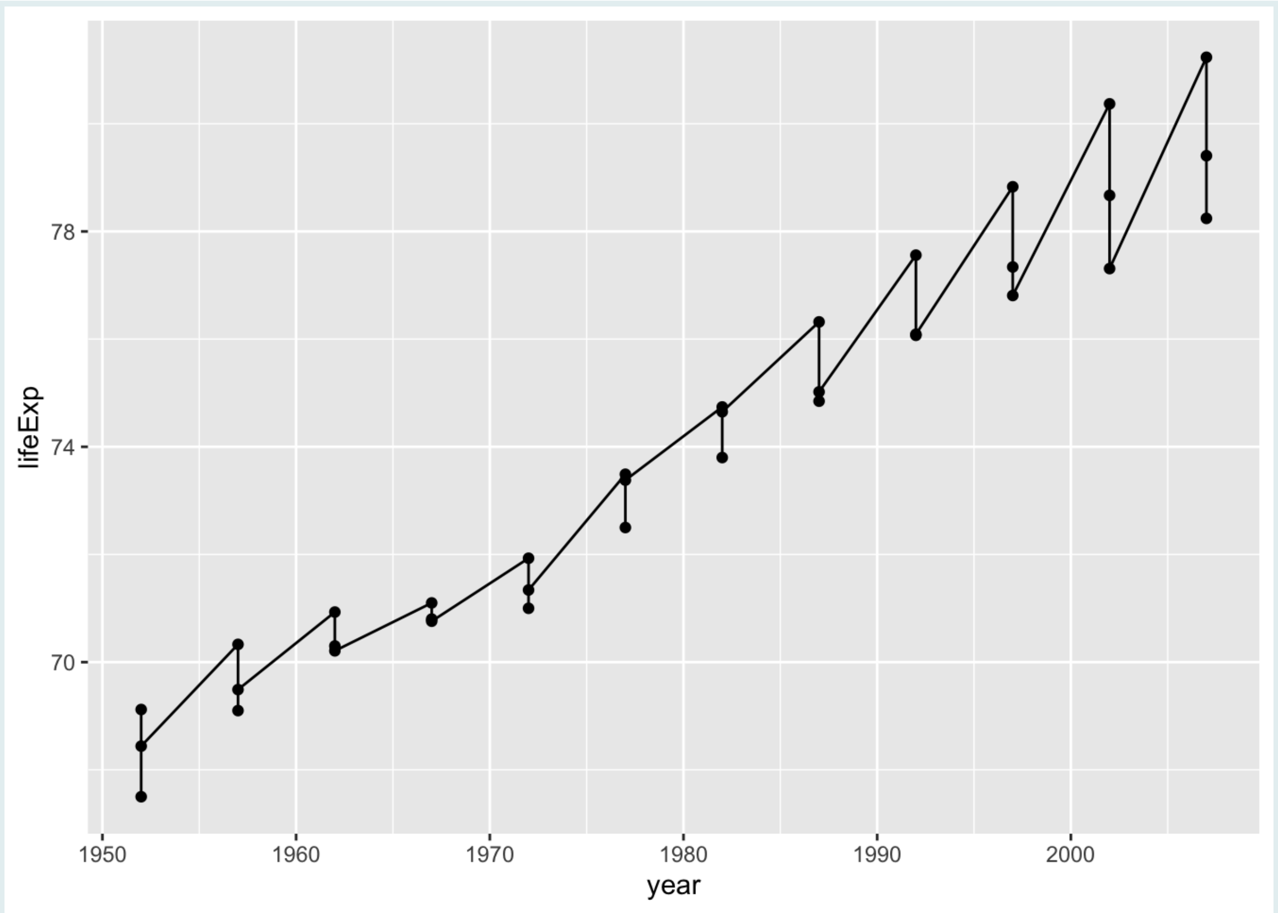
In the previous section, we only looked at data from one country, but what if we want to plot data for multiple countries and compare?

First let's add two more countries to our data subset:

```r
# Create data subset for visualizing multiple categories
gap_mini <- filter(gapminder,
                   country %in% c("United States",
                                  "Australia",
                                  "Germany"))
gap_mini
```

If we simply enter it using the same code and change the data layer, the lines are not automatically separated by country:

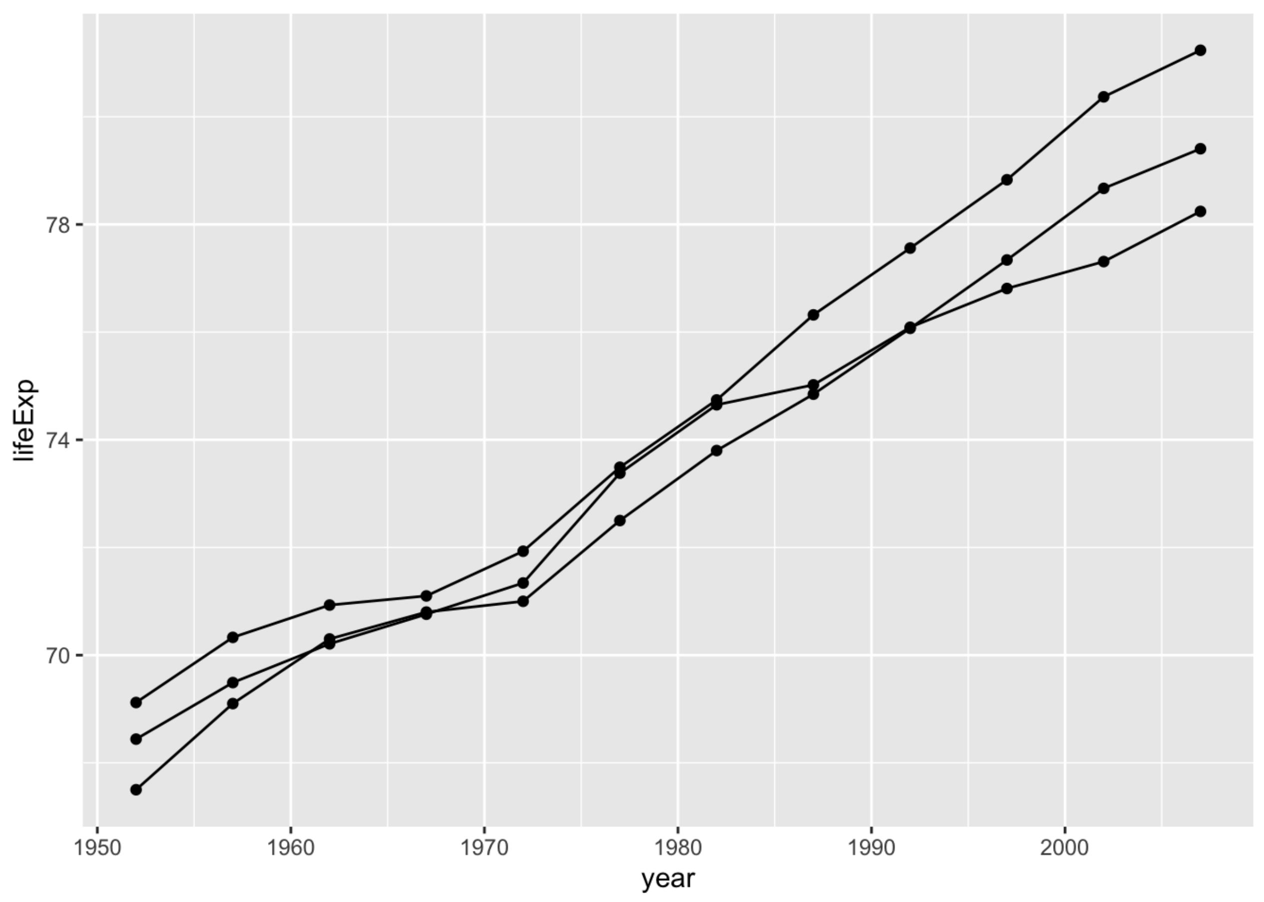
```r
# Line graph with no grouping aesthetic
ggplot(data = gap_mini,
       mapping = aes(y = lifeExp,
                     x = year)) +
  geom_line() +
  geom_point()
```



This is not a very helpful plot for comparing trends between groups.

To tell `ggplot()` to map the data from each country separately, we can the `group` argument as an as aesthetic mapping:

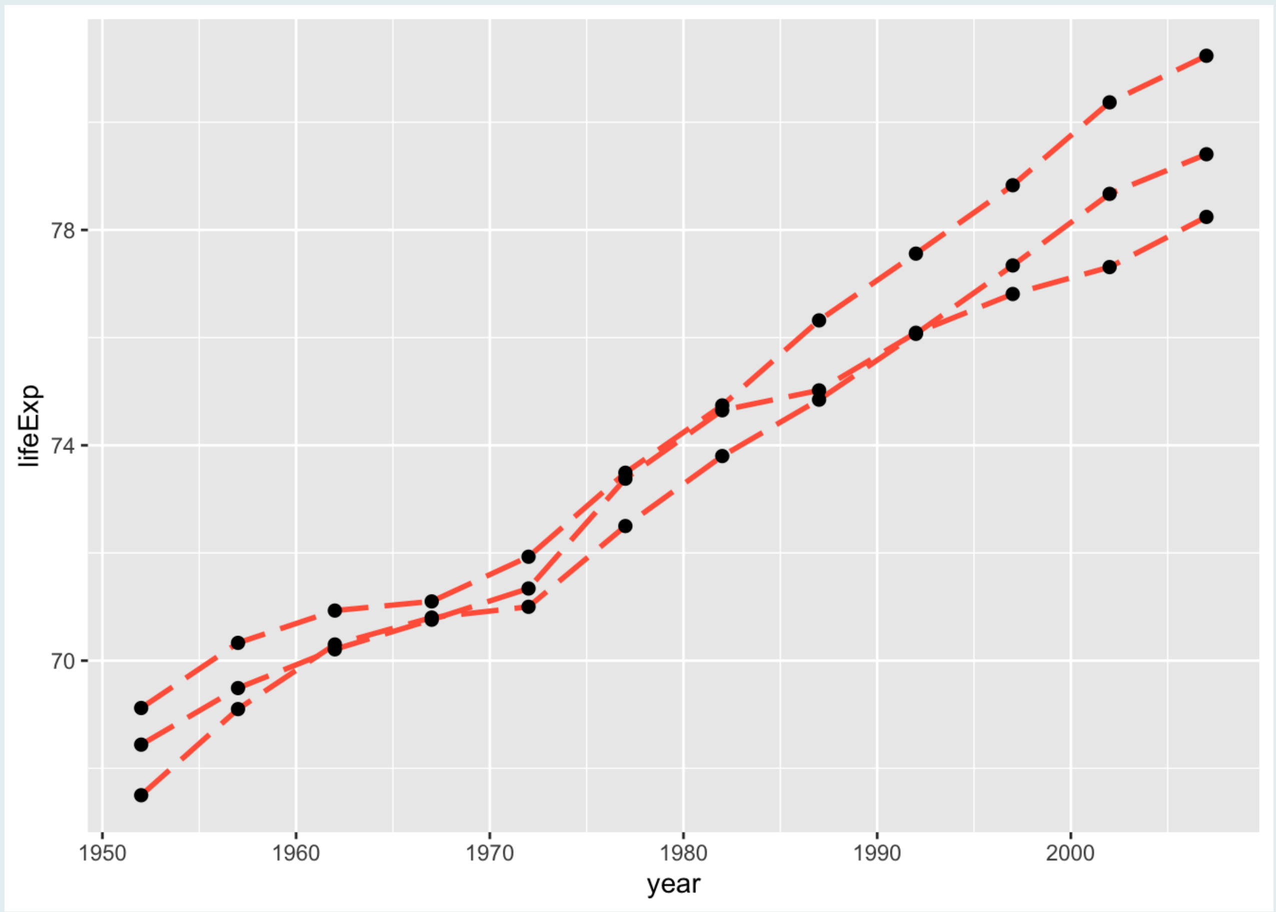
```r
# Line graph with grouping by a categorical variable
ggplot(data = gap_mini,
       mapping = aes(y = lifeExp,
                     x = year,
                     group = country)) +
  geom_line() +
  geom_point()
```



Now that the data is grouped by country, we have 3 separate lines - one for each level of the `country` variable.

We can also apply fixed aesthetics to the geometric layers.

