Data visualization with ggplot2

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Section 1: Overview

No questions or code given for this section

Section 2: Background

Q. For which phases is data visualization important in our scientific workflows?

All of the above

Q.True or False? The ggplot2 package comes already installed with R?

False

Section 3: Getting Organized

No questions or code given for this section

Section 4: Common Plot Types

Q. Which plot types are typically NOT used to compare distributions of numeric variables?

Network graphs

Q. Which statement about data visualization with ggplot2 is incorrect?

ggplot2 is the only way to create plots in R

Section 5: Creating Scatter Plots

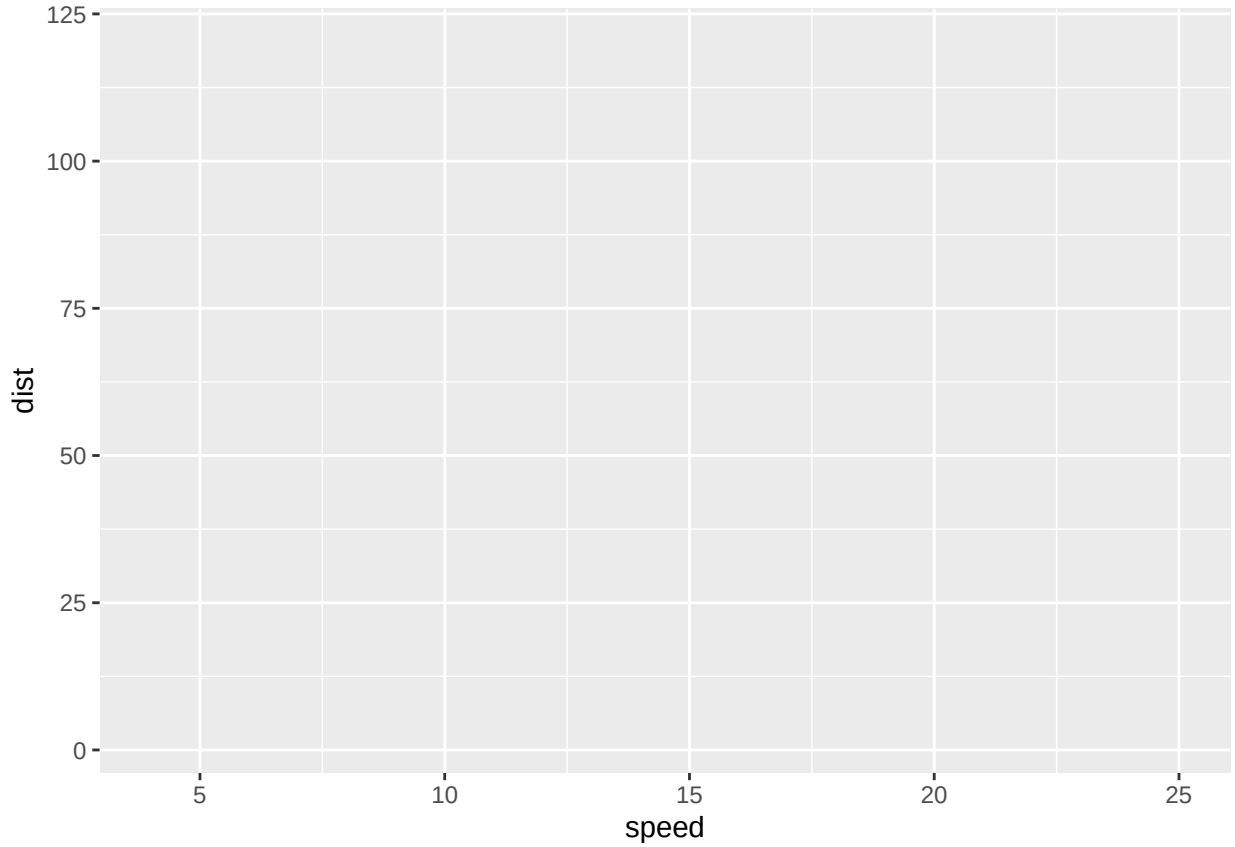
Specifying a dataset with ggplot()

```
# install.packages("ggplot2") ## un-comment if necessary
library(ggplot2)
ggplot(cars)
```

Specifying aesthetic mappings with aes()

Now set the x and y axis coordinates

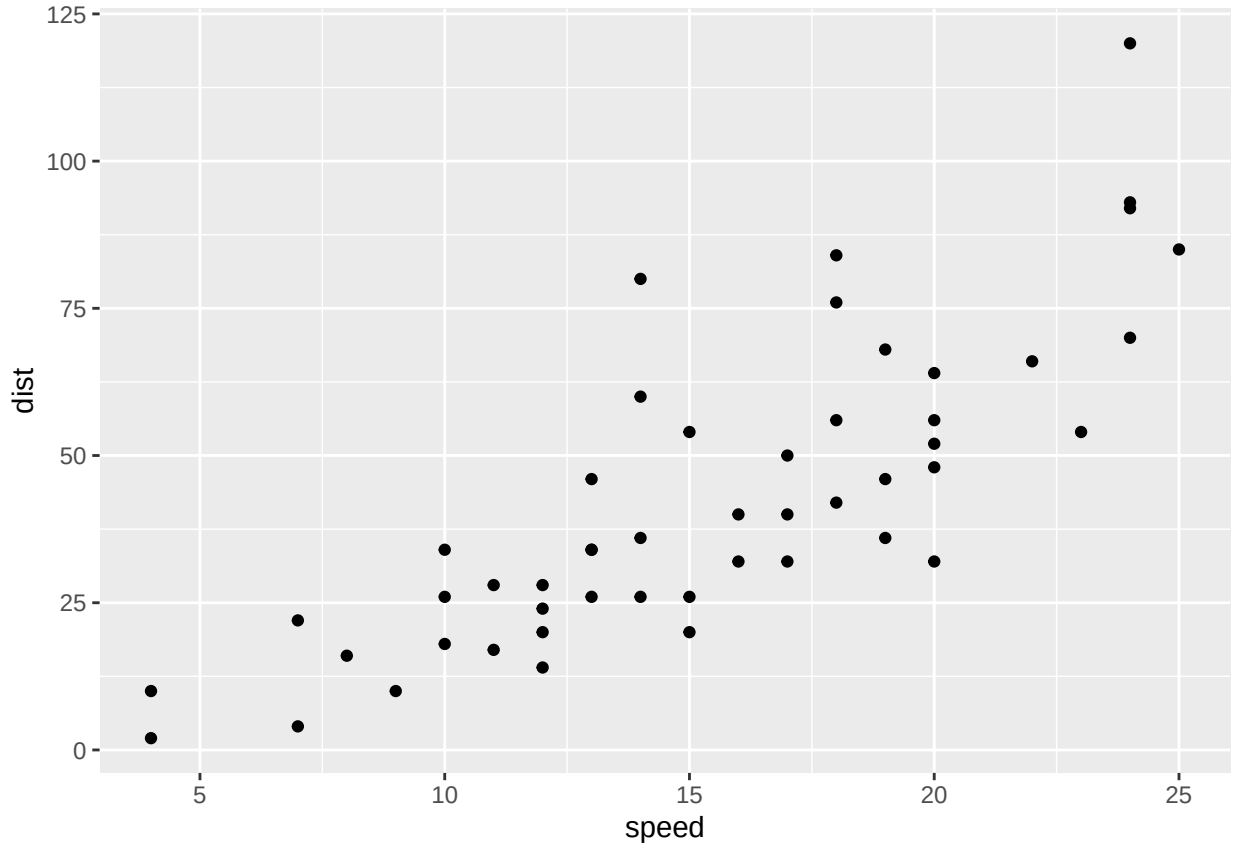
```
ggplot(cars) +
  aes(x=speed, y=dist)
```



Specifying a geom layer with geom_point()

Add geom_point() to get a point layer

```
ggplot(cars) +
  aes(x=speed, y=dist) +
  geom_point()
```



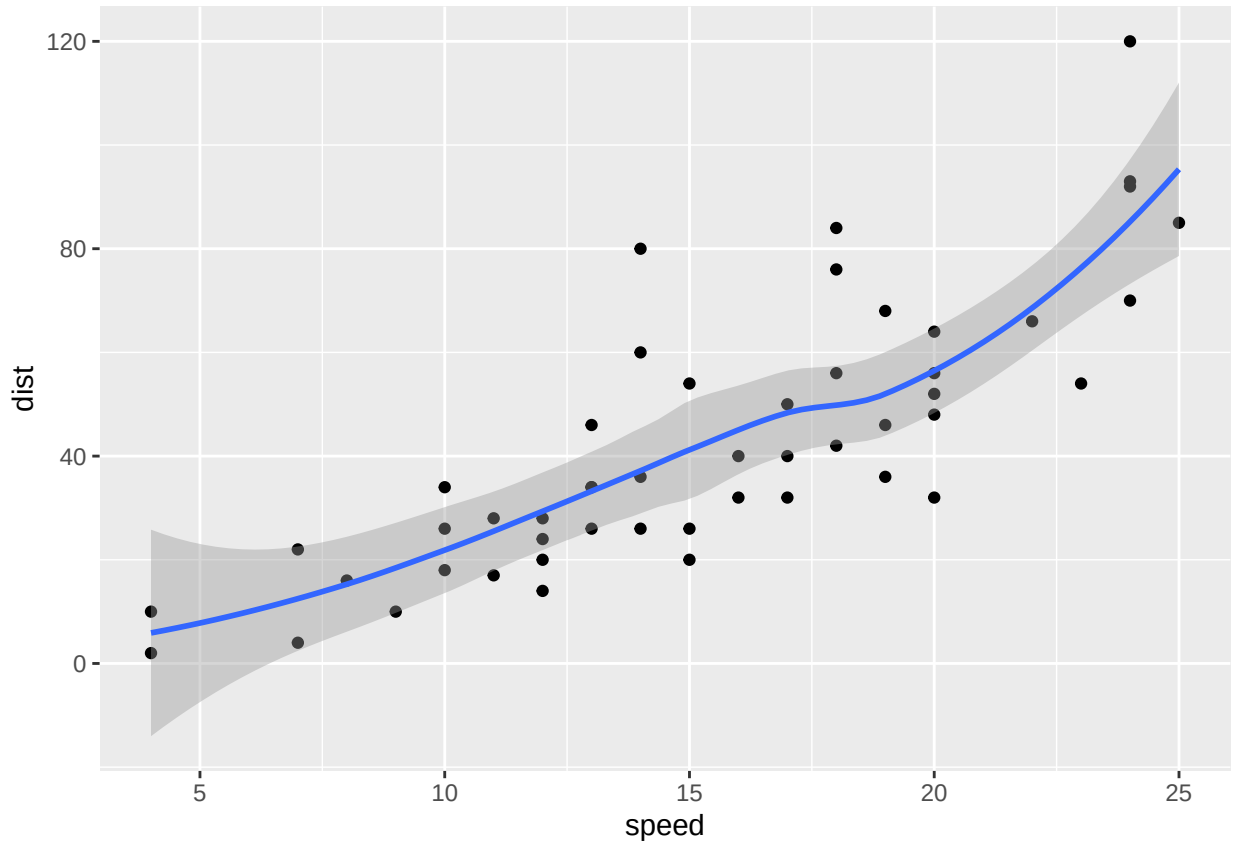
Q. Which geometric layer should be used to create scatter plots in ggplot2?

geom_point()

Q. In your own RStudio can you add a trend line layer to help show the relationship between the plot variables with the geom_smooth() function?

```
library(ggplot2)
p <- ggplot(data=cars) +
  aes(x=speed, y=dist) +
  geom_point()

p + geom_smooth()
```

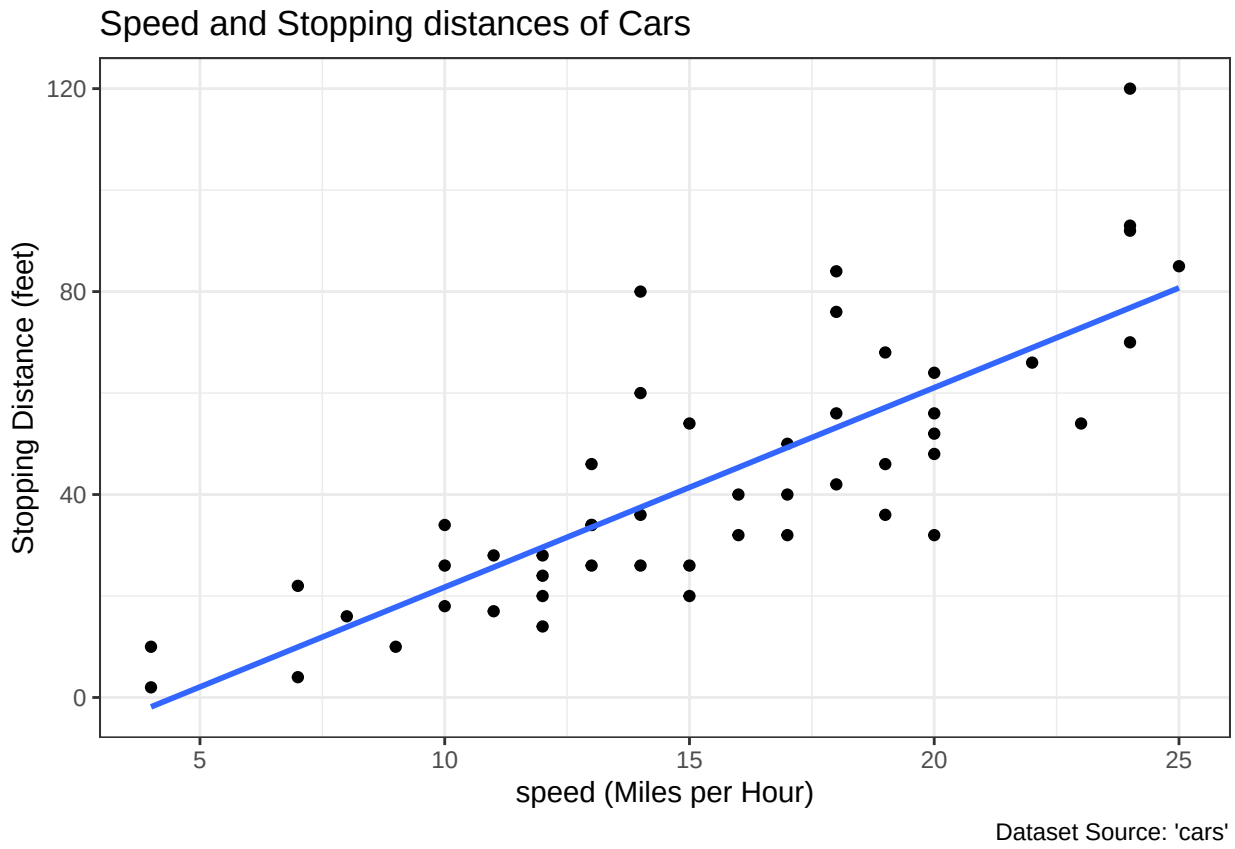
```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



Q. Can you finish this plot by adding various label annotations with the labs() function and changing the plot look to a more conservative "black & white" theme by adding the theme_bw() function:

```
p + labs(title = "Speed and Stopping distances of Cars",
         x = "speed (Miles per Hour)",
         y = "Stopping Distance (feet)",
         caption = "Dataset Source: 'cars'") +
  geom_smooth(method = "lm", se = FALSE) +
  theme_bw()
```

```
## `geom_smooth()` using formula 'y ~ x'
```



Adding more plot aesthetics through aes()

```
url <- "https://bioboot.github.io/bimm143_S20/class-material/up_down_expression.txt"
genes <- read.delim(url)
head(genes)
```

```
##         Gene Condition1 Condition2      State
## 1      A4GNT -3.6808610 -3.4401355 unchanging
## 2       AAAS  4.5479580  4.3864126 unchanging
## 3      AASDH  3.7190695  3.4787276 unchanging
## 4       AATF  5.0784720  5.0151916 unchanging
## 5       AATK  0.4711421  0.5598642 unchanging
## 6 AB015752.4 -3.6808610 -3.5921390 unchanging
```

Q. Use the nrow() function to find out how many genes are in this dataset. What is your answer?

There are 5196 genes in this dataset.

```
nrow(genes)
```

```
## [1] 5196
```

Q. Use the colnames() function and the ncol() function on the genes data frame to find out what the column names are (we will need these later) and how many columns there are. How many columns did you find?

There are 4 columns.

```
colnames(genes)
```

```
## [1] "Gene"       "Condition1" "Condition2" "State"
```

```
ncol(genes)
```

```
## [1] 4
```

Q. Use the table() function on the State column of this data.frame to find out how many 'up' regulated genes there are. What is your answer?

There are 127 up-regulated genes.

```
table(genes$State)
```

```
##
##       down unchanging         up
##         72       4997        127
```

Q. Using your values above and 2 significant figures. What fraction of total genes is up-regulated in this dataset?

The fraction of the total genes that are up-regulated in this data set rounded at two significant figures is 2.44

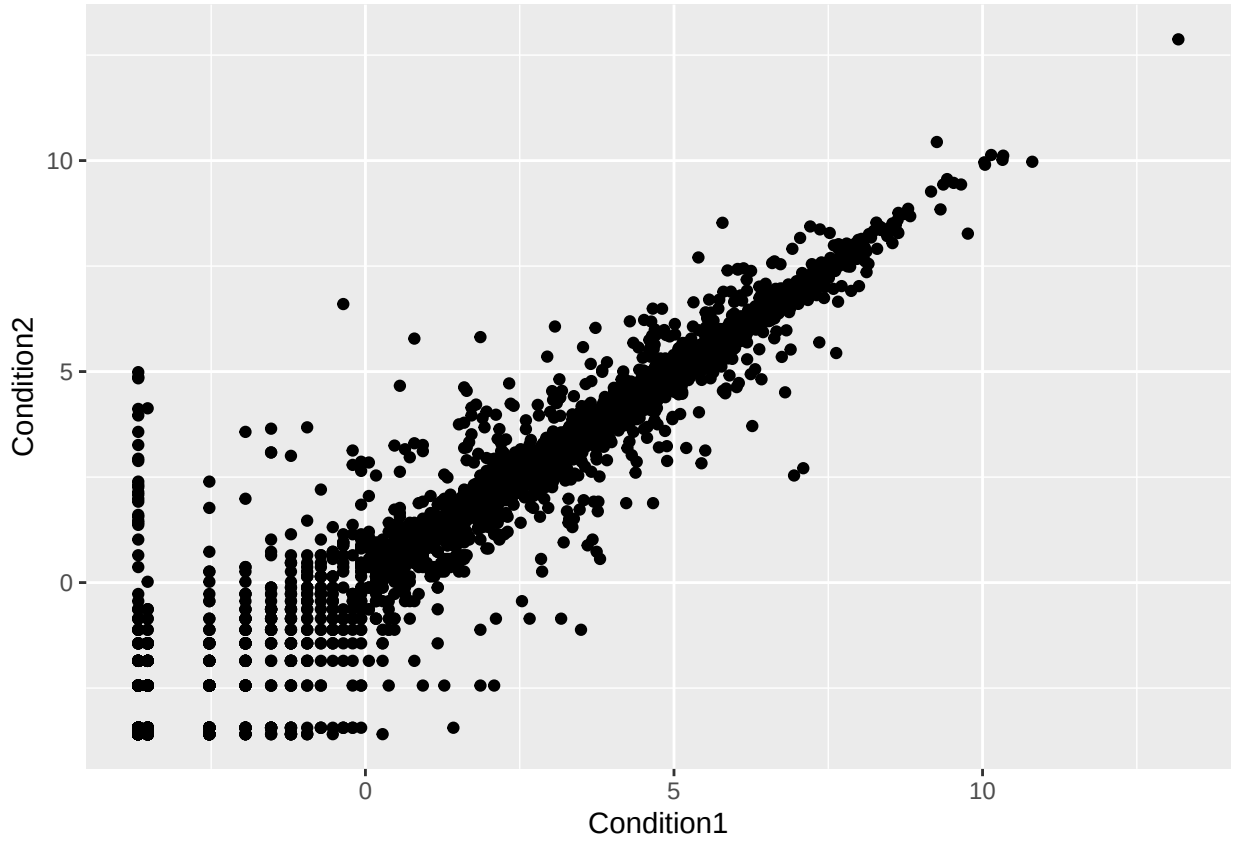
```
q <- table(genes$State)/nrow(genes)*100
round(q, 2)
```

```
##
##       down unchanging         up
##       1.39      96.17       2.44
```

Q. Complete the code below to produce the following plot

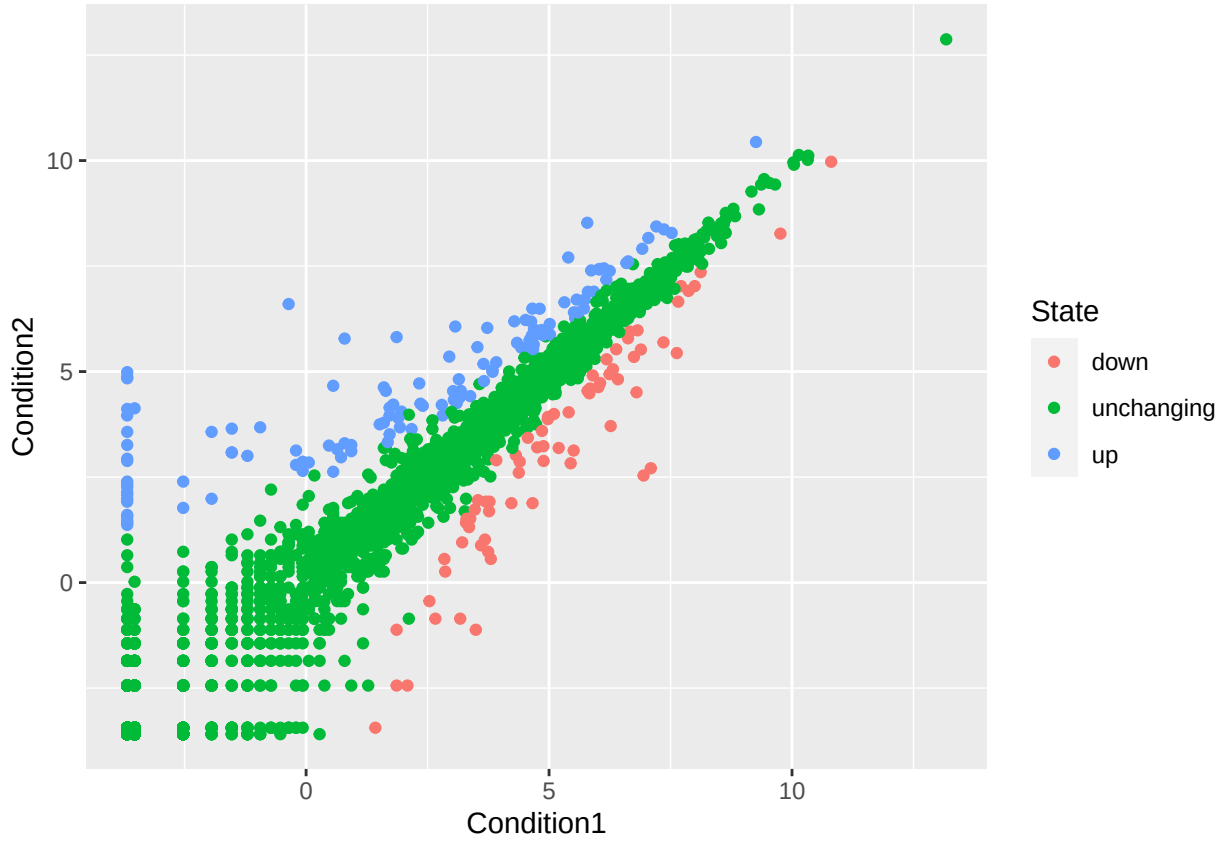
The completed code is:

```
ggplot(genes) +
  aes(x=Condition1, y=Condition2) +
  geom_point()
```



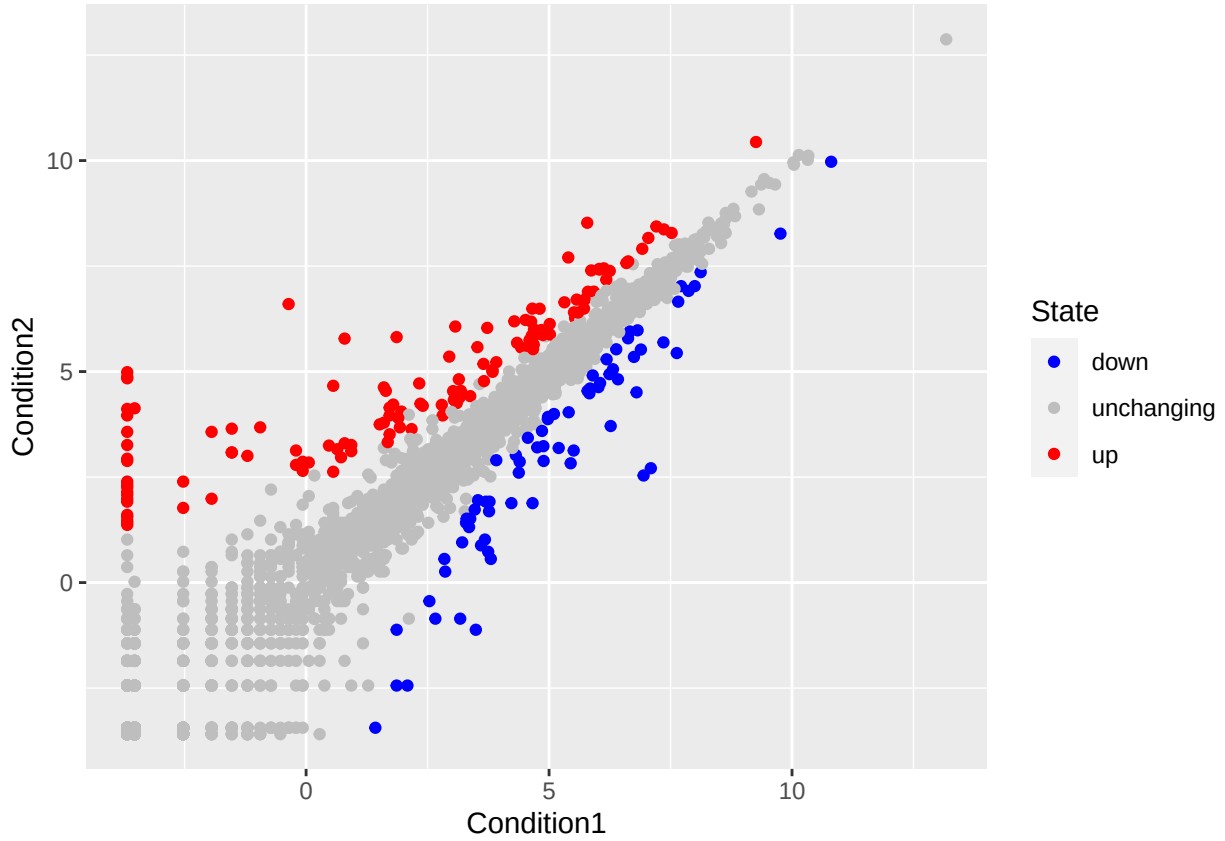
Map the state column to point color

```
p <- ggplot(genes) +
    aes(x=Condition1, y=Condition2, col=State) +
    geom_point()
p
```



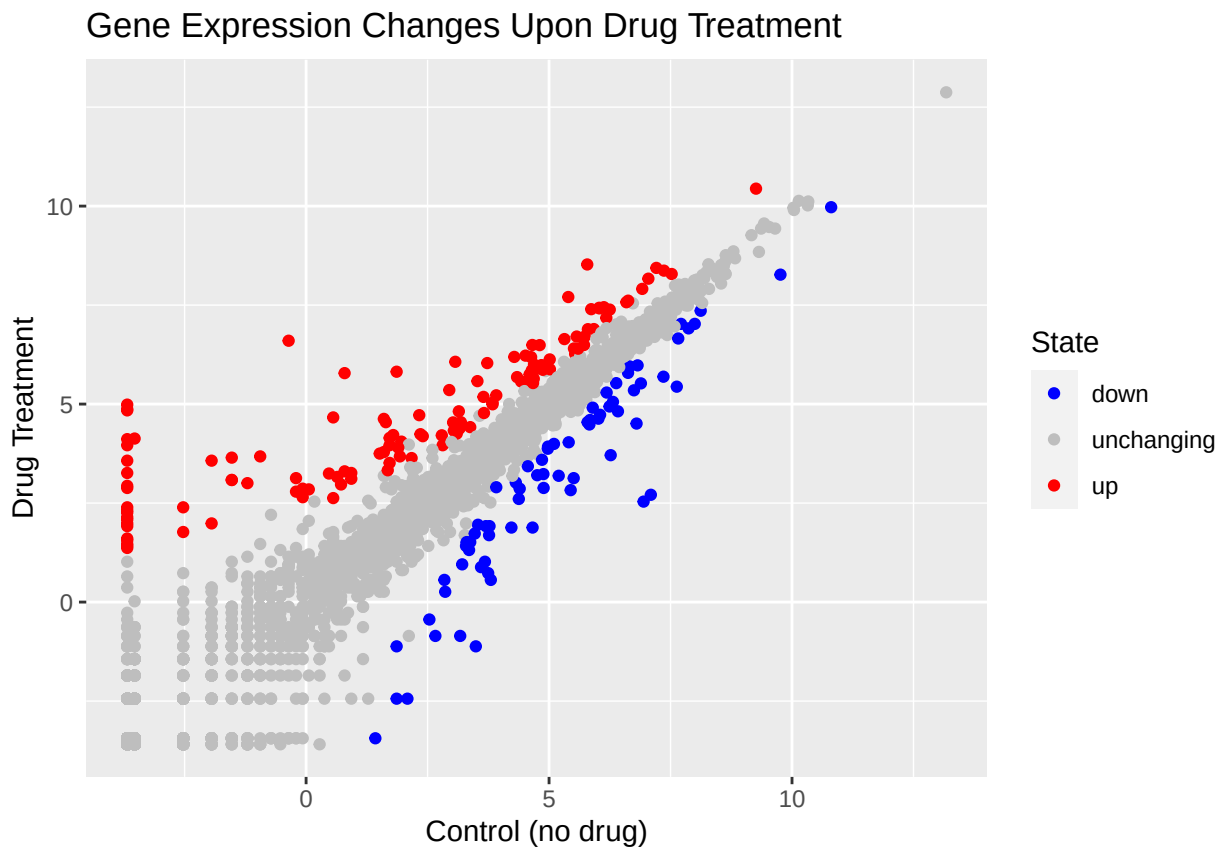
Change the colors to blue, gray, red.

```
p + scale_colour_manual( values=c("blue","gray","red") )
```



Q. Nice, now add some plot annotations to the p object with the labs() function so your plot looks like the following:

```
r <- ggplot(genes) +
  aes(x=Condition1, y=Condition2, colour=State) +
  geom_point()
r + scale_colour_manual(values = c("blue", "gray", "red")) +
  labs(title = "Gene Expression Changes Upon Drug Treatment",
       x = "Control (no drug)",
       y = "Drug Treatment")
```



Section 6 OPTIONAL: Going Further

```
# install.packages("gapminder")  ## un-comment to install if necessary
# install.packages("dplyr")  ## un-comment to install if necessary
library(gapminder)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

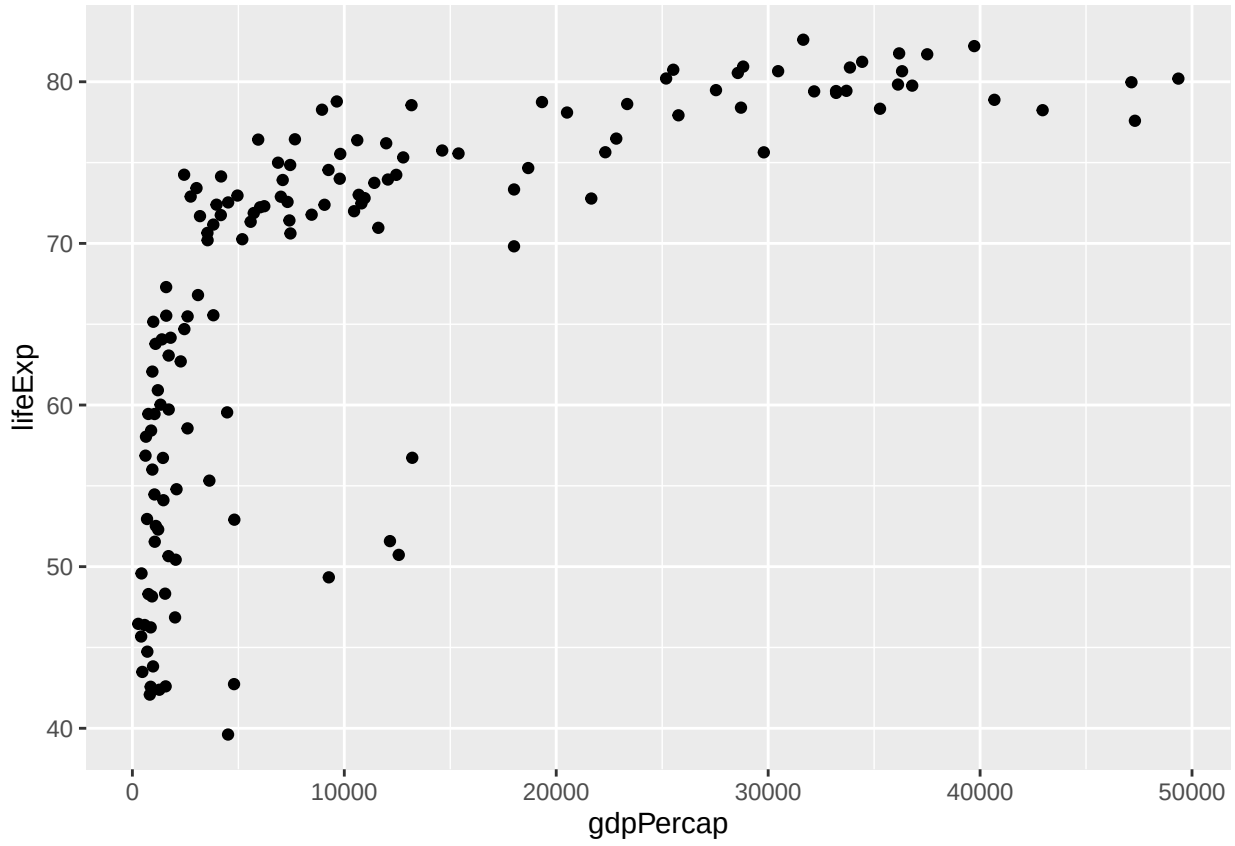
```
gapminder_2007 <- gapminder%>%filter(year==2007)
```

Let's consider the gapminder_2007 dataset which contains the variables GDP per capita gdpPercap and life expectancy lifeExp for 142 countries in the year 2007

Q. Complete the code below to produce a first basic scatter plot of this gapminder_2007 dataset:

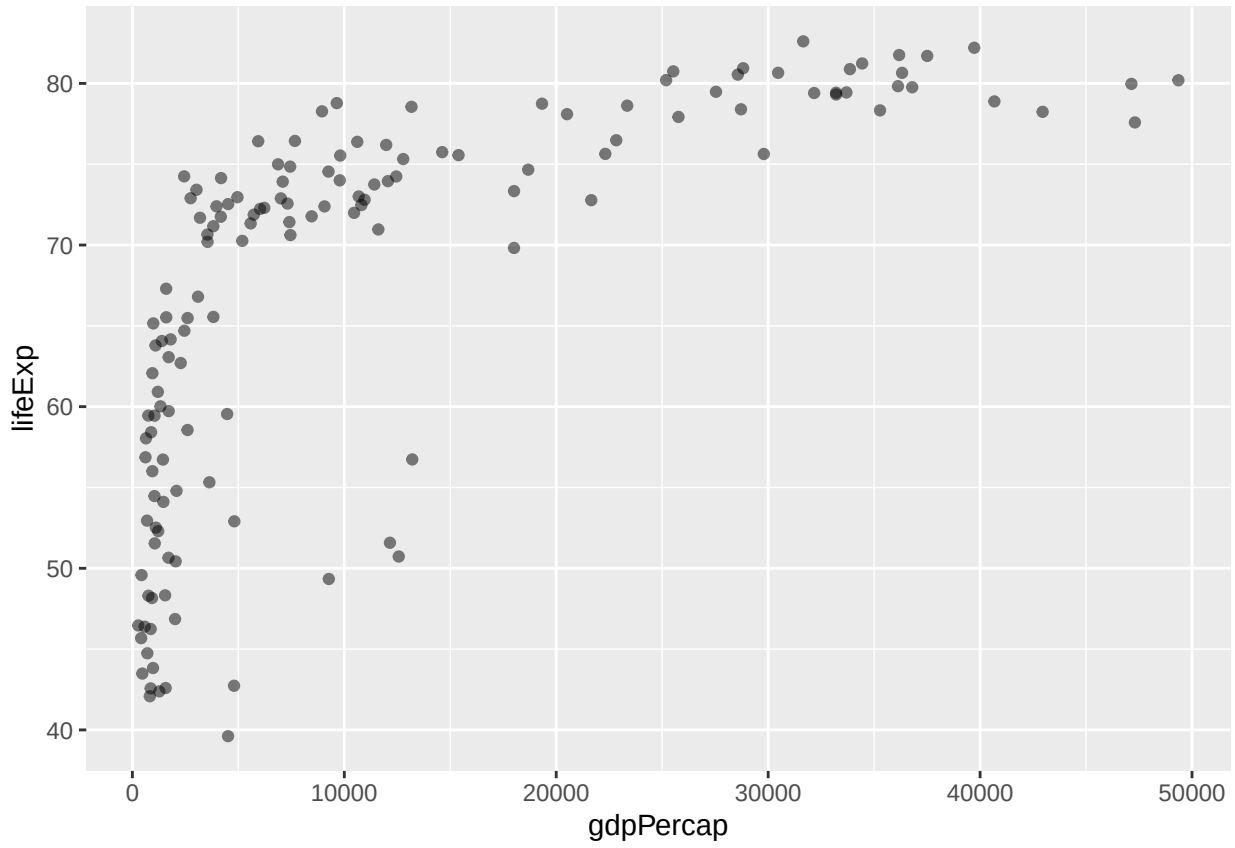
The completed code is:

```
ggplot(gapminder_2007) +
  aes(x=gdpPercap, y=lifeExp) +
  geom_point()
```



Now make the points slightly transparent (set alpha=0.5)

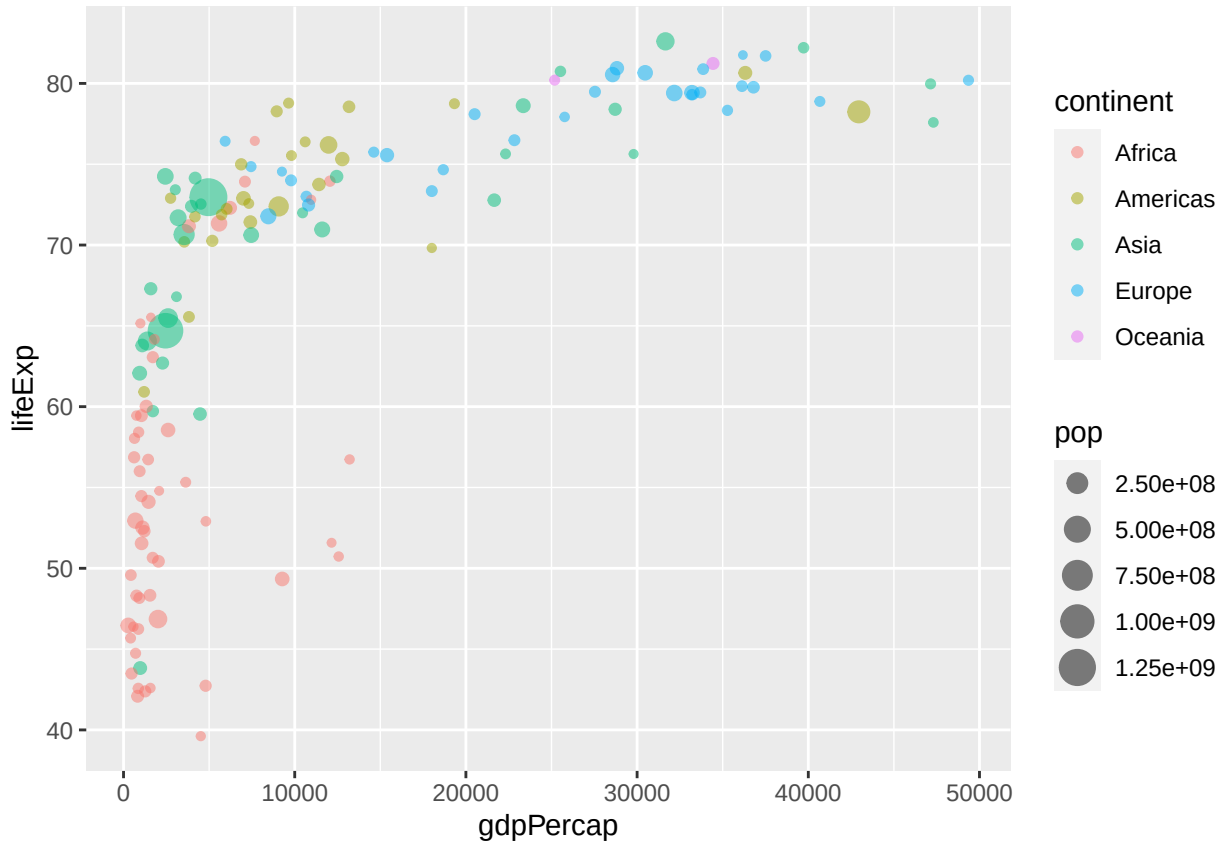
```
ggplot(gapminder_2007) +
  aes(x=gdpPercap, y=lifeExp) +
  geom_point(alpha=0.5)
```



Adding more variables to aes()

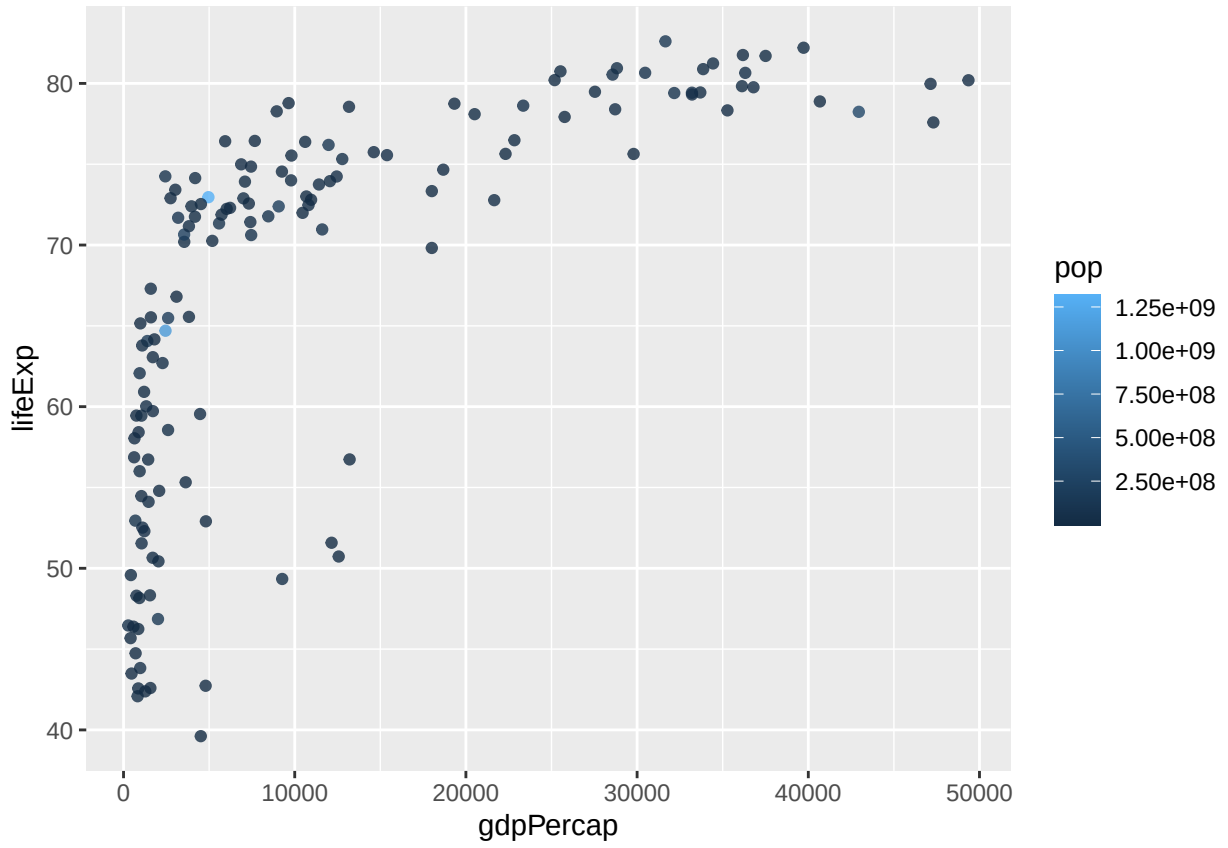
Now map the continent variable to the point color aesthetic and population through the point size argument of aes().

```
ggplot(gapminder_2007) +
  aes(x=gdpPercap, y=lifeExp, color=continent, size=pop) +
  geom_point(alpha=0.5)
```



Now change the plot so that the points are colored by the numeric variable: population.