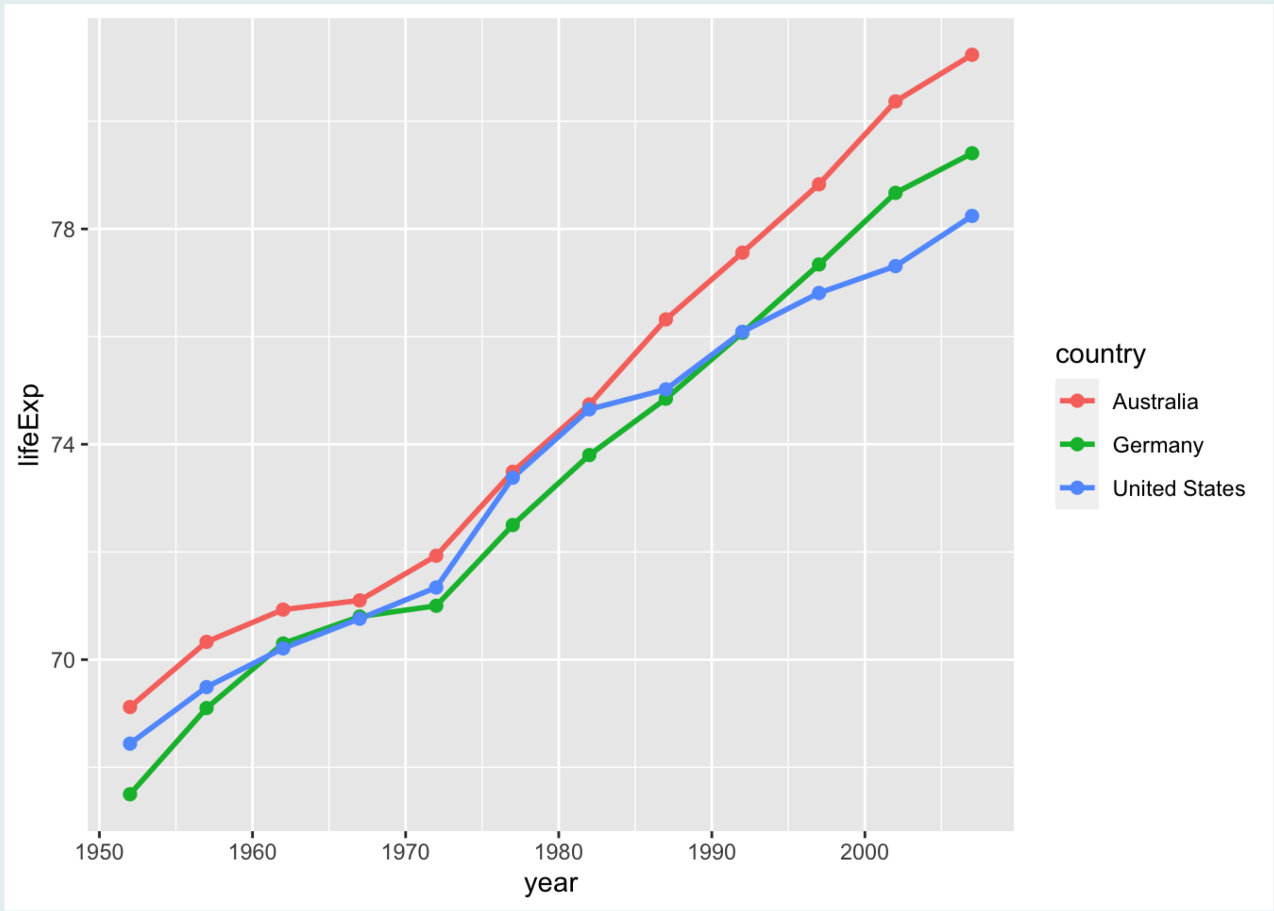
```r
# Applying fixed aesthetics to multiple lines
ggplot(data = gap_mini,
       mapping = aes(y = lifeExp,
                     x = year,
                     group = country)) +
  geom_line(linetype="longdash",         # set line type
            color="tomato",              # set line color
            size=1) +                    # set line size
  geom_point(size = 2)                   # set point size
```



In the graphs above, line types, colors and sizes are the same for the three groups.

This doesn't tell us which is which though. We should add an aesthetic mapping that can help us identify which line belongs to which country, like color or line type.

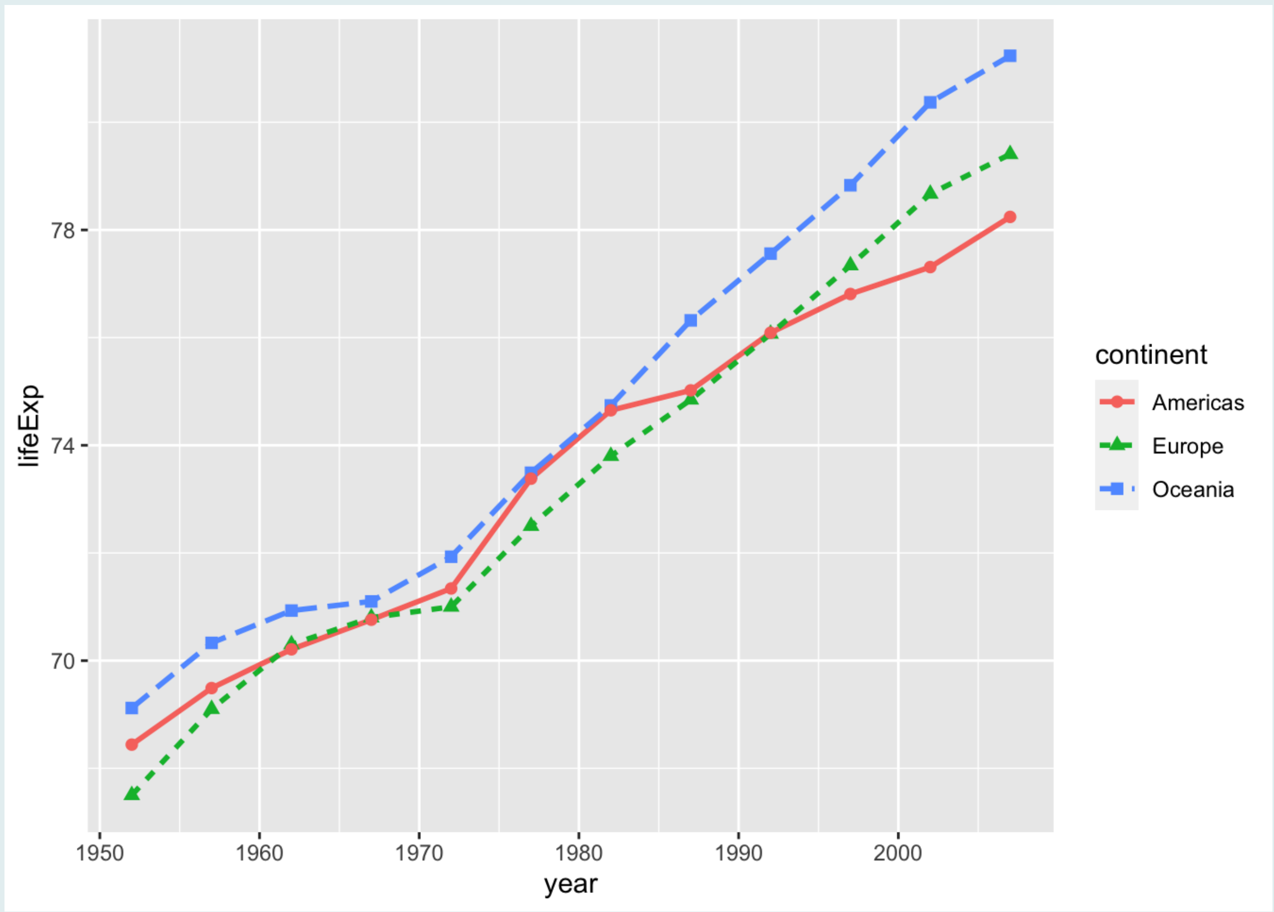
```
# Map country to color
ggplot(data = gap_mini,
       mapping = aes(y = lifeExp, x = year,
                     group = country,
                     color = country)) +
  geom_line(size = 1) +
  geom_point(size = 2)
```



Aesthetic mappings specified within `ggplot()` function call are passed down to subsequent layers.

Instead of grouping by `country`, we can also group by `continent`:

```
# Map continent to color, line type, and shape
ggplot(data = gap_mini,
       mapping = aes(x = year,
                     y = lifeExp,
                     color = continent,
                     lty = continent,
                     shape = continent)) +
  geom_line(size = 1) +
  geom_point(size = 2)
```



When given multiple mappings and geoms, {ggplot2} can discern which mappings apply to which geoms.

Here `color` was inherited by both points and lines, but `lty` was ignored by `geom_point()` and shape was ignored by `geom_line()`, since they don't apply.

CHALLENGE

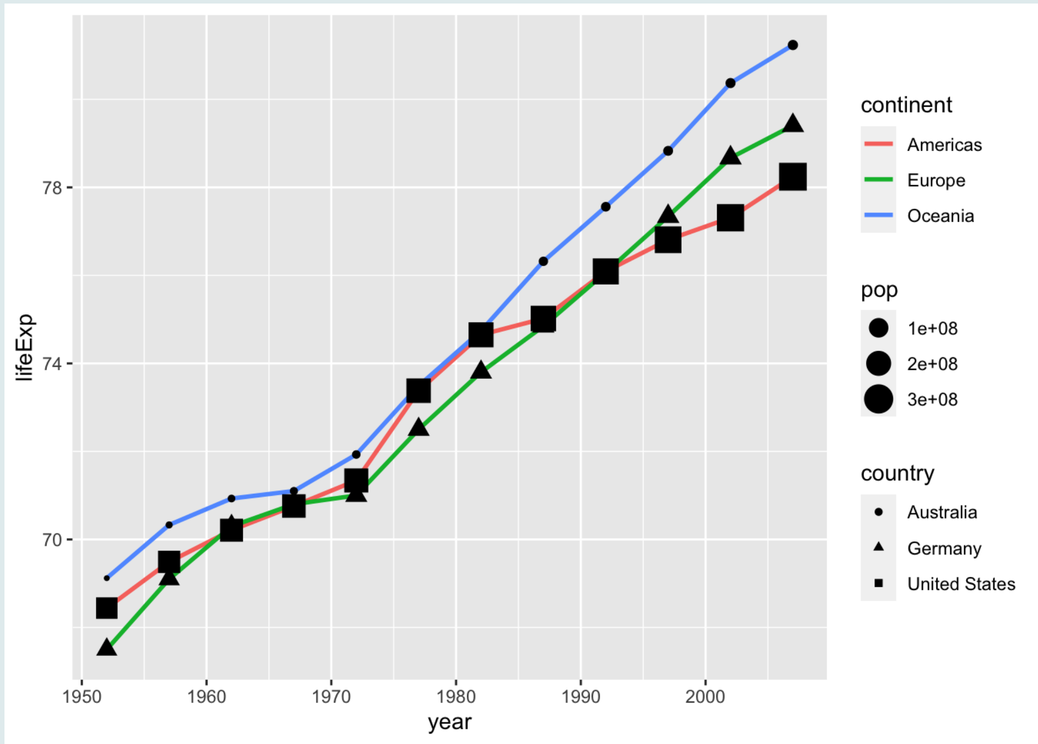
Challenge

Mappings can either go in the `ggplot()` function or in `geom_*()` layer.

For example, aesthetic mappings can go in `geom_line()` and will only be applied to that layer:

```
ggplot(data = gap_mini,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1, mapping = aes(color =
continent)) +
```

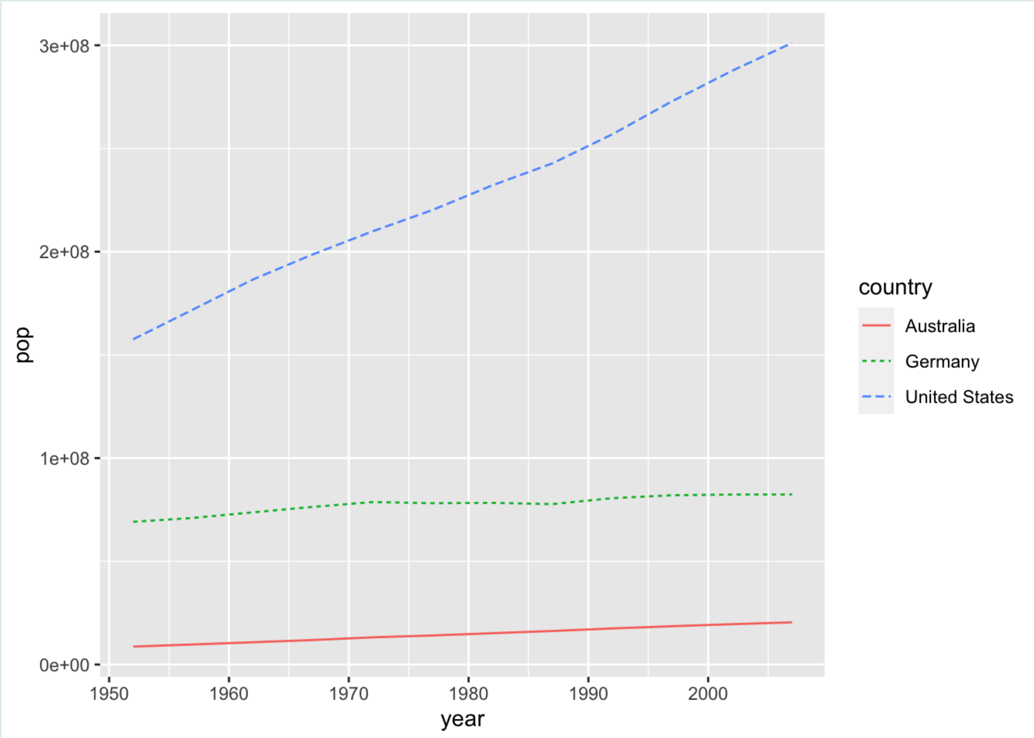
CHALLENGE



Try adding `mapping = aes()` in `geom_point()` and map `continent` to any valid aesthetic!