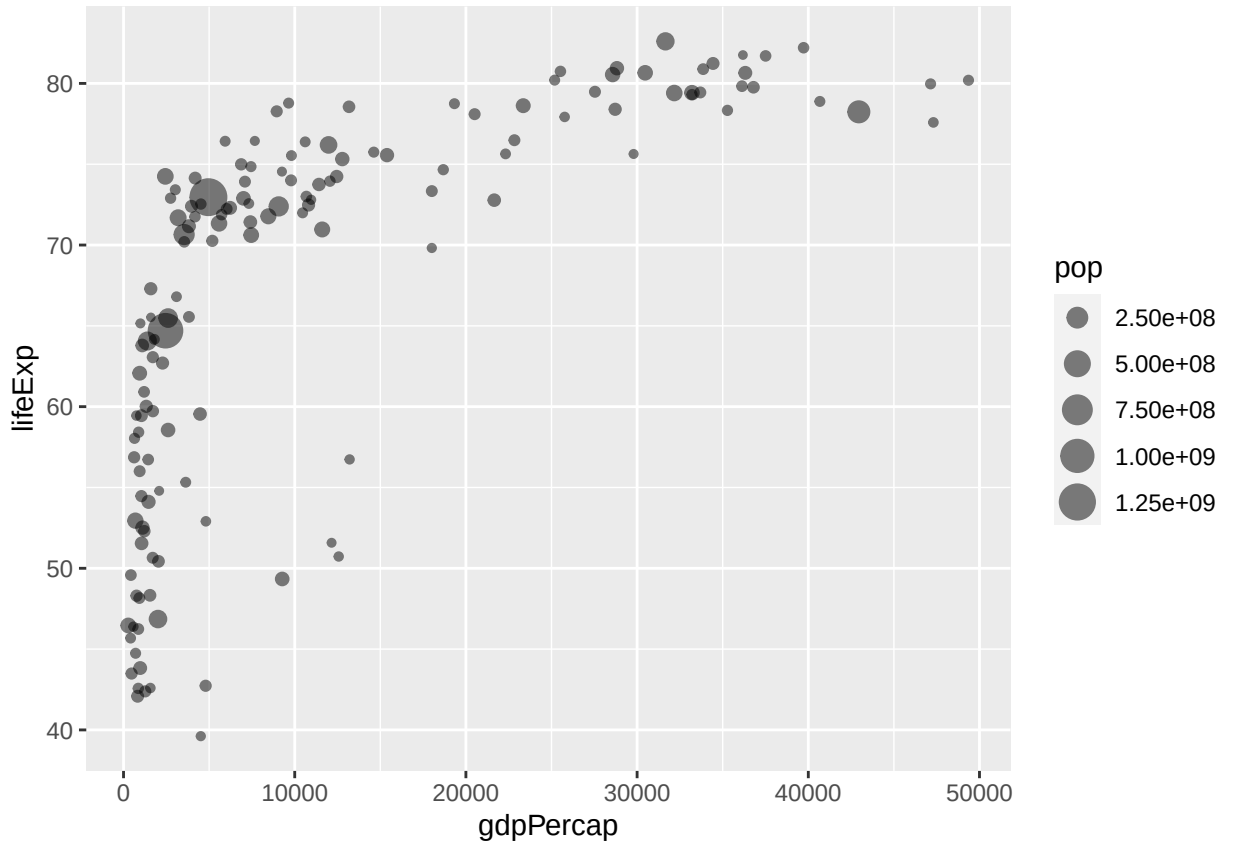
```
ggplot(gapminder_2007) +
  aes(x = gdpPercap, y = lifeExp, color = pop) +
  geom_point(alpha=0.8)
```



Adjusting point size

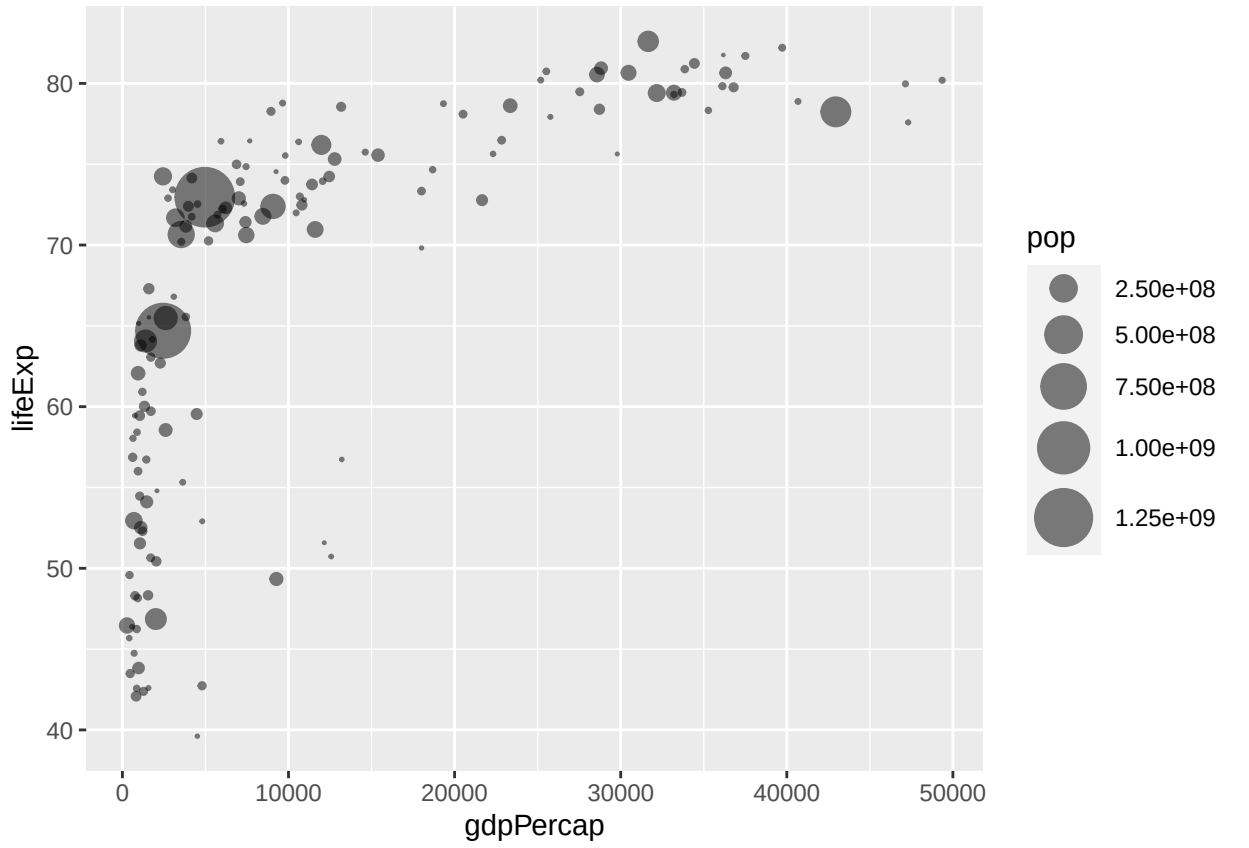
Now change the plot so that point size is based on the population of each country.

```
ggplot(gapminder_2007) +
  aes(x = gdpPercap, y = lifeExp, size = pop) +
  geom_point(alpha=0.5)
```



Improve the plot to reflect the actual population differences by the point size. Use scale_size_area() instead.

```
ggplot(gapminder_2007) +
  geom_point(aes(x = gdpPercap, y = lifeExp,
                 size = pop), alpha=0.5) +
  scale_size_area(max_size = 10)
```



Q. Can you adapt the code you have leaqrned thus far to reproduce our gapminder scatter plot for the year 1957? What do you notice abouyt this plot is it easy to compare with the one for 2007?

Steps to produce your 1957 plot should include

Use dplyr to filter the gapmider dataset to include only the year 1957 (check above for how we did this for 2007).

Save your result as gapminder_1957.

Use the ggplot() function and specify the gapminder_1957 dataset as input

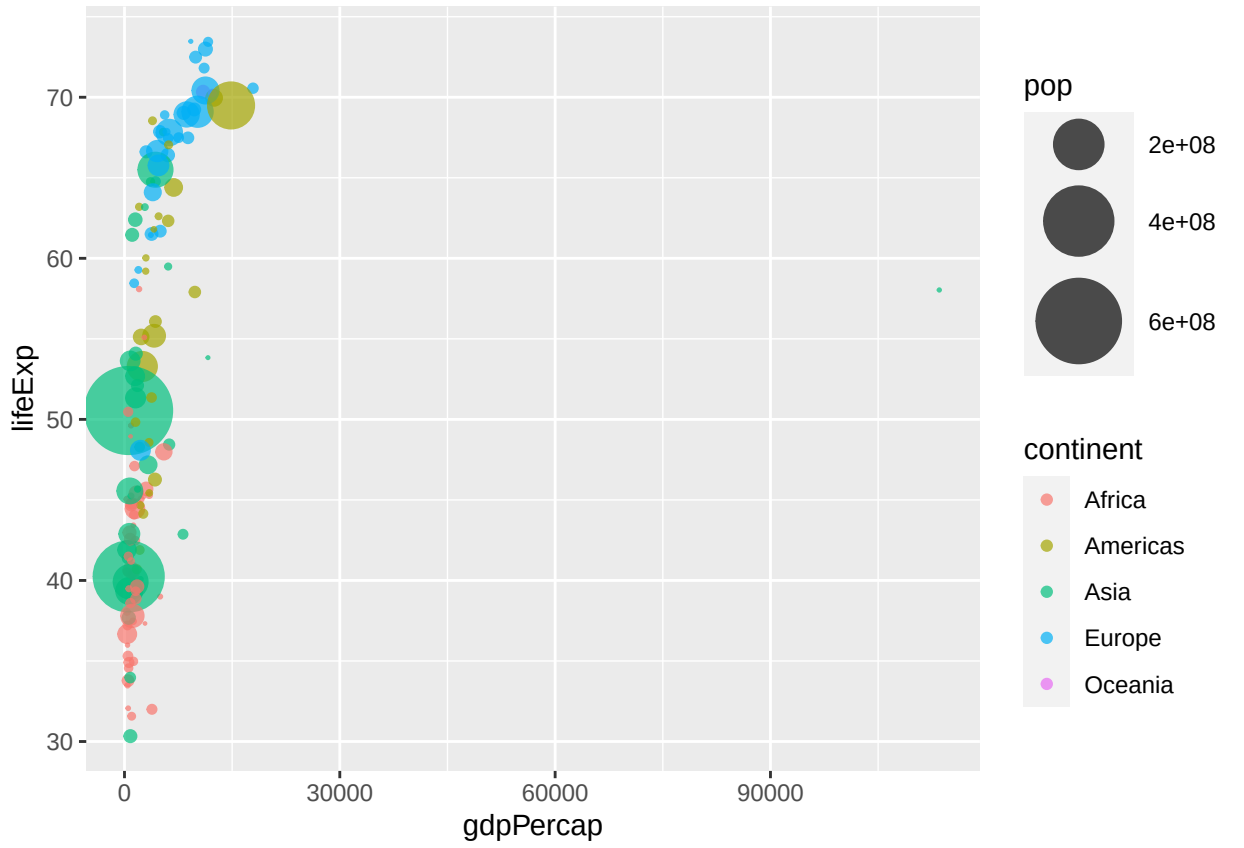
Add a geom_point() layer to the plot and create a scatter plot showing the GDP per capita gdpPercap on the x-axis and the life expectancy lifeExp on the y-axis

Use the color aesthetic to indicate each continent by a different color

Use the size aesthetic to adjust the point size by the population pop

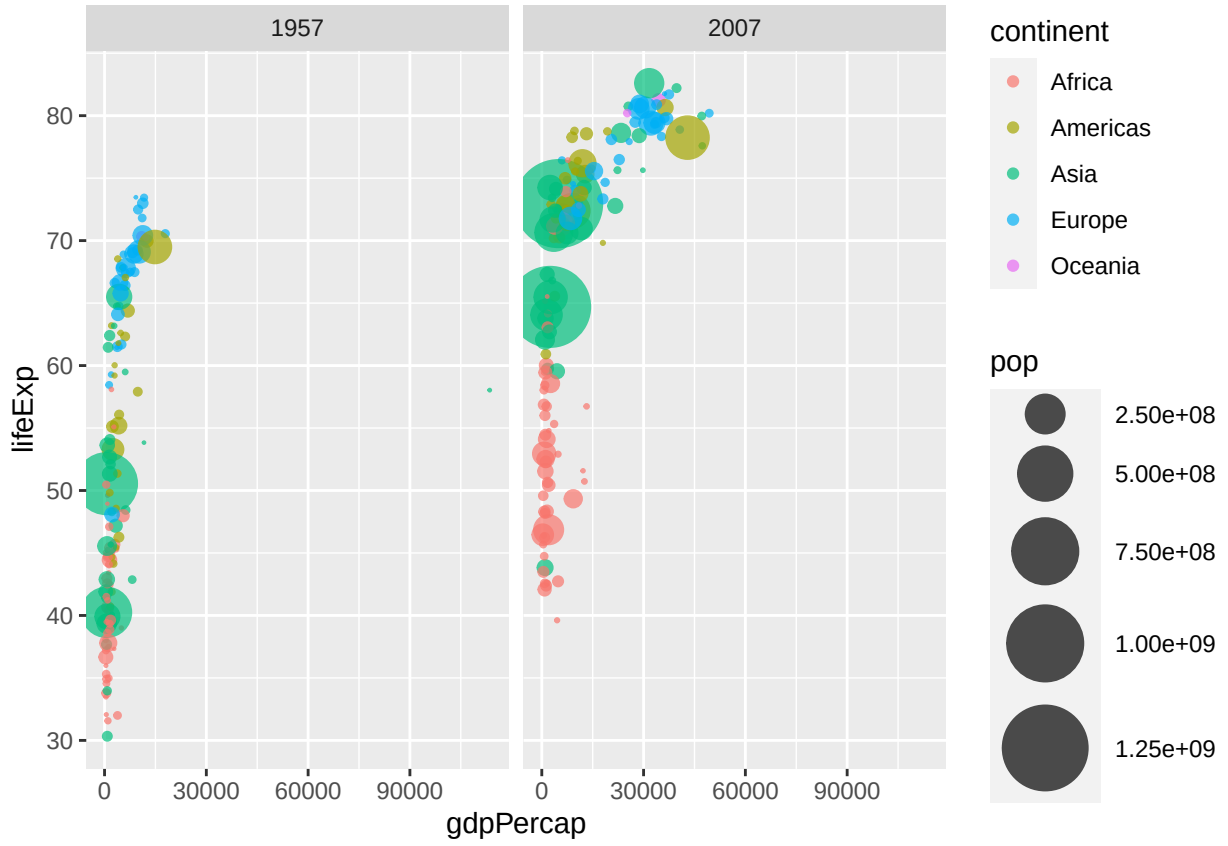
Use scale_size_area() so that the point sizes reflect the actual population differences and set the max_size of each point to 15 -Set the opacity/transparency of each point to 70% using the alpha=0.7 parameter

```
gapminder_1957 <- gapminder%>%filter(year==1957)
ggplot(gapminder_1957) +
  aes(x=gdpPercap, y=lifeExp, colour=continent, size=pop) +
  scale_size_area(max_size = 15) +
  geom_point(alpha=0.7)
```



Q. Do the same steps above but include 1957 and 2007 in your input dataset for ggplot(). You should now include the layer facet_wrap(~year) to produce the following plot:

```
gapminder_1957_2007 <- gapminder%>%filter(year==1957 | year==2007)
ggplot(gapminder_1957_2007) +
  aes(x=gdpPercap, y=lifeExp, colour=continent, size=pop) +
  scale_size_area(max_size = 15) +
  geom_point(alpha=0.7) +
  facet_wrap(~year)
```



Section 7 OPTIONAL: Bar Charts

Introduction to bar charts

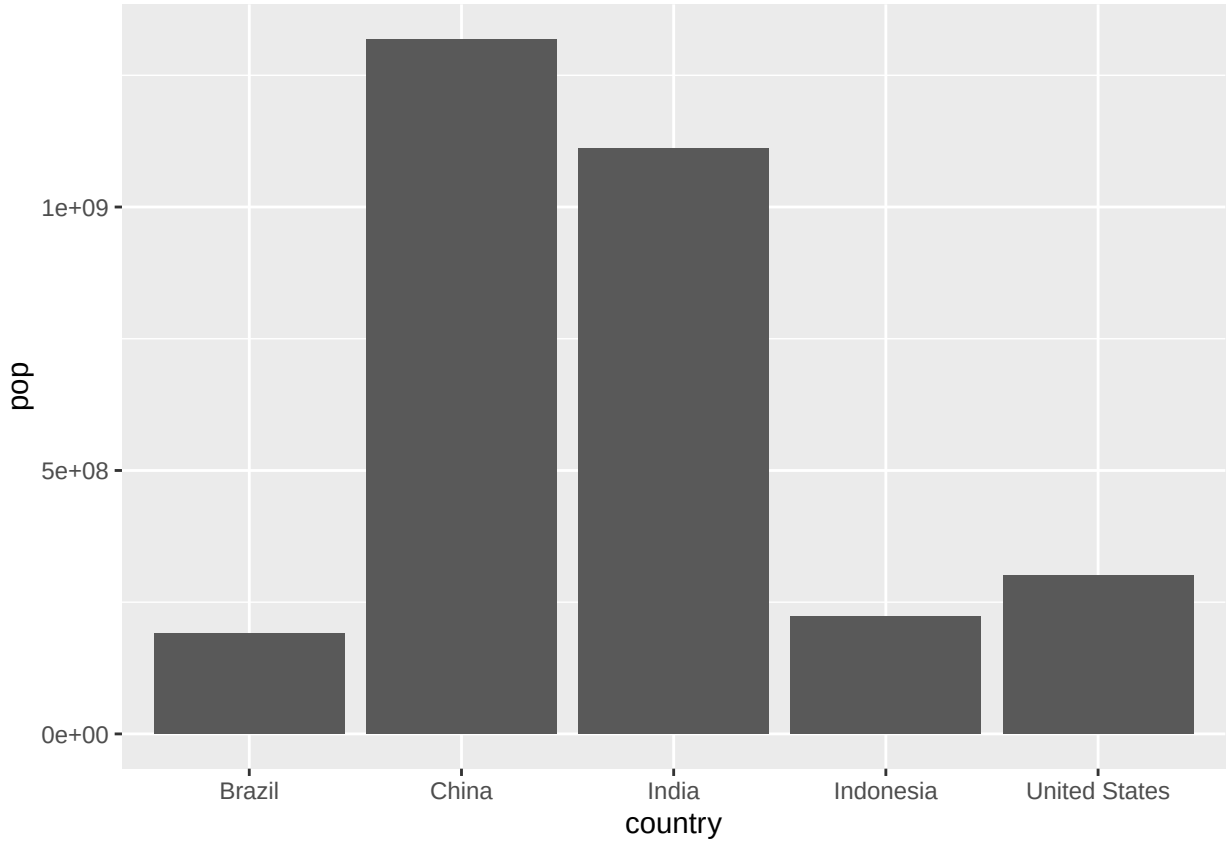
```
gapminder_top5 <- gapminder %>%
  filter(year==2007) %>%
  arrange(desc(pop)) %>%
  top_n(5, pop)

gapminder_top5
```

```
## # A tibble: 5 x 6
##   country       continent  year lifeExp        pop gdpPercap
##   <fct>         <fct>     <int>   <dbl>      <int>     <dbl>
## 1 China         Asia       2007    73.0 1318683096     4959.
## 2 India         Asia       2007    64.7 1110396331     2452.
## 3 United States Americas   2007    78.2  301139947    42952.
## 4 Indonesia     Asia       2007    70.6  223547000     3541.
## 5 Brazil        Americas   2007    72.4  190010647     9066.
```

Creating a simple bar chart

Now create a bar chart with gapminder_top5 dataset (countries are in alphabetical order by default).

```
ggplot(gapminder_top5) +
  geom_col(aes(x = country, y = pop))
```



Q. Plot life expectancy by country

Create a bar chart showing the life expectancy of the five biggest countries by population in 2007.

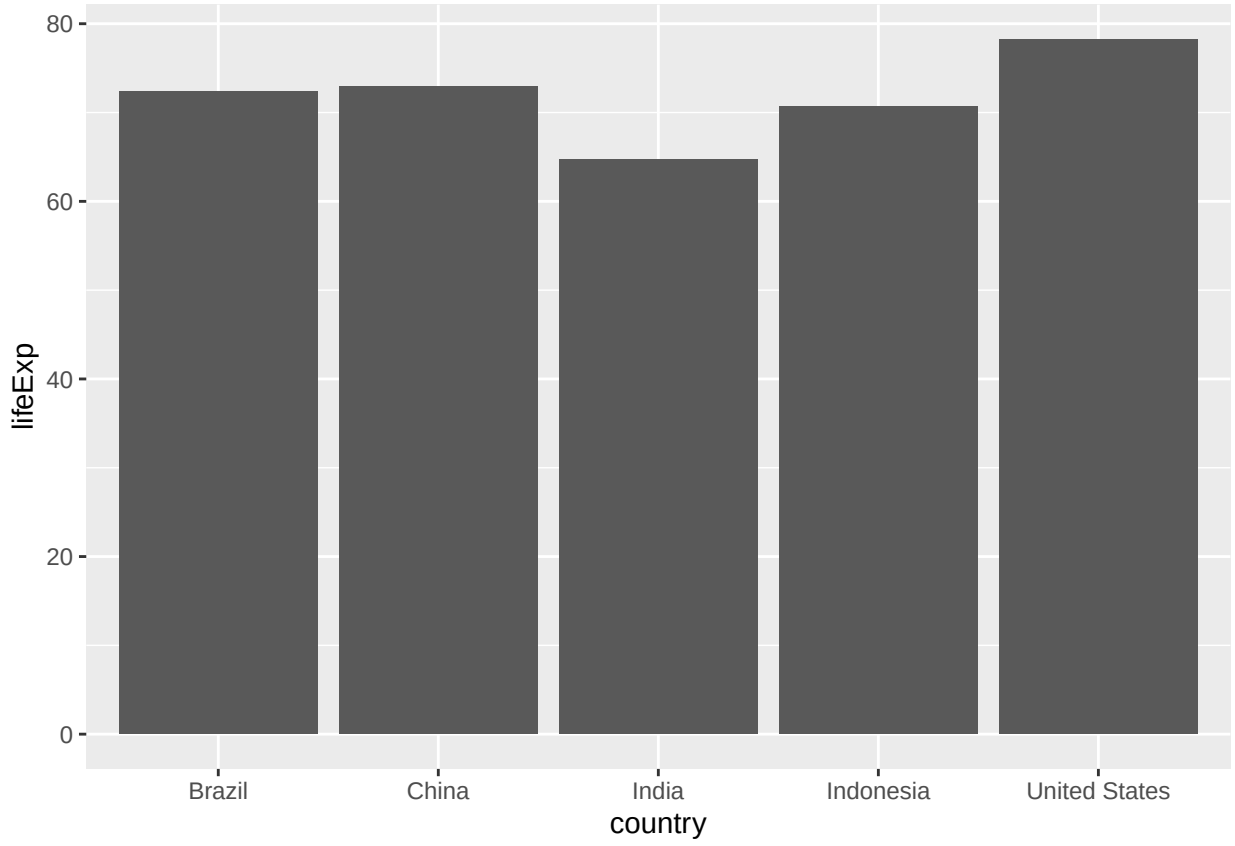
Use the ggplot() function and specify the gapminder_top5 dataset as input

Add a geom_col() layer to the plot

Plot one bar for each country (x aesthetic)

Use life expectancy lifeExp as bar height (y aesthetic)

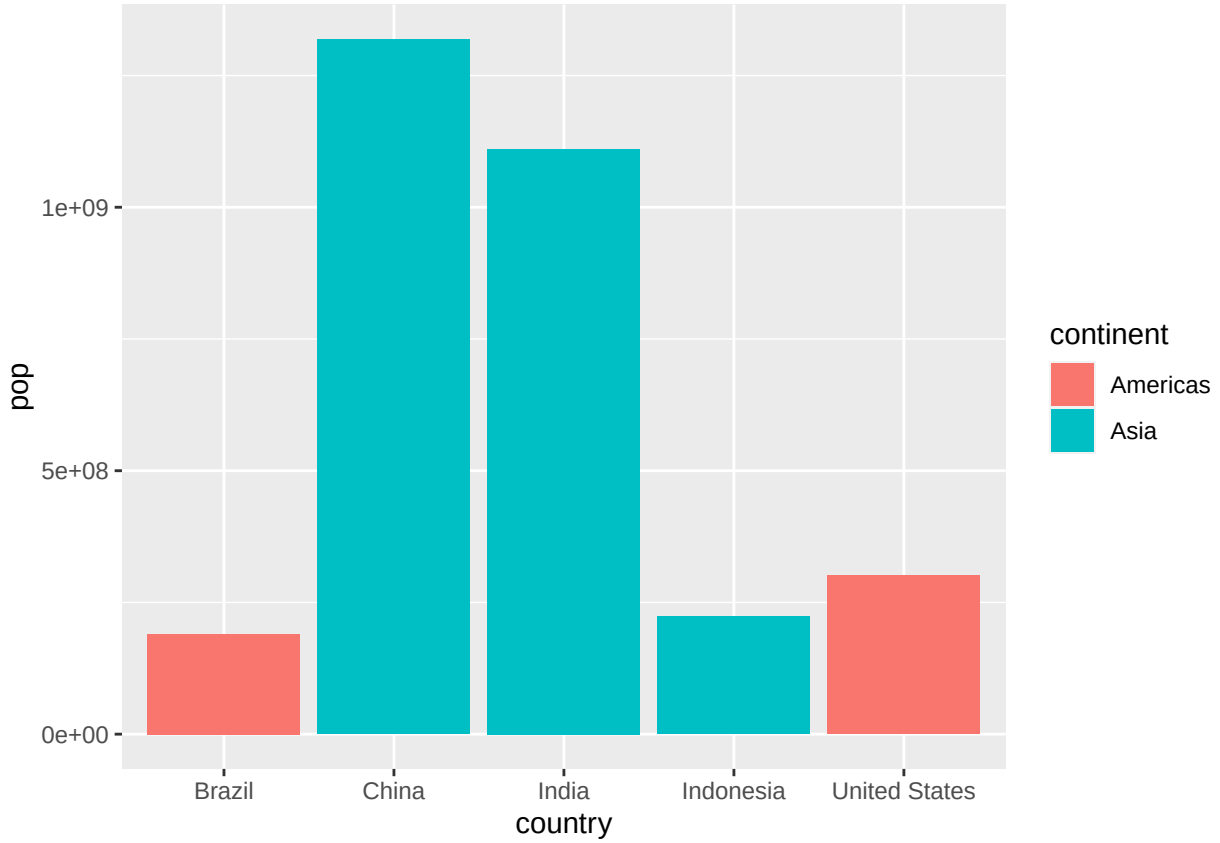
```
ggplot(gapminder_top5) +
  geom_col(aes(x = country, y = lifeExp))
```



Filling bars with color

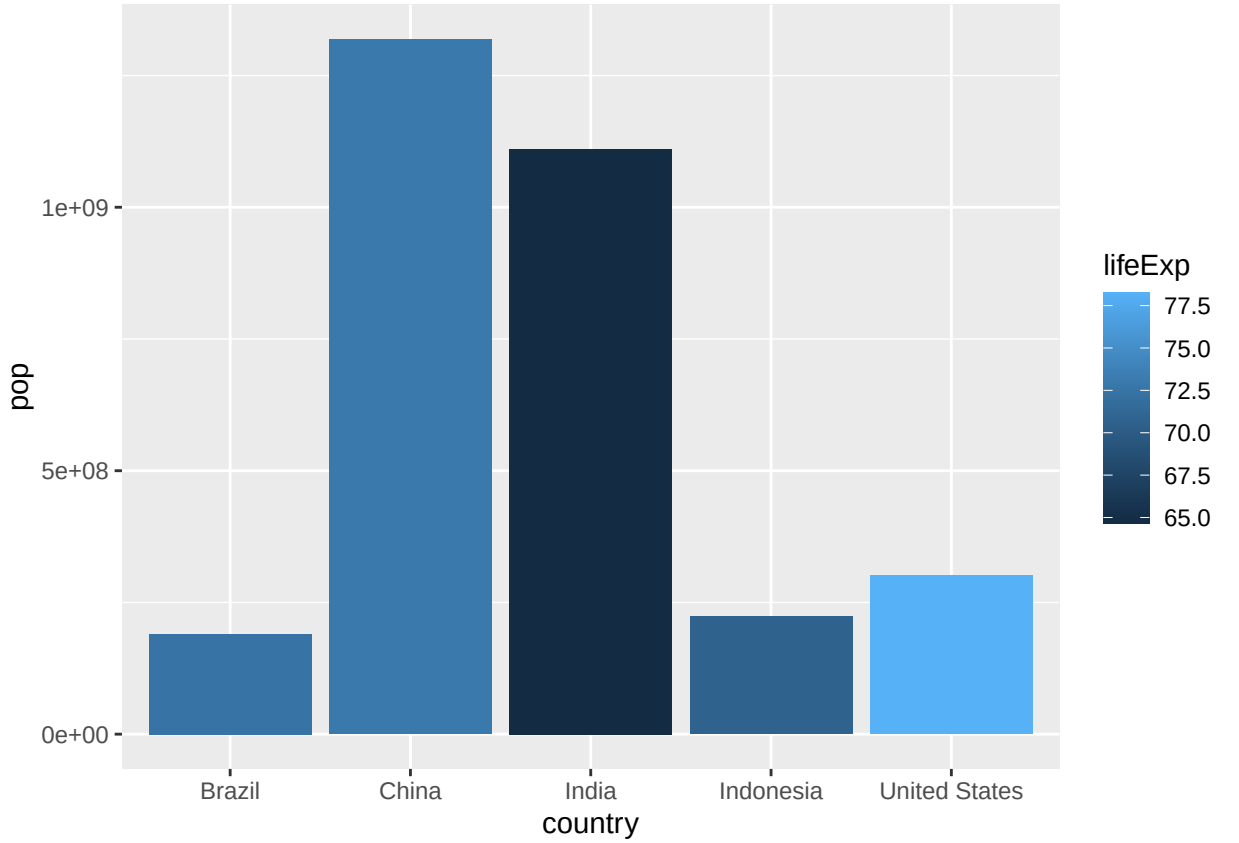
Plot the population of the biggest countires and use the contient variable to color each bar.

```
ggplot(gapminder_top5) +
  geom_col(aes(x = country, y = pop, fill = continent))
```



Now use the life expectancy variable to fill the colors for the bars.

```
ggplot(gapminder_top5) +
  geom_col(aes(x = country, y = pop, fill = lifeExp))
```



Q. Plot population size by country

Create a bar chart showing the population (in millions) of the five biggest countries by population in 2007.

Use the ggplot() function and specify the gapminder_top5 dataset as input

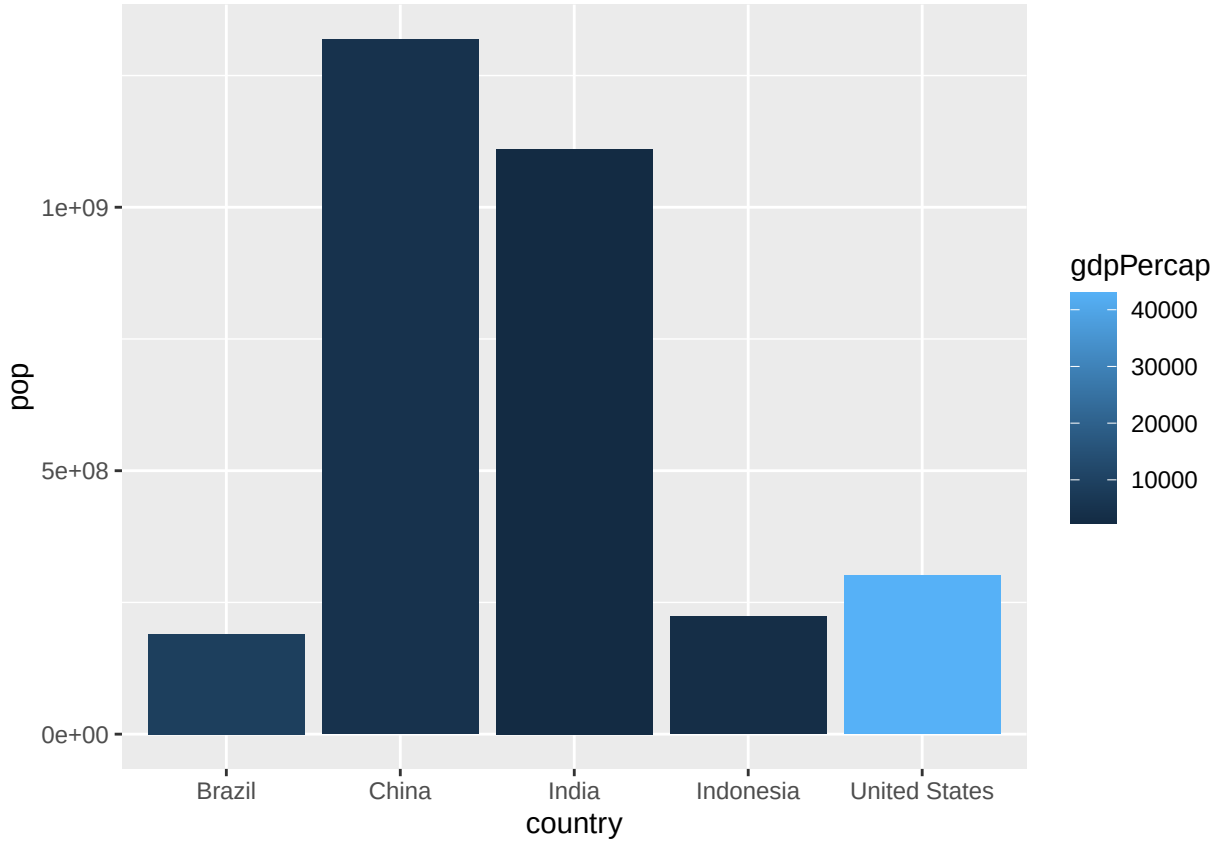
Add a geom_col() layer to the plot

Plot one bar for each country (x aesthetic)

Use population pop as bar height (y aesthetic)

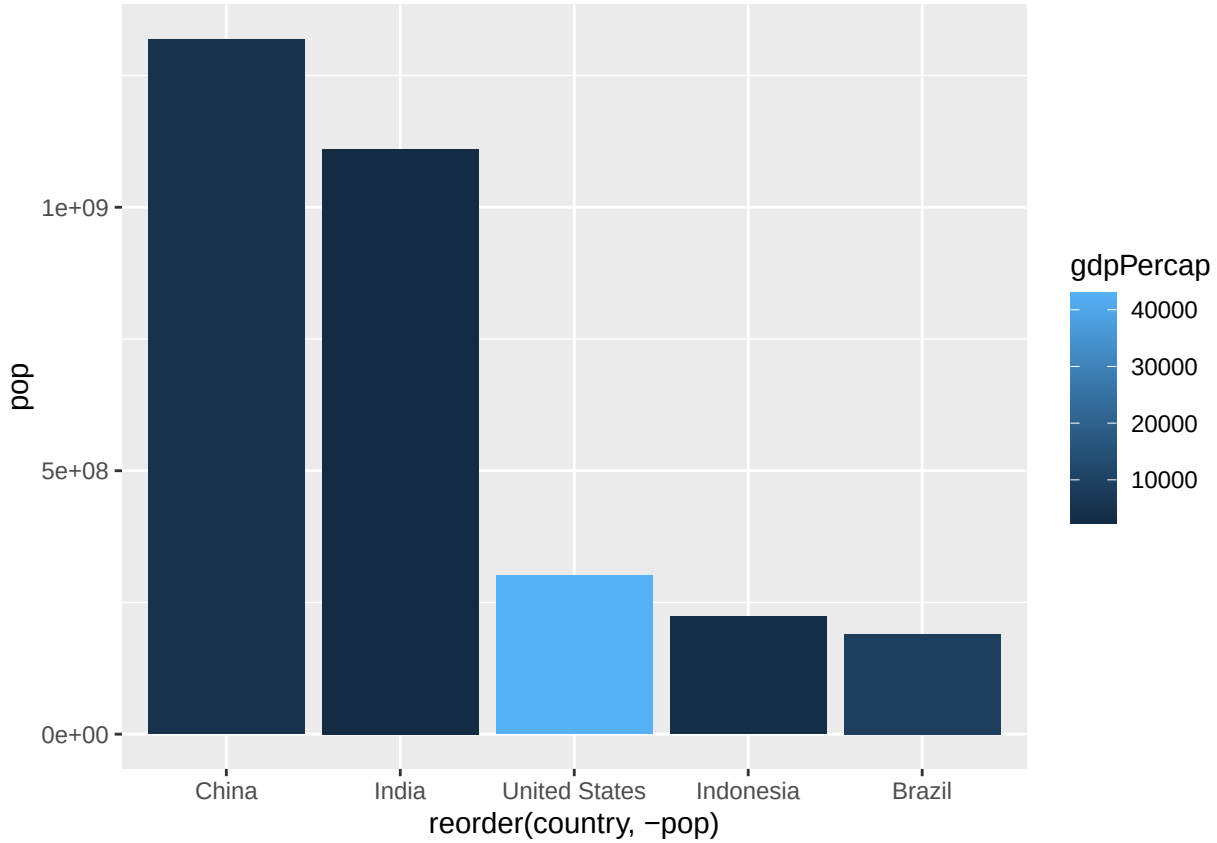
Use the GDP per capita gdpPercap as fill aesthetic

```
ggplot(gapminder_top5) +
  geom_col(aes(x=country, y=pop, fill=gdpPercap))
```



Now change the orders of the bars

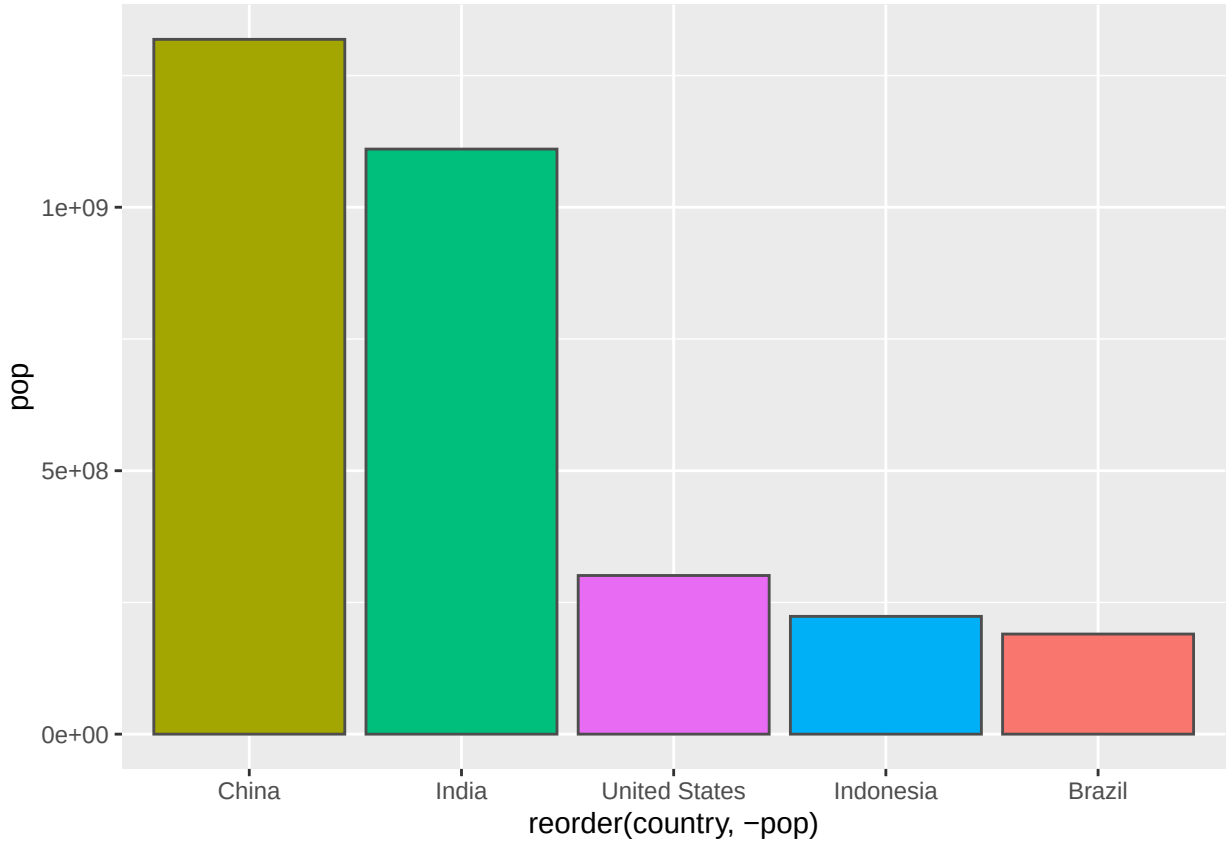
```
ggplot(gapminder_top5) +
  geom_col(aes(x=reorder(country, -pop), y=pop, fill=gdpPercap))
```



Now just fill by country

```
ggplot(gapminder_top5) +
  aes(x=reorder(country, -pop), y=pop, fill=country) +
  geom_col(col="gray30") +
  guides(fill=FALSE)
```

```
## Warning: `guides(<scale> = FALSE)` is deprecated. Please use `guides(<scale> =
## "none")` instead.
```

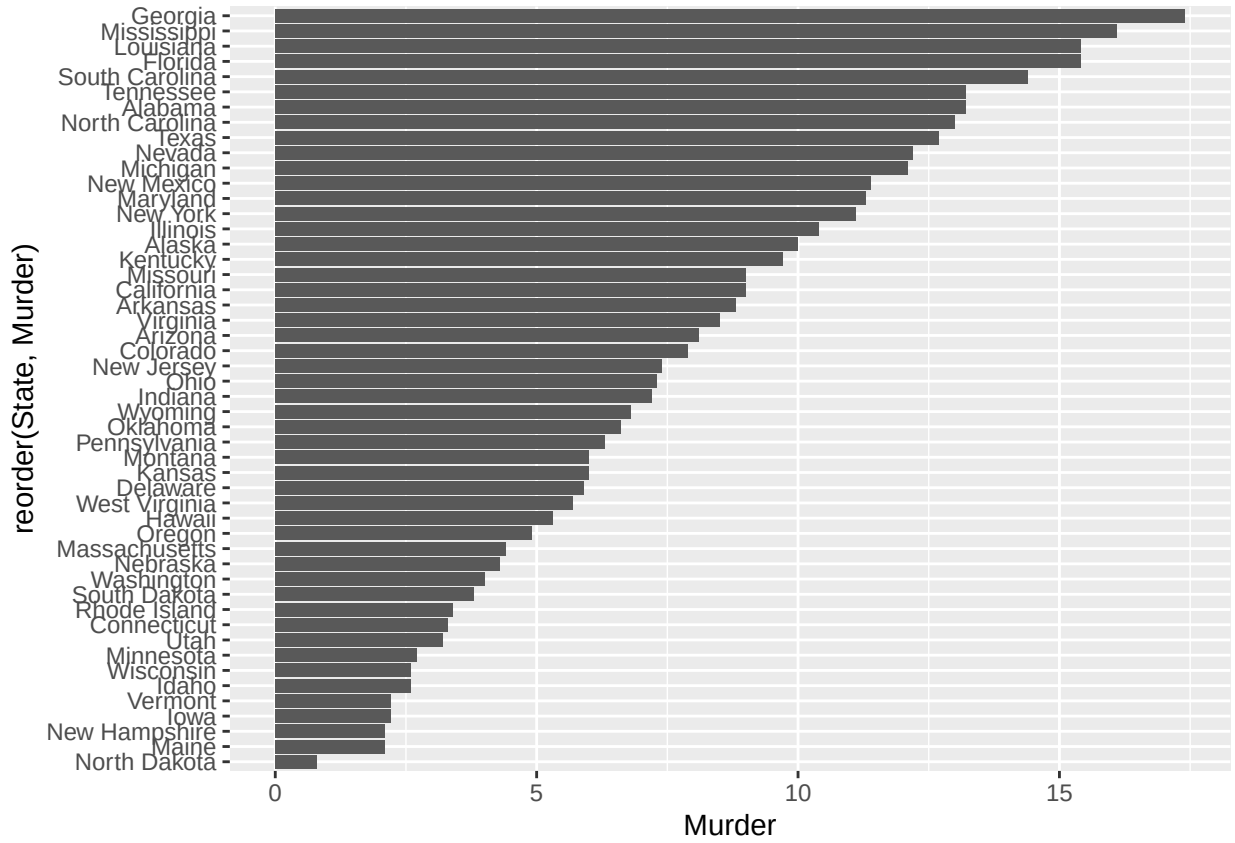


Flipping bar charts

```
head(USArrests)
```

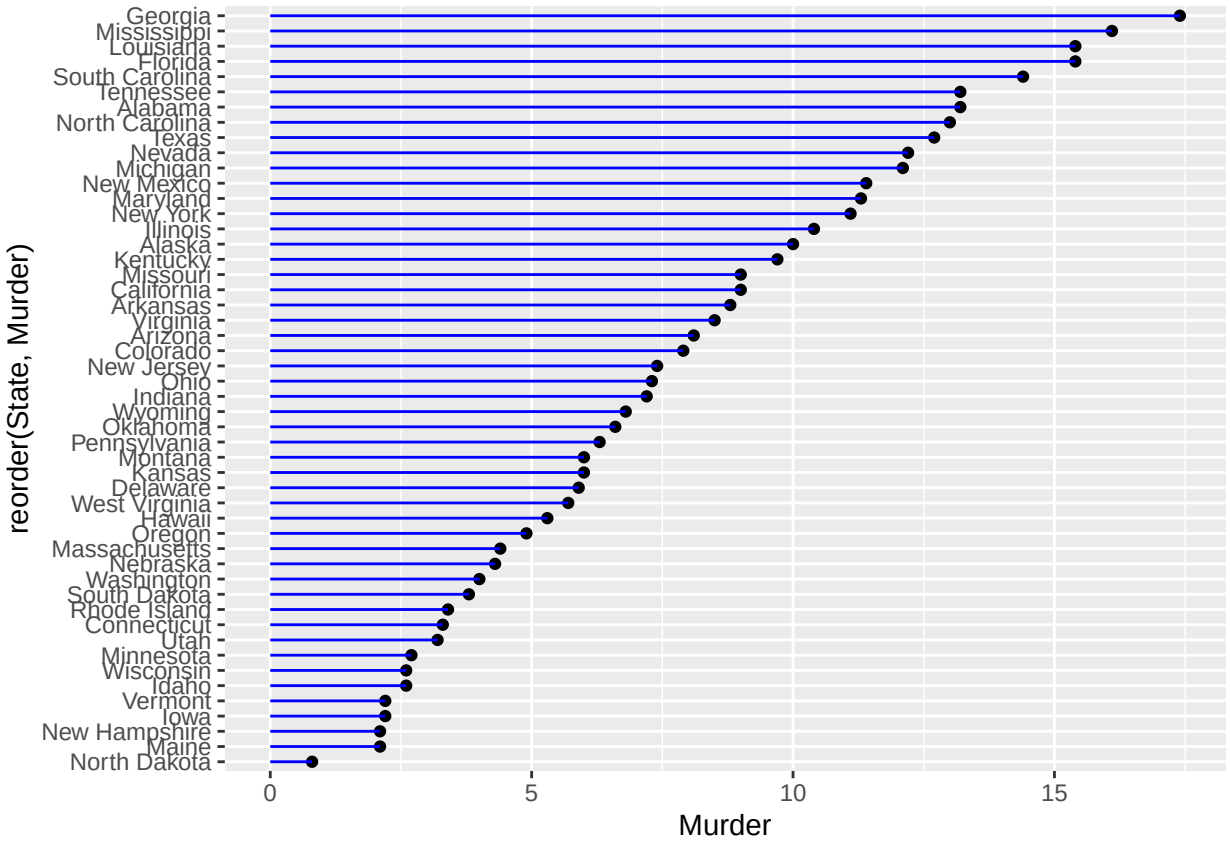
```
##            Murder Assault UrbanPop Rape
## Alabama      13.2     236       58 21.2
## Alaska       10.0     263       48 44.5
## Arizona       8.1     294       80 31.0
## Arkansas      8.8     190       50 19.5
## California    9.0     276       91 40.6
## Colorado      7.9     204       78 38.7
```

```
USArrests$State <- rownames(USArrests)
ggplot(USArrests) +
  aes(x=reorder(State,Murder), y=Murder) +
  geom_col() +
  coord_flip()
```



A bit crowded, use an alternative custom visualization. Combine geom_point() and geom_segment() to do this

```
ggplot(USArrests) +
  aes(x=reorder(State,Murder), y=Murder) +
  geom_point() +
  geom_segment(aes(x=State,
                   xend=State,
                   y=0,
                   yend=Murder), color="blue") +
  coord_flip()
```

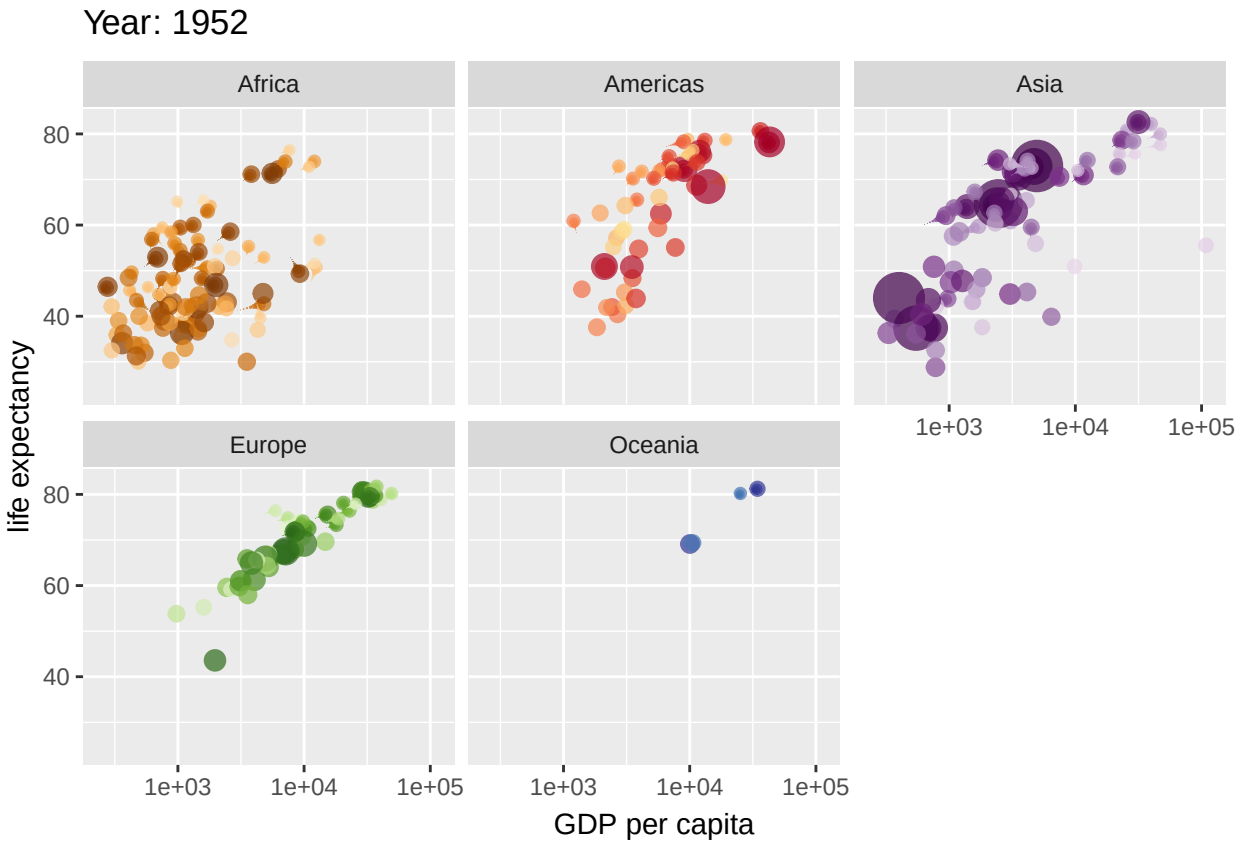


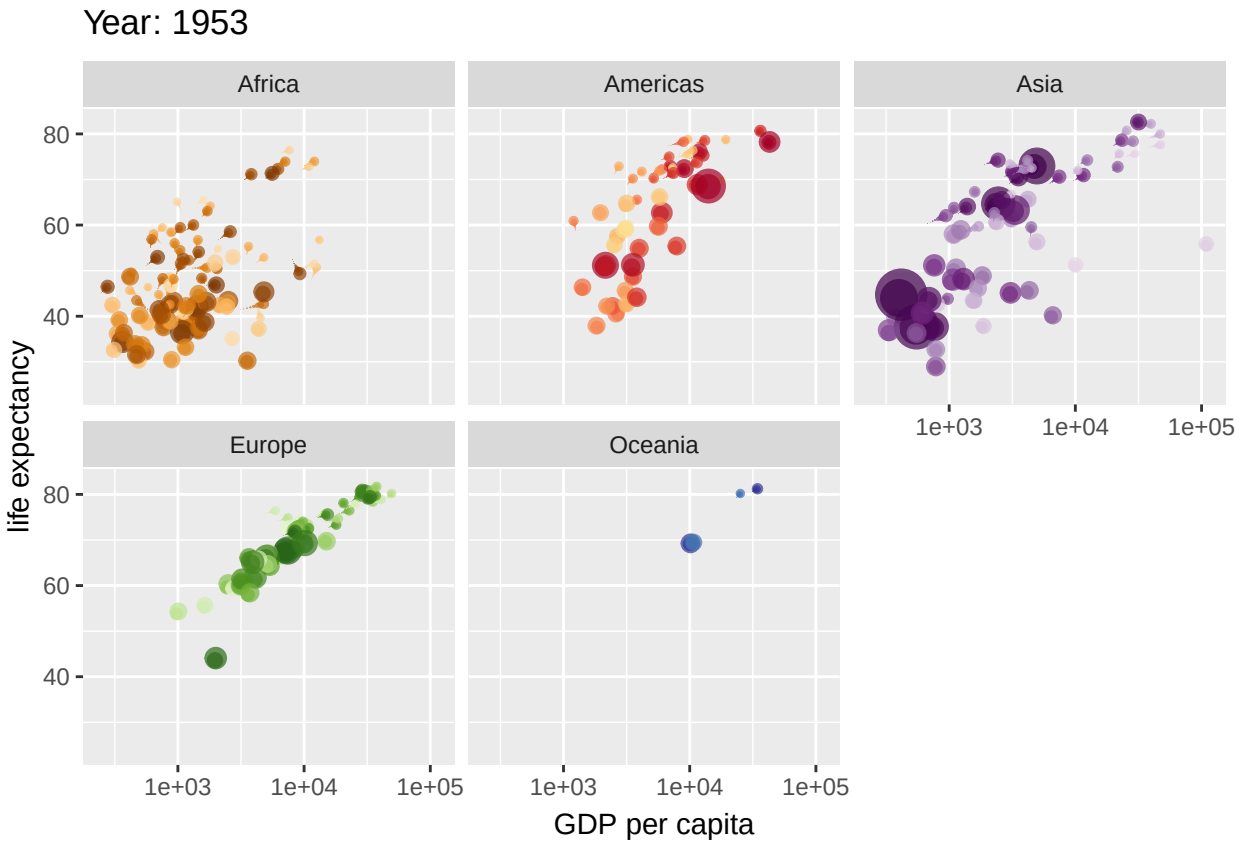
SECTION 8 ADVANCED: Plot Animation

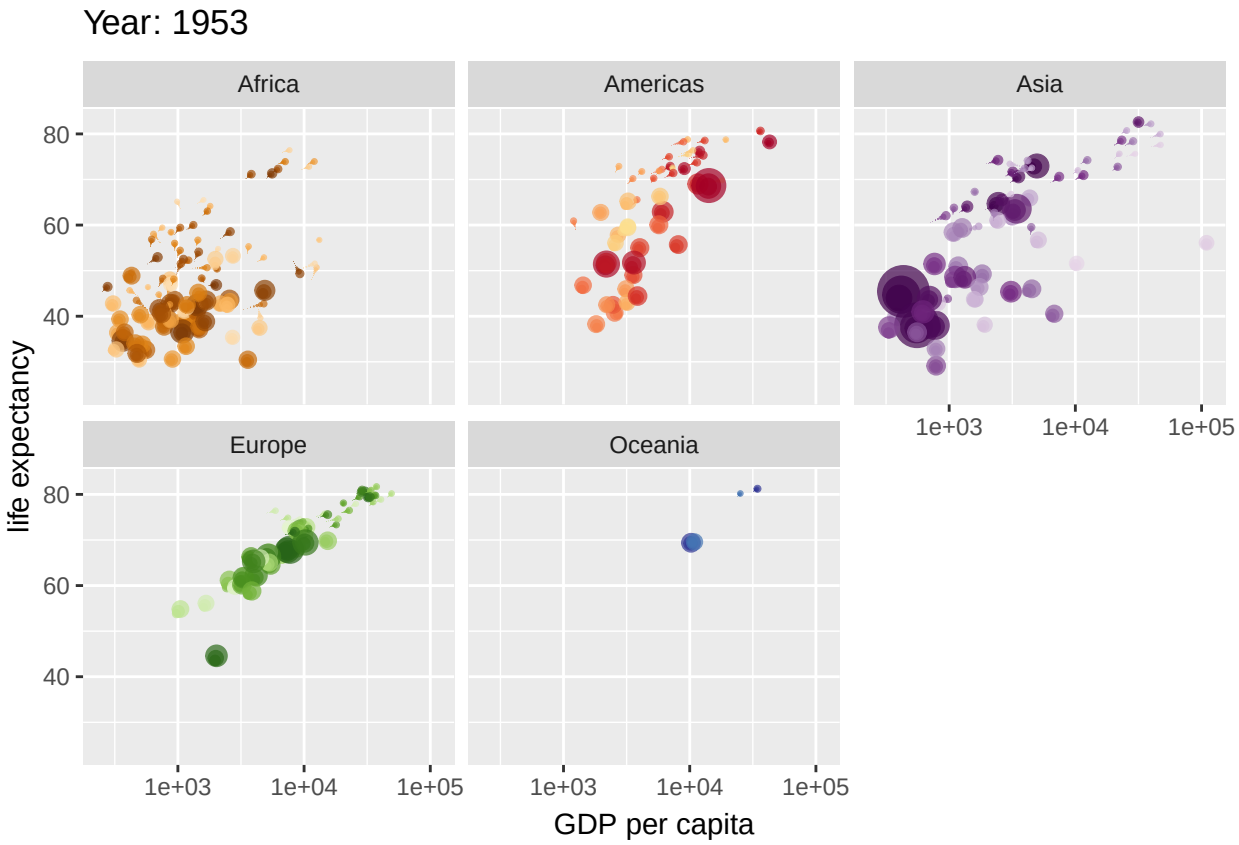
```
# install.packages("gifski") ## un-comment to install if necessary
# install.packages("gganimate") ## un-comment to install if necessary
```

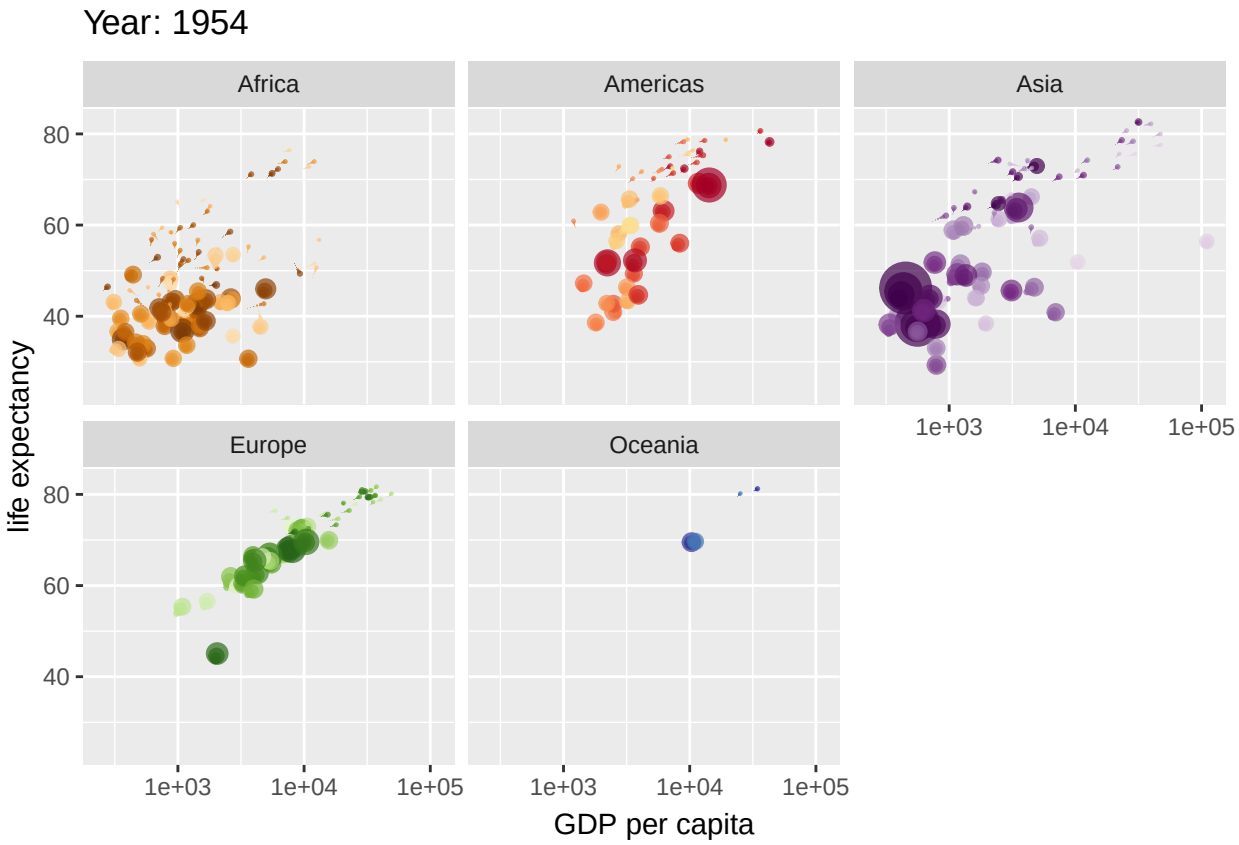
For this exercise, we only show the images first and last year generated for this pdf (1952 and 2007 respectively).

```
library(gganimate)

ggplot(gapminder, aes(gdpPercap, lifeExp, size = pop, colour = country)) +
  geom_point(alpha = 0.7, show.legend = FALSE) +
  scale_colour_manual(values = country_colors) +
  scale_size(range = c(2, 12)) +
  scale_x_log10() +
  # Continent facet wrap
  facet_wrap(~continent) +
  # The following code is for gganimate
  labs(title = 'Year: {frame_time}', x = 'GDP per capita', y = 'life expectancy') +
  transition_time(year) +
  shadow_wake(wake_length = 0.1, alpha = FALSE)
```


Year: 1952
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1953
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1953
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1954
Africa
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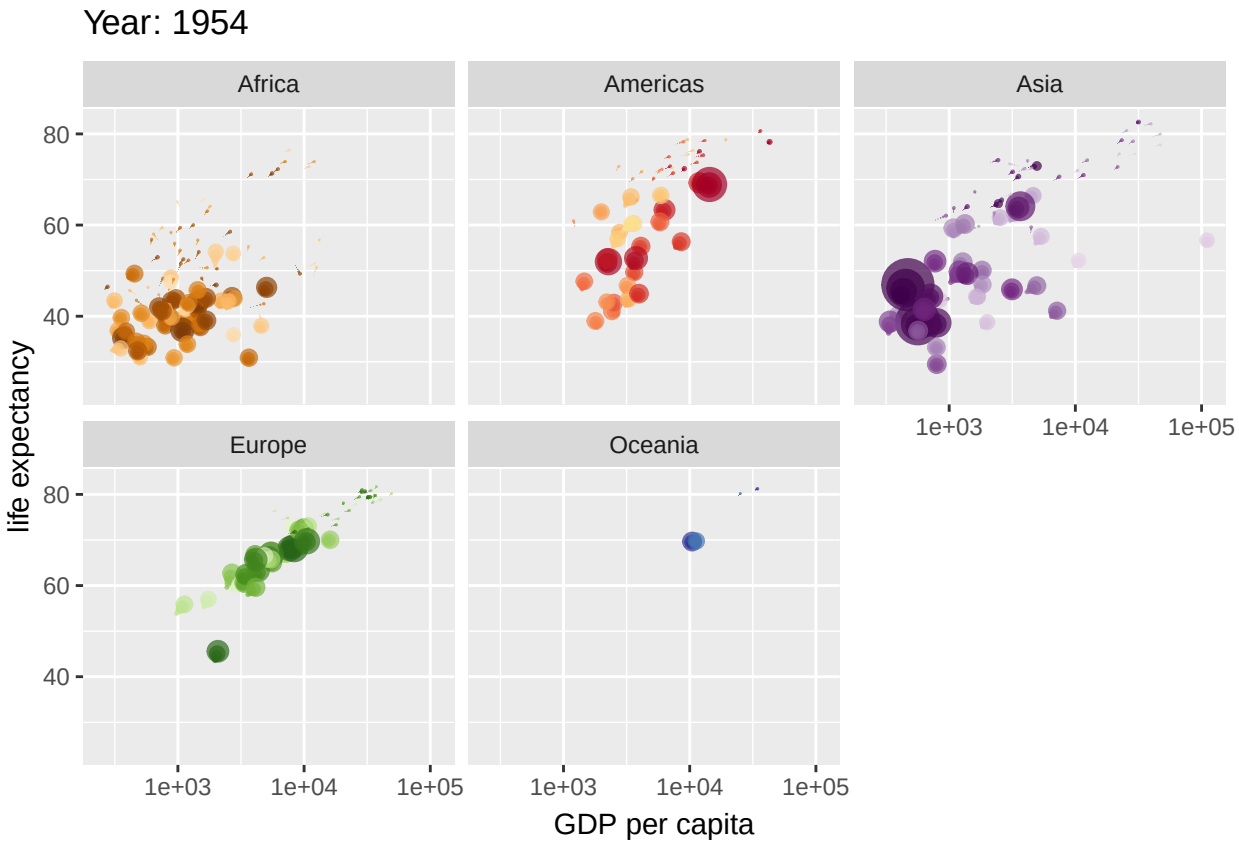
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1954
Africa
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Asia
Europe
Oceania
life expectancy
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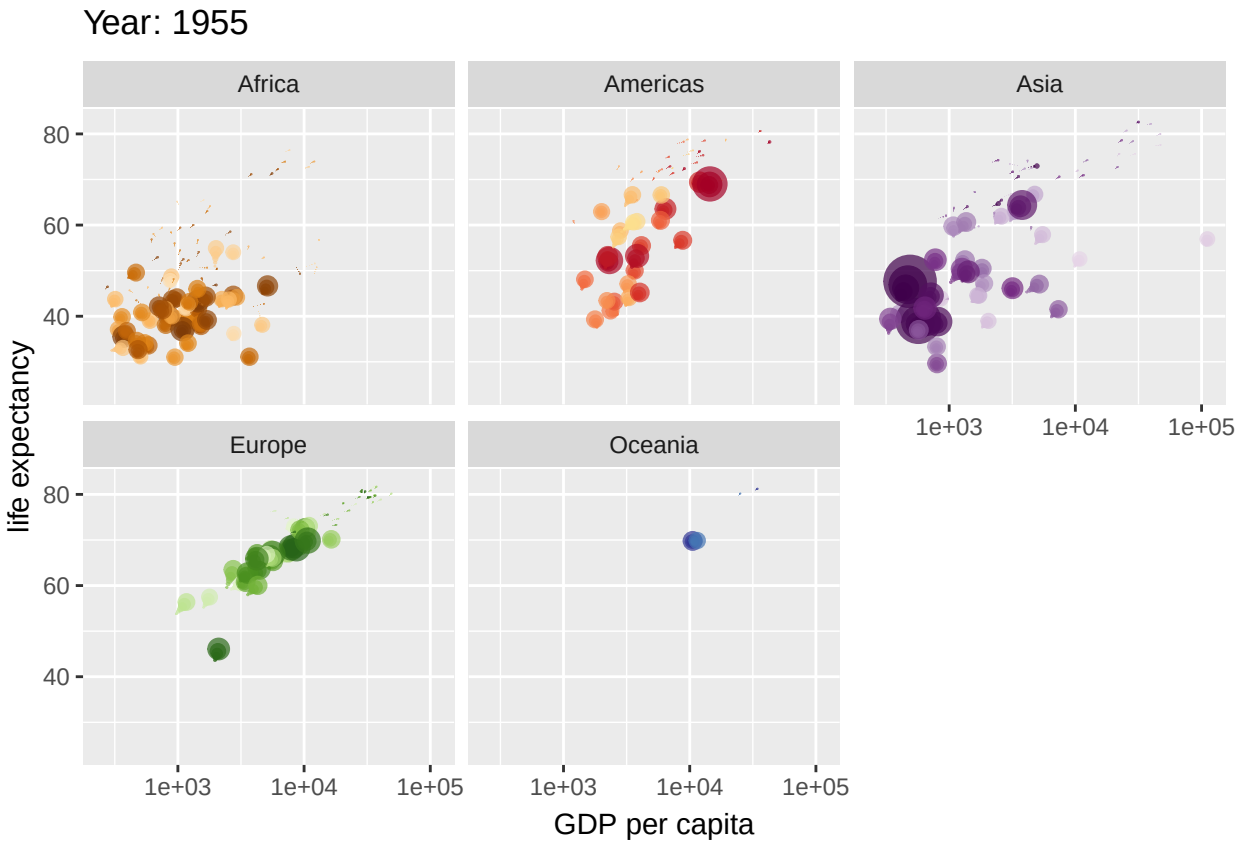
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1955
Africa
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Europe
Oceania
life expectancy
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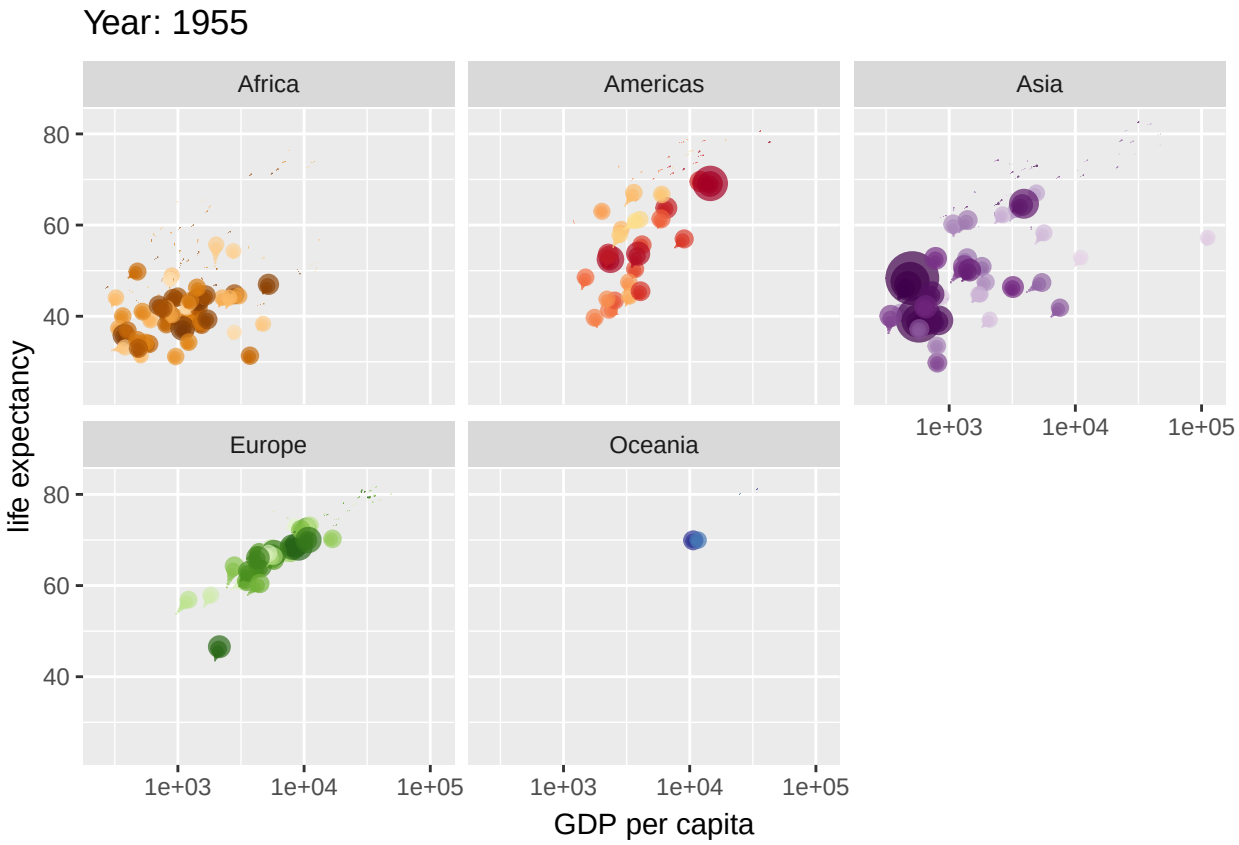
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1955
Africa
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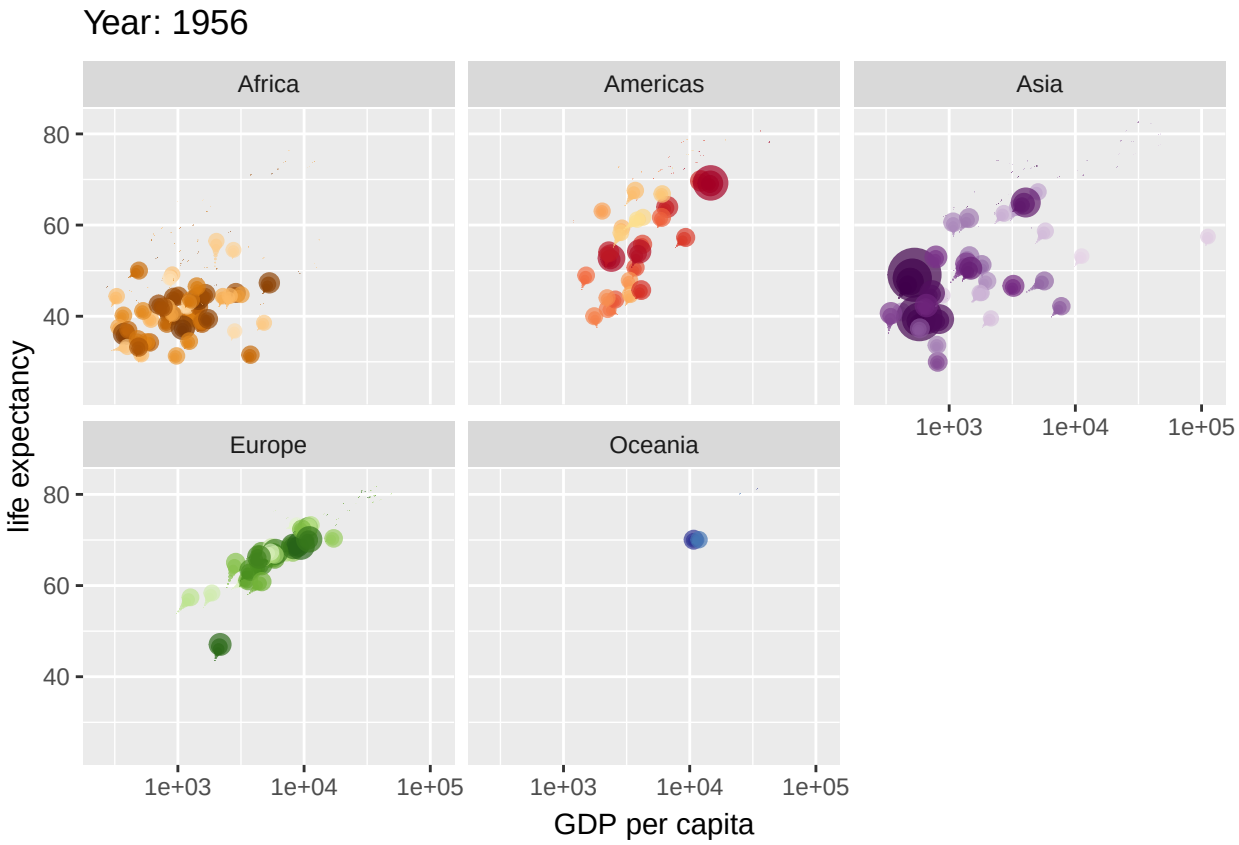
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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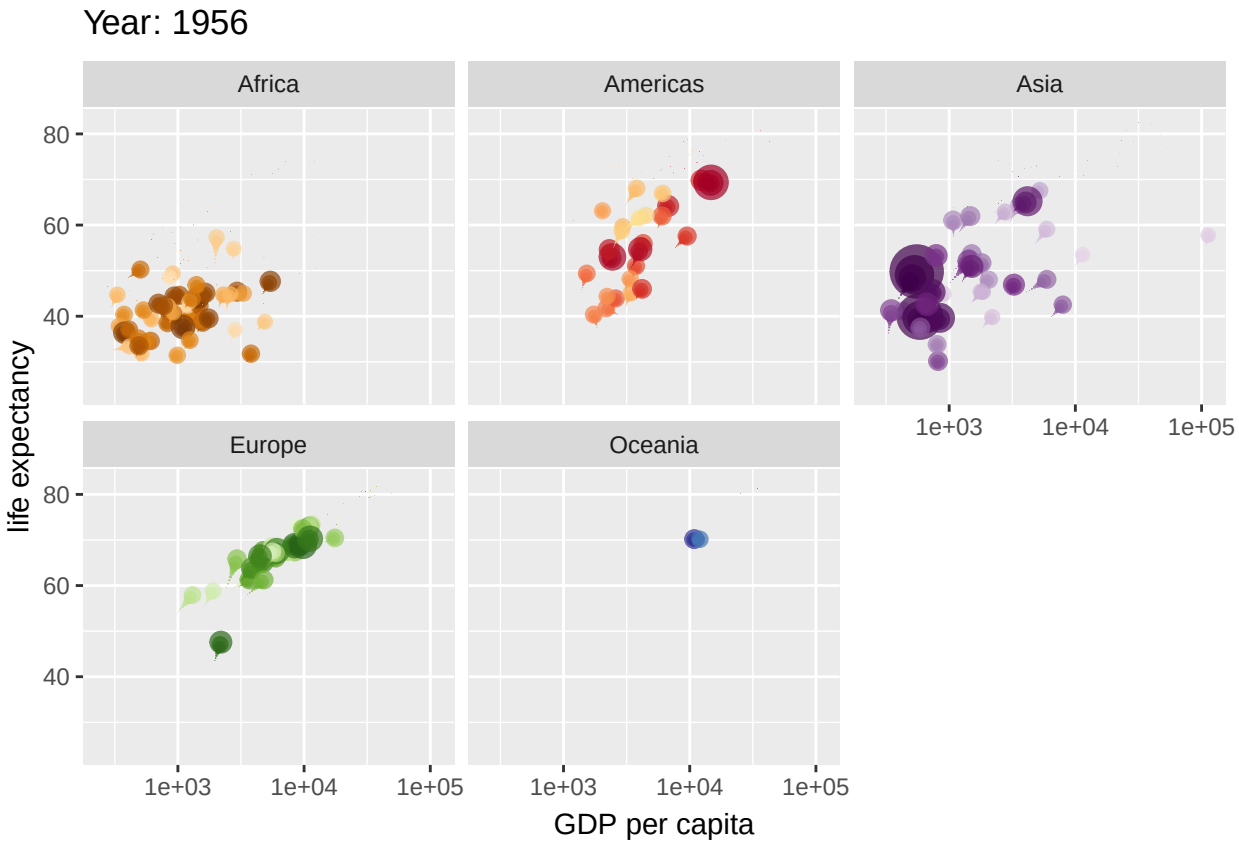
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1956
Africa
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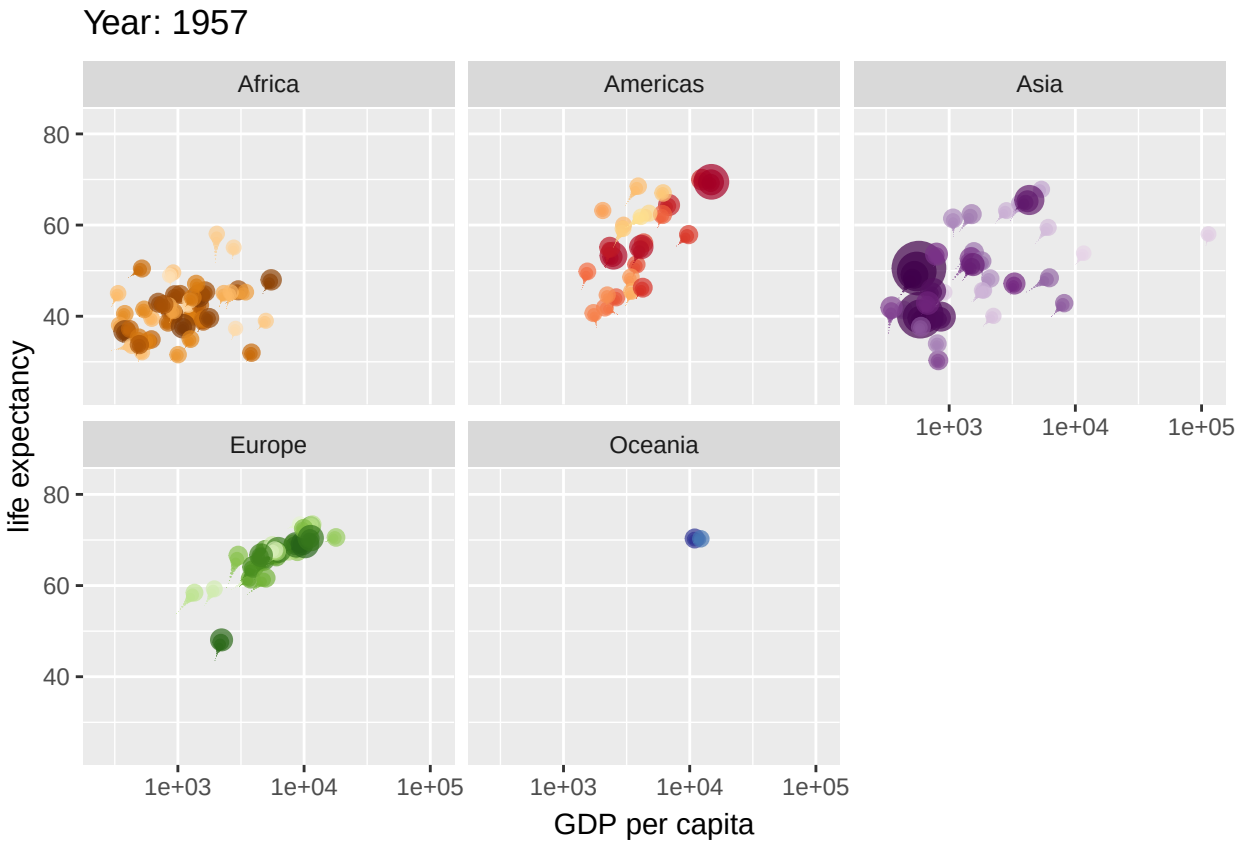
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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Europe
Oceania
life expectancy
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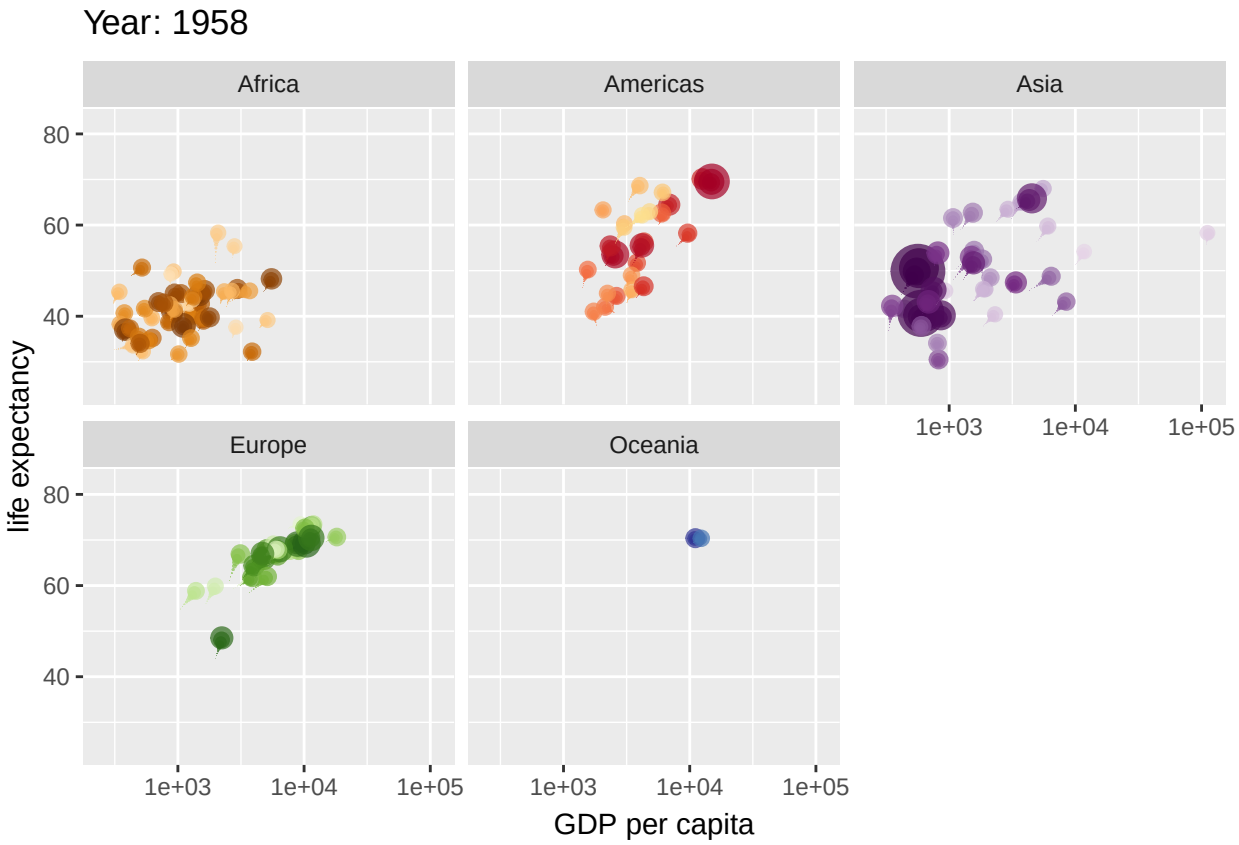
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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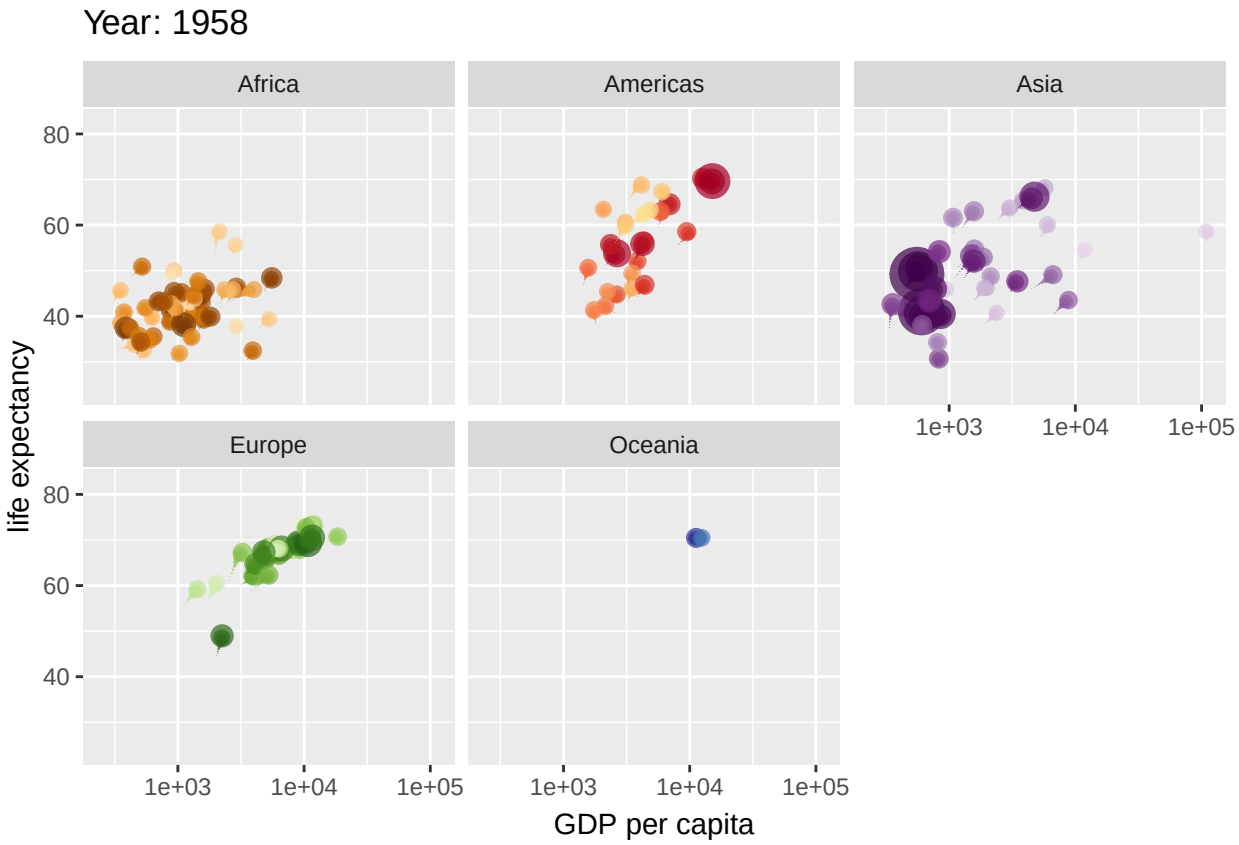
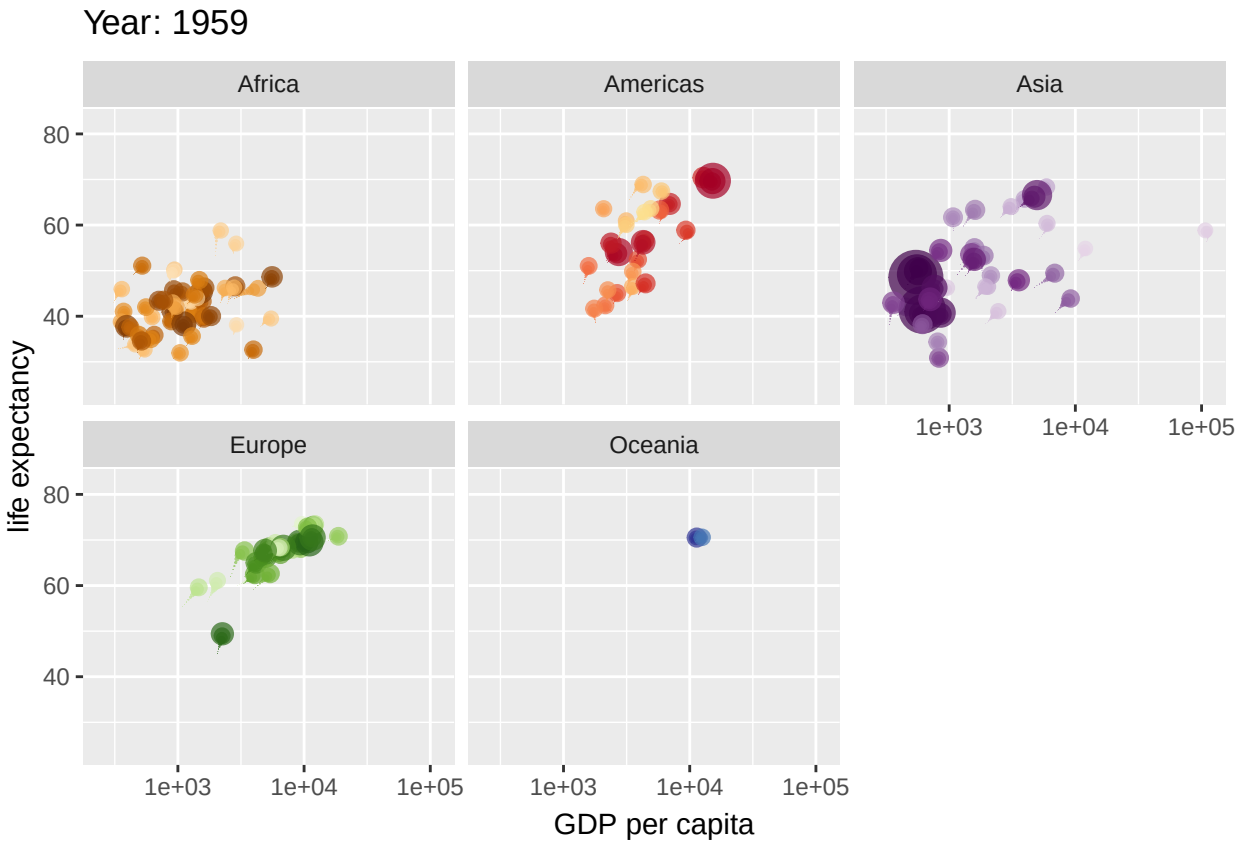
1e+03
1e+04
1e+05
GDP per capita