PRACTICE (in RMD)

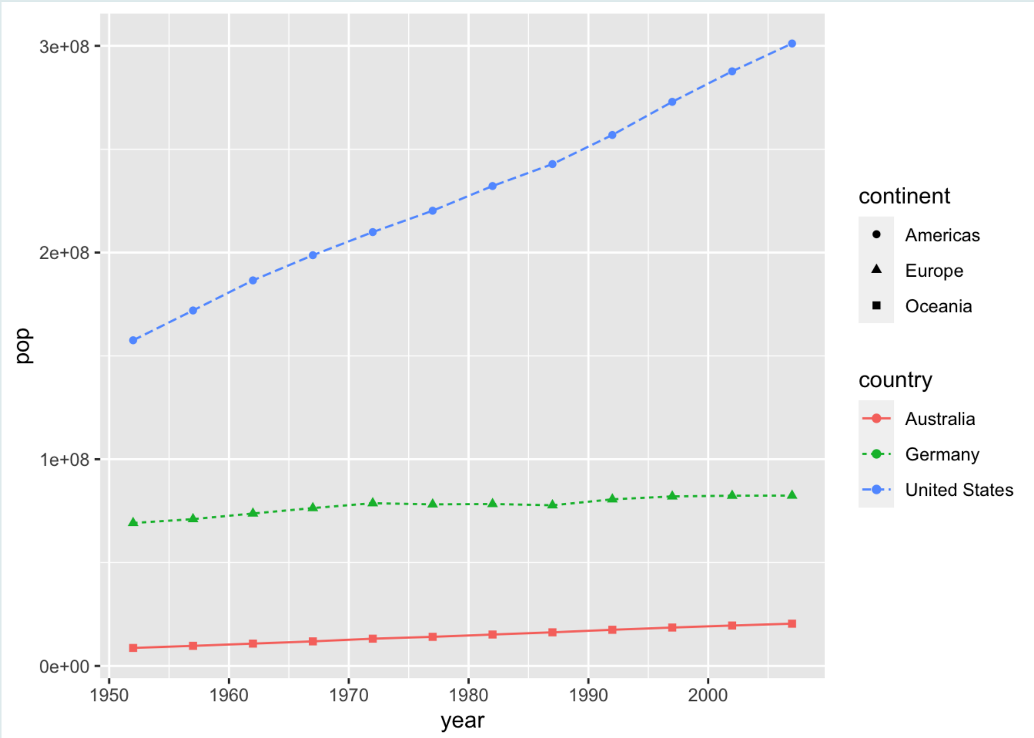
Using the `gap_mini` data frame, create a **population** growth chart with these aesthetic mappings:



PRACTICE

(in RMD)

Next, add a layer of points to the previous plot, and add the required aesthetic mappings to produce a plot that looks like this:

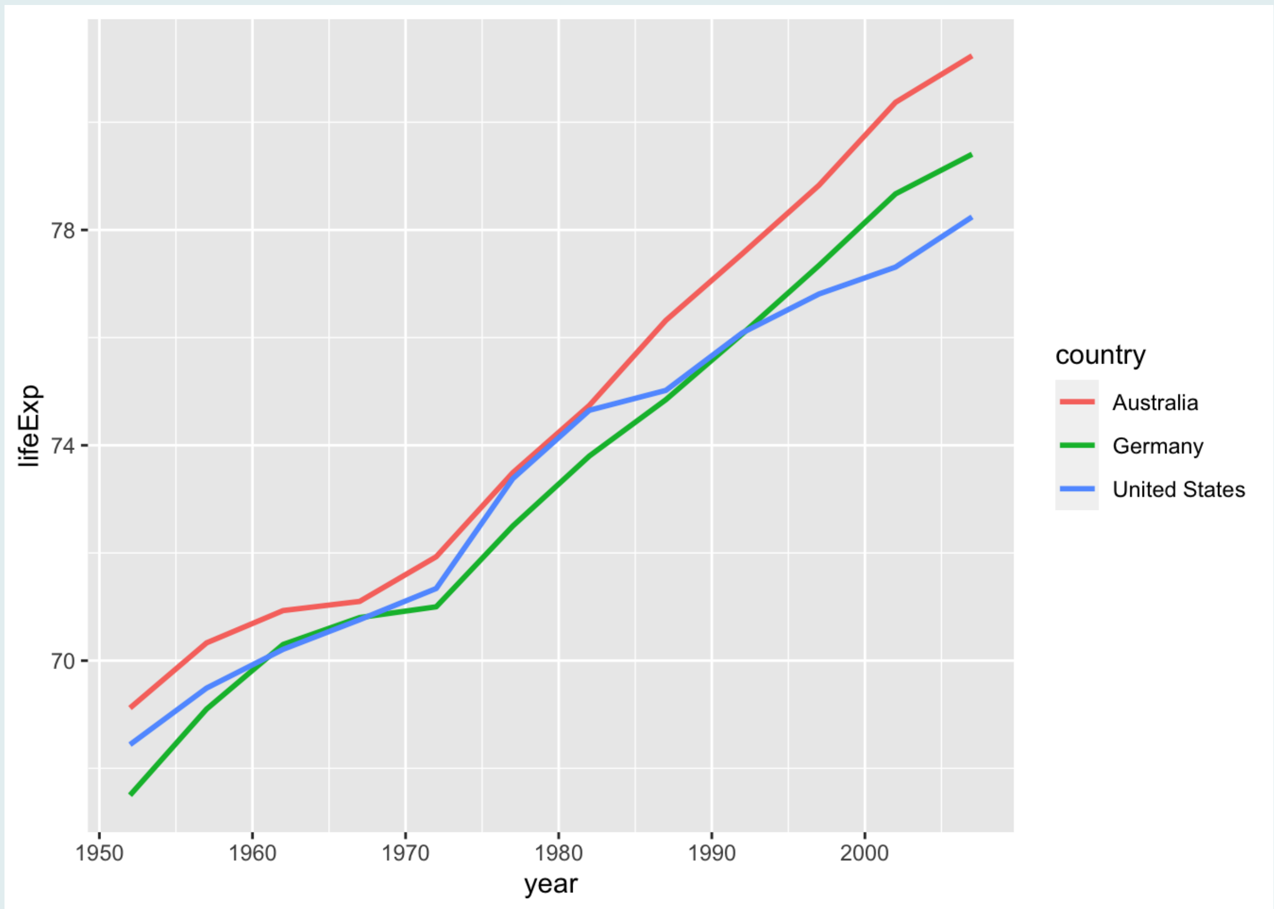


Don't worry about any fixed aesthetics, just make sure the mapping of data variables is the same.

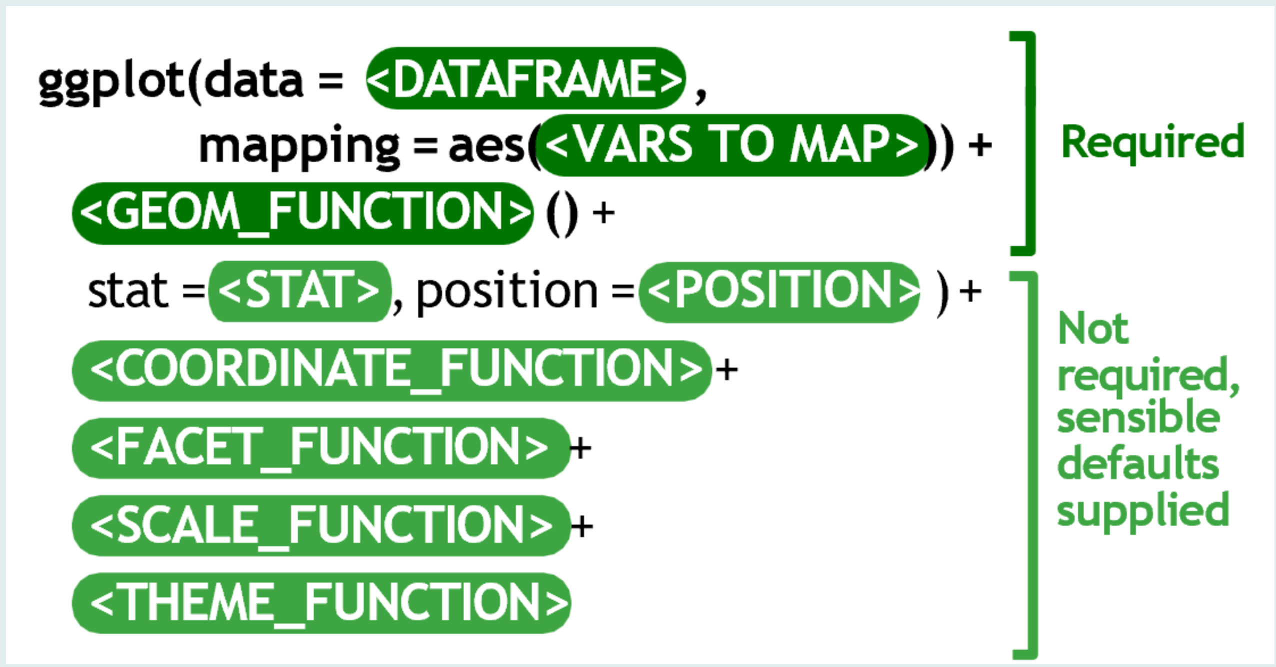
Modifying continuous x & y scales

{ggplot2} automatically scales variables to an aesthetic mapping according to type of variable it's given.

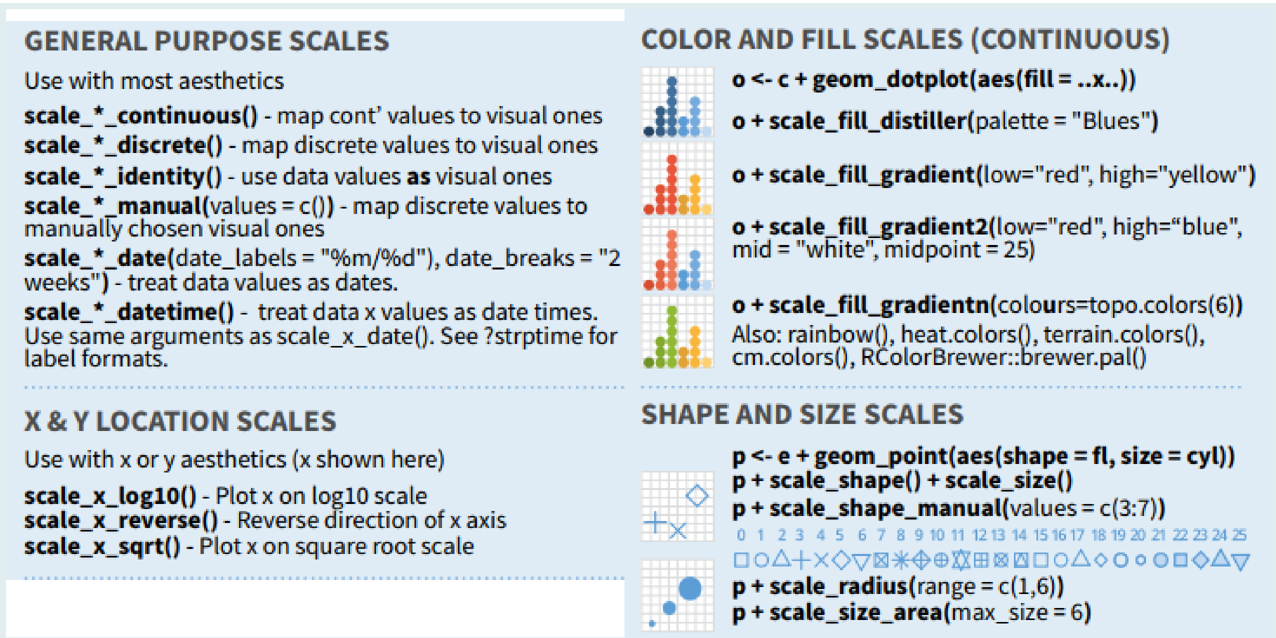
```
# Automatic scaling for x, y, and color
ggplot(data = gap_mini,
       mapping = aes(x = year,
                     y = lifeExp,
                     color = country)) +
  geom_line(size = 1)
```



In some cases the we might want to transform the axis scaling for better visualization. We can customize these scales with the `scale_*()` family of functions.