Year: 1958
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1959
Africa
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Asia
Europe
Oceania
life expectancy
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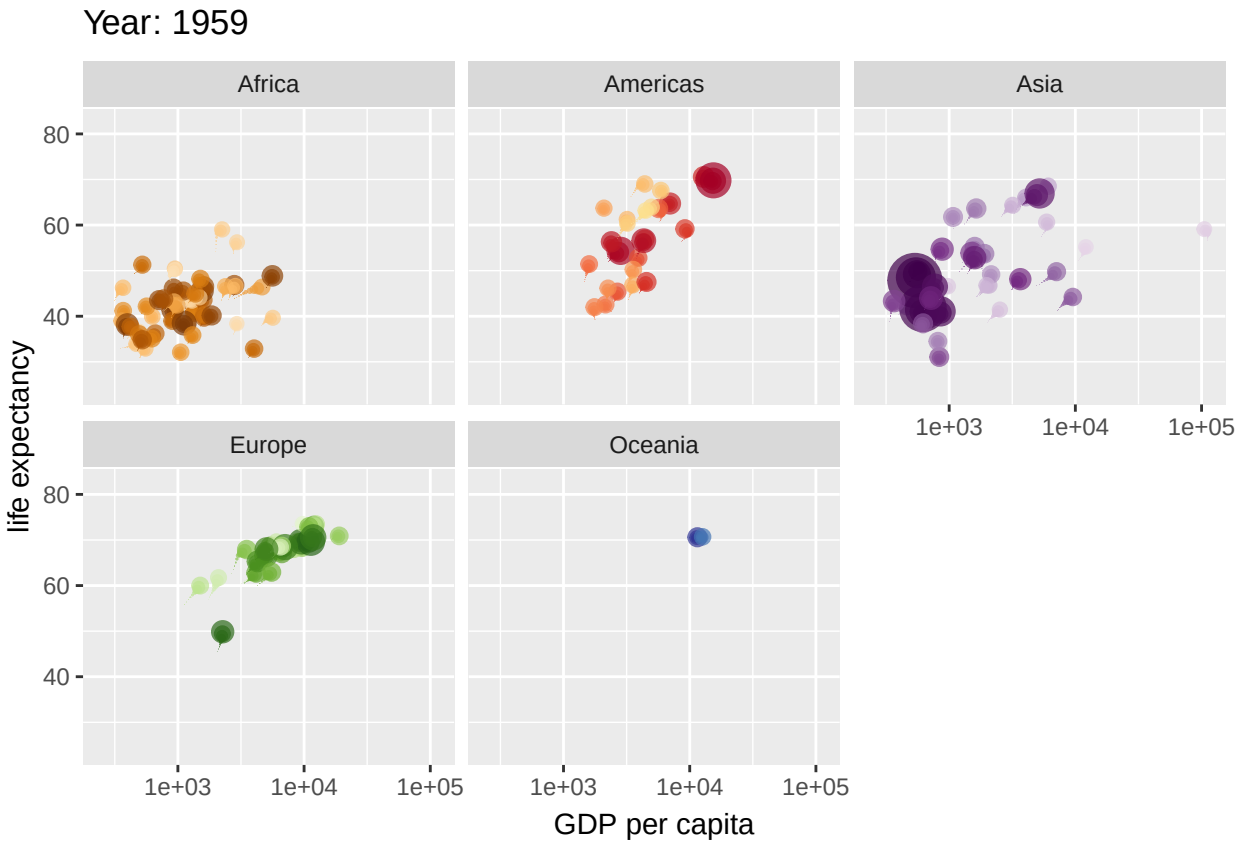
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1959
Africa
Americas
Asia
Europe
Oceania
life expectancy
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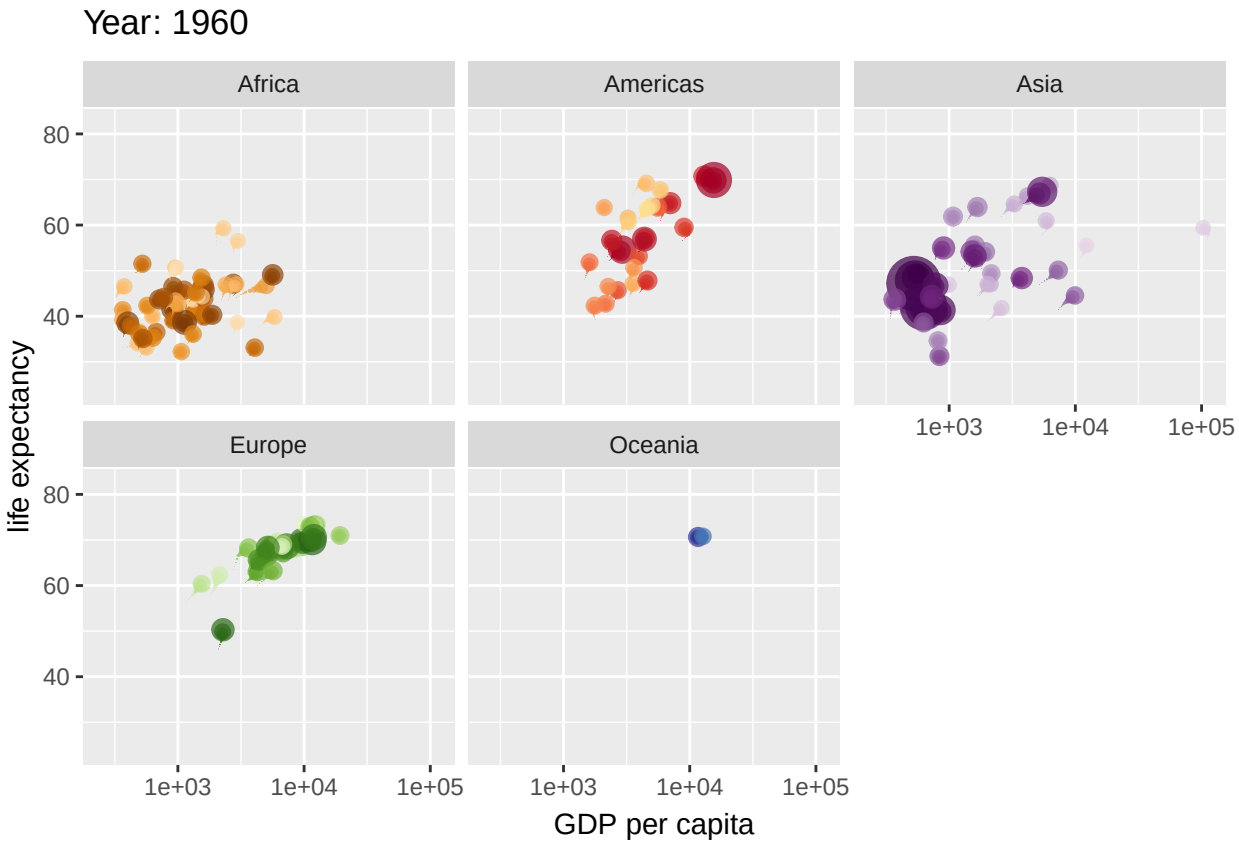
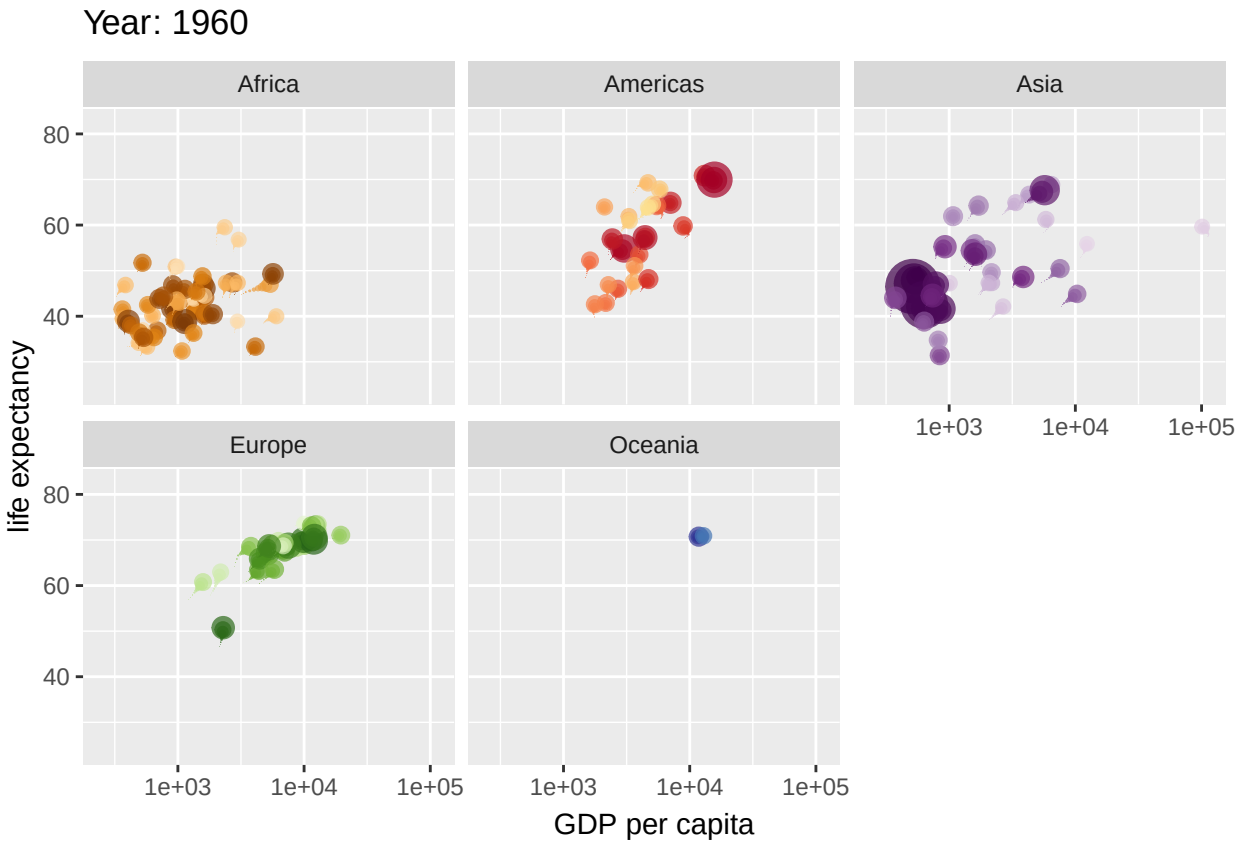
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1960
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1960
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
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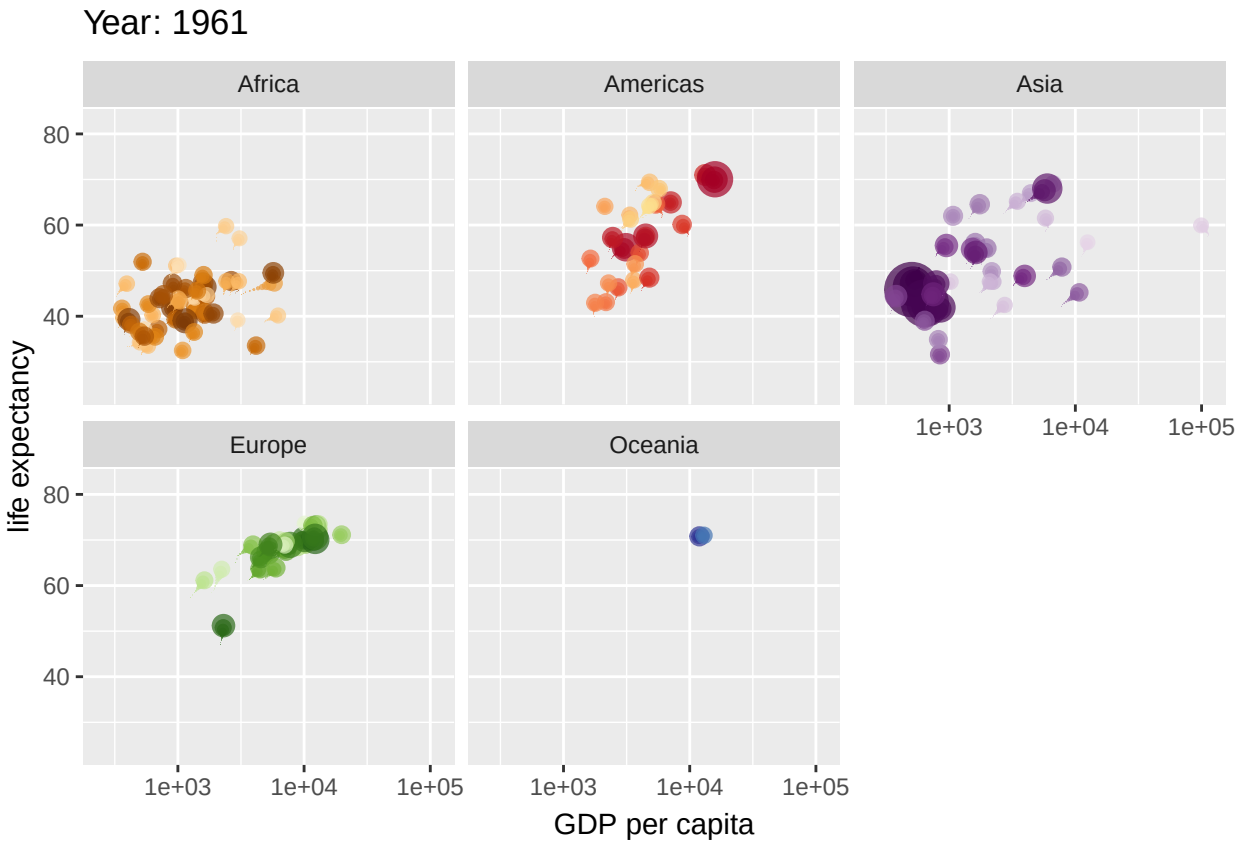
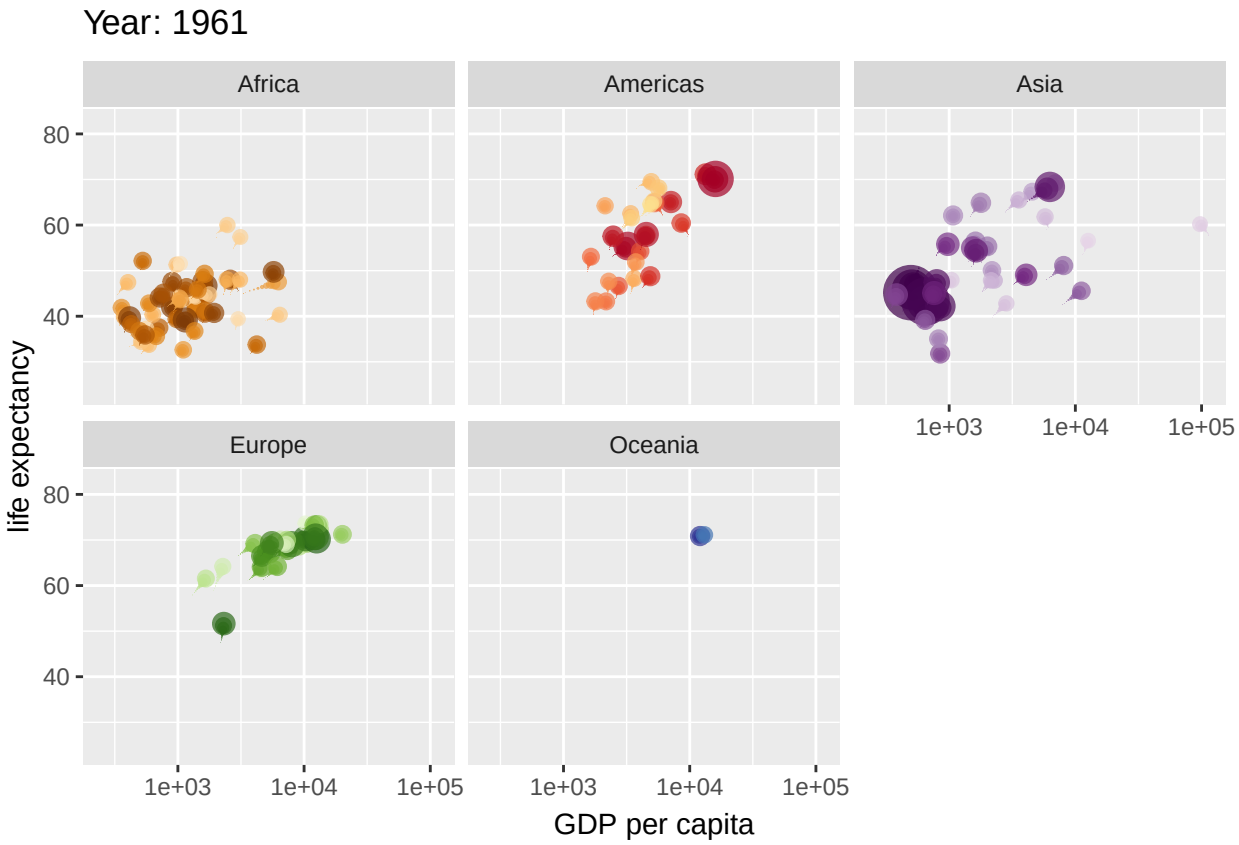
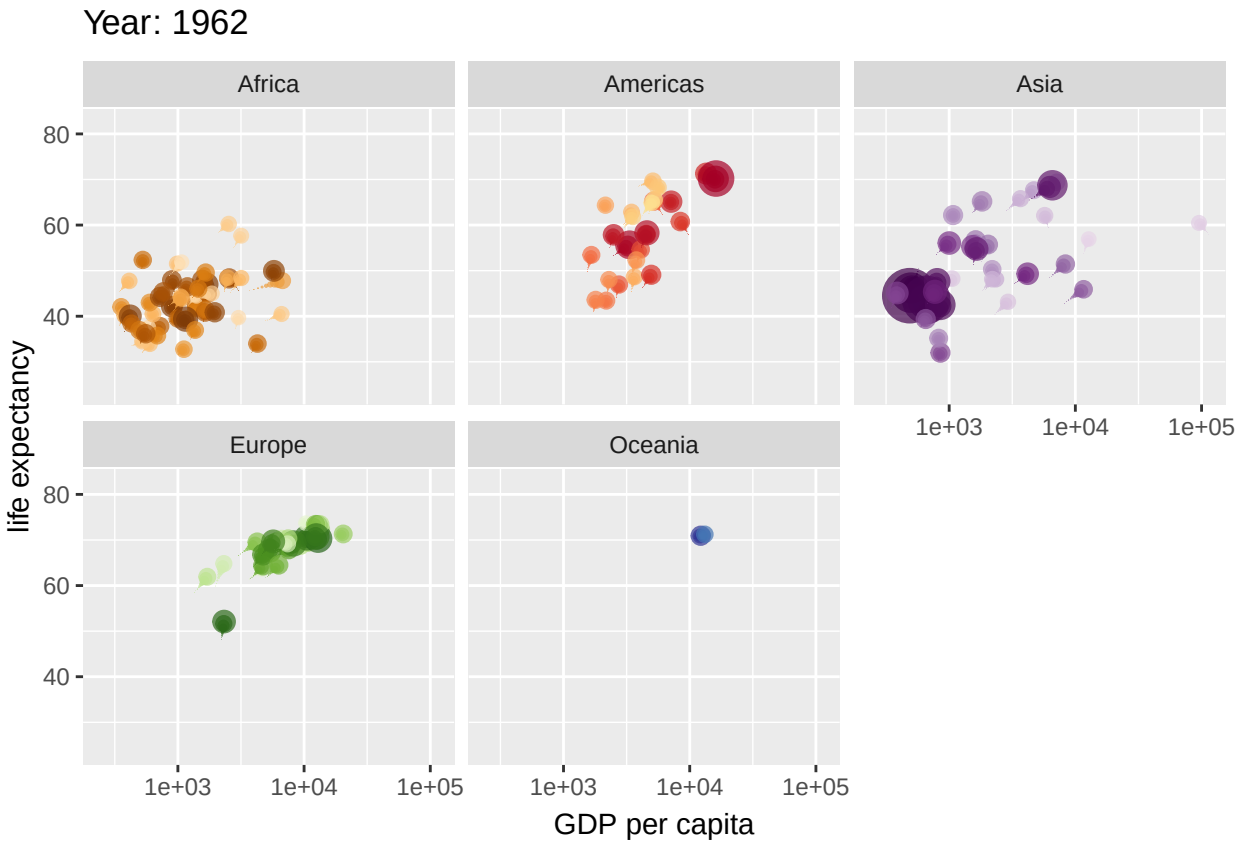
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1961
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1961
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1962
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
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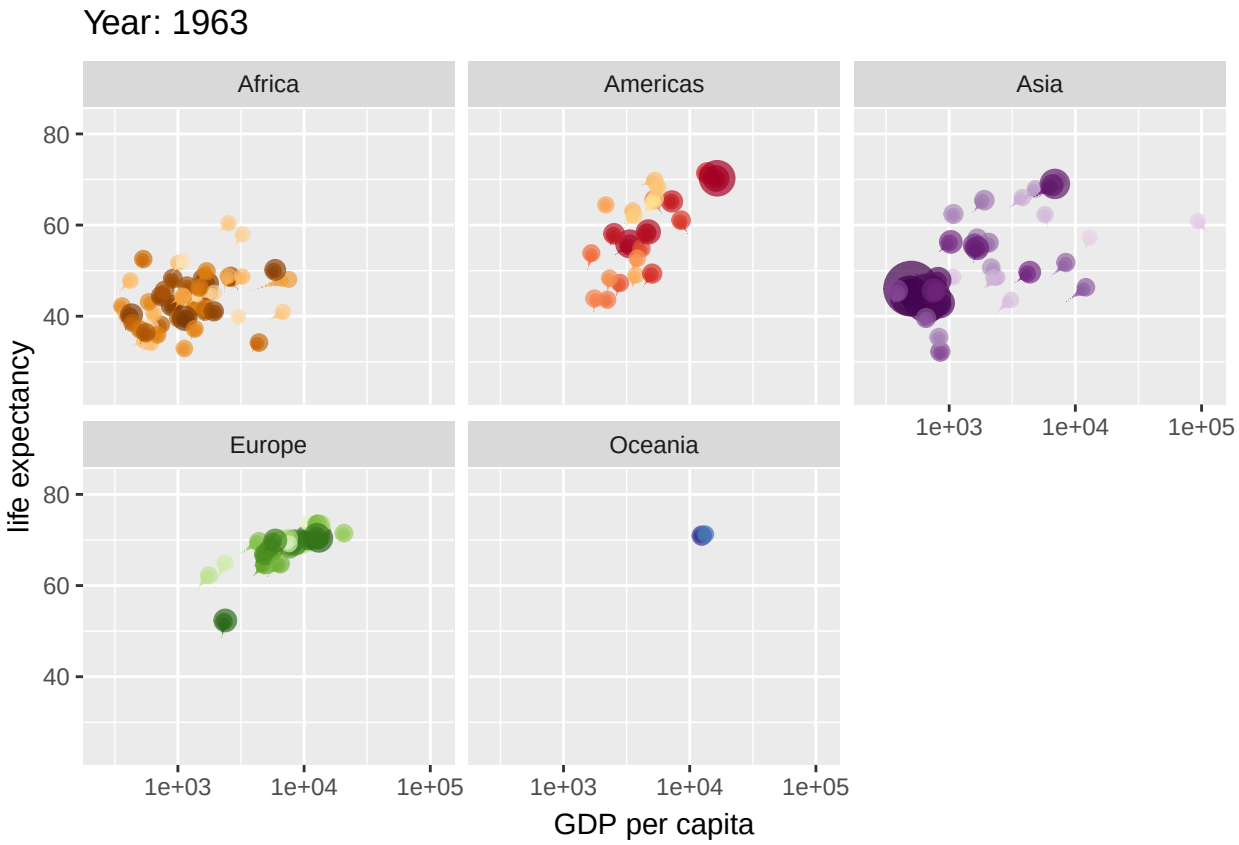
1e+03
1e+04
1e+05
GDP per capita


Year: 1963
Africa
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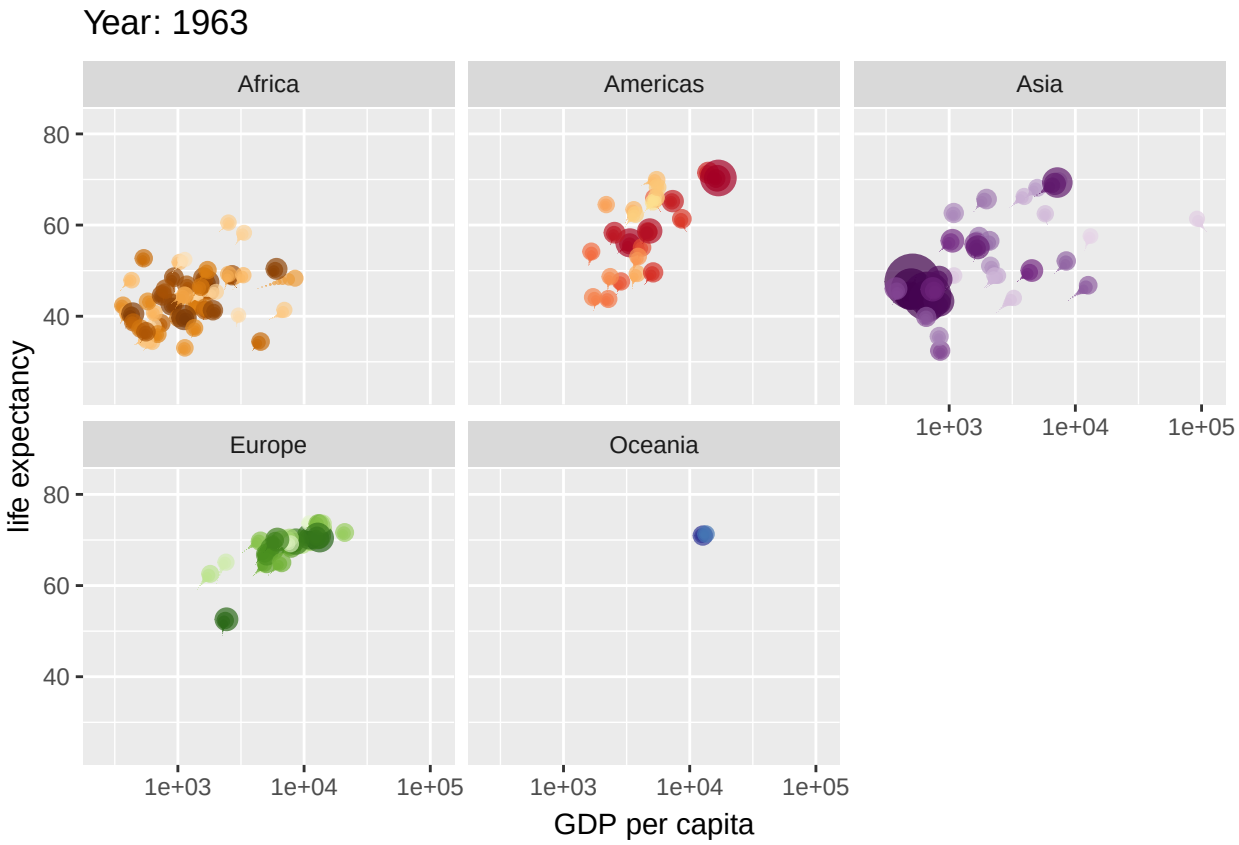
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1963
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
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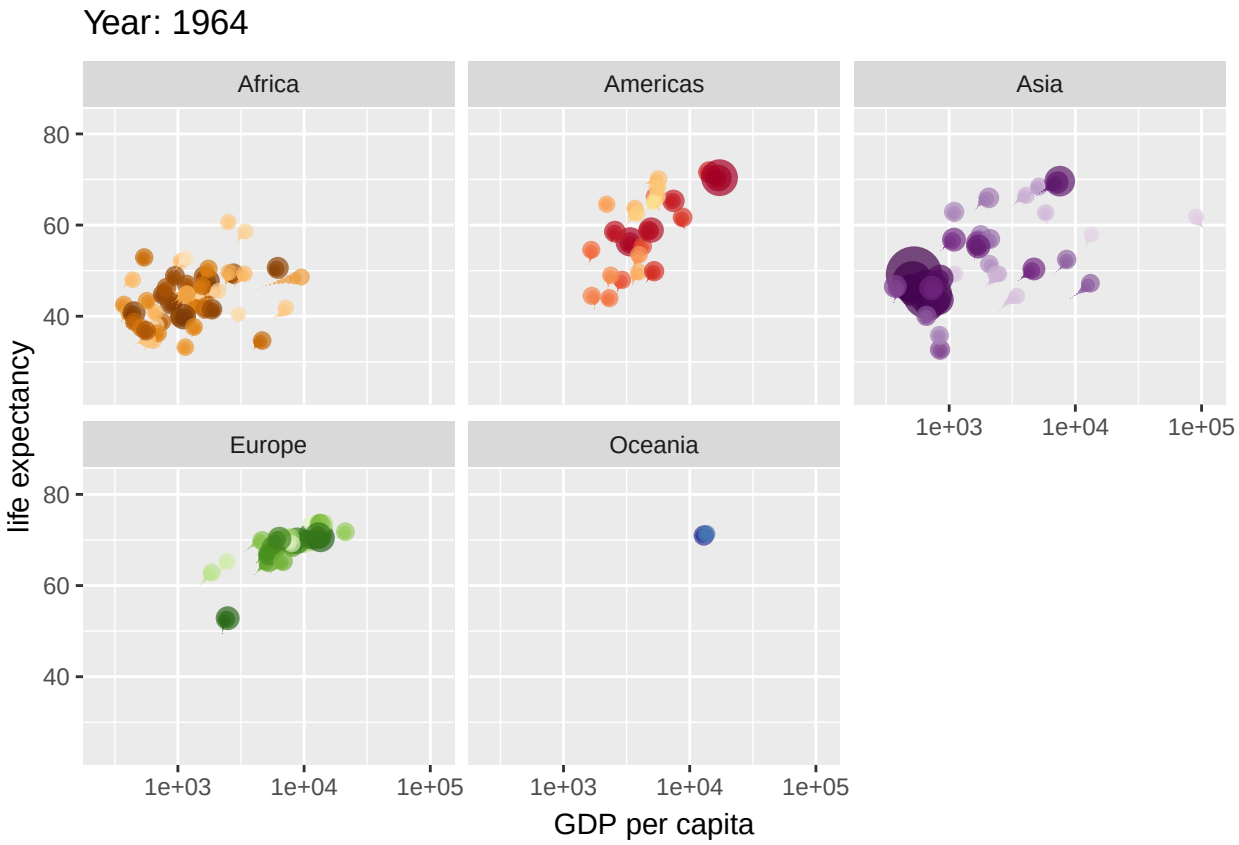
1e+03
1e+04
1e+05
GDP per capita


Year: 1964
Africa
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Europe
Oceania
life expectancy
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60
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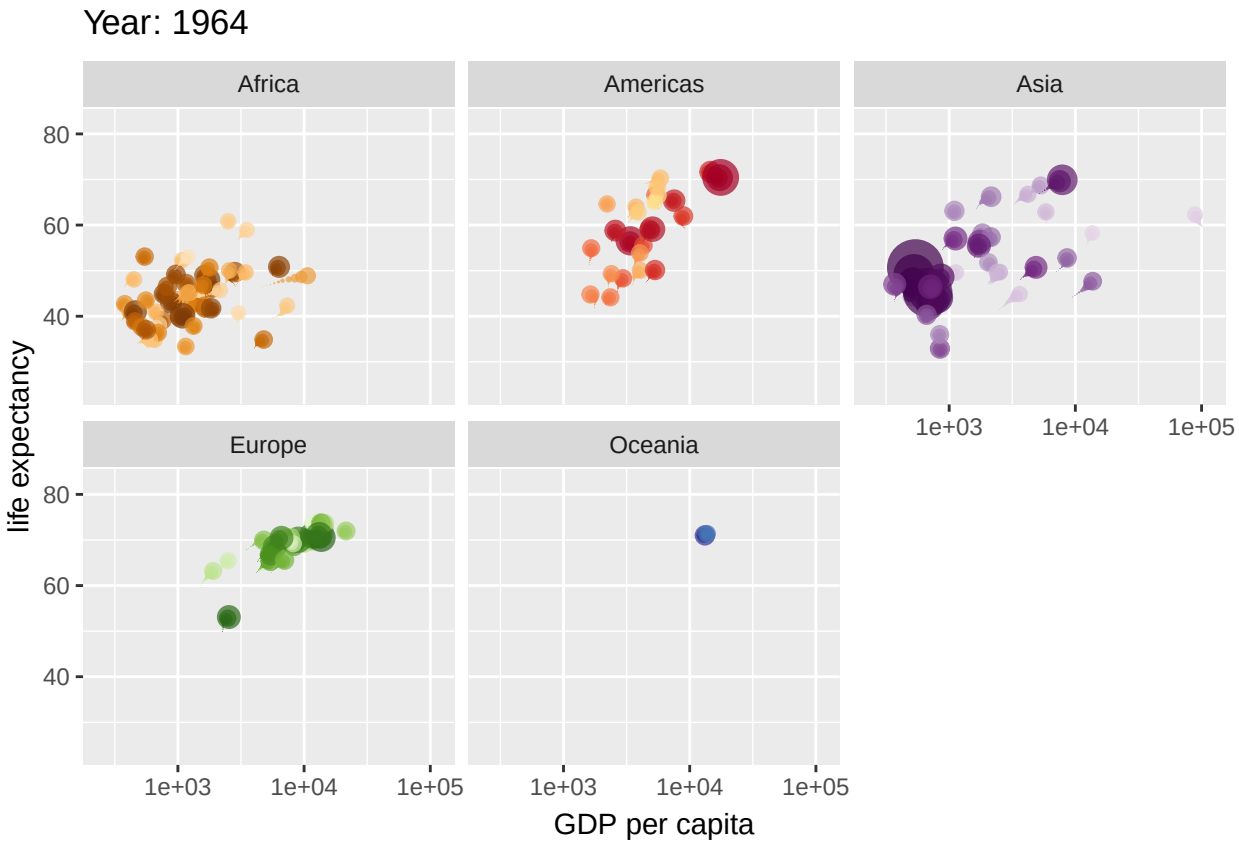
1e+03
1e+04
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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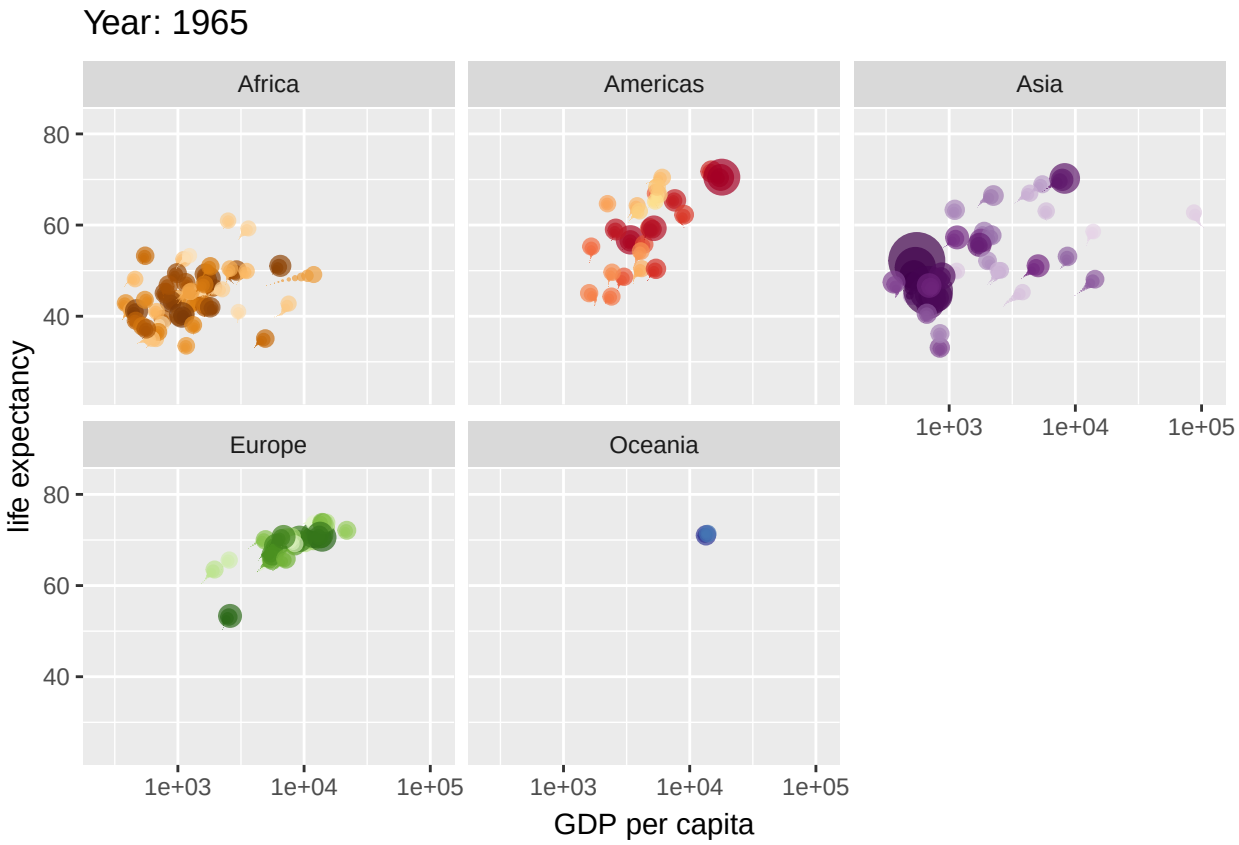
1e+03
1e+04
1e+05
GDP per capita


Year: 1965
Africa
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Europe
Oceania
life expectancy
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60
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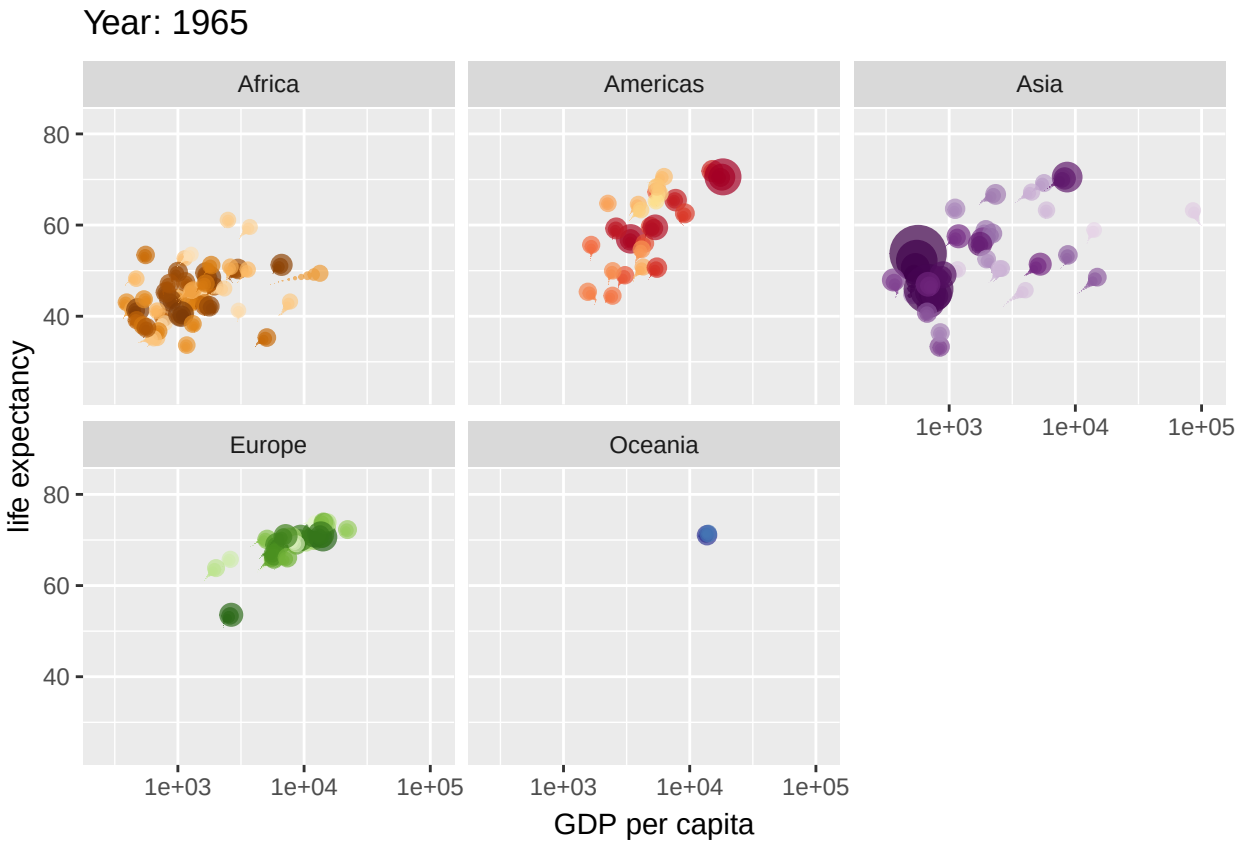
1e+03
1e+04
1e+05
GDP per capita


Year: 1965
Africa
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Europe
Oceania
life expectancy
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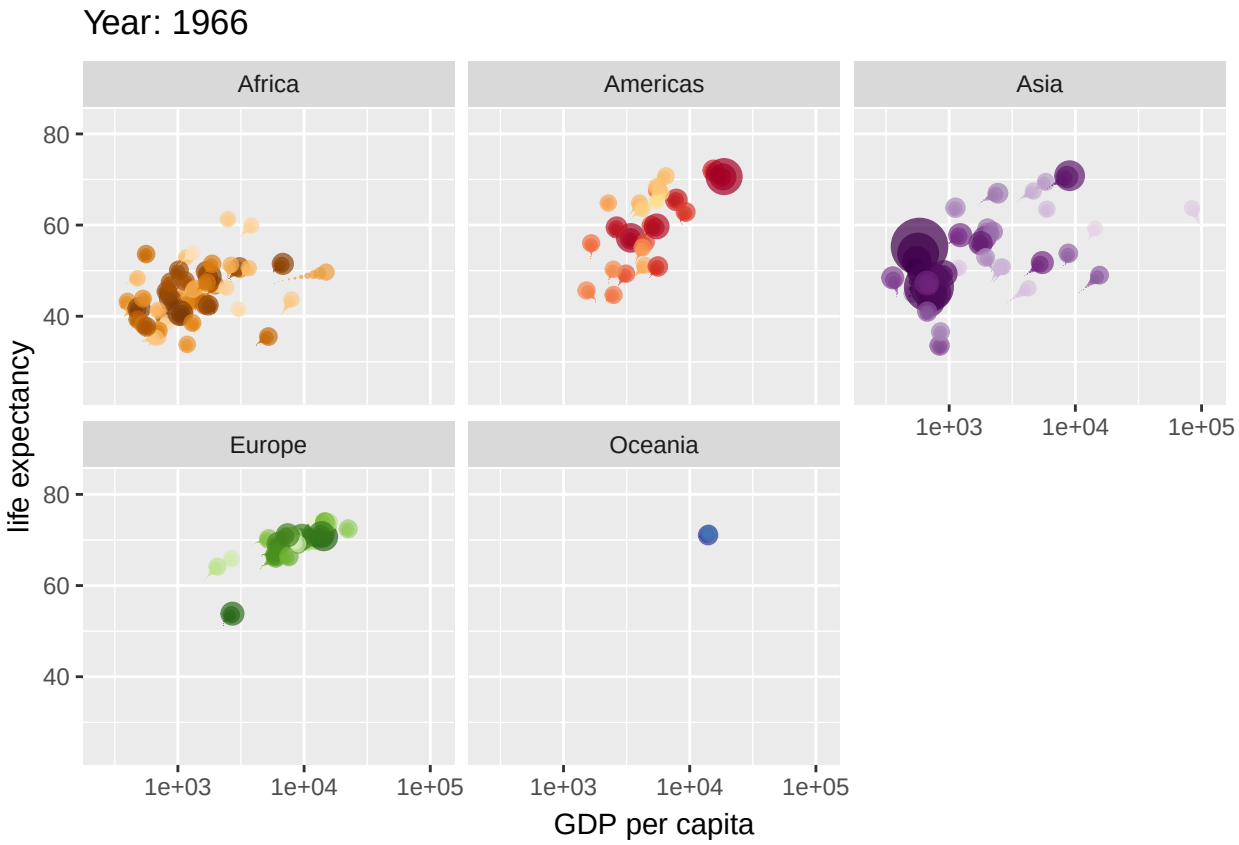
1e+03
1e+04
1e+05
GDP per capita


Year: 1966
Africa
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Europe
Oceania
life expectancy
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1e+03
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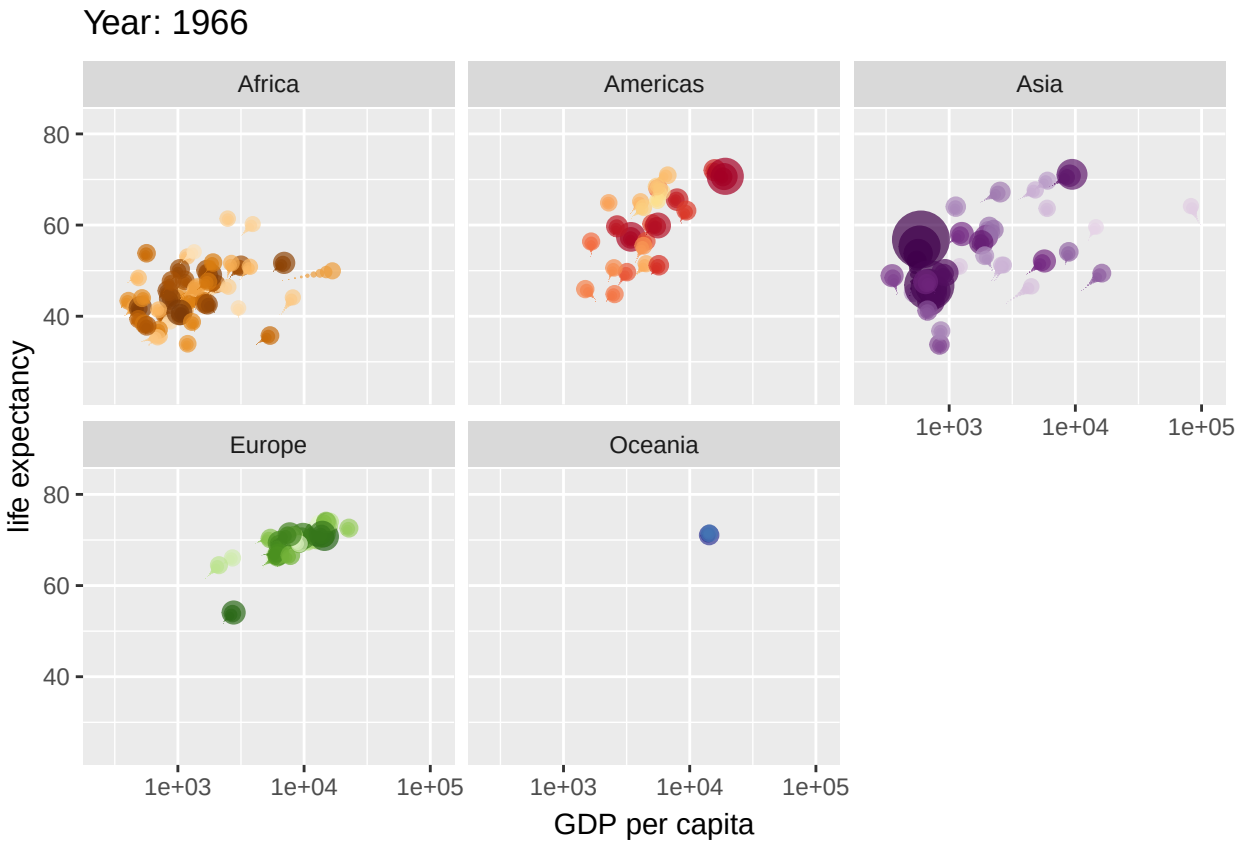
1e+05
GDP per capita


Year: 1966
Africa
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Europe
Oceania
life expectancy
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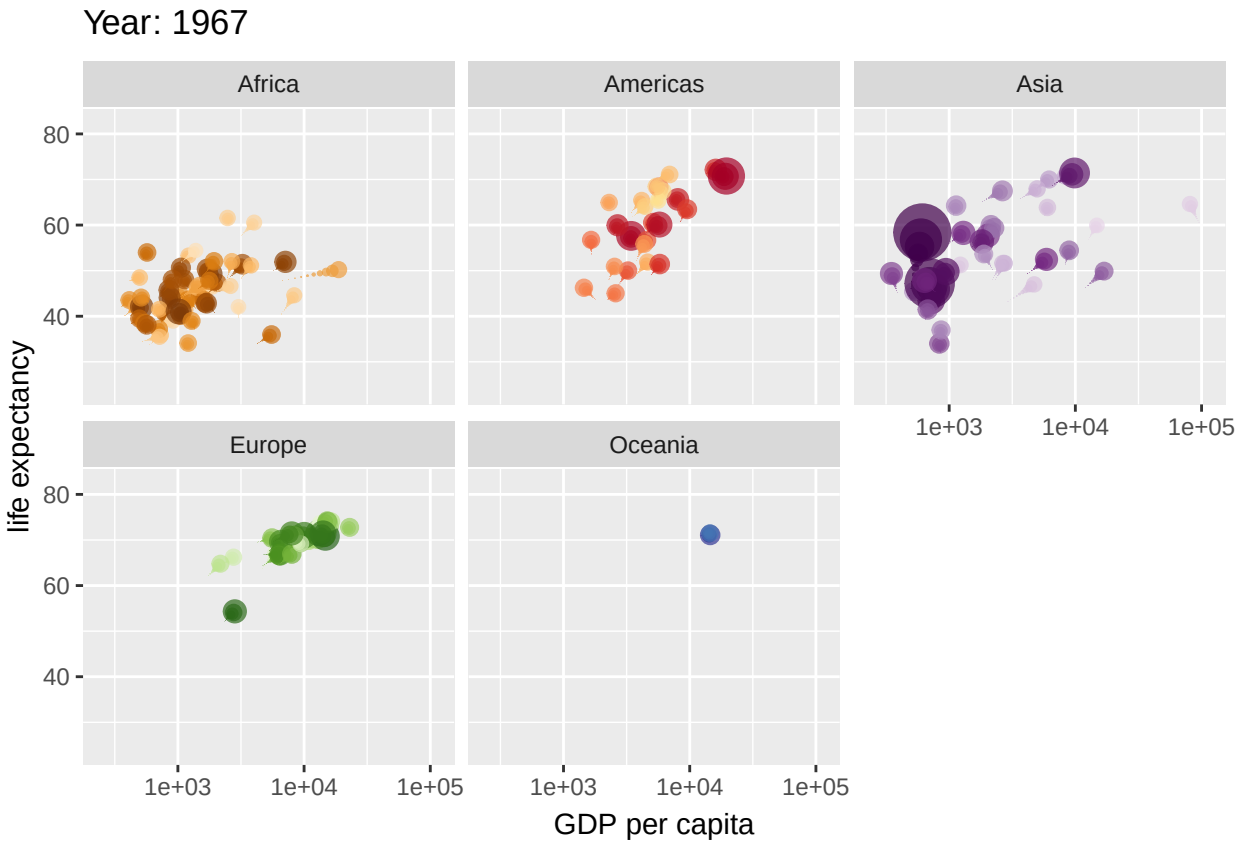
1e+05
GDP per capita


Year: 1967
Africa
Americas
Asia
Europe
Oceania
life expectancy
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60
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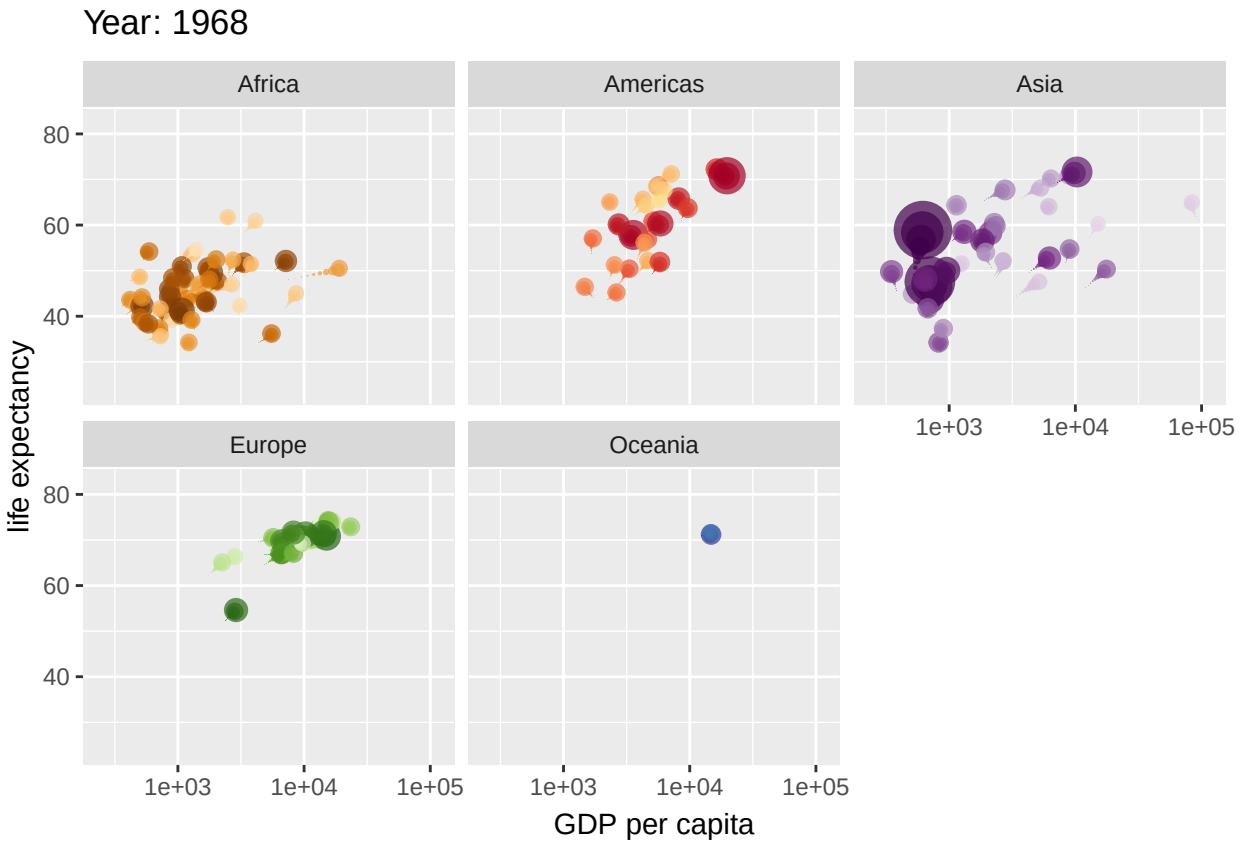
1e+03
1e+04
1e+05
GDP per capita


Year: 1968
Africa
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Asia
Europe
Oceania
life expectancy
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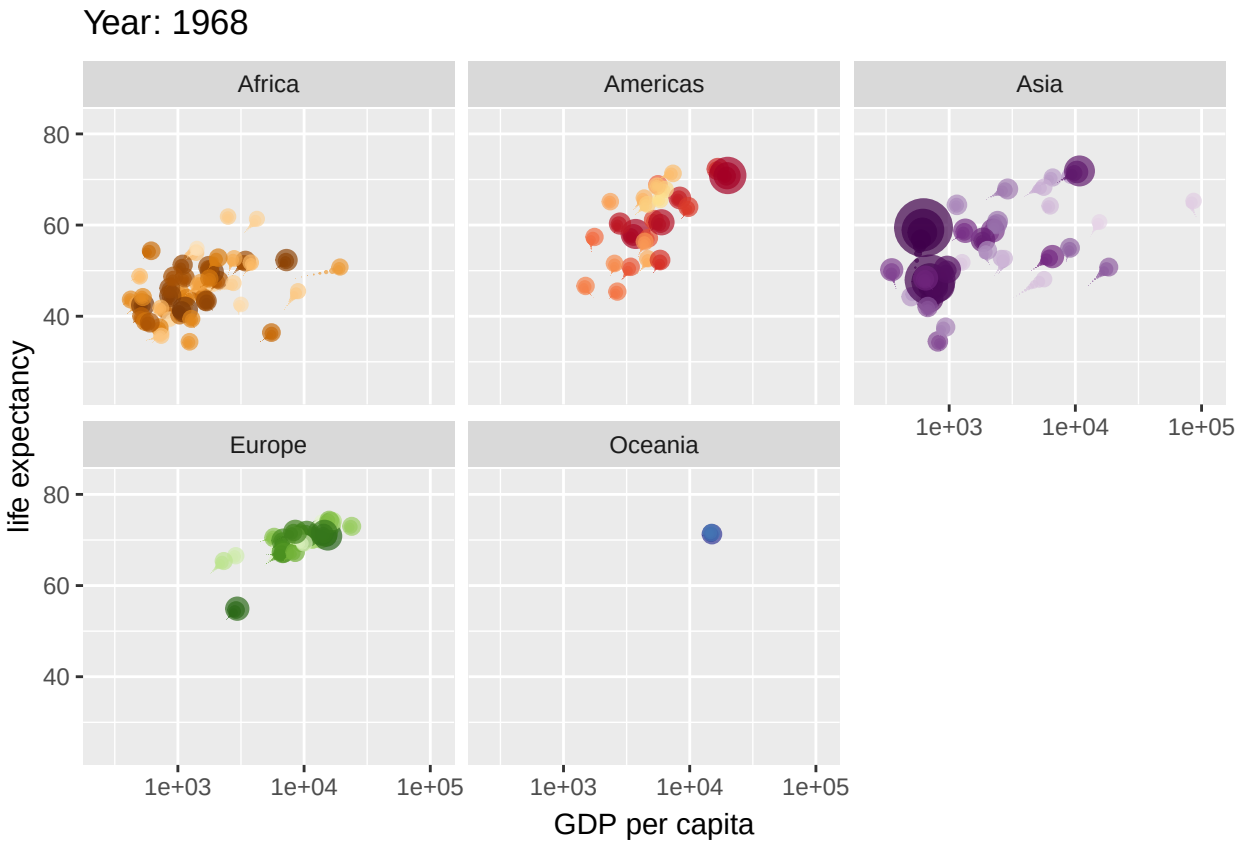
1e+03
1e+04
1e+05
GDP per capita


Year: 1968
Africa
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Asia
Europe
Oceania
life expectancy
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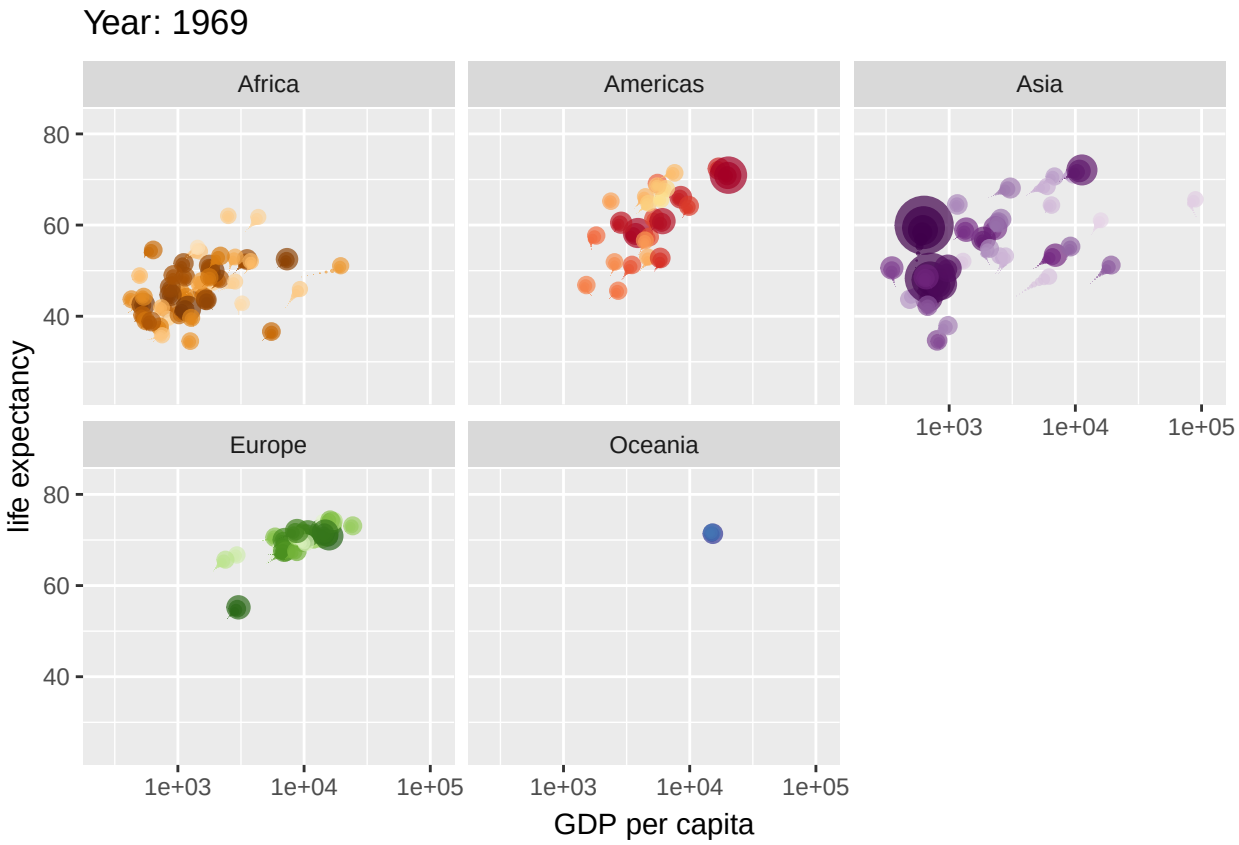
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1969
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Asia
Europe
Oceania
life expectancy
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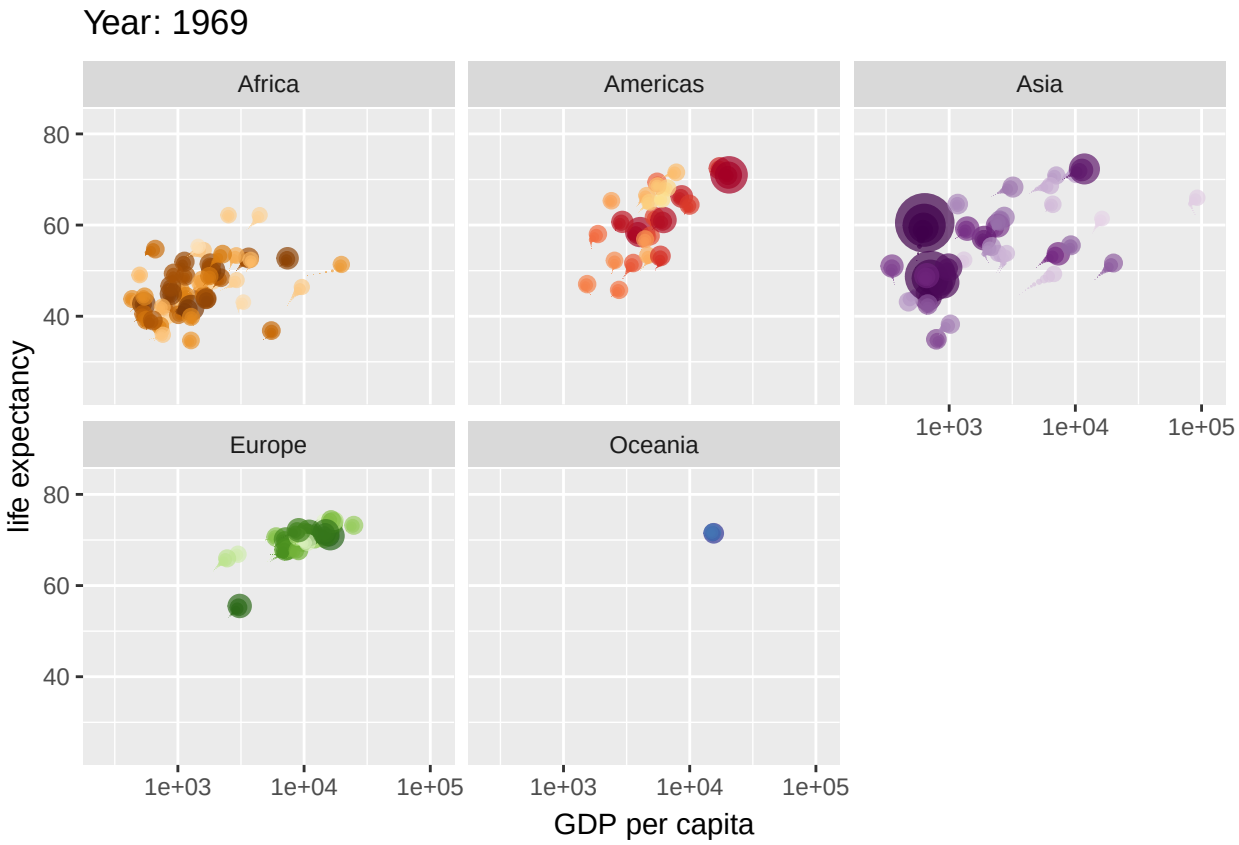
1e+05
GDP per capita


Year: 1969
Africa
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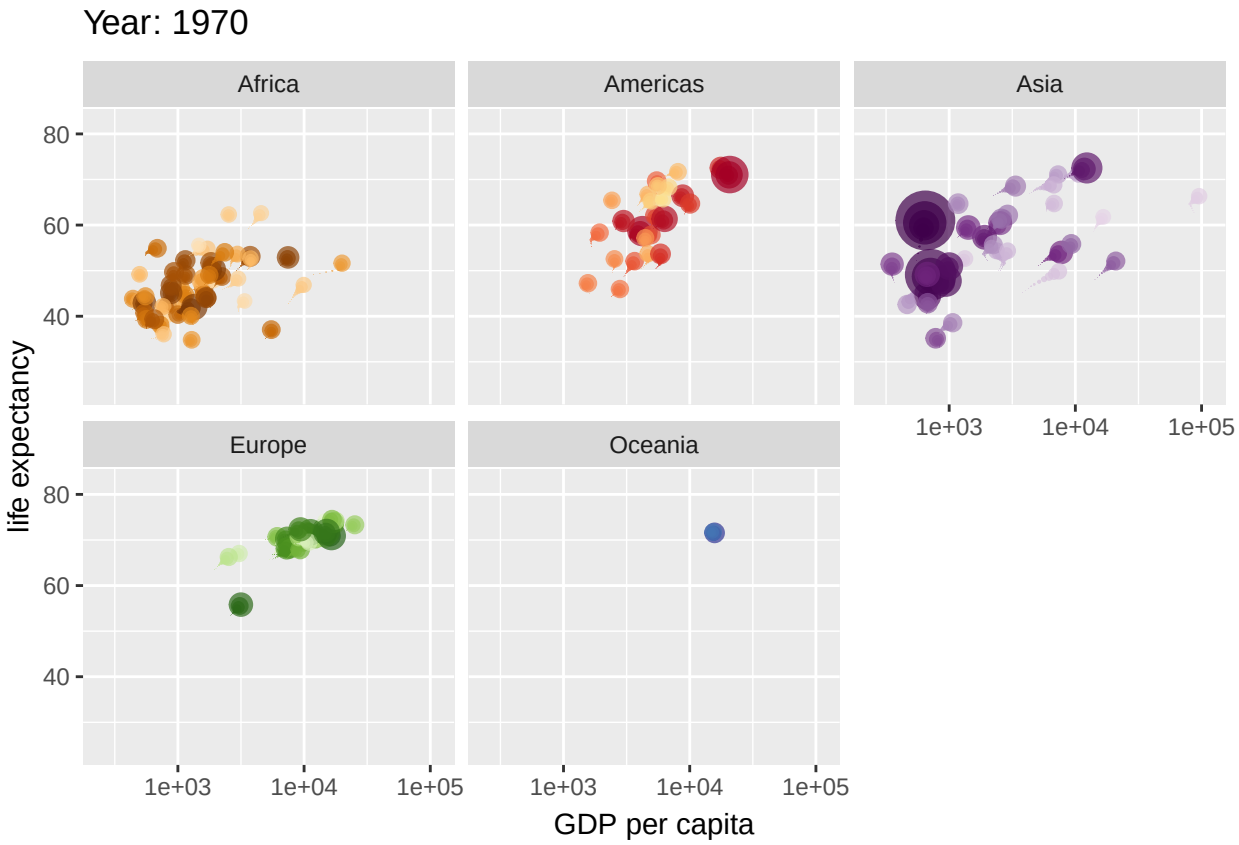
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1970
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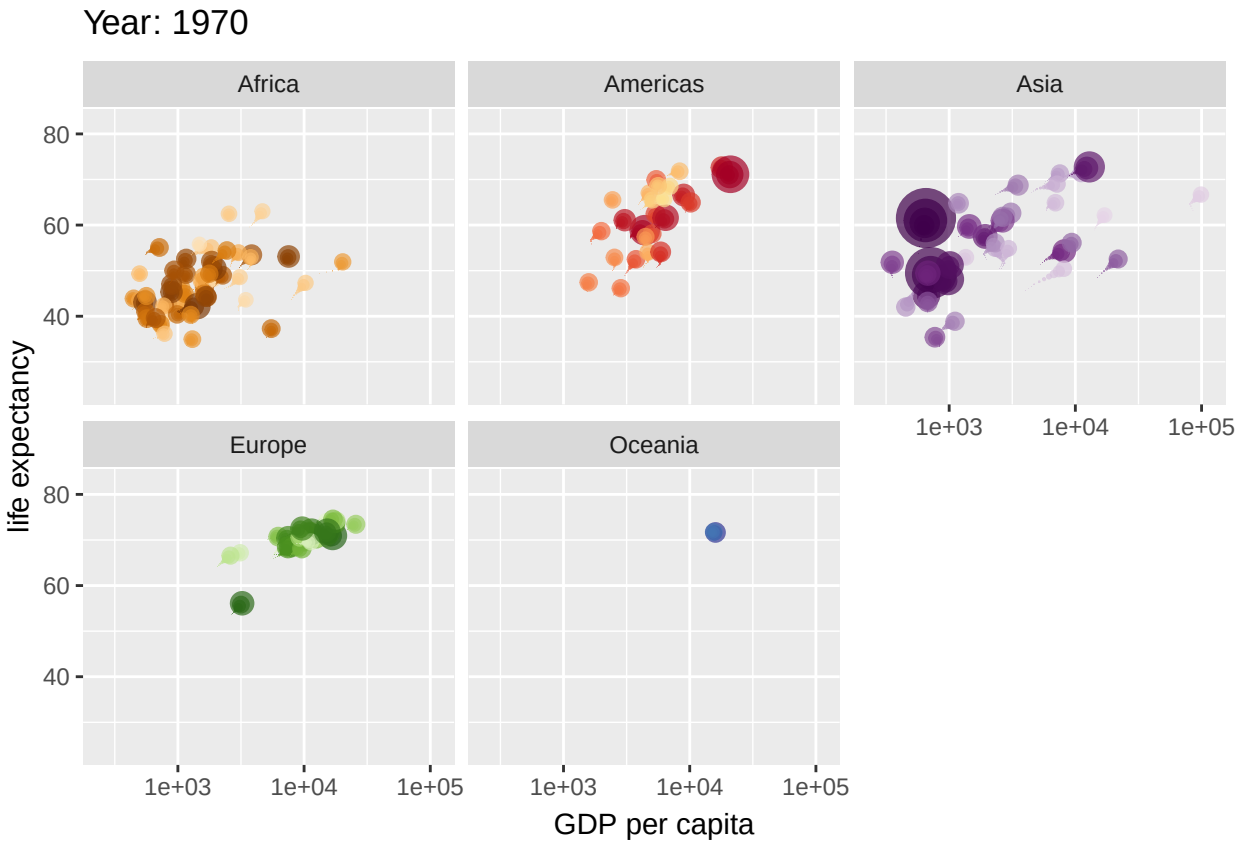
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1970
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Asia
Europe
Oceania
life expectancy
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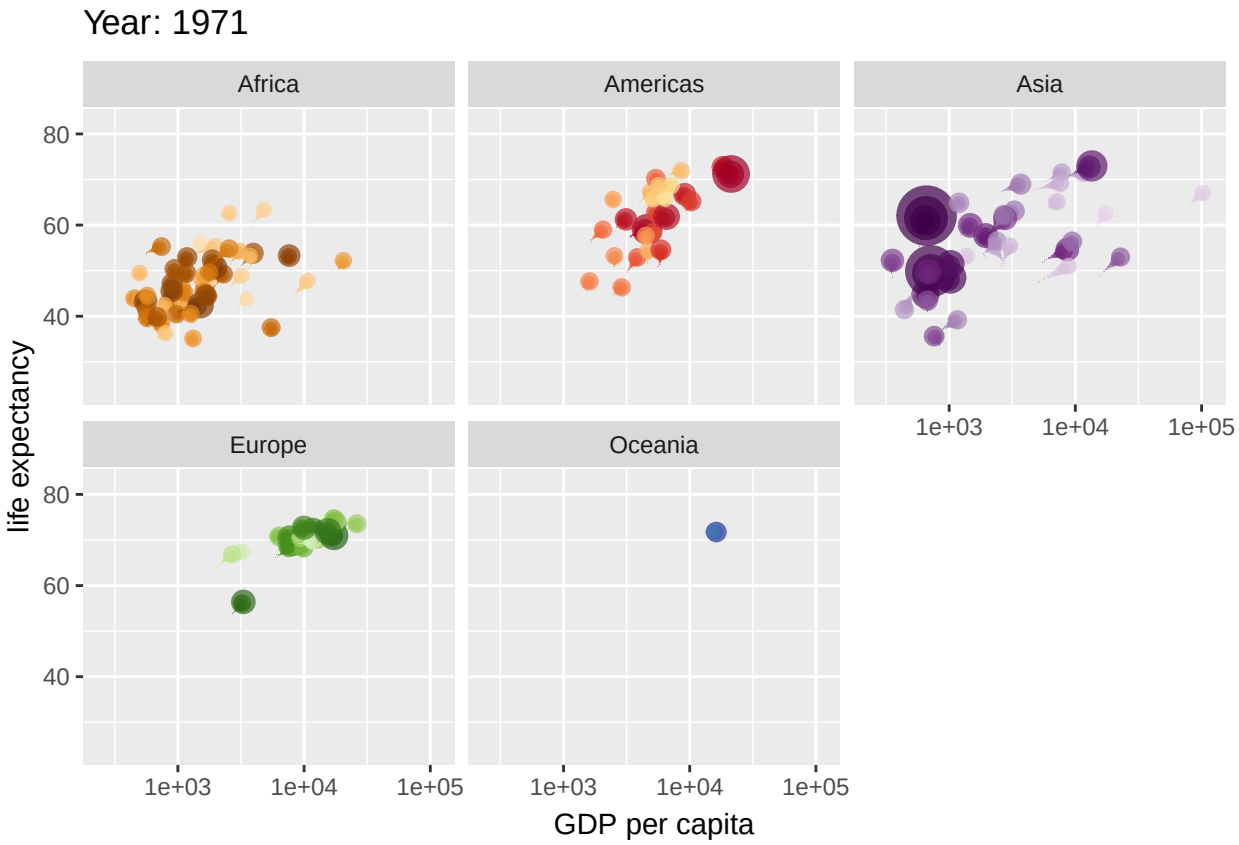
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1971
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Asia
Europe
Oceania
life expectancy
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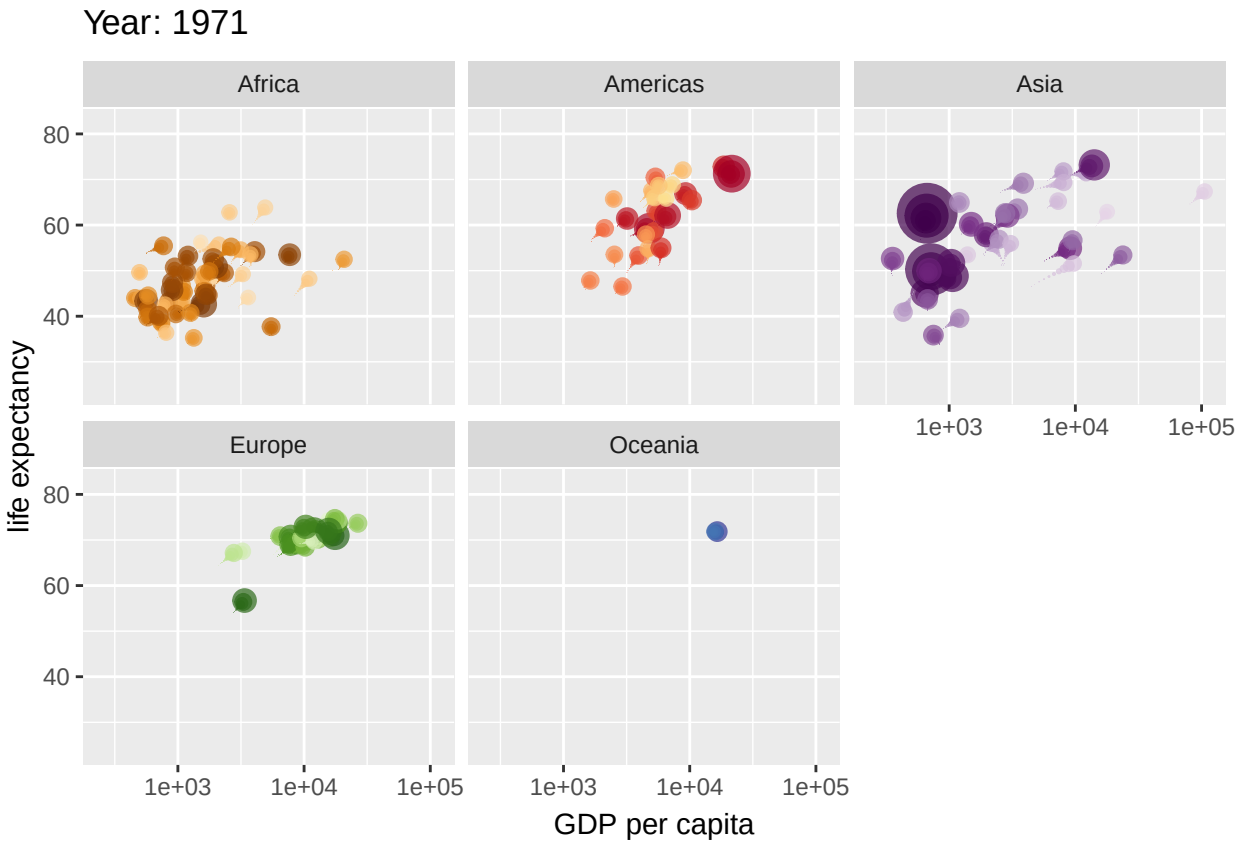
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1971
Africa
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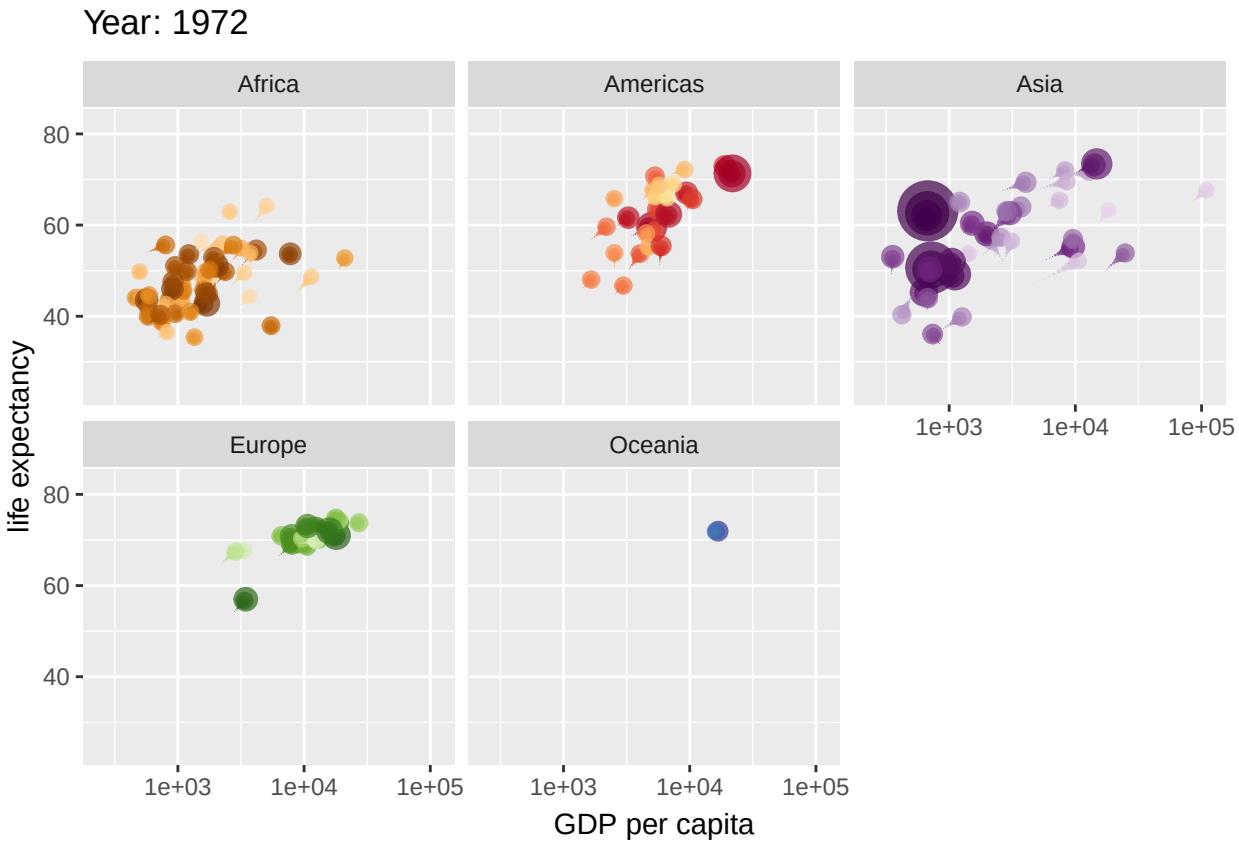
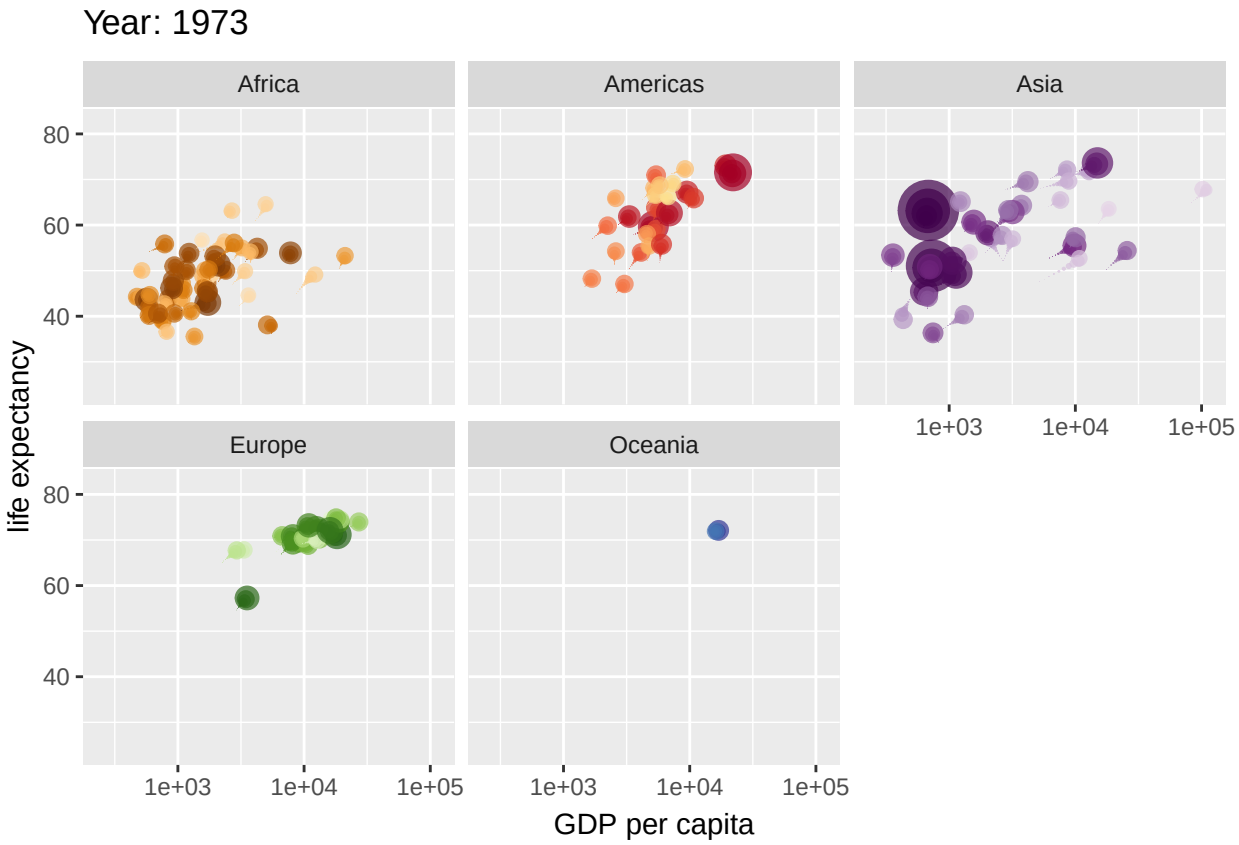
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1972
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1973
Africa
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Asia
Europe
Oceania
life expectancy
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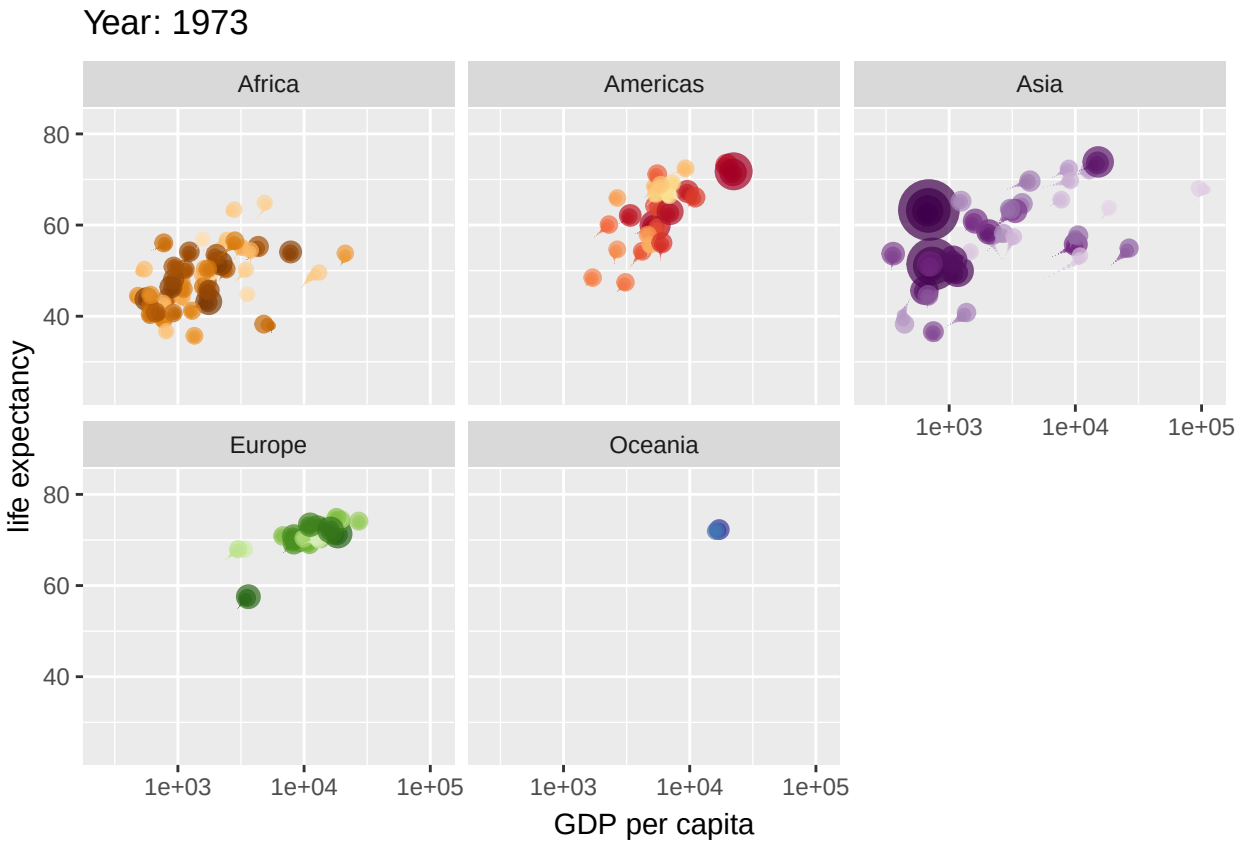
1e+03
1e+04
1e+05
GDP per capita