`scale_x_continuous()` and `scale_y_continuous()` are the default scale functions for continuous x and y aesthetics.



Scale breaks

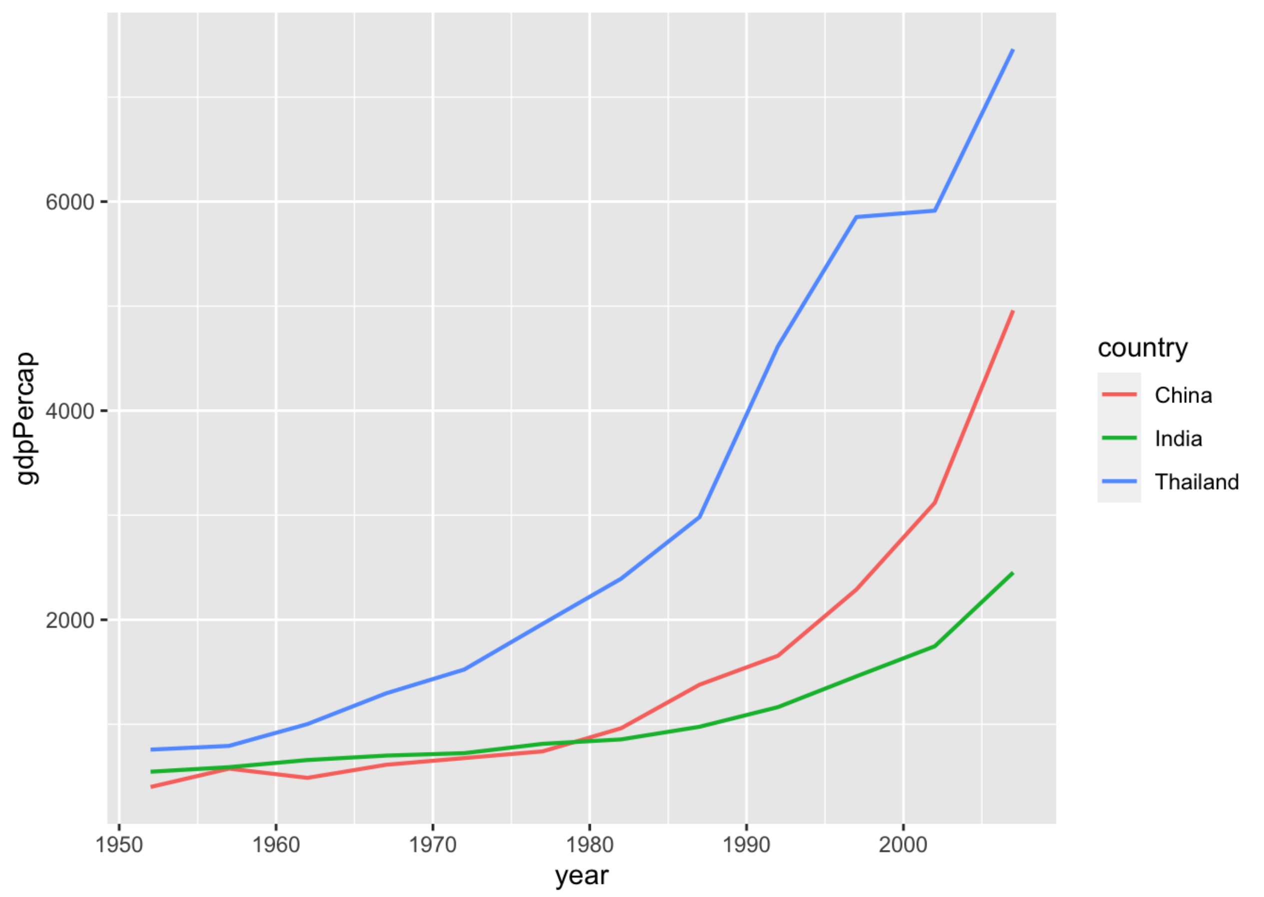
Let's create a new subset of countries from `gapminder`, and this time we will plot changes in GDP over time.

```
# Data subset to include India, China, and Thailand
gap_mini2 <- filter(gapminder,
                    country %in% c("India",
```

```
                                                  "China",
"Thailand"))        gap_mini2
```

Here we will change the y-axis mapping from `lifeExp` to `gdpPercap`:

```
ggplot(data = gap_mini2,
       mapping = aes(x = year,
                     y = gdpPercap,
                     group = country,
                     color = country)) +
  geom_line(size = 0.75)
```



The x-axis labels for `year` in don't match up with the dataset.

```
gap_mini2$year %>% unique()
```

```
##  [1] 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 2002
## [12] 2007
```

We can specify exactly where to label the axis by providing a numeric vector.

```r
# You can manually enter scale breaks (don't do this)
c(1952, 1957, 1962, 1967, 1972, 1977, 1982, 1987, 1992, 1997, 2002,
2007)
```

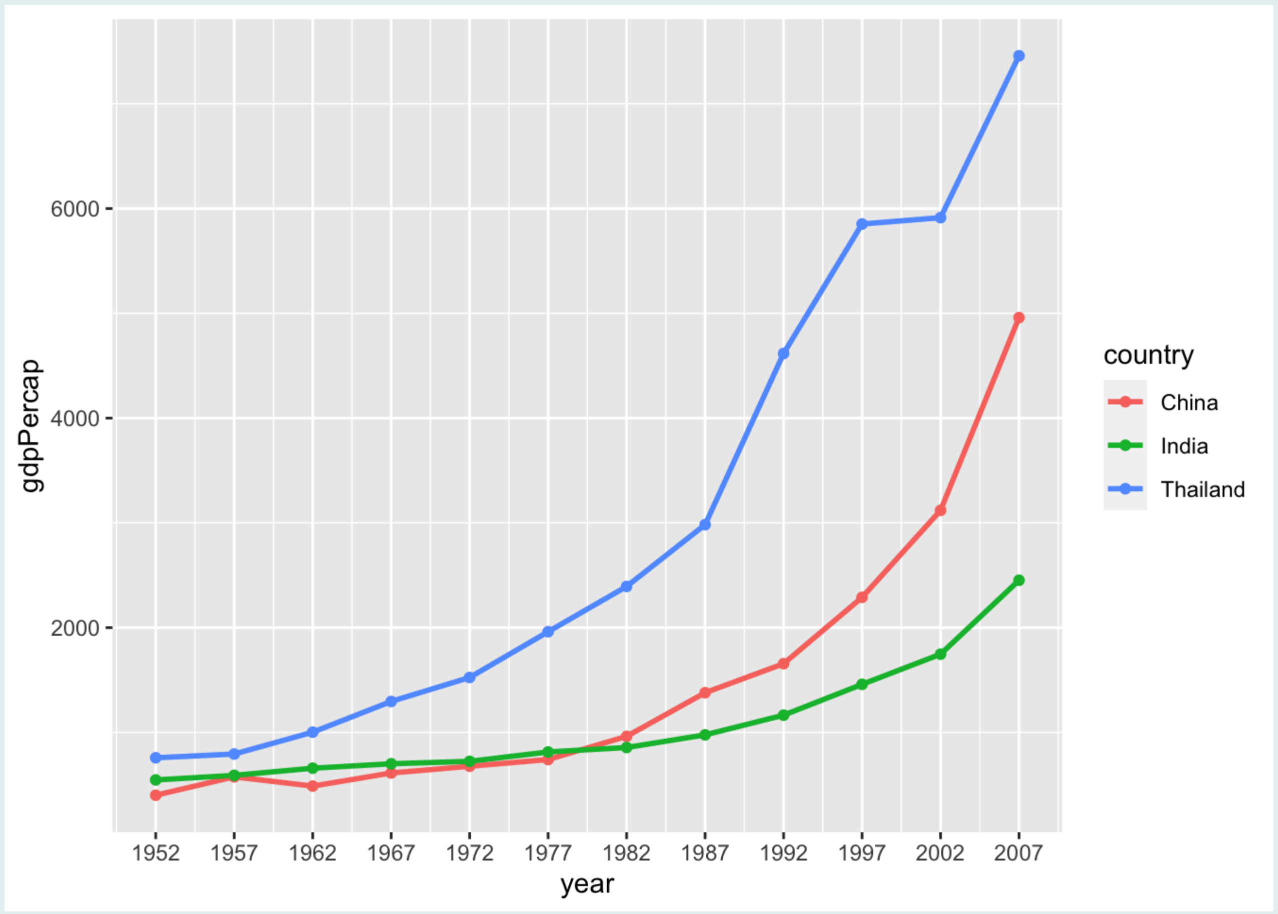
```
##  [1] 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 2002
## [12] 2007
```

```r
# It's better to create the vector with seq()
seq(from = 1952, to = 2007, by = 5)
```

```
##  [1] 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 2002
## [12] 2007
```

Use `scale_x_continuous` to make the axis breaks match up with the dataset:

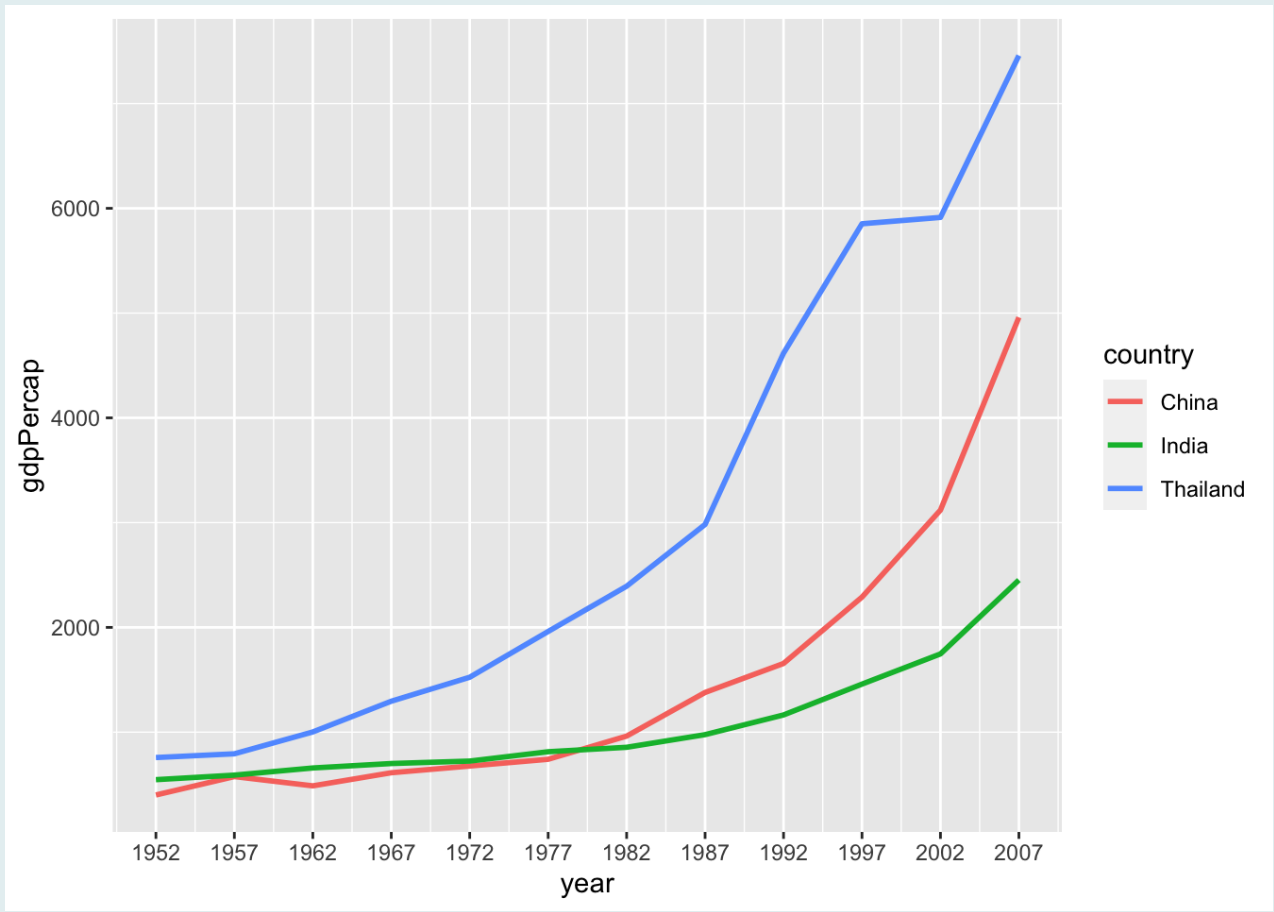
```r
# Customize x-axis breaks with `scale_x_continuous(breaks = VECTOR)`
ggplot(data = gap_mini2,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1) +
  scale_x_continuous(breaks = seq(from = 1952, to = 2007, by = 5)) +
  geom_point()
```