Year: 1973
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
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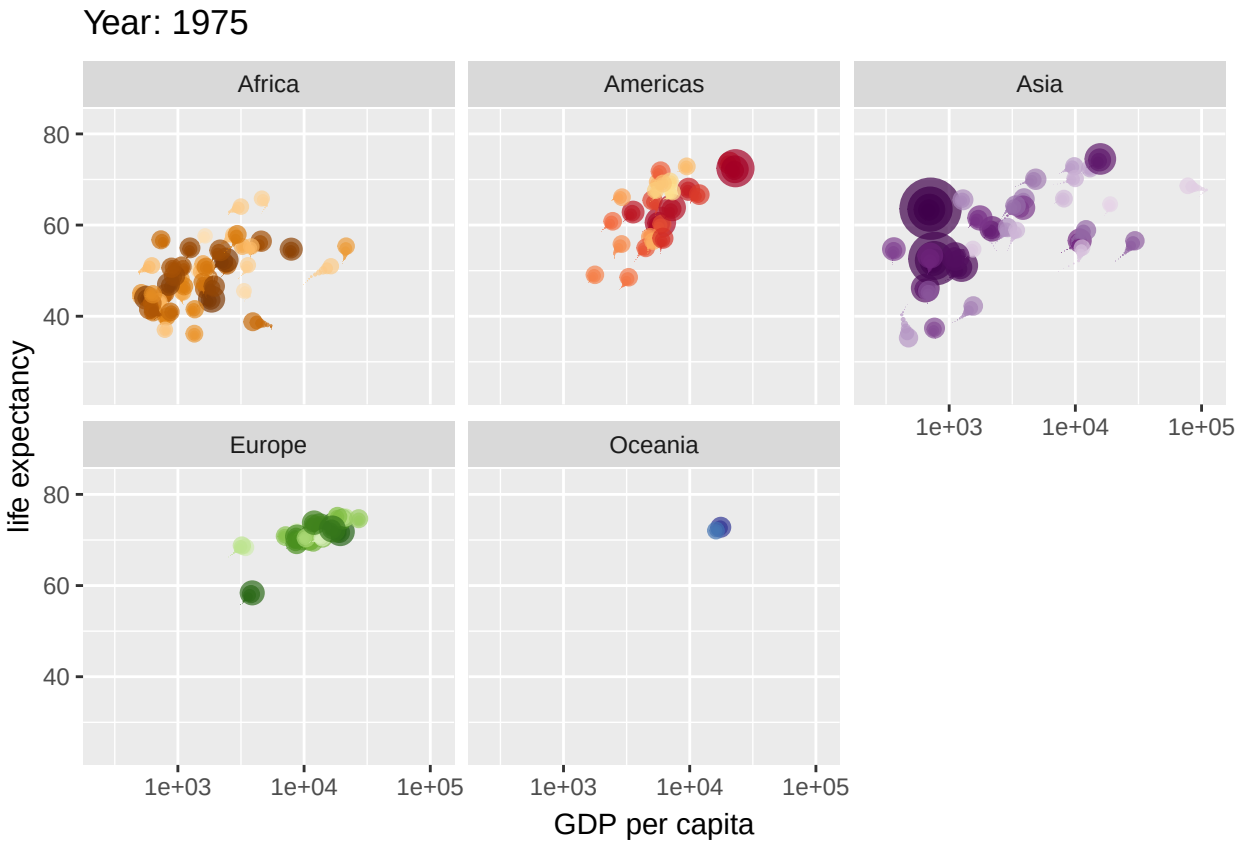
1e+03
1e+04
1e+05
GDP per capita


Year: 1974
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1974
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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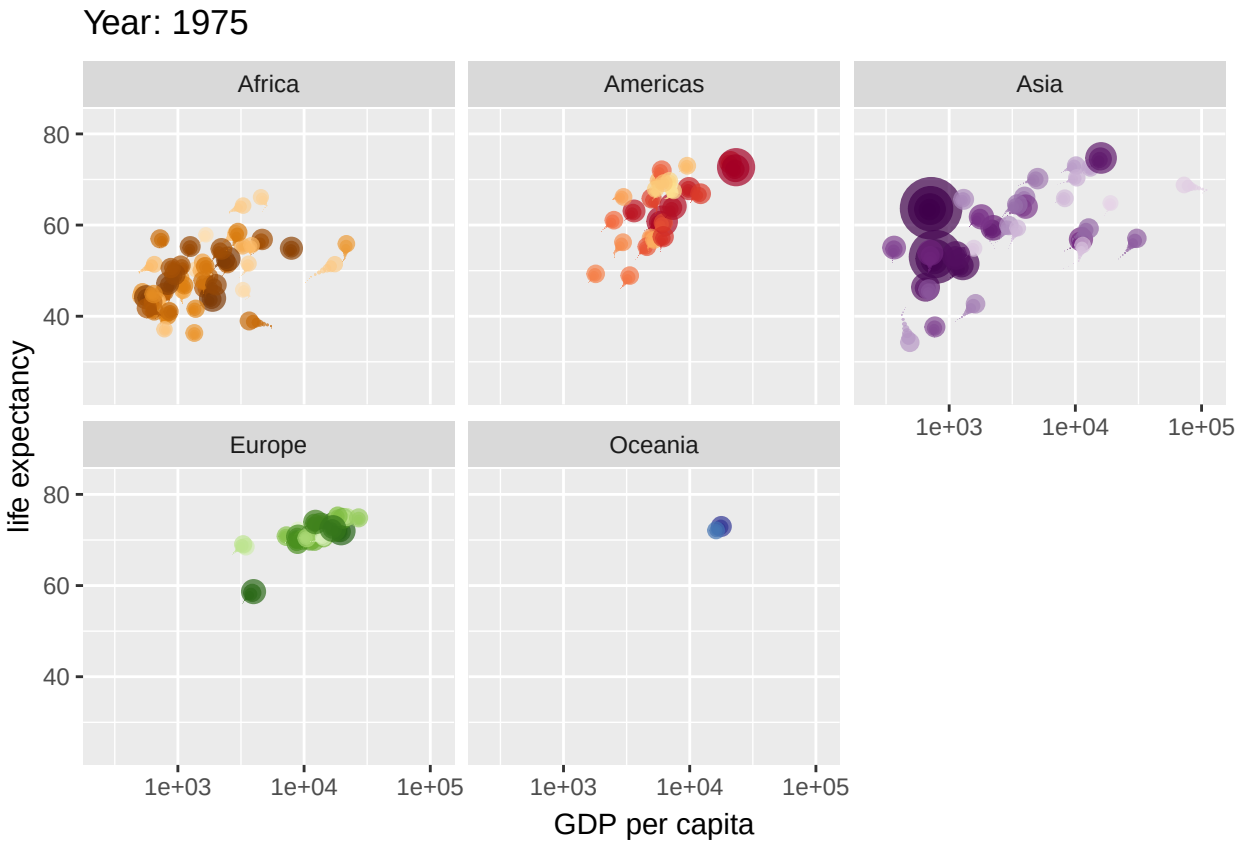
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1976
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1976
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Europe
Oceania
life expectancy
80
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40
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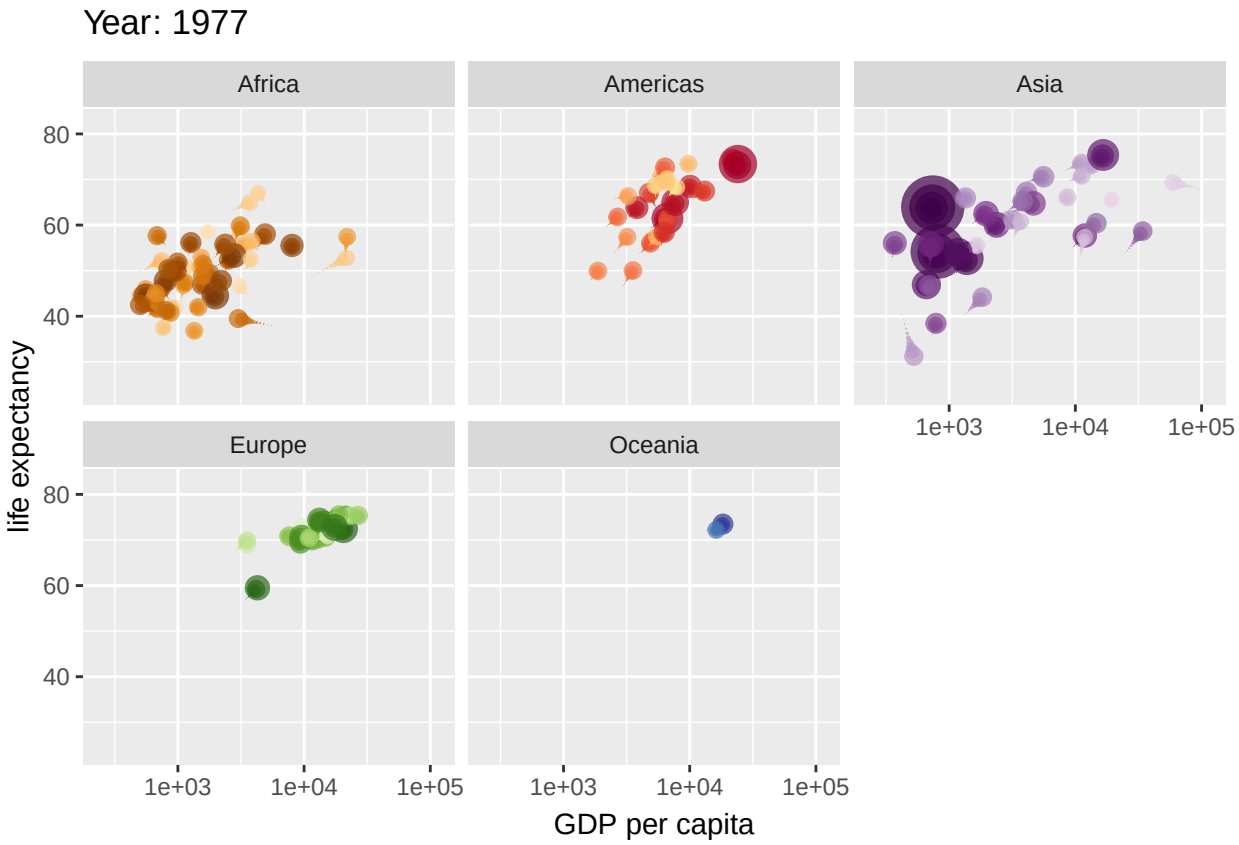
1e+05
GDP per capita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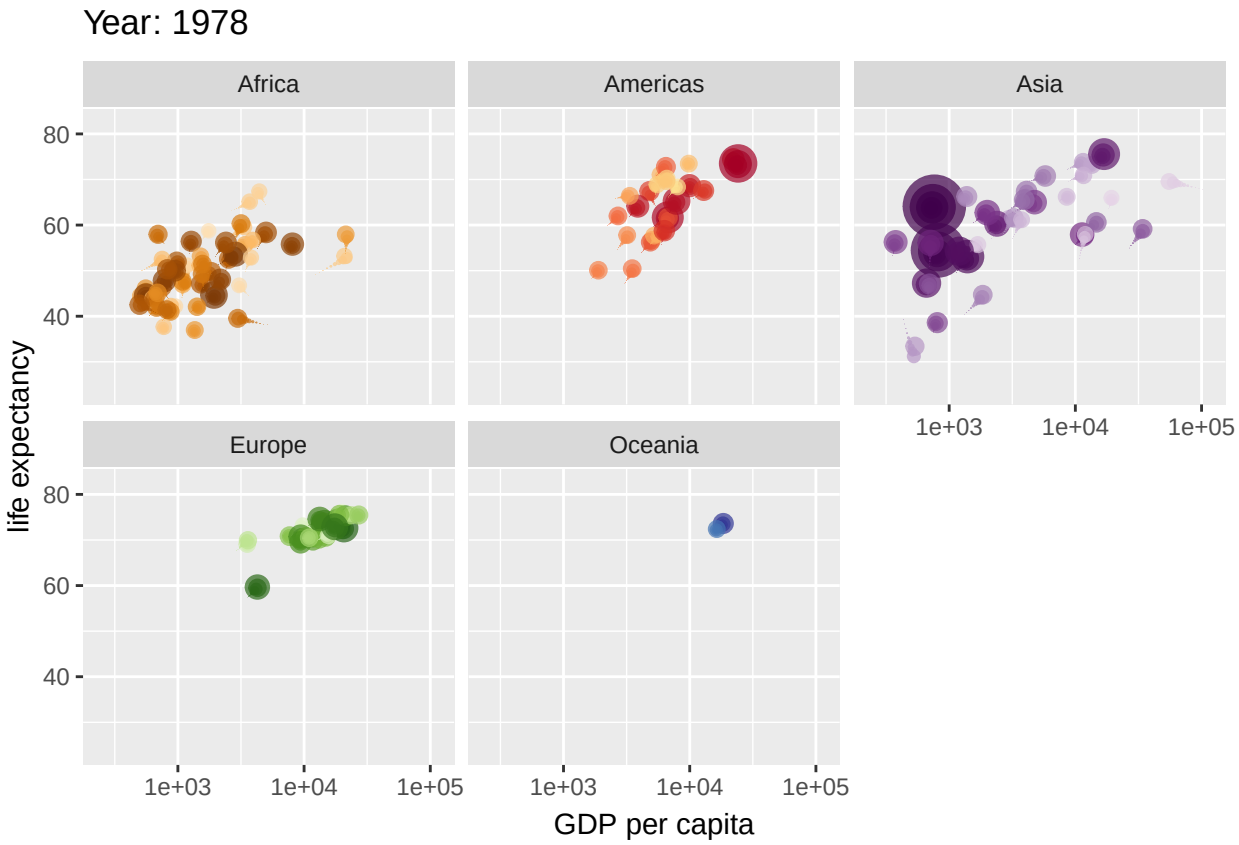
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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life expectancy
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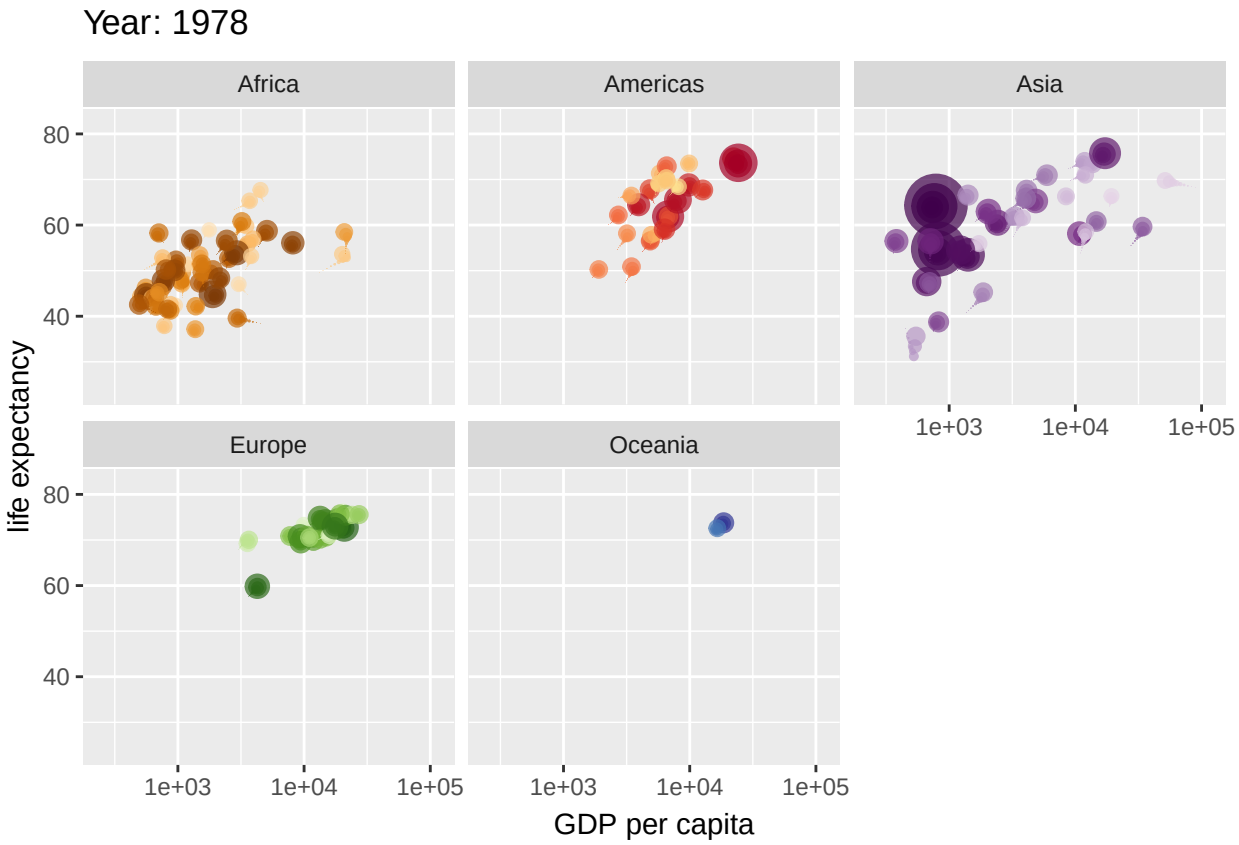
1e+05
GDP per capita


Year: 1978
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Oceania
life expectancy
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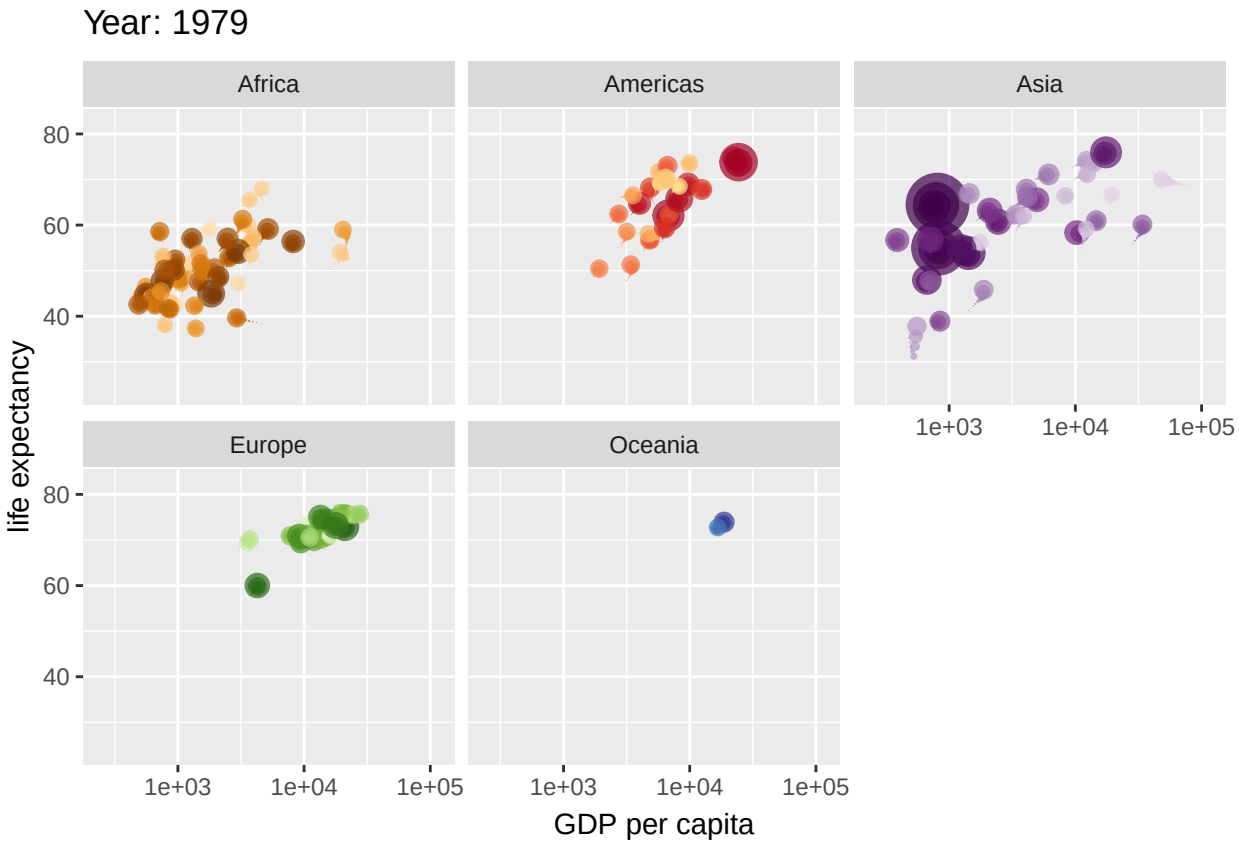
40
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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1e+03
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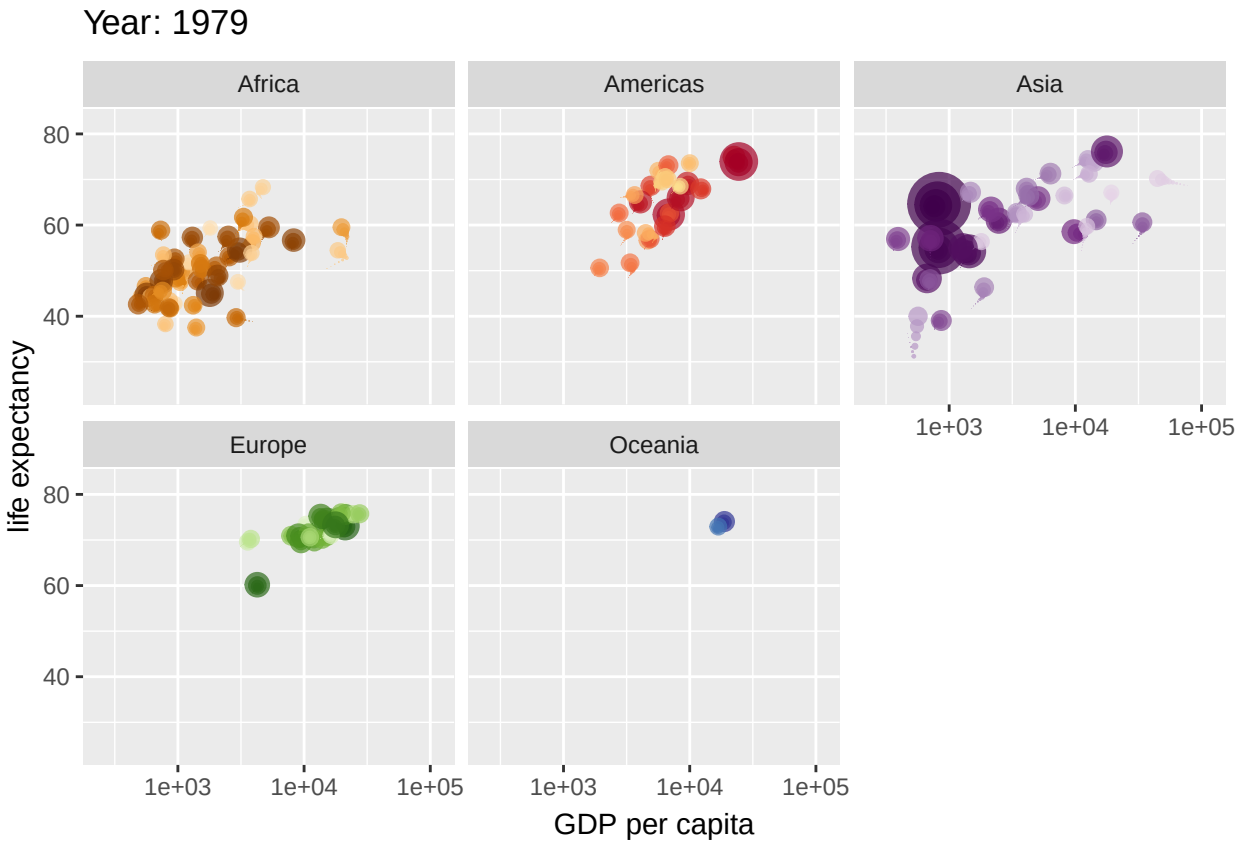
1e+05
GDP per capita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Africa
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life expectancy
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60
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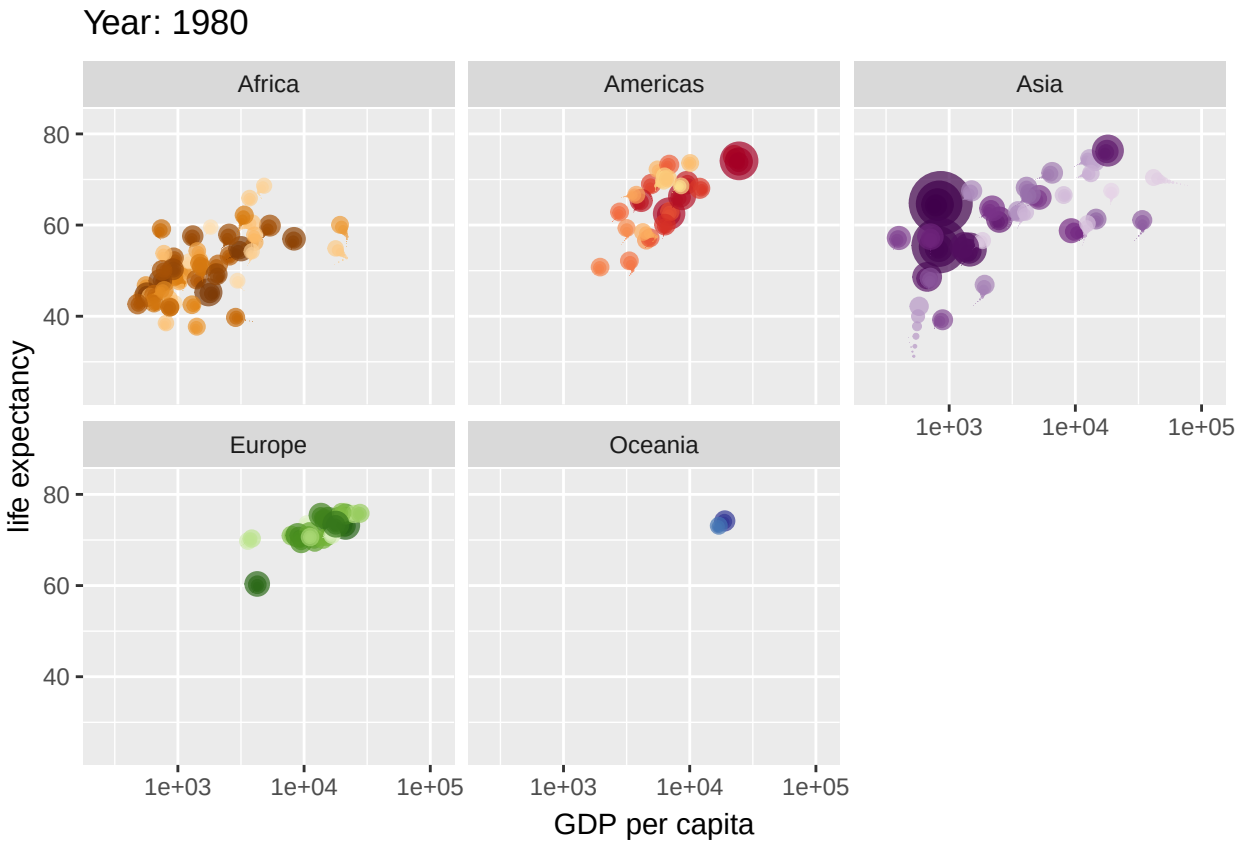
1e+03
1e+04
1e+05
GDP per capita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life expectancy
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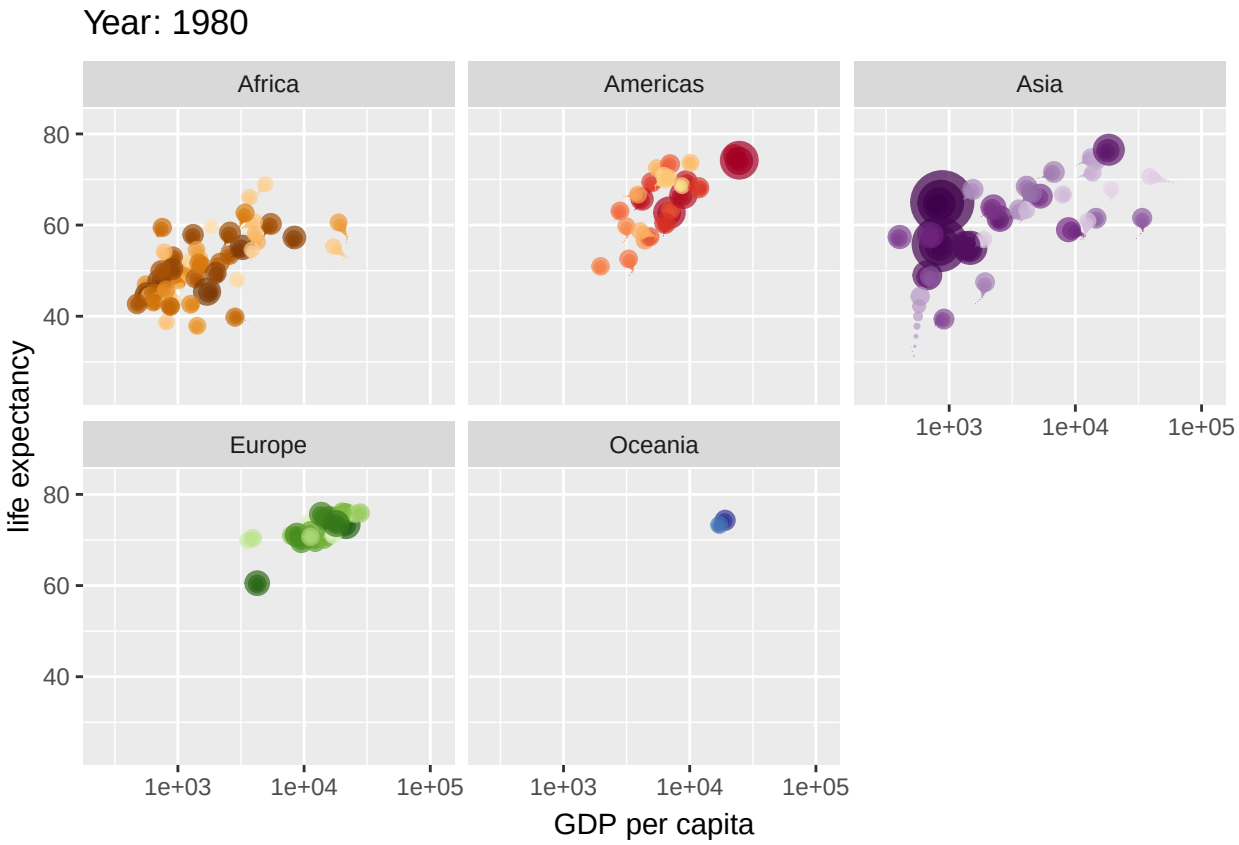
1e+03
1e+04
1e+05
GDP per capita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life expectancy
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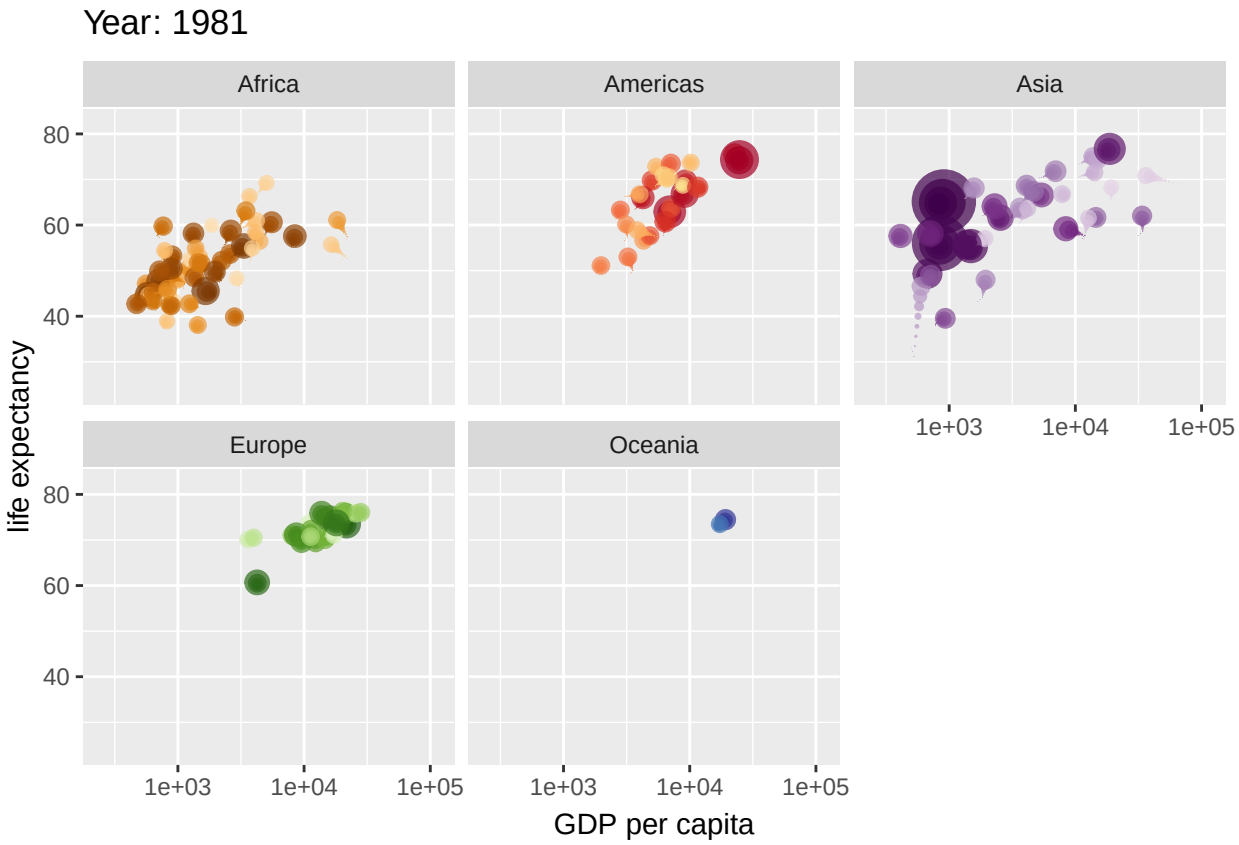
1e+03
1e+04
1e+05
GDP per capita


Year: 1981
Africa
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Europe
Oceania
life expectancy
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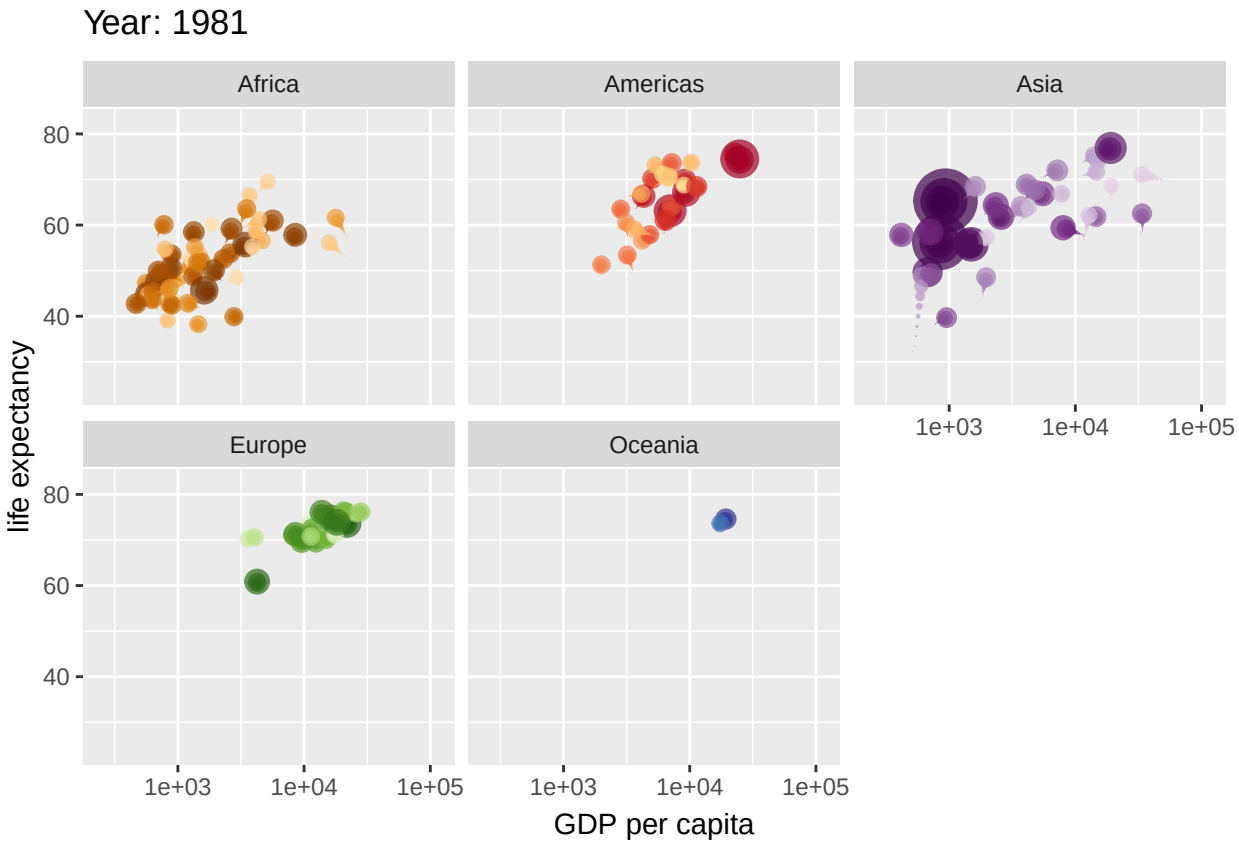
1e+03
1e+04
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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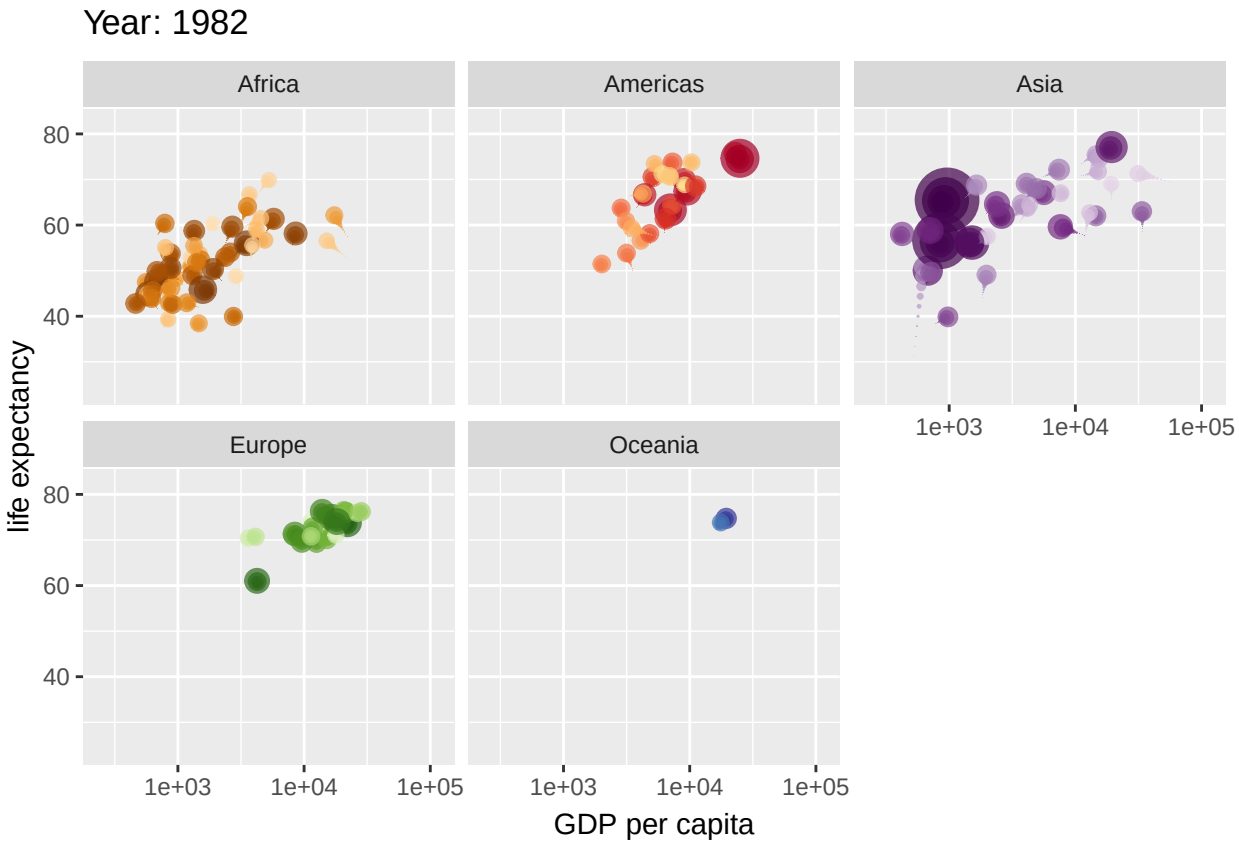
1e+03
1e+04
1e+05
GDP per capita


Year: 1982
Africa
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Asia
Europe
Oceania
life expectancy
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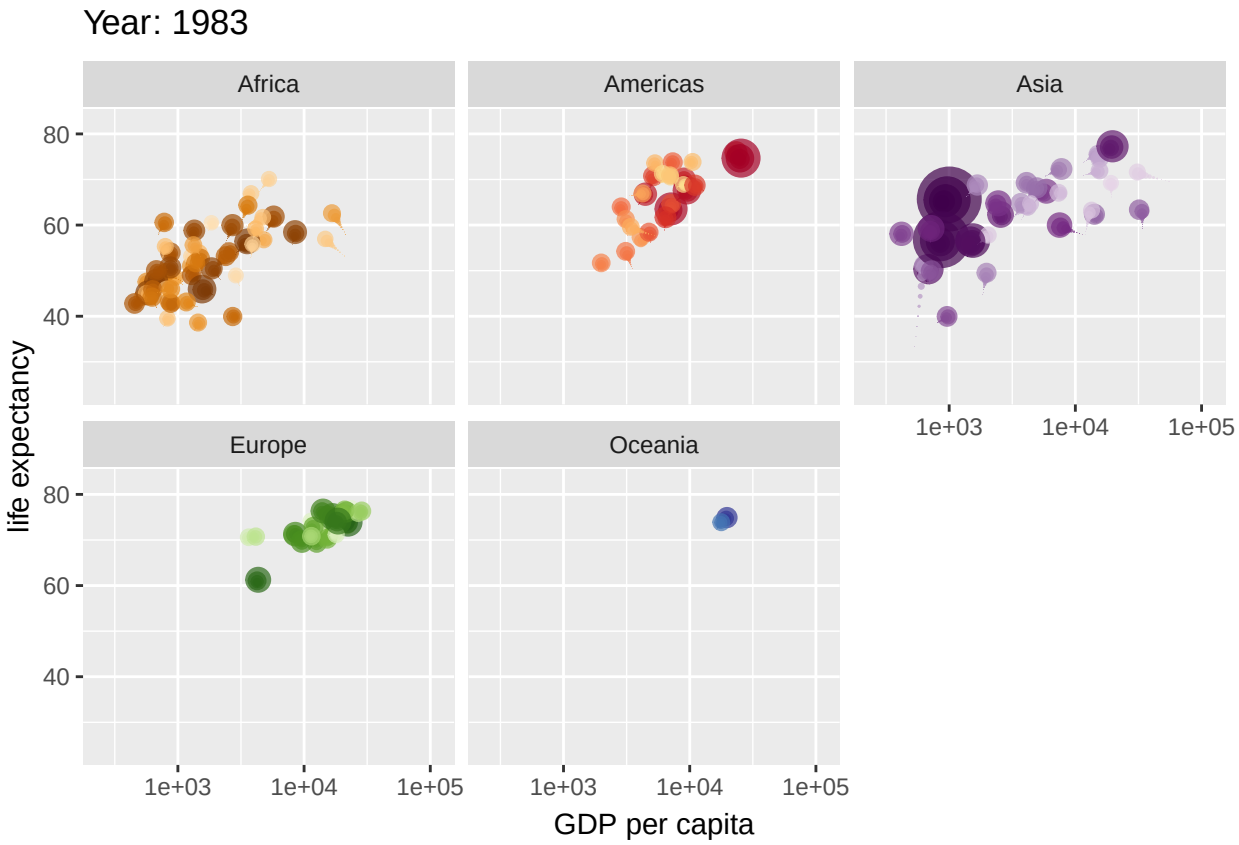
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1983
Africa
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Europe
Oceania
life expectancy
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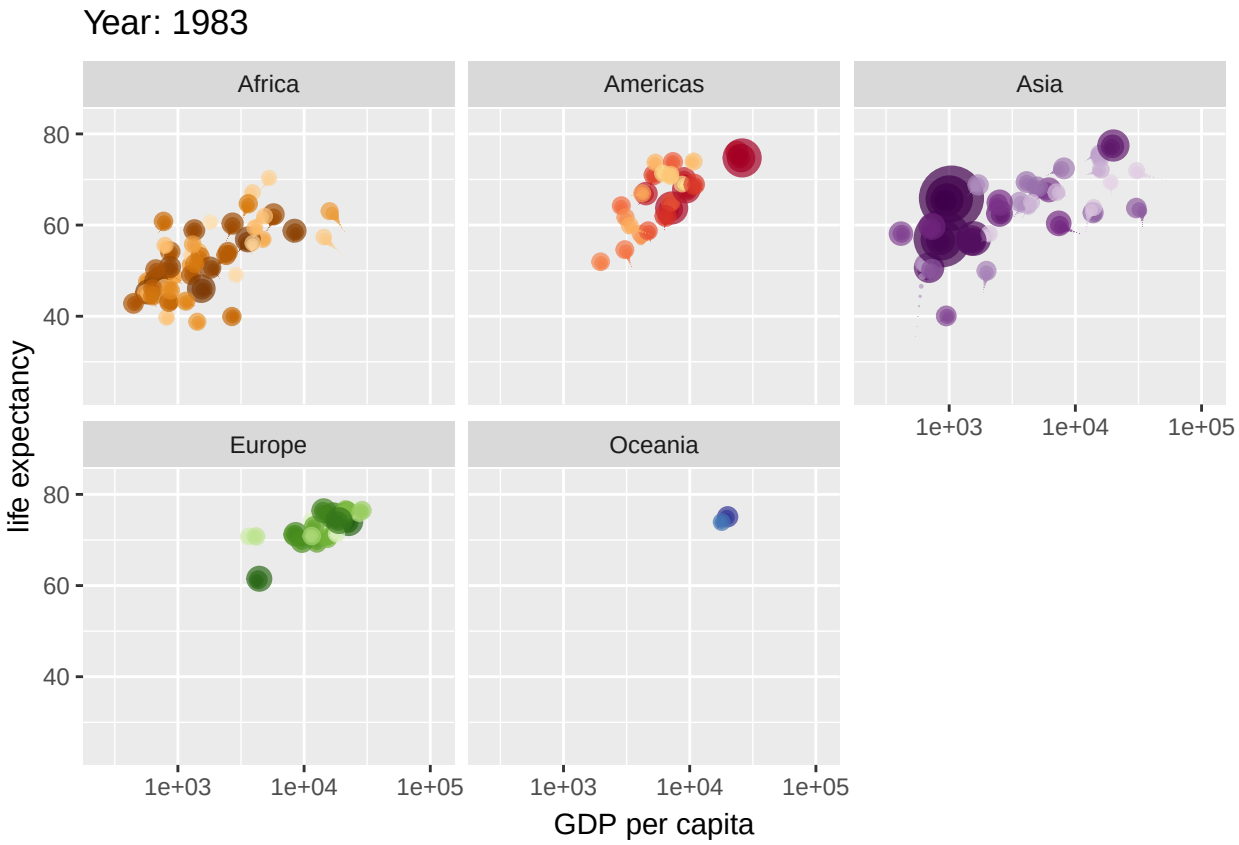
1e+03
1e+04
1e+05
GDP per capita


Year: 1983
Africa
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Europe
Oceania
life expectancy
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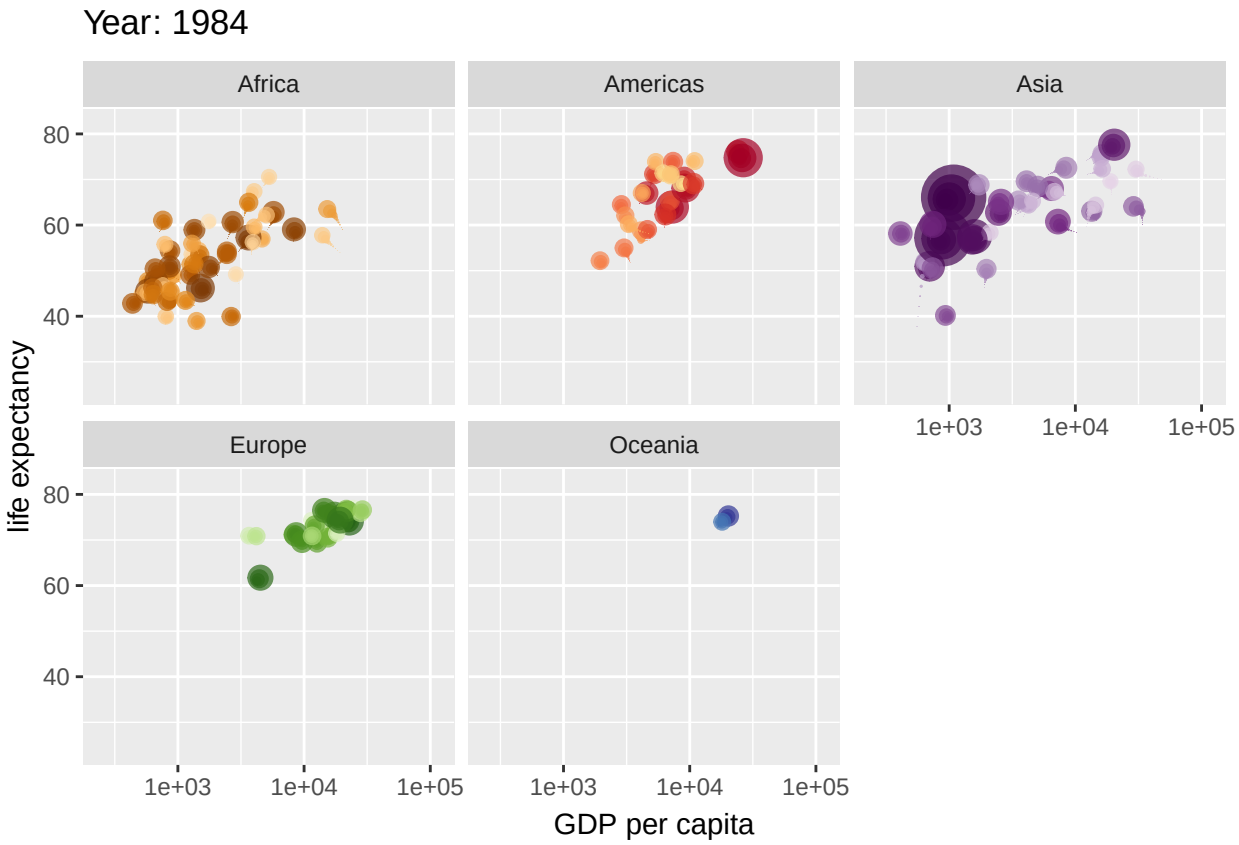
1e+03
1e+04
1e+05
GDP per capita


Year: 1984
Africa
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Asia
Europe
Oceania
life expectancy
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60
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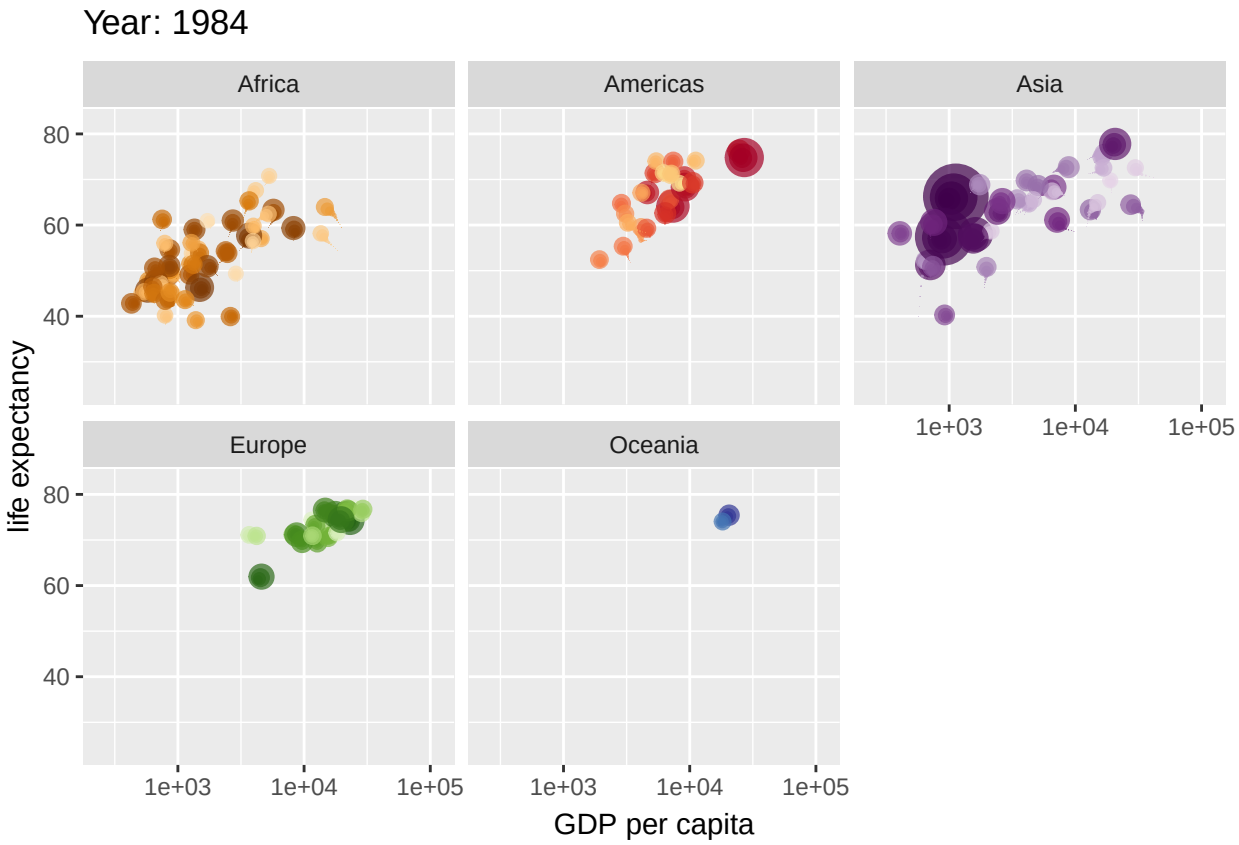
1e+03
1e+04
1e+05
GDP per capita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Africa
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Europe
Oceania
life expectancy
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1e+03
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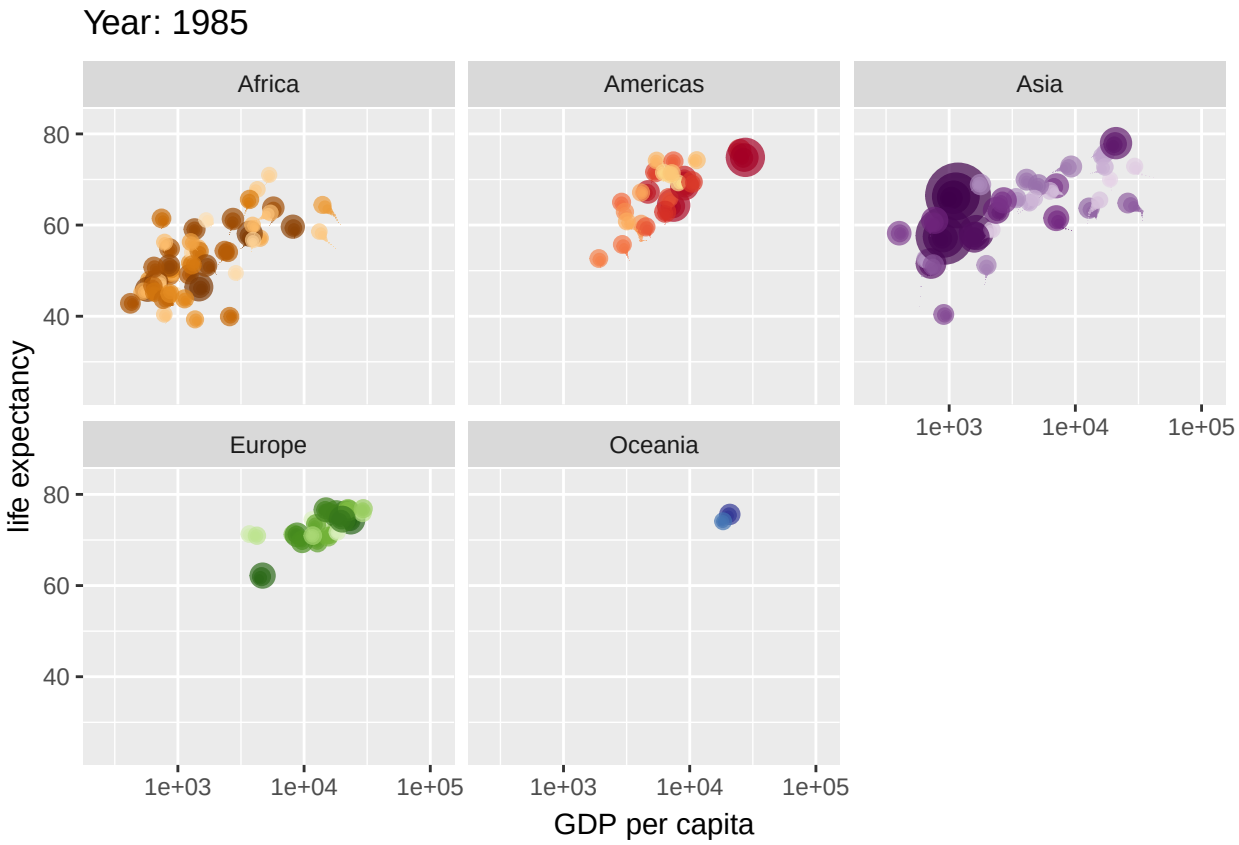
1e+05
GDP per capita


Year: 1985
Africa
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Europe
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life expectancy
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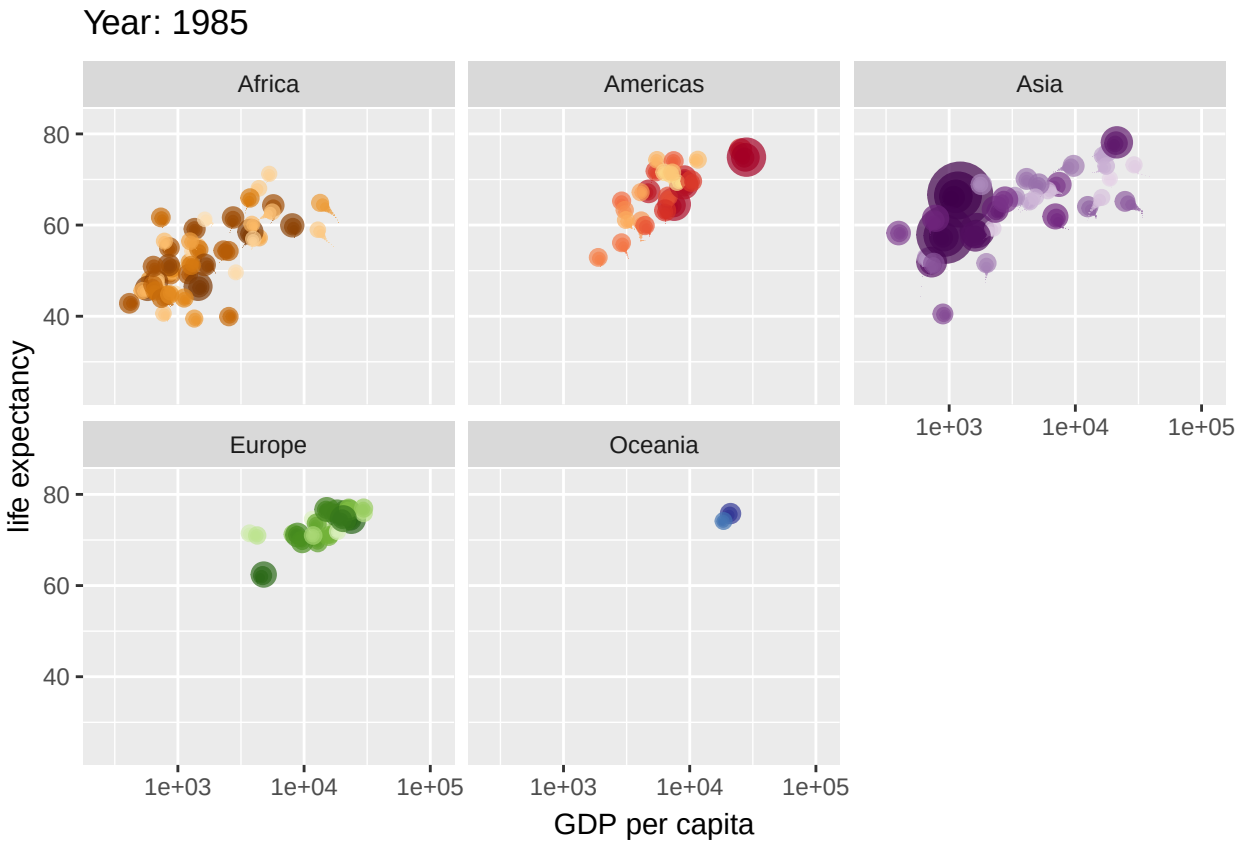
1e+03
1e+04
1e+05
GDP per capita


Year: 1985
Africa
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Oceania
life expectancy
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1e+03
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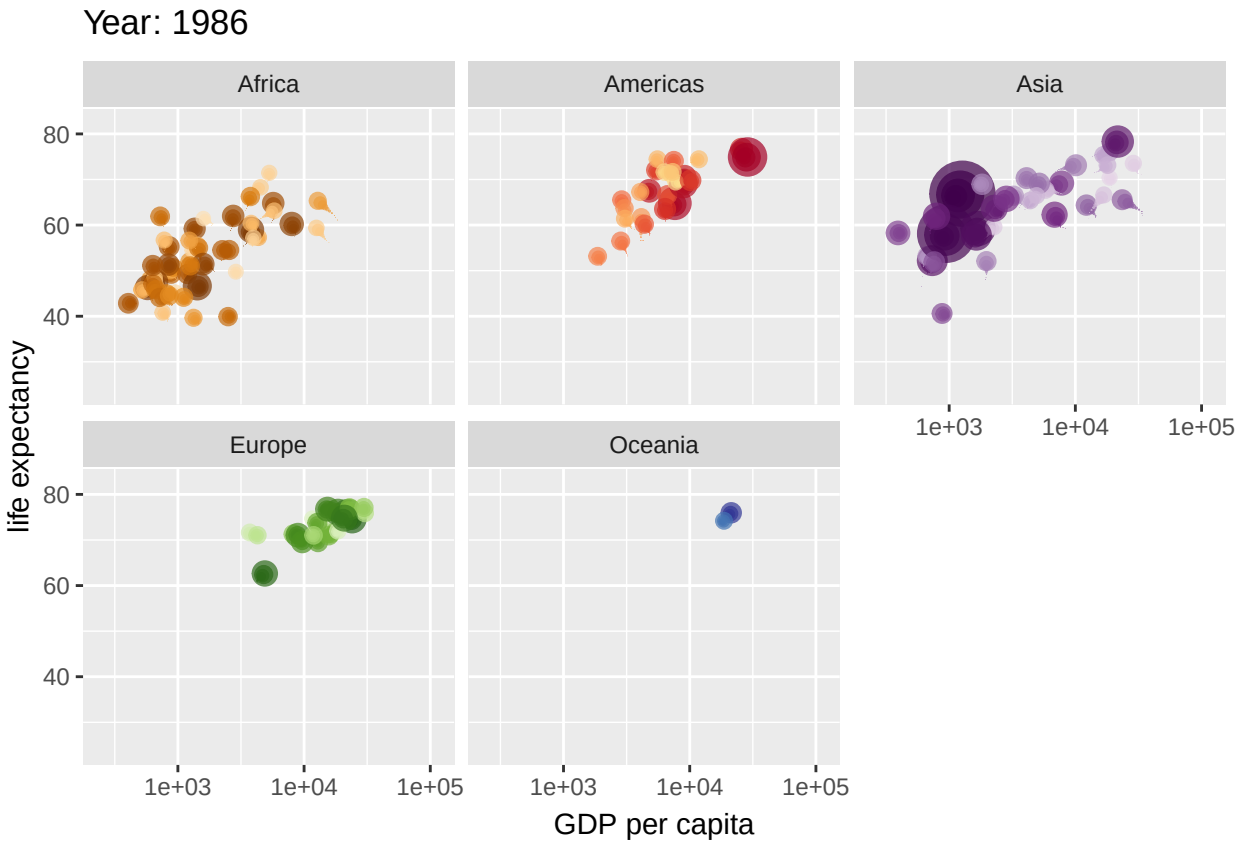
1e+05
GDP per capita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Africa
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life expectancy
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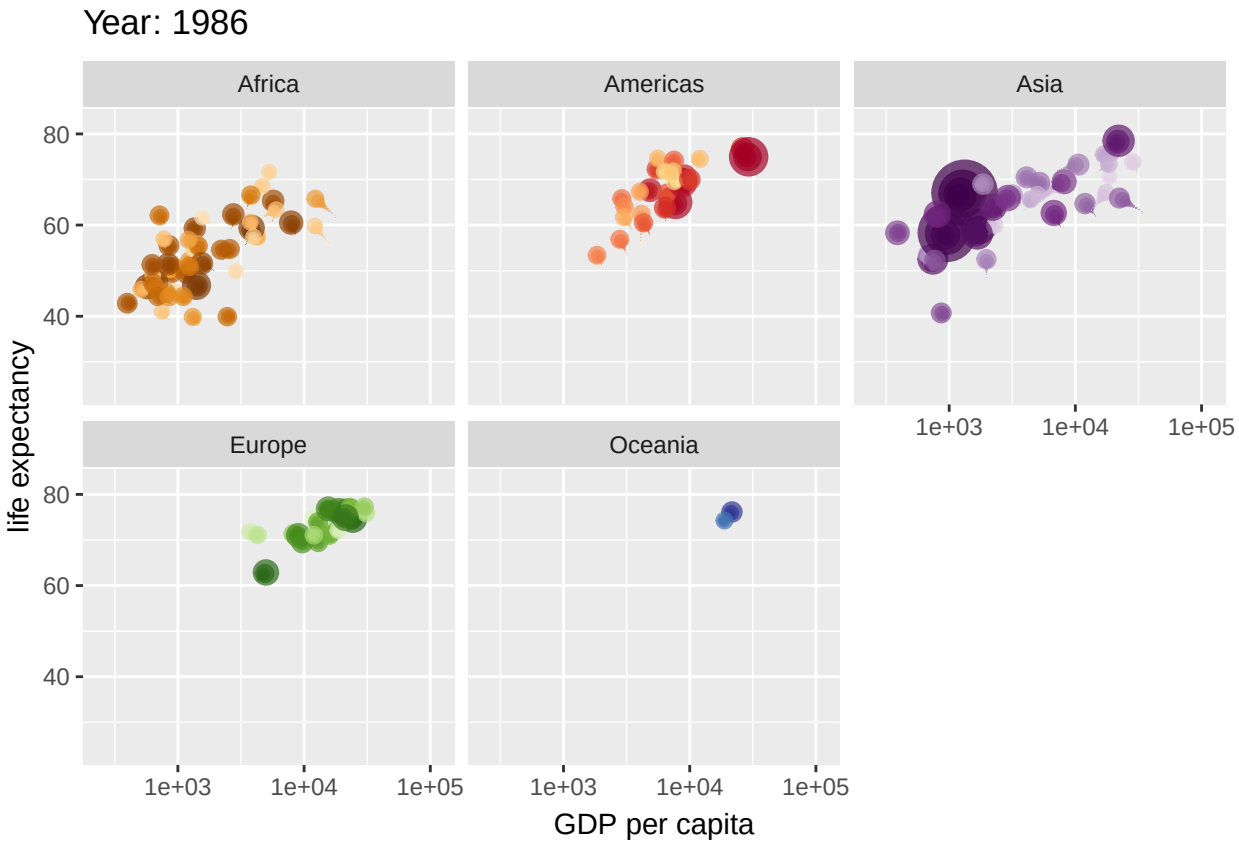
1e+03
1e+04
1e+05
GDP per capita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Africa
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life expectancy
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1e+03
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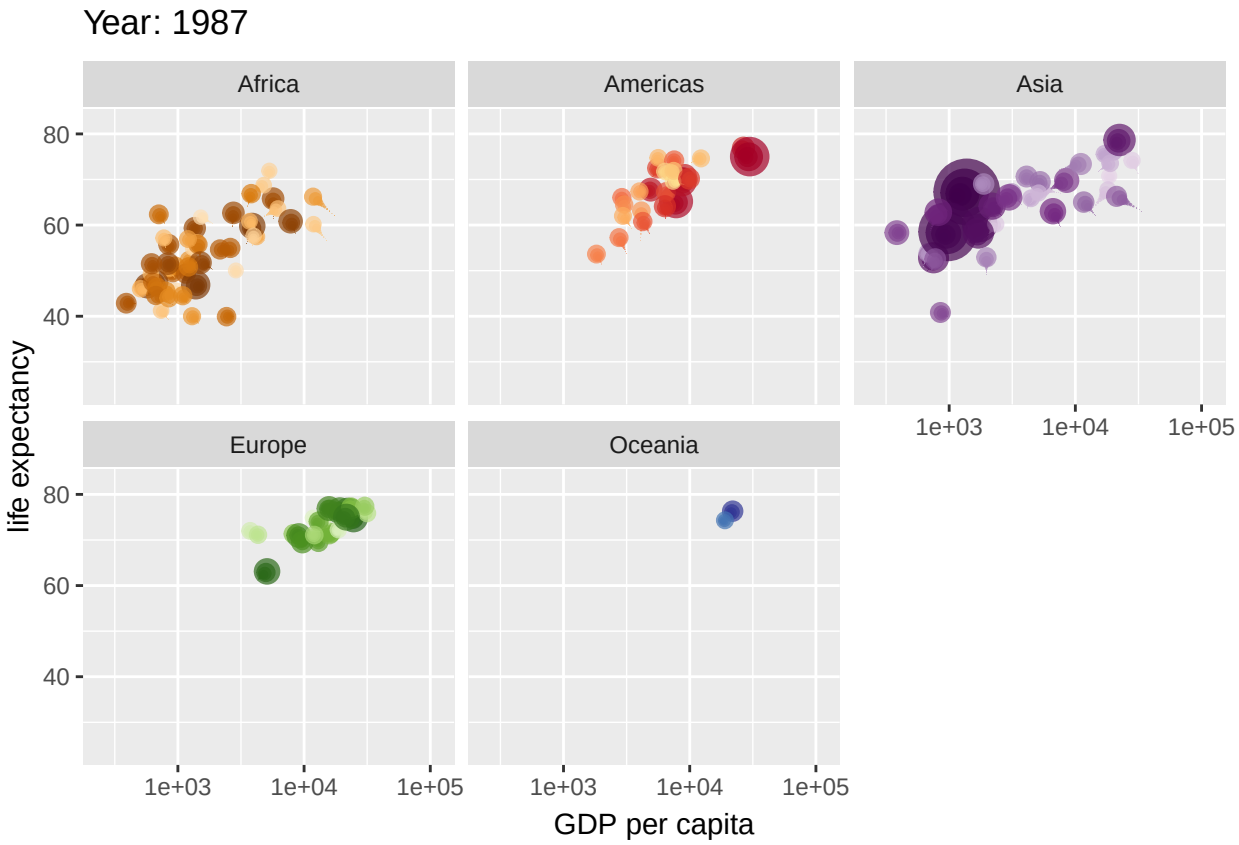
1e+05
GDP per capita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Oceania
life expectancy
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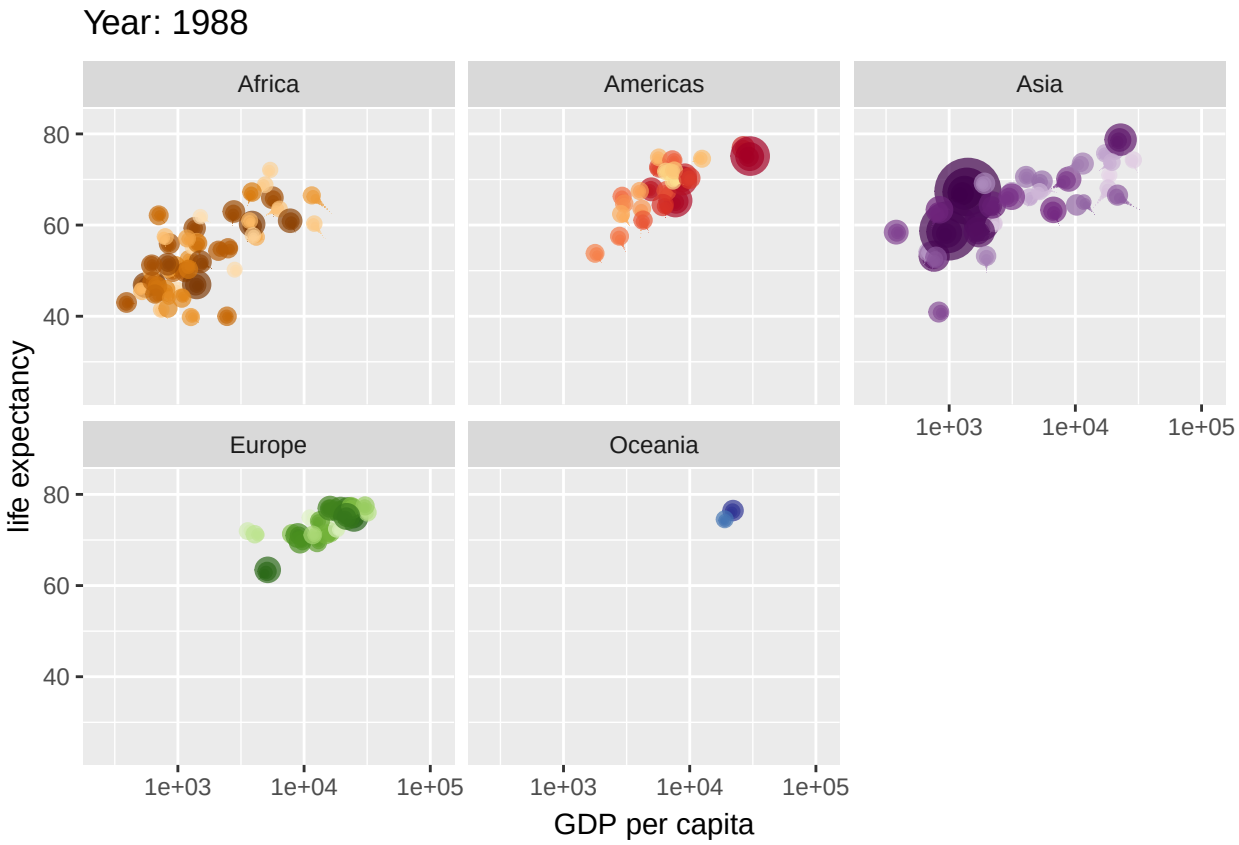
1e+03
1e+04
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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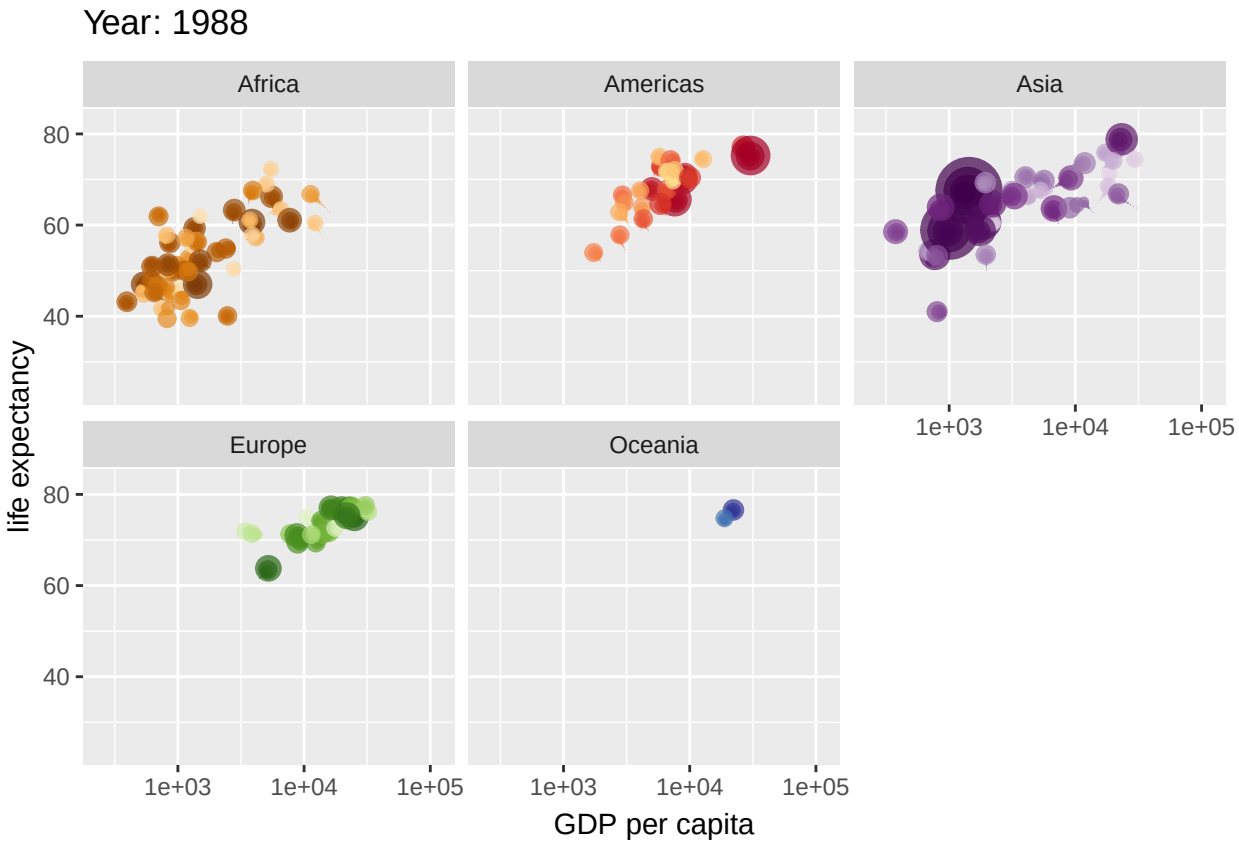
1e+03
1e+04
1e+05
GDP per capita