Store scale break values as an R object for easier reference:

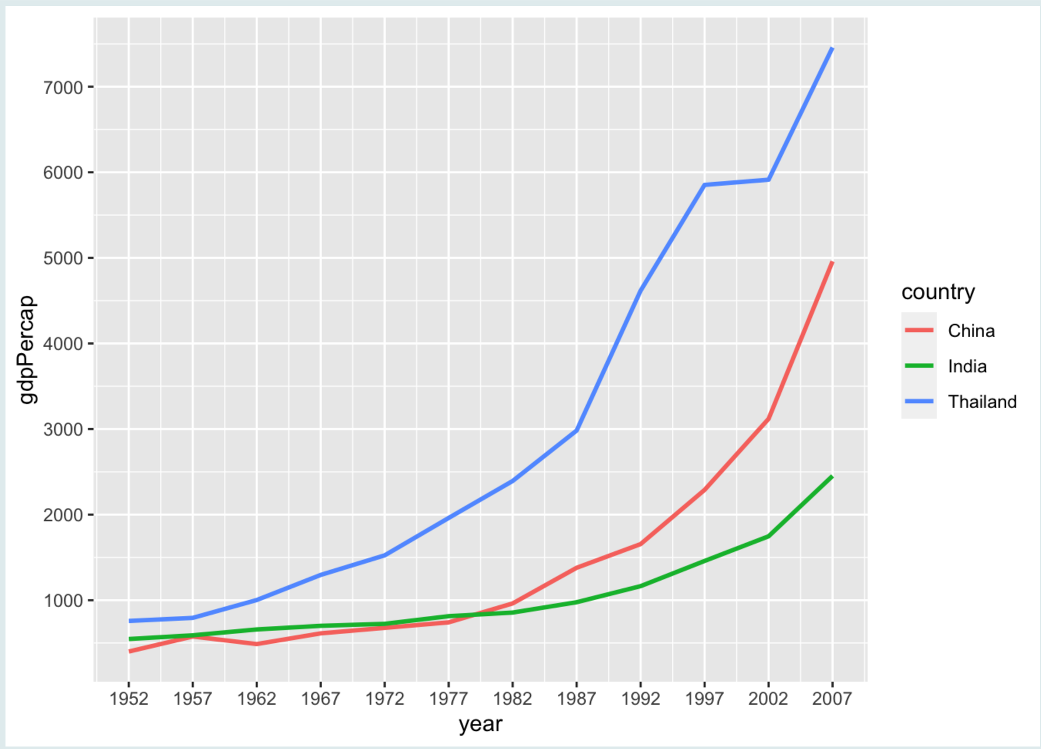
```
# Store numeric vector to a named object
gap_years <- seq(from = 1952, to = 2007, by = 5)
```

```
# Replace seq() code with named vector
ggplot(data = gap_mini2,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1) +
  scale_x_continuous(breaks = gap_years)
```



We can customize scale breaks on a continuous **y**-axis values with **`scale_y_continuous()`**.

Copy the code from the last example, and add `scale_y_continuous()` to add the following y-axis breaks:



Logarithmic scaling

In the last two mini sets, I chose three countries that had similar range of GDP or life expectancy for good scaling and readability so that we can make out these changes.

But if we add a country to the group that significantly differs, default scaling is not so great.

We'll look at an example plot where you may want to rescale the axes from linear to a log scale.

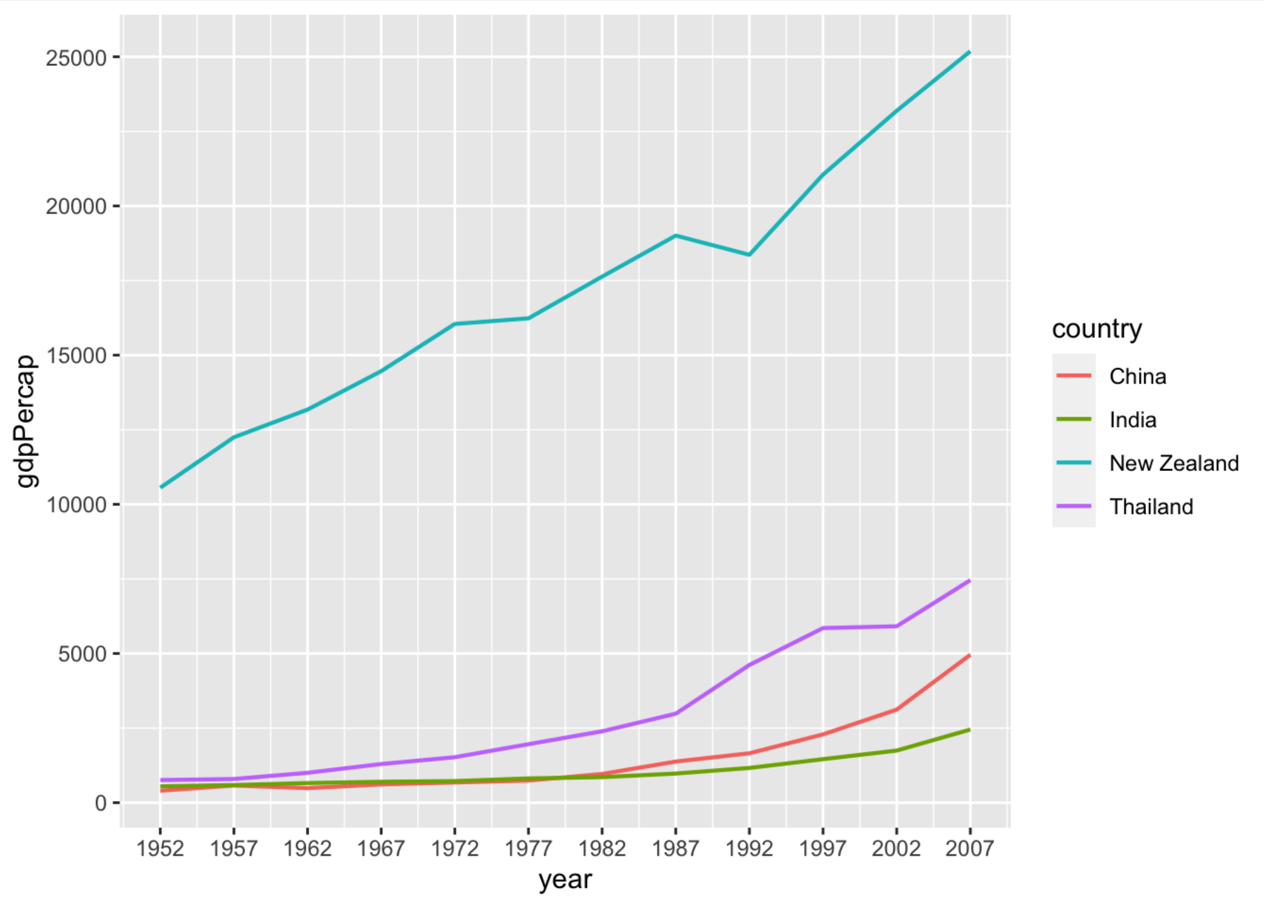
Let's add New Zealand to the previous set of countries and create `gap_mini3`:

```
# Data subset to include India, China, Thailand, and New Zealand
gap_mini3 <- filter(gapminder,
                    country %in% c("India",
                                   "China",
                                   "Thailand",
                                   "New Zealand"))
gap_mini3
```

Now we will recreate the plot of GDP over time with the new data subset:

```
ggplot(data = gap_mini3,
       mapping = aes(x = year,
                     y = gdpPercap,
```

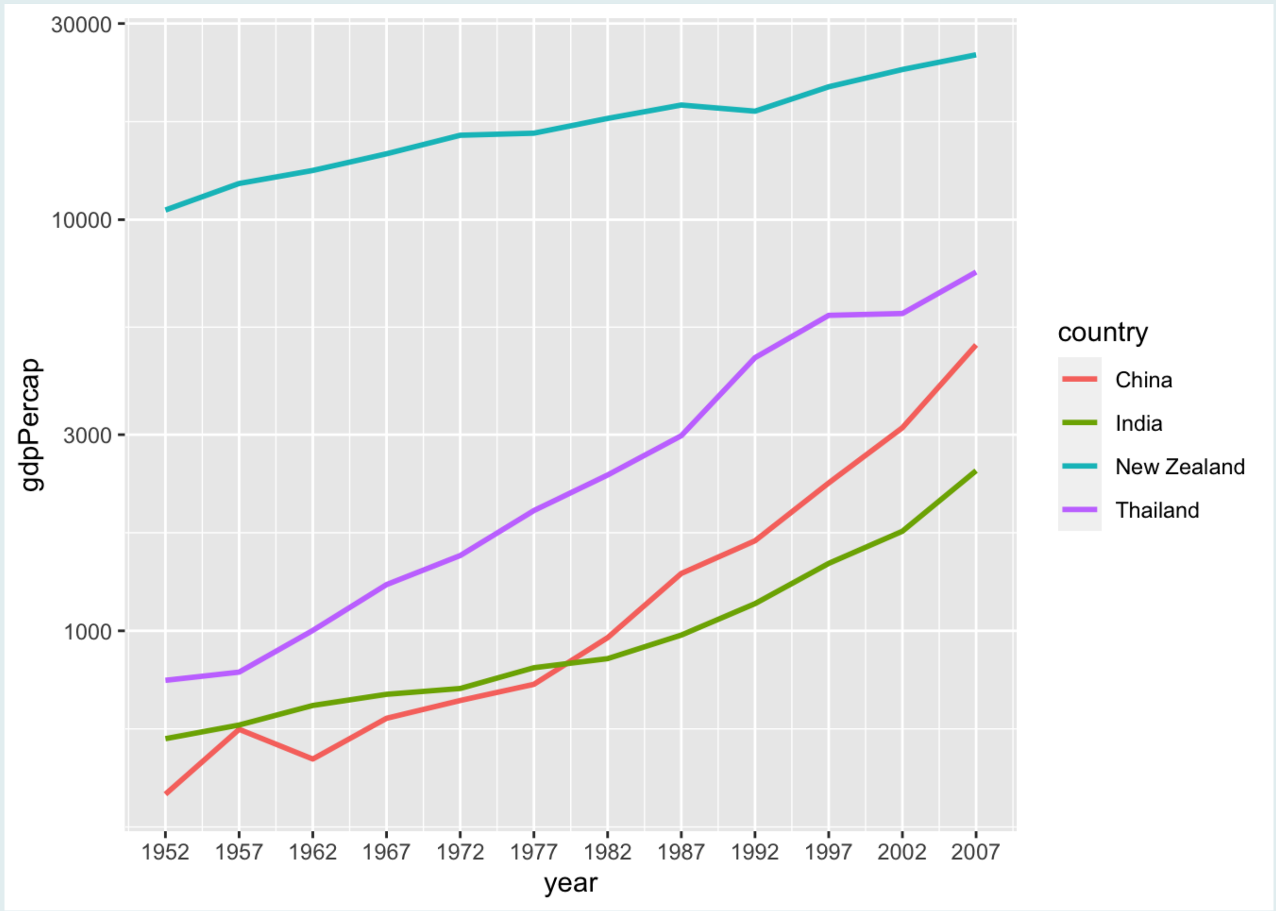
```
                    color = country)) +          geom_line(size =
0.75) +          scale_x_continuous(breaks = gap_years)
```



The curves for India and China show an exponential increase in GDP per capita. However, the y-axes values for these two countries are much lower than that of New Zealand, so the lines are a bit squashed together. This makes the data hard to read. Additionally, the large empty area in the middle is not a great use of plot space.

We can address this by log-transforming the y-axis using `scale_y_log10()`, which log-scales the y -axis (as the name suggests). We will add this function as a new layer after a + sign, as usual:

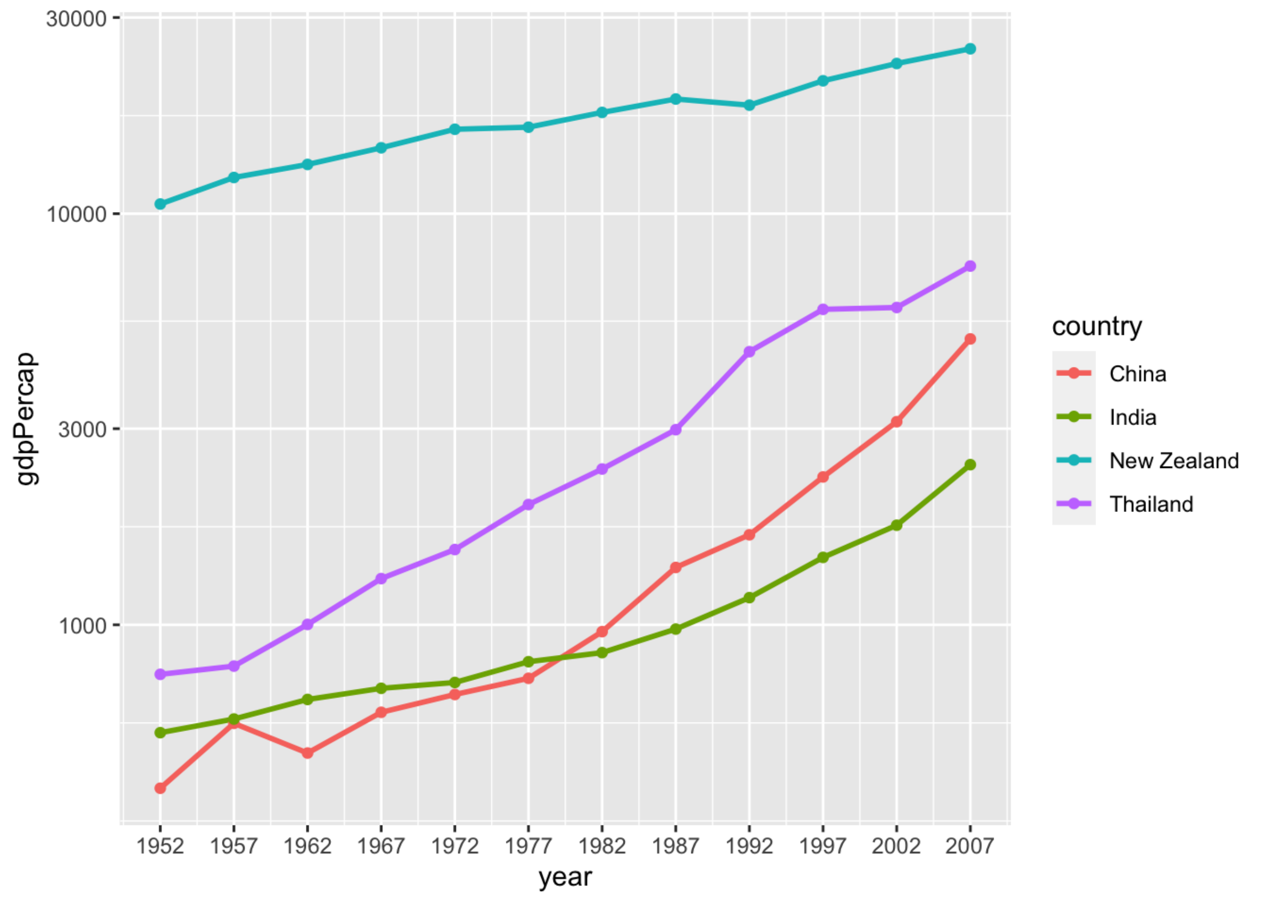
```
# Add scale_y_log10()
ggplot(data = gap_mini3,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1) +
  scale_x_continuous(breaks = gap_years) +
  scale_y_log10()
```



Now the y-axis values are rescaled, and the scale break labels tell us that it is nonlinear.

We can add a layer of points to make this clearer:

```
ggplot(data = gap_mini3,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1) +
  scale_x_continuous(breaks = gap_years) +
  scale_y_log10() +
  geom_point()
```



First subset `gapminder` to only the rows containing data for **Uganda:**

Now, use **gap_Uganda** to create a time series plot of population (**pop**) over time (**`year`**). Transform the y axis to a log scale, edit the scale breaks to **`gap_years`**, change the line color to `forestgreen` and the size to 1mm.

Next, we can change the text of the axis labels to be more descriptive, as well as add titles, subtitles, and other informative text to the plot.

Labeling with `labs()`

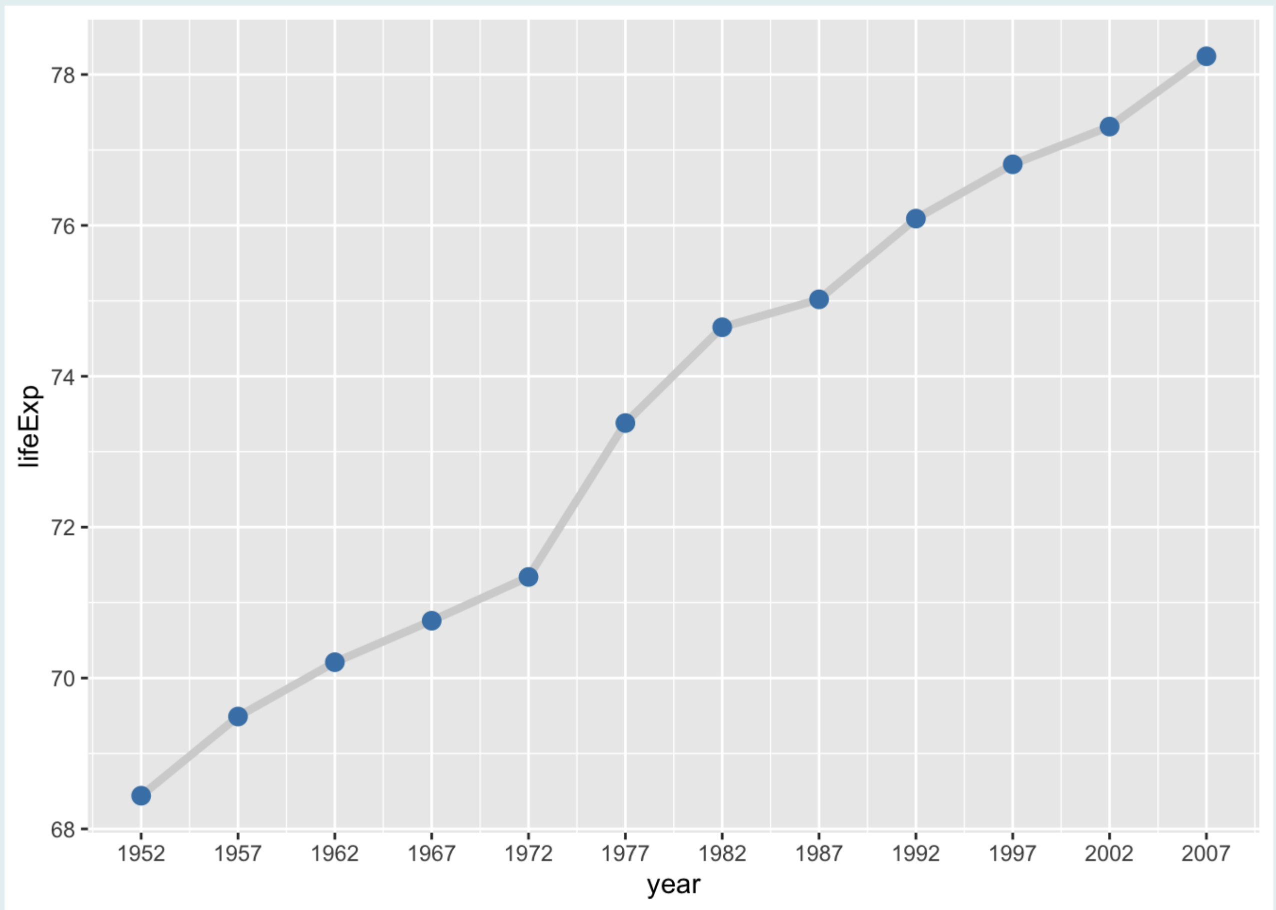
You can add labels to a plot with the `labs()` function. Arguments we can specify with the `labs()` function include:

- `title`: Change or add a title

- `subtitle`: Add subtitle below the title
- x: Rename *x*-axis
- y: Rename *y*-axis
- `caption`: Add caption below the graph

Let's start with this plot and start adding labels to it:

```
# Time series plot of life expectancy in the United States
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1.5,
            color = "lightgrey") +
  geom_point(size = 3,
             color = "steelblue") +
  scale_x_continuous(breaks = gap_years)
```

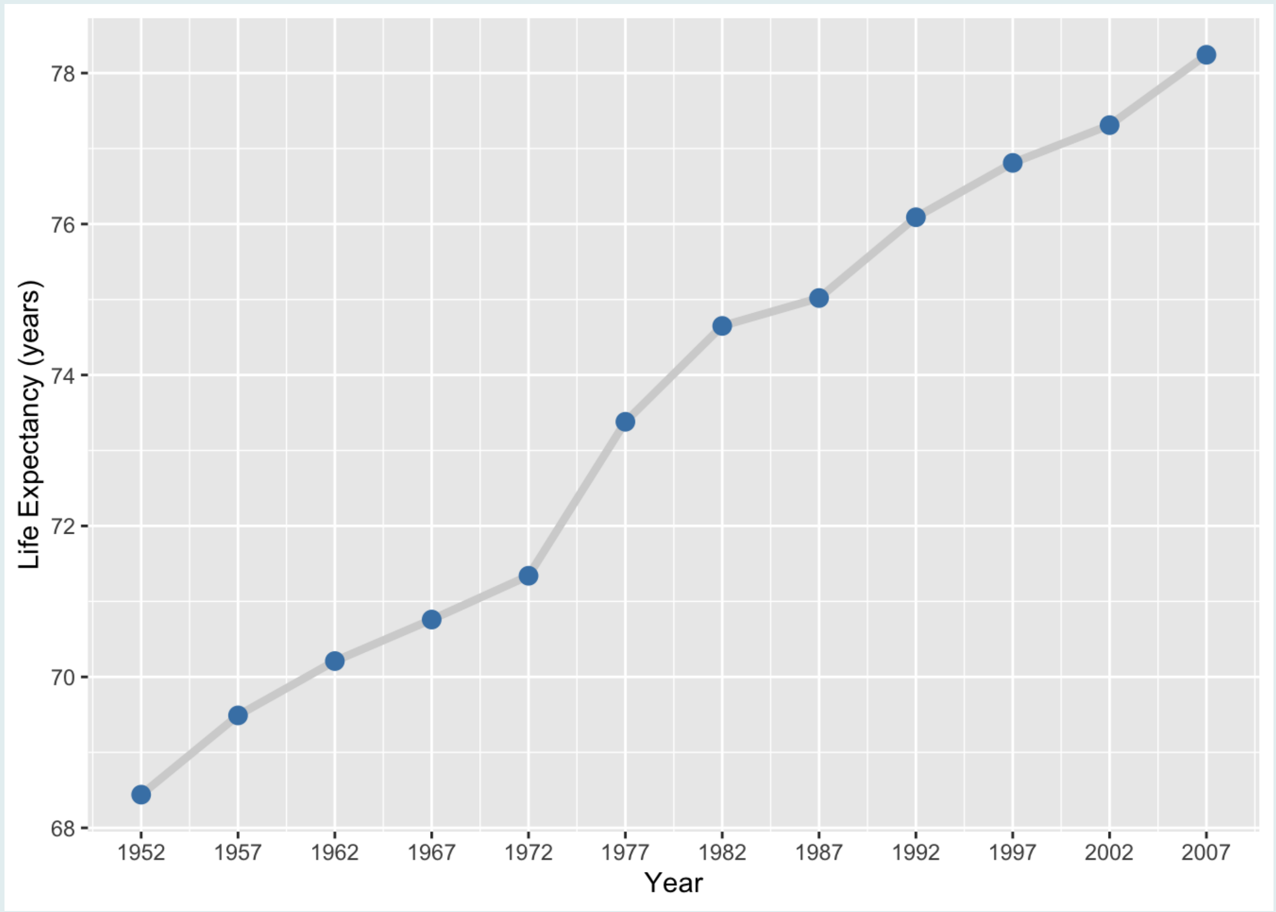


We add the `labs()` to our code using a + sign.

First we will add the x and y arguments to `labs()`, and change the axis titles from the default (variable name) to something more informative.

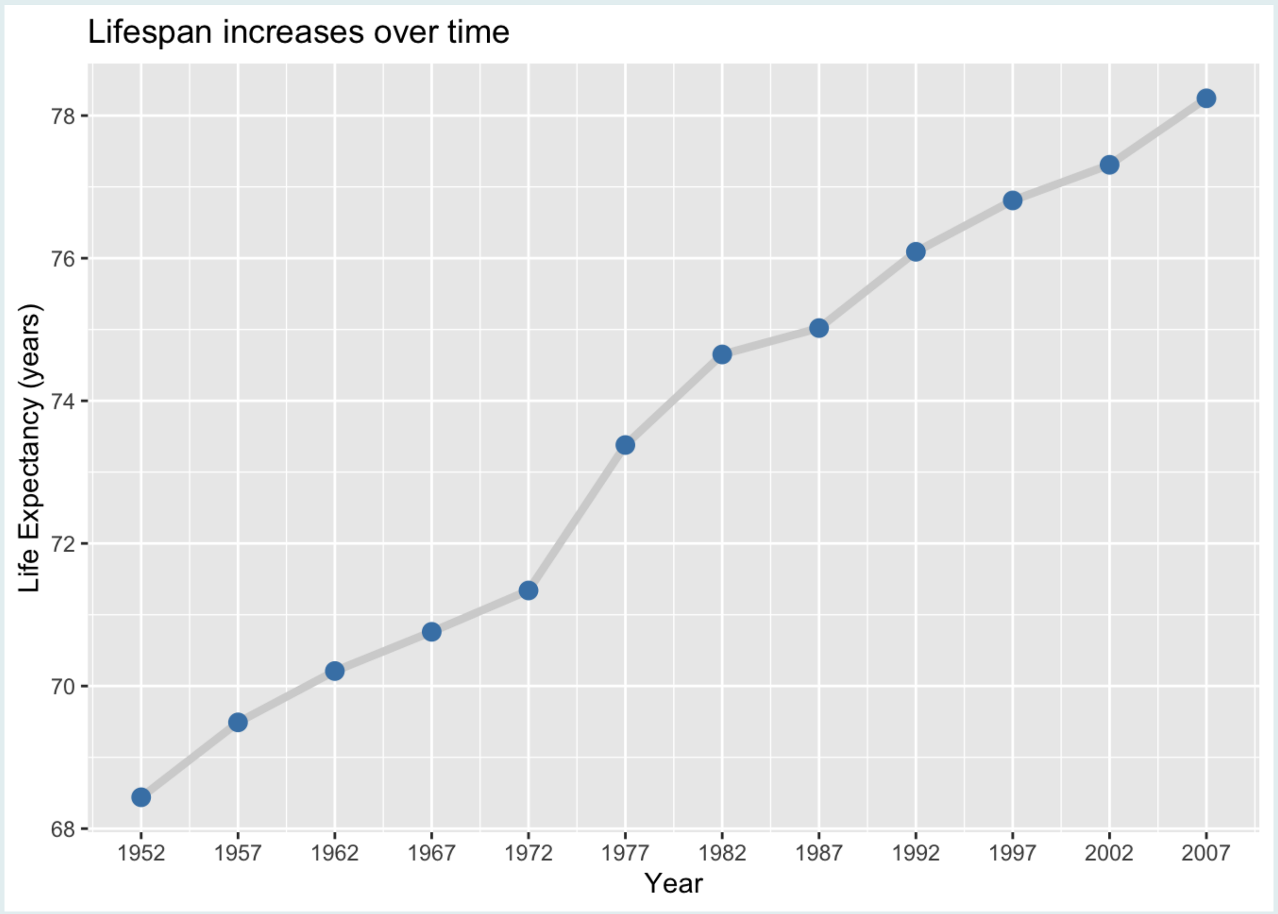
```
# Rename axis titles
ggplot(data = gap_US,
```

```
                 mapping = aes(x = year,                                    y =
lifeExp)) +            geom_line(size = 1.5,                           color =
"lightgrey") +            geom_point(size = 3,                           color =
"steelblue") +            scale_x_continuous(breaks = gap_years) +
labs(x = "Year",                y = "Life Expectancy (years)")
```



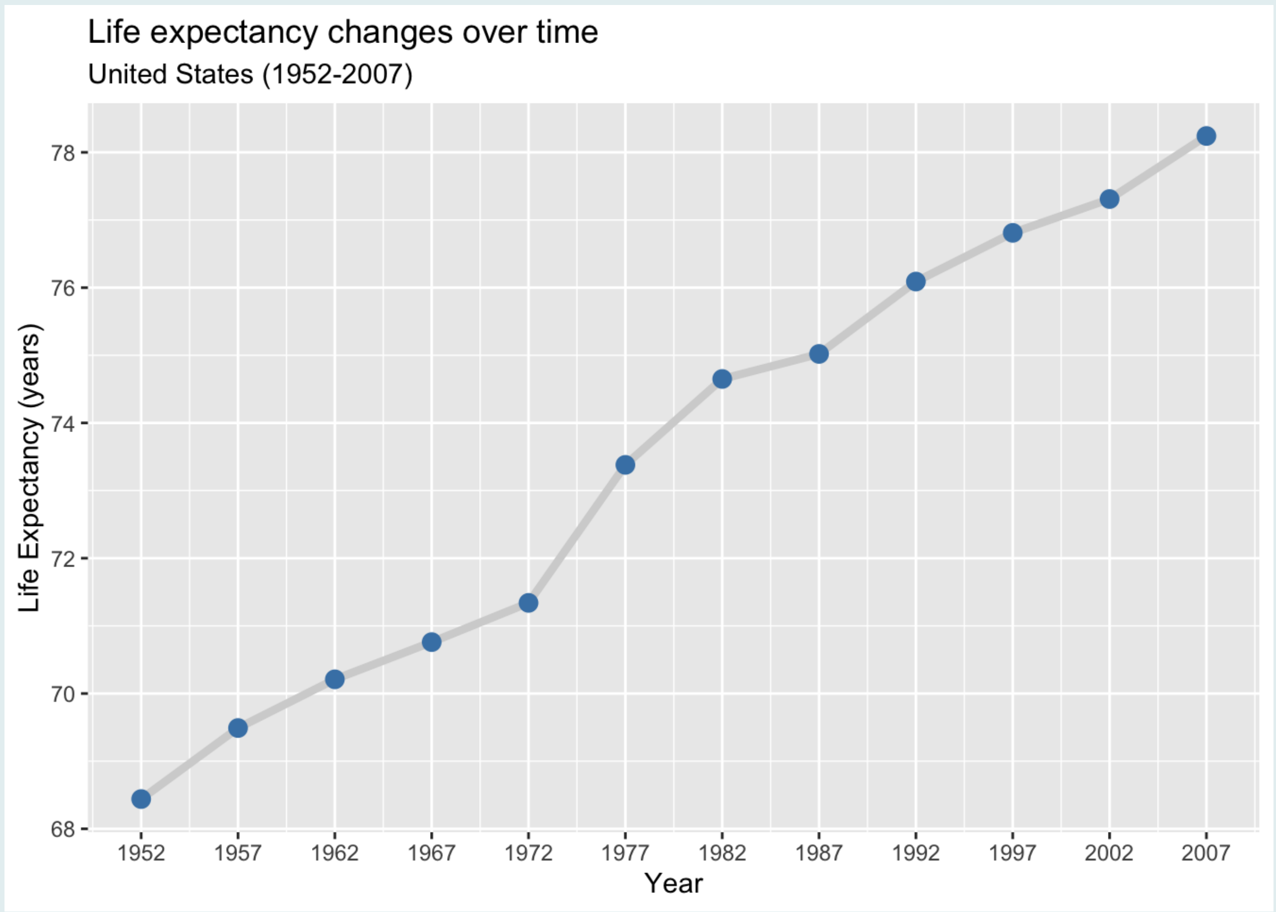
Next we supply a character string to the `title` argument to add large text above the plot.

```
# Add main title: "Lifespan increases over time"
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1.5,
            color = "lightgrey") +
  geom_point(size = 3,
             color = "steelblue") +
  scale_x_continuous(breaks = gap_years) +
  labs(x = "Year",
       y = "Life Expectancy (years)",
       title = "Lifespan increases over time")
```



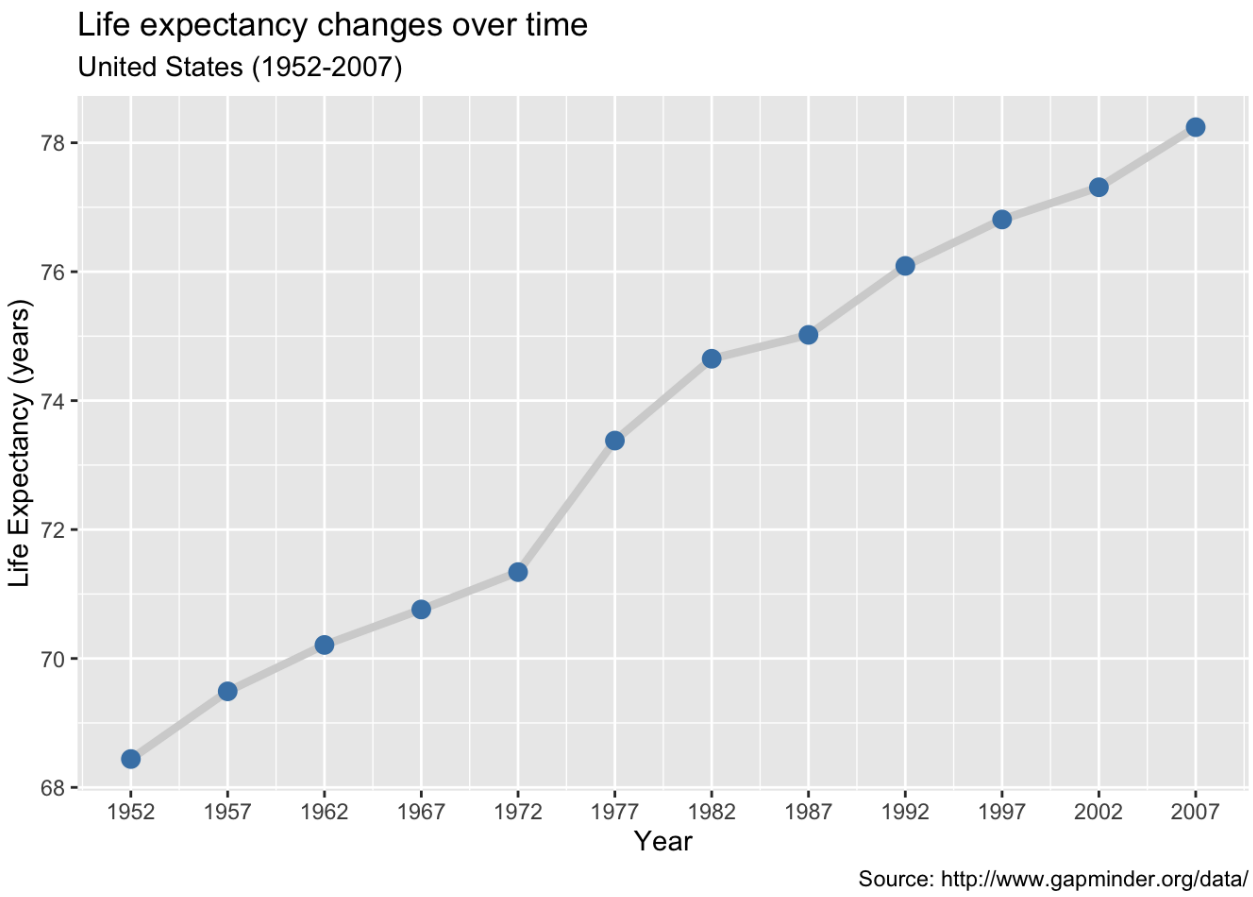
The `subtitle` argument adds smaller text below the main title.

```
# Add subtitle with location and time frame
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1.5,
            color = "lightgrey") +
  geom_point(size = 3,
             color = "steelblue") +
  scale_x_continuous(breaks = gap_years) +
  labs(x = "Year",
       y = "Life Expectancy (years)",
       title = "Life expectancy changes over time",
       subtitle = "United States (1952-2007)")
```



Finally, we can supply the caption argument to add small text to the bottom-right corner below the plot.

```
# Add caption with data source: "Source: www.gapminder.org/data"
ggplot(data = gap_US,
       mapping = aes(x = year,
                     y = lifeExp)) +
  geom_line(size = 1.5,
            color = "lightgrey") +
  geom_point(size = 3,
             color = "steelblue") +
  scale_x_continuous(breaks = gap_years) +
  labs(x = "Year",
       y = "Life Expectancy (years)",
       title = "Life expectancy changes over time",
       subtitle = "United States (1952-2007)",
       caption = "Source: http://www.gapminder.org/data/")
```



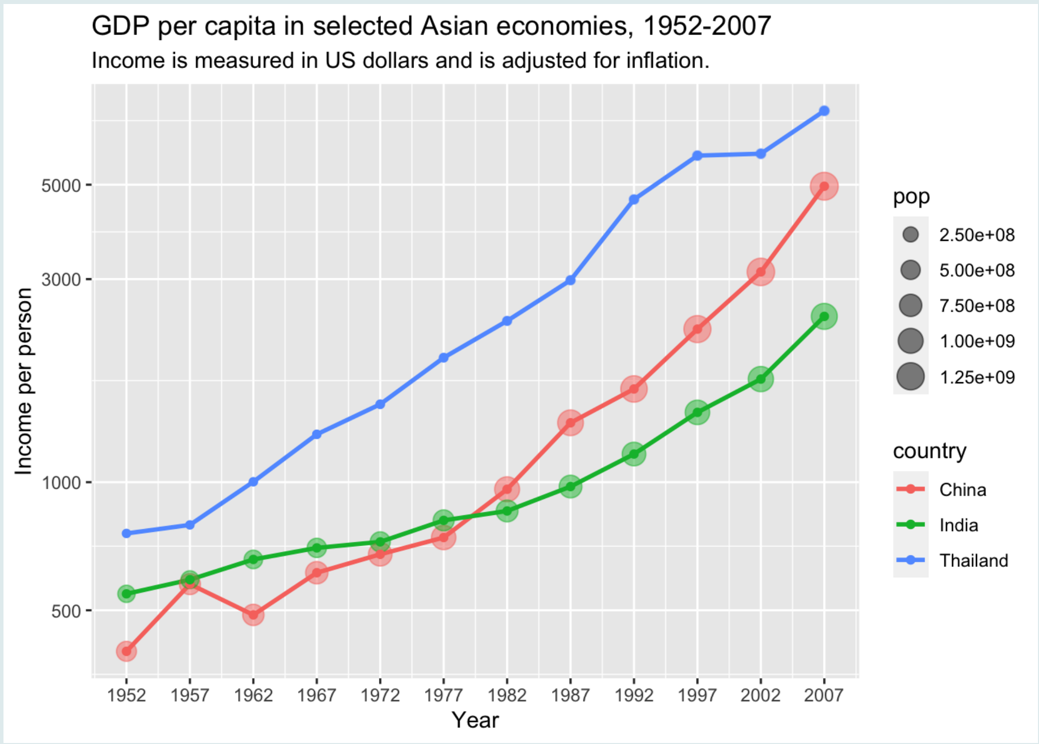
CHALLENGE

When you use an aesthetic mapping (e.g., color, size), {ggplot2} automatically scales the given aesthetic to match the data and adds a legend.

Here is an updated version of the `gap_mini3` plot we made before. We are changing the of points *and* lines by setting `aes(color = country)` in `ggplot()`. Then the `size` of *points* is scaled to the `pop` variable. See that `labs()` is used to change the title, subtitle, and axis labels.

```
ggplot(data = gap_mini2,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1) +
  geom_point(mapping = aes(size = pop),
                      alpha = 0.5) +
  geom_point() +
  scale_x_continuous(breaks = gap_years) +
  scale_y_log10()  +
  labs(x = "Year",
       y = "Income per person",
```

```
             title = "GDP per capita in selected Asian
economies, 1952-2007",                subtitle = "Income is
measured in US dollars and is adjusted for inflation.")
```



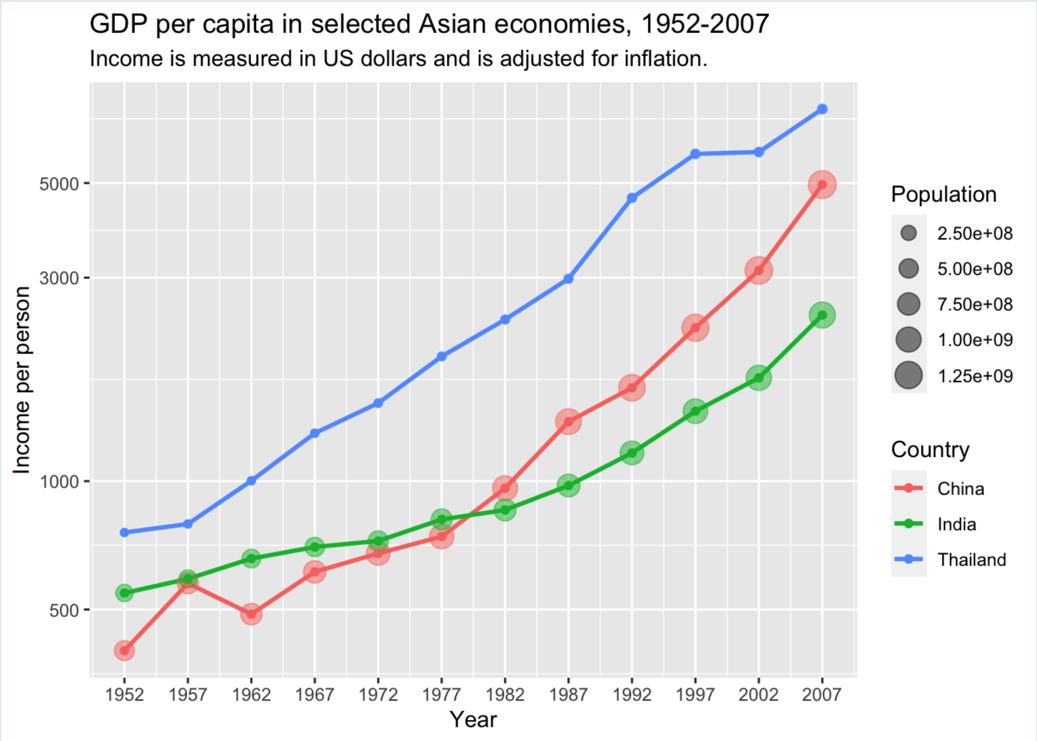
CHALLENGE

The default title of a legend or key is the name of the data variable it corresponds to. Here the color lengend is titled `country`, and the size legend is titled `pop`.

We can also edit these in `labs()` by setting `AES_NAME = "CUSTOM_TITLE"`.

```
          ggplot(data = gap_mini2,
                 mapping = aes(x = year,
                               y = gdpPercap,
                               color = country)) +
            geom_line(size = 1) +
            geom_point(mapping = aes(size = pop),
                                     alpha = 0.5) +
            geom_point() +
            scale_x_continuous(breaks = gap_years) +
            scale_y_log10()  +
            labs(x = "Year",
                 y = "Income per person",
                 title = "GDP per capita in selected Asian
economies, 1952-2007",
                 subtitle = "Income is measured in US dollars
and is adjusted for inflation.",
```

```
                color = "Country",                size =
"Population")
```



CHALLENGE

The same syntax can be used to edit legend titles for other aesthetic mappings. A common mistake is to use the variable name instead of the aesthetic name in `labs()`, so watch out for that!

PRACTICE (in RMD)

Create a time series plot comparing the trends in GDP per capita from 1952-2007 for **three countries** in the `gapminder` data frame.

First, subset the data to three countries of your choice:

Use **`my_gap_mini`** to create a plot with the following attributes:

- Add points to the line graph
- Color the lines and points by country
- Increase the width of lines to 1mm and the size of points to 2mm
- Make the lines 50% transparent

- Change the x-axis scale breaks to match years in dataset

Finally, add the following labels to your plot:

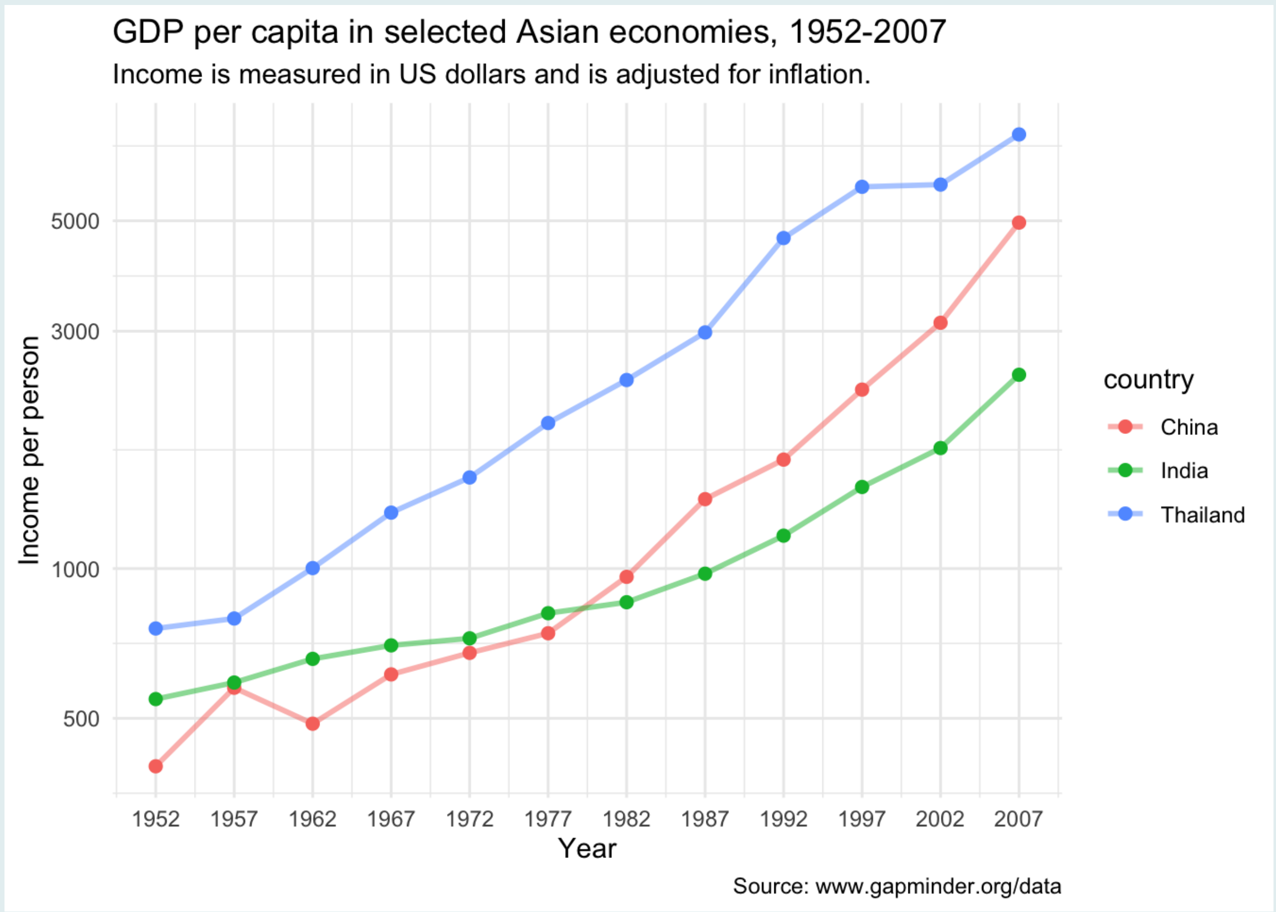
- Title: “Health & wealth of nations”
- Axis titles: “Longevity” and “Year”
- Capitalize legend title

(Note: subtitle requirement has been removed.)

Preview: Themes

In the next lesson, you will learn how to use `theme` functions.

```
# Use theme_minimal()
ggplot(data = gap_mini2,
       mapping = aes(x = year,
                     y = gdpPercap,
                     color = country)) +
  geom_line(size = 1, alpha = 0.5) +
  geom_point(size = 2) +
  scale_x_continuous(breaks = gap_years) +
  scale_y_log10() +
  labs(x = "Year",
       y = "Income per person",
       title = "GDP per capita in selected Asian economies, 1952–
2007",
       subtitle = "Income is measured in US dollars and is adjusted
for inflation.",
       caption = "Source: www.gapminder.org/data") +
  theme_minimal()
```



Wrap up

Line graphs, just like scatterplots, display the relationship between two numerical variables. When one of the two variables represents time, a line graph can be a more effective method of displaying relationship. Therefore, it is preferred to use line graphs over scatterplots when the variable on the x-axis (i.e., the explanatory variable) has an inherent ordering, such as some notion of time, like the `year` variable of `gapminder`.

We can change scale breaks and transform scales to make plots easier to read, and label them to add more information.

Hope you found this lesson helpful!

Contributors

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ADMIN TEAM

GRAPH Courses Administration Team
The GRAPH Courses team is building epidemiological training courses to enhance disease surveillance and data science for public health across the globe

References

Some material in this lesson was adapted from the following sources:

- Ismay, Chester, and Albert Y. Kim. 2022. *A ModernDive into R and the Tidyverse*. https://moderndive.com/.
- Kabacoff, Rob. 2020. *Data Visualization with R*. https://rkabacoff.github.io/datavis/.
- https://www.rebeccabarter.com/blog/2017-11-17-ggplot2_tutorial/