Year: 1988
Africa
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Oceania
life expectancy
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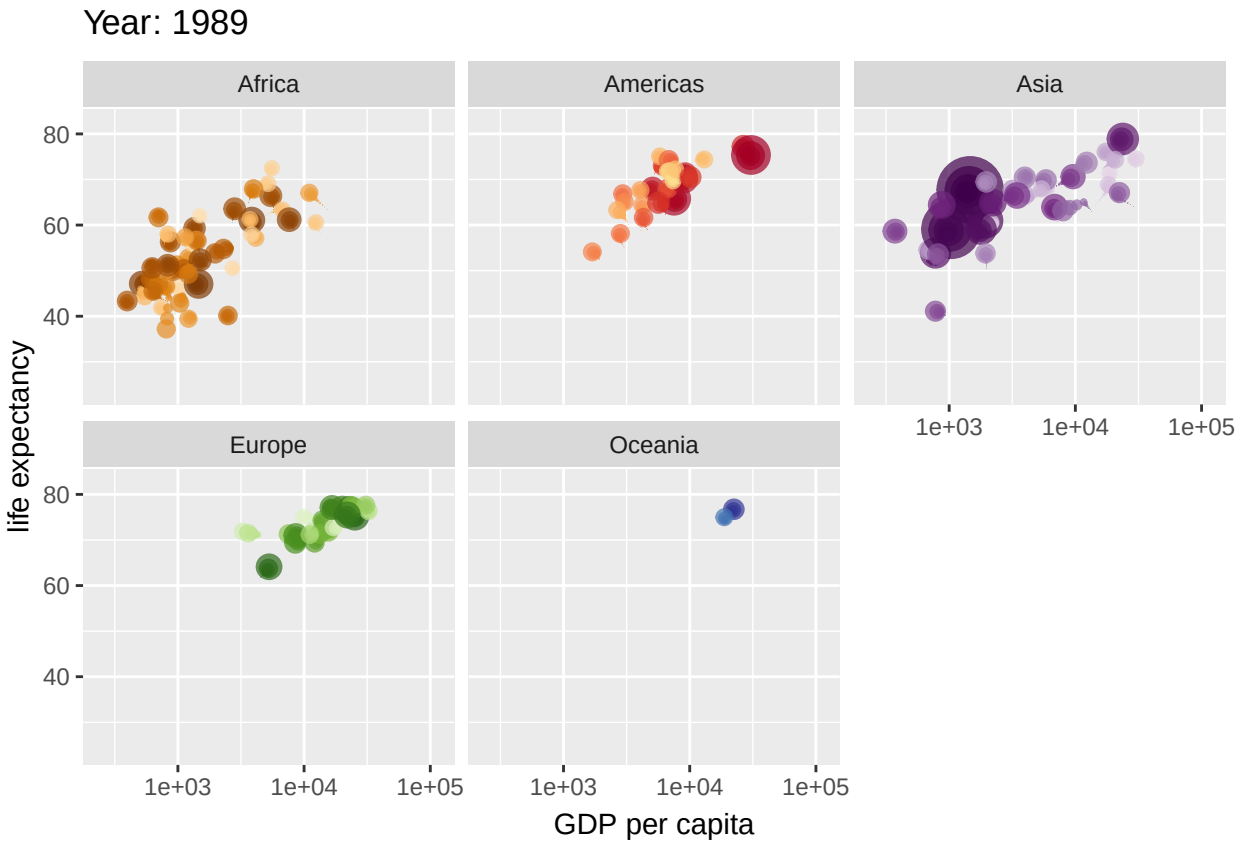
GDP per capita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life expectancy
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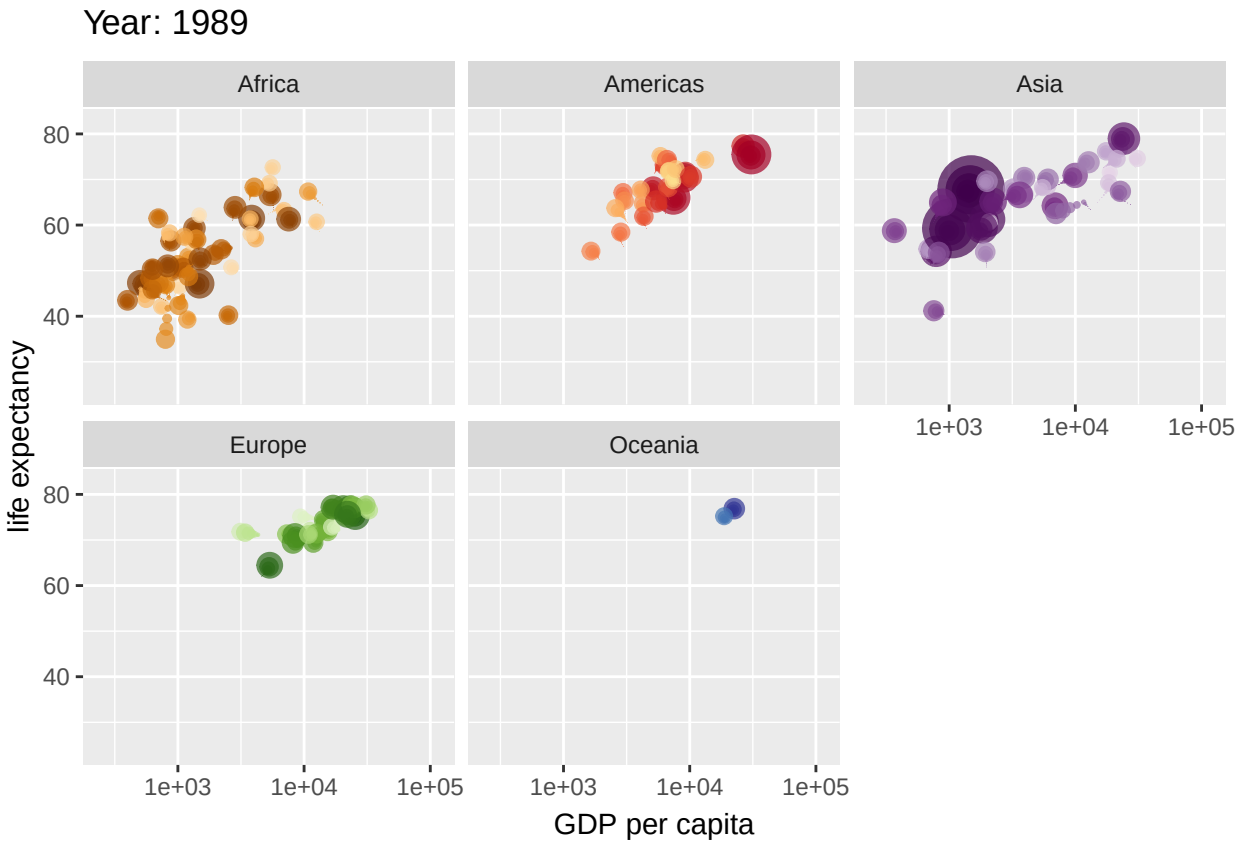
GDP per capita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Africa
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life expectancy
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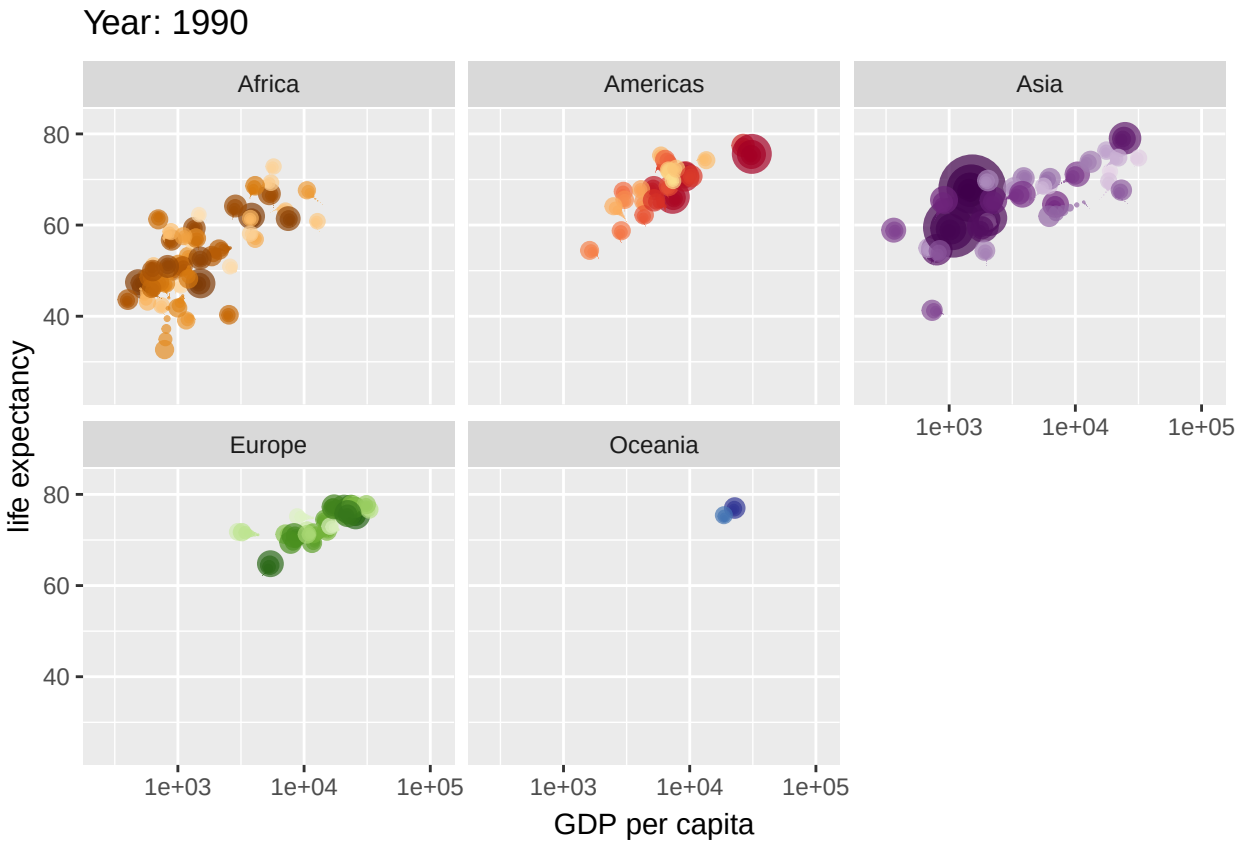
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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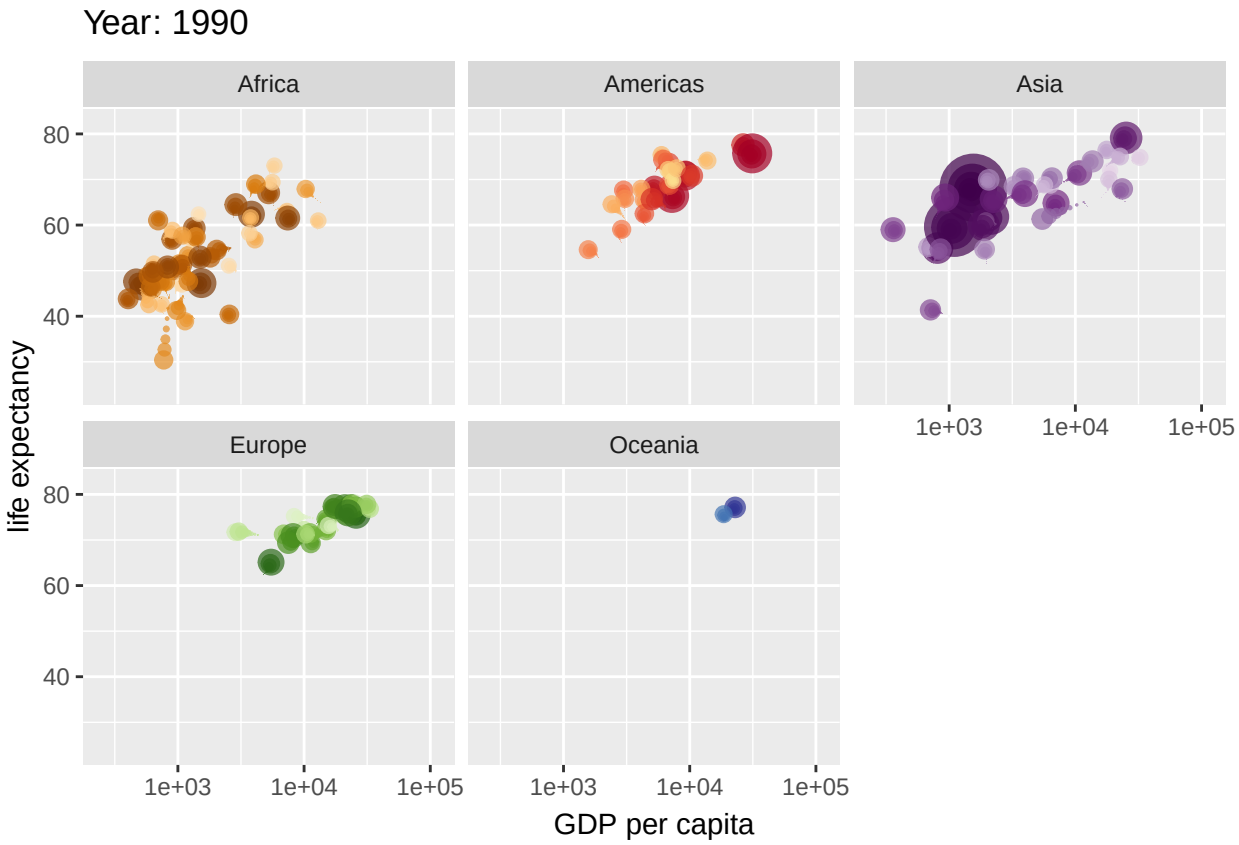
1e+05
GDP per capita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Oceania
life expectancy
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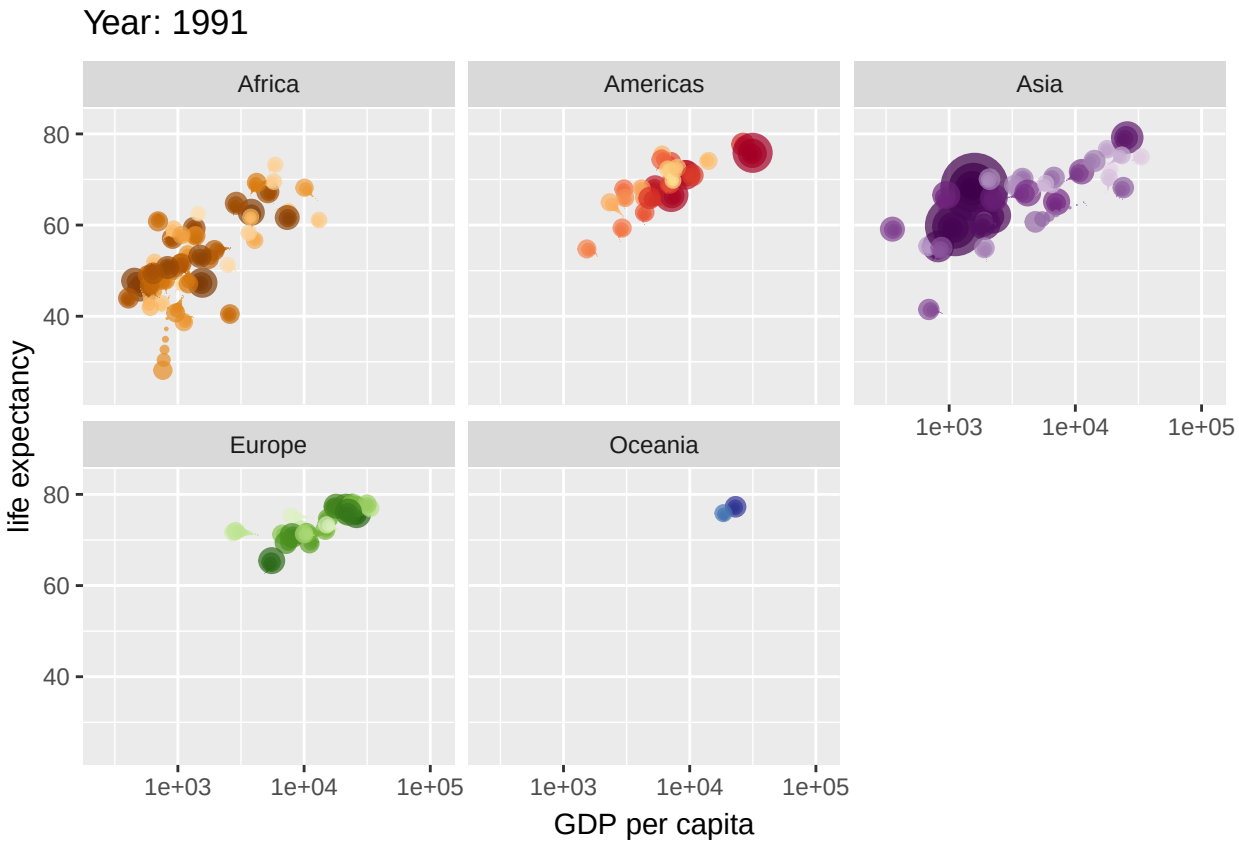
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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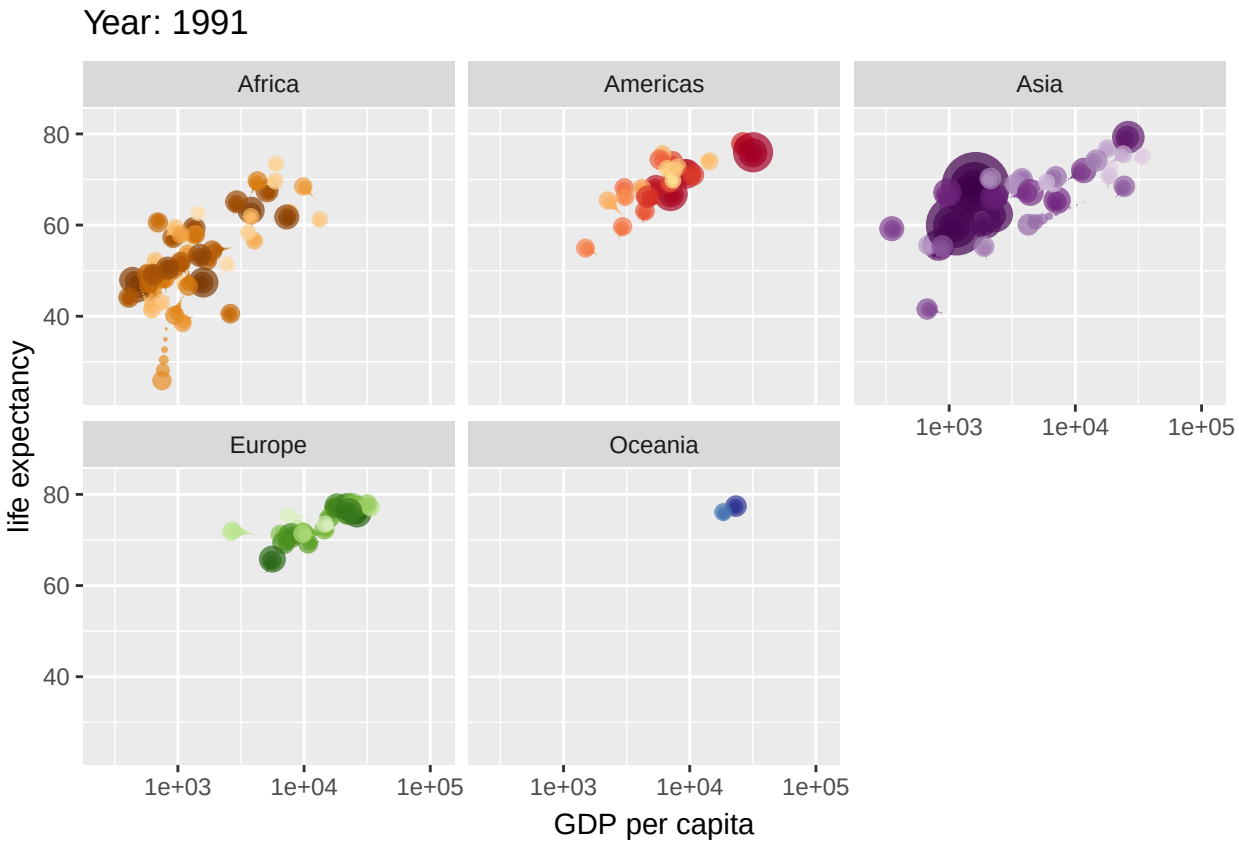
1e+05
GDP per capita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Oceania
life expectancy
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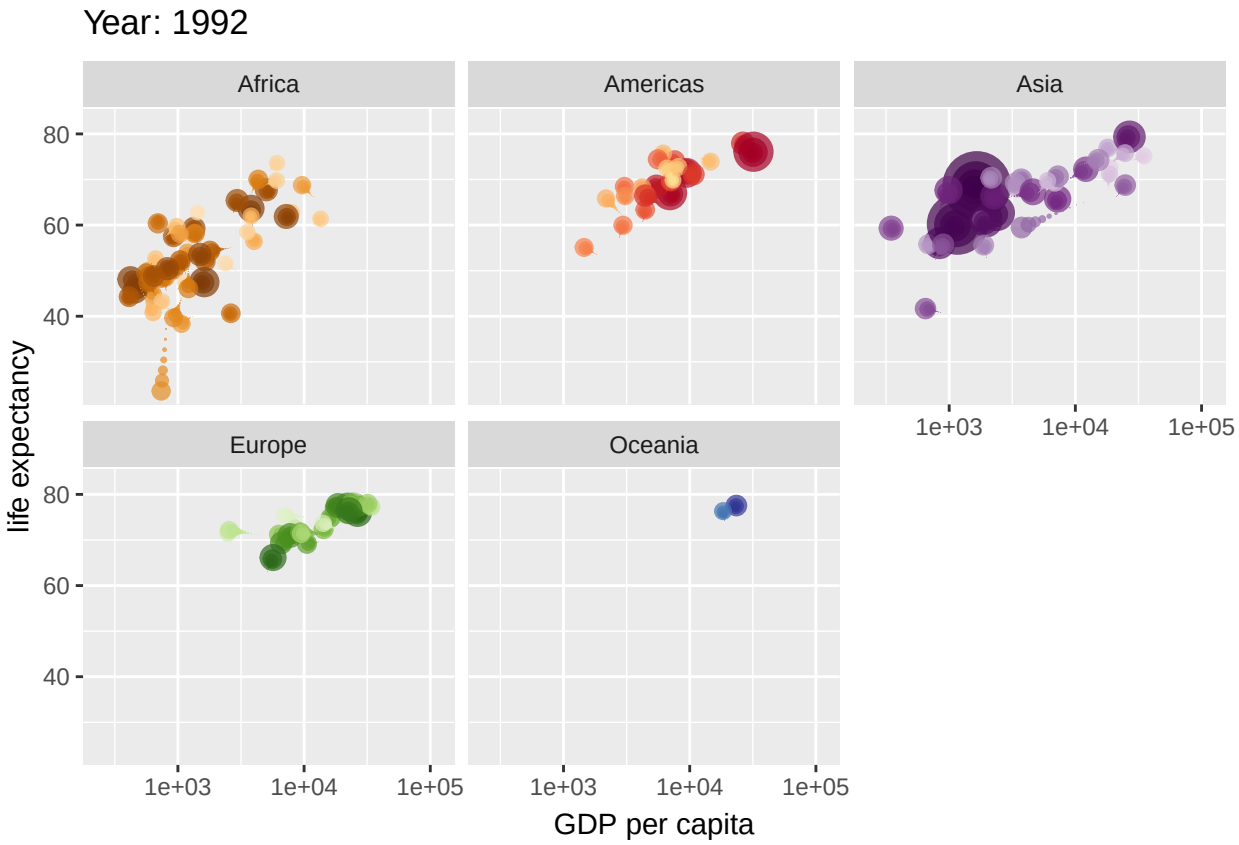
GDP per capita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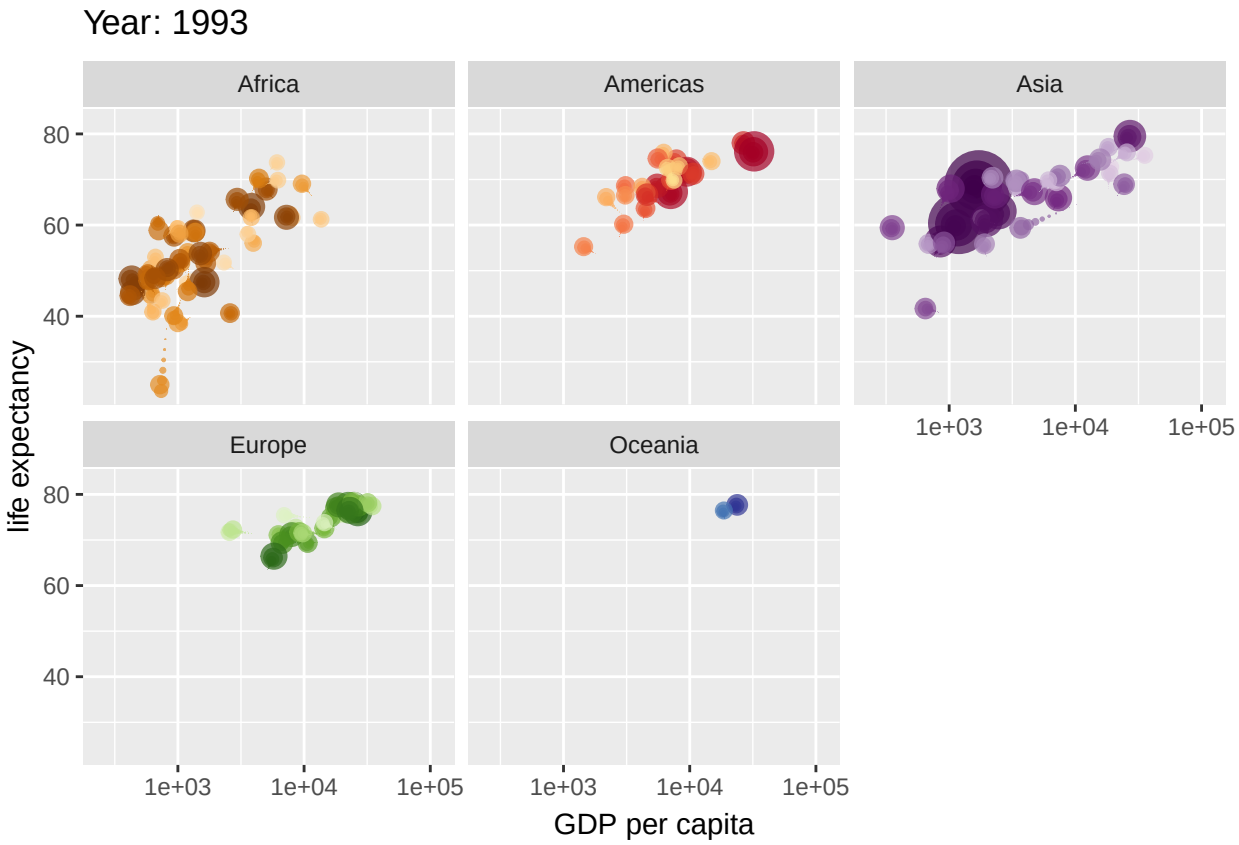
GDP per capita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Oceania
life expectancy
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1e+03
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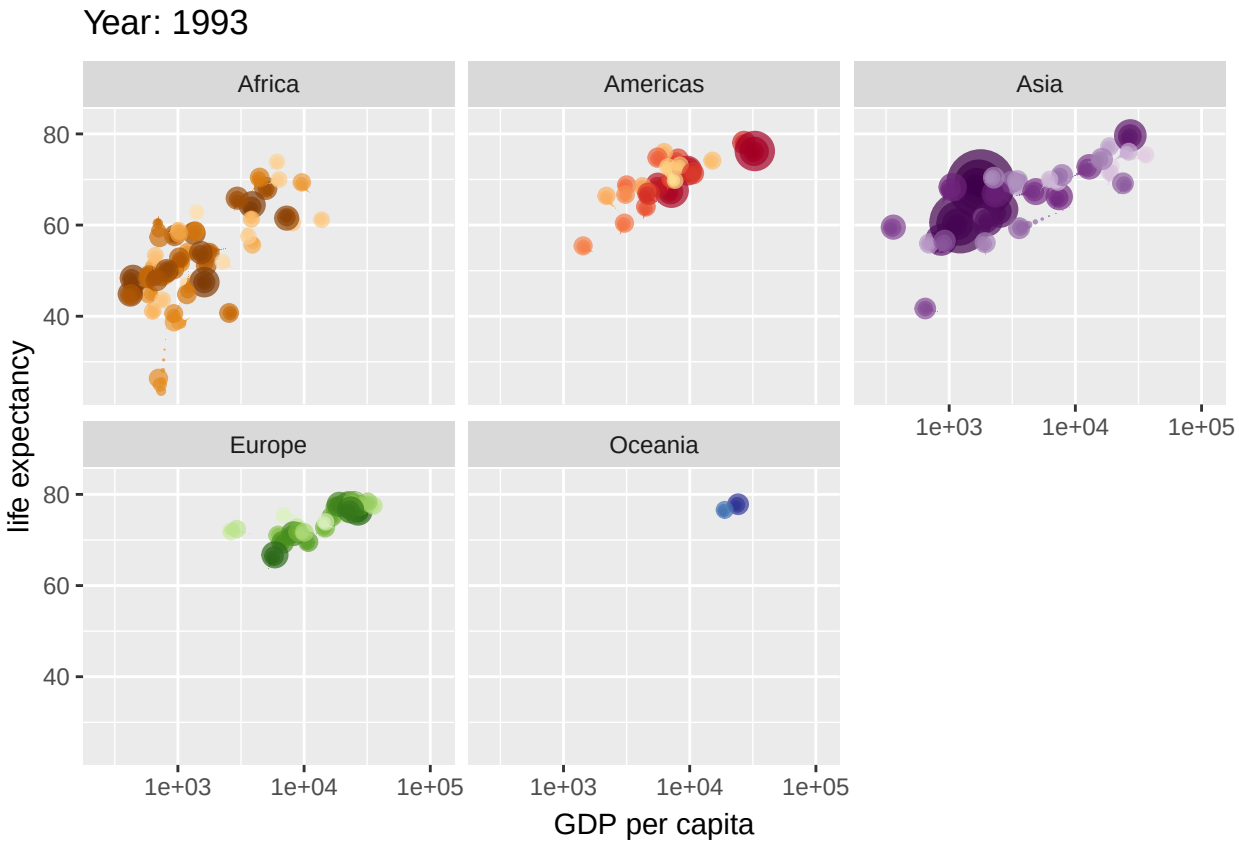
1e+05
GDP per capita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Oceania
life expectancy
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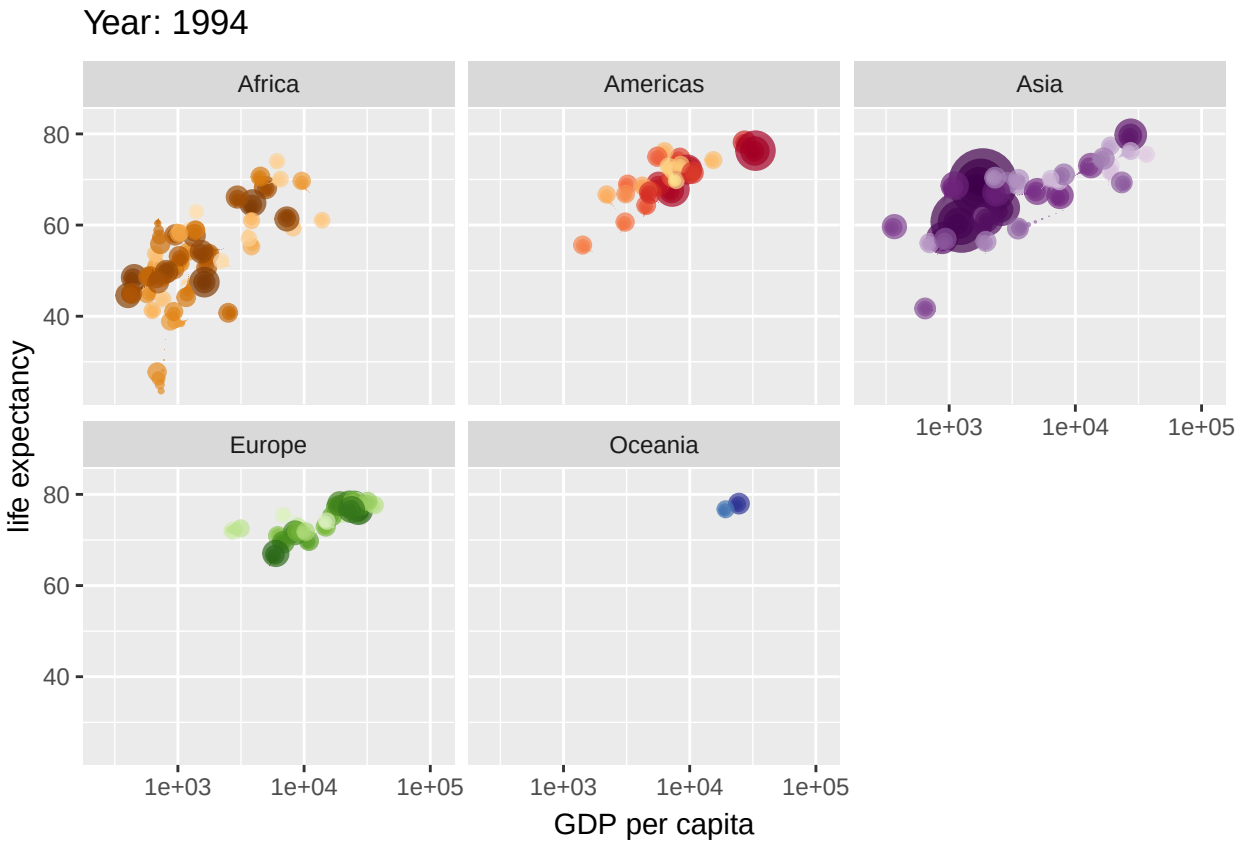
1e+04
1e+05
GDP per capita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Europe
Oceania
life expectancy
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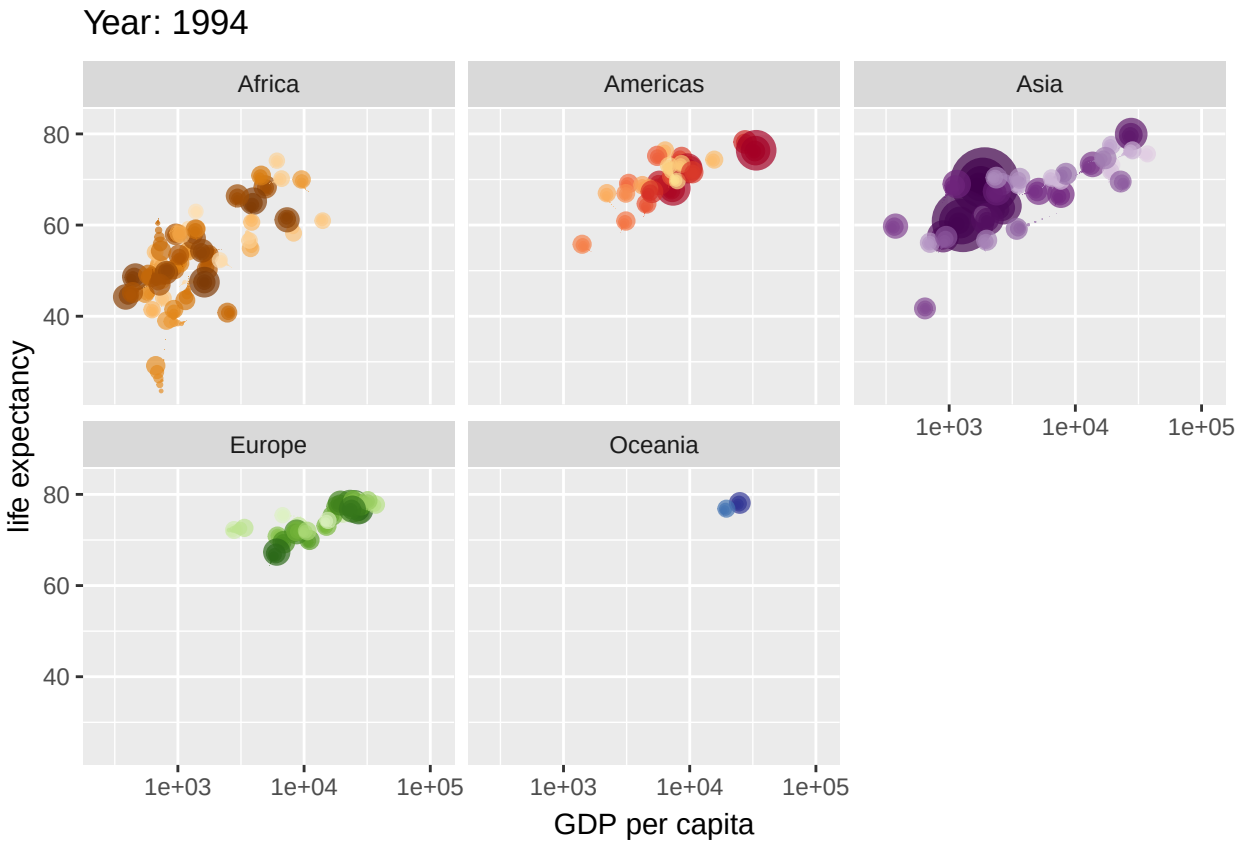
1e+03
1e+04
1e+05
GDP per capita


Year: 1994
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Asia
Europe
Oceania
life expectancy
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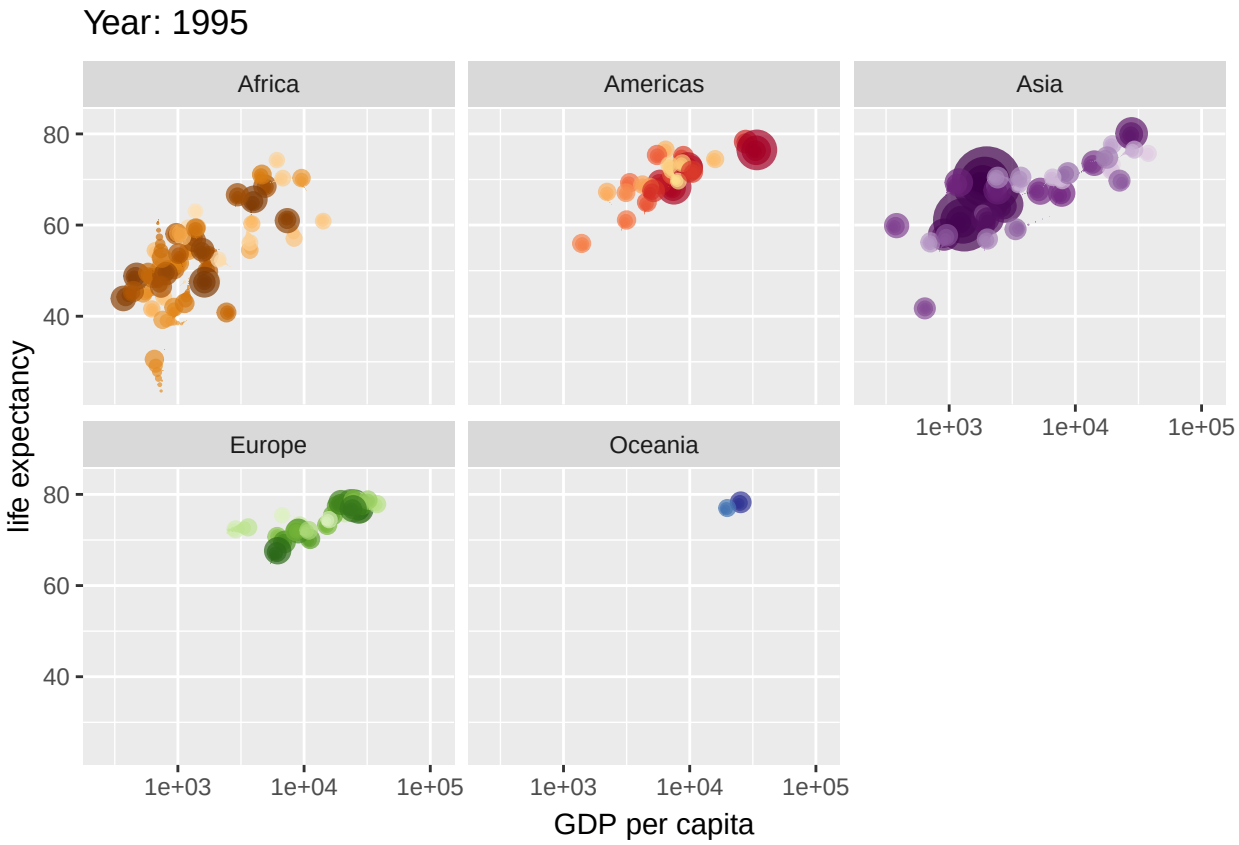
1e+04
1e+05
GDP per capita


Year: 1995
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Asia
Europe
Oceania
life expectancy
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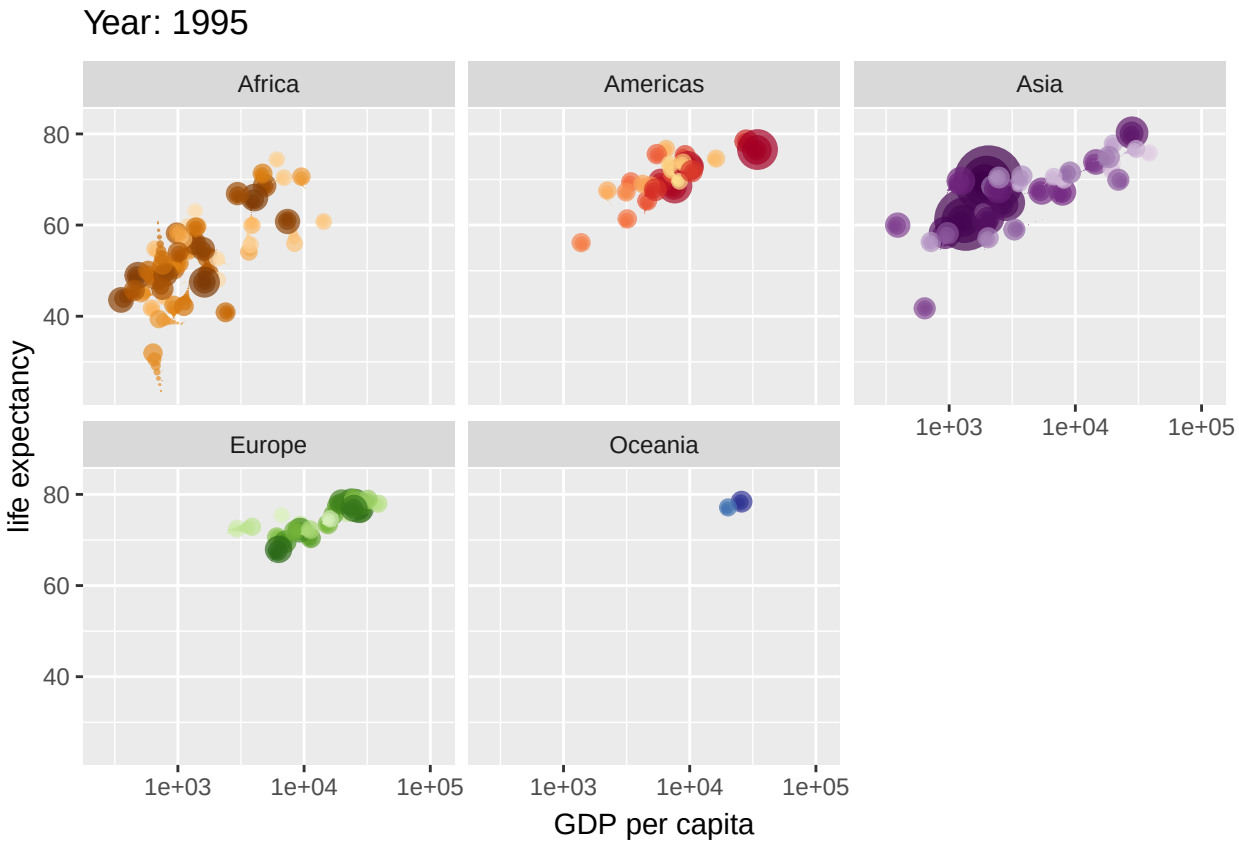
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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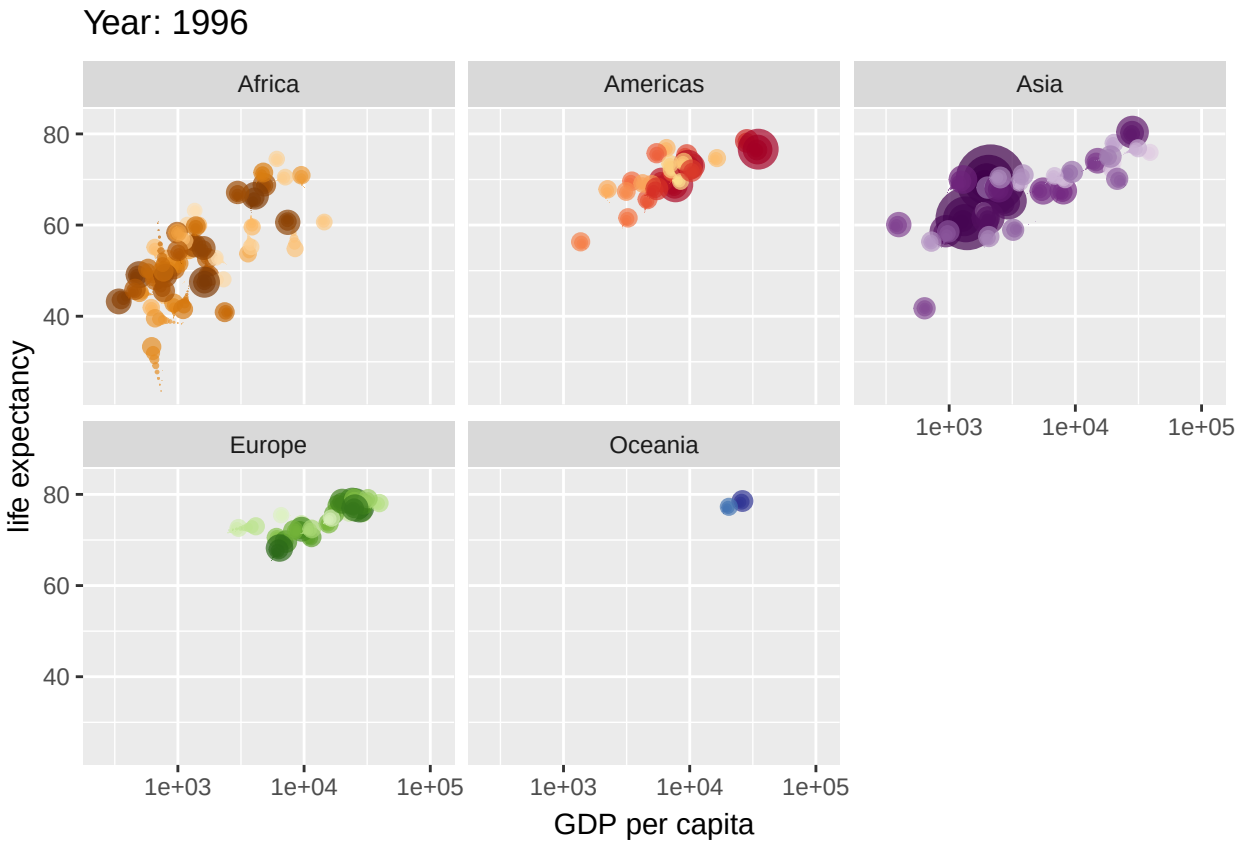
1e+03
1e+04
1e+05
GDP per capita


Year: 1996
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Asia
Europe
Oceania
life expectancy
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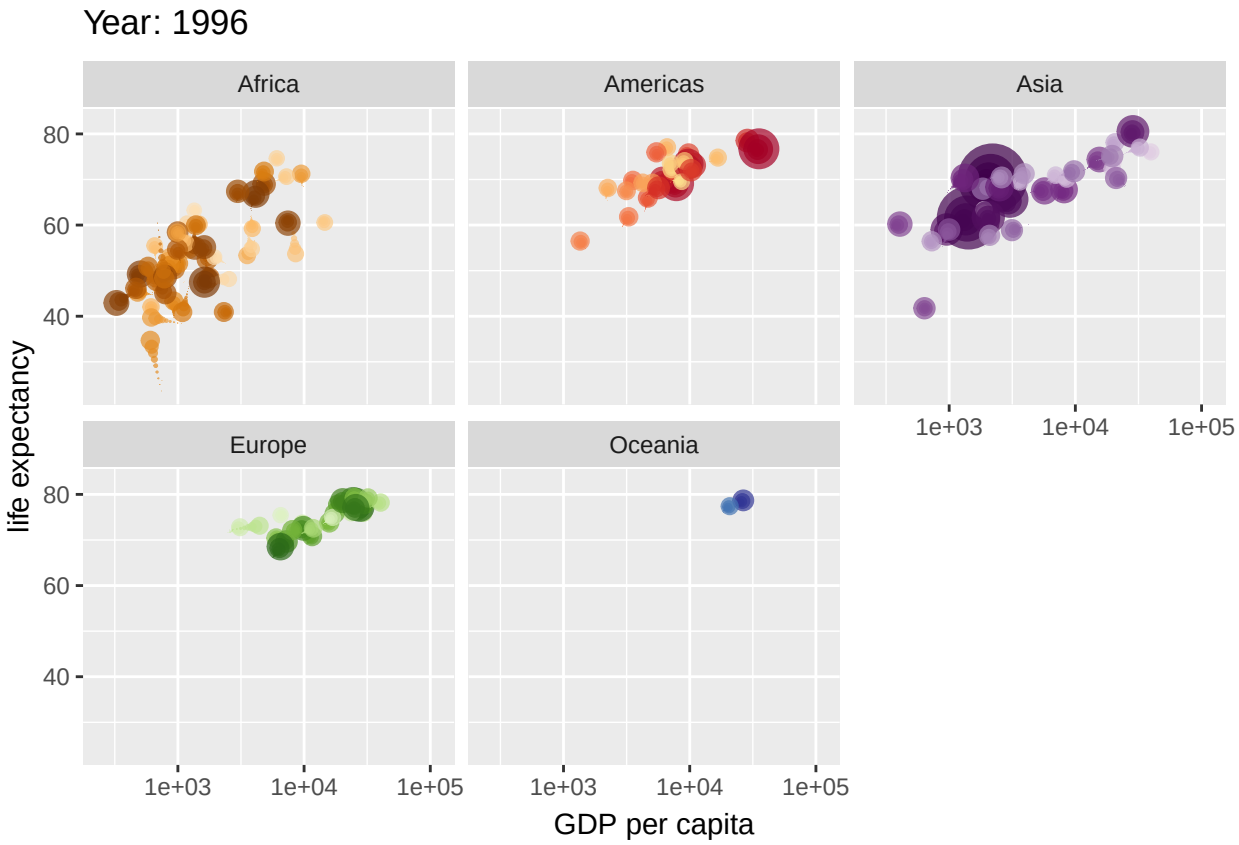
1e+03
1e+04
1e+05
GDP per capita


Year: 1996
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
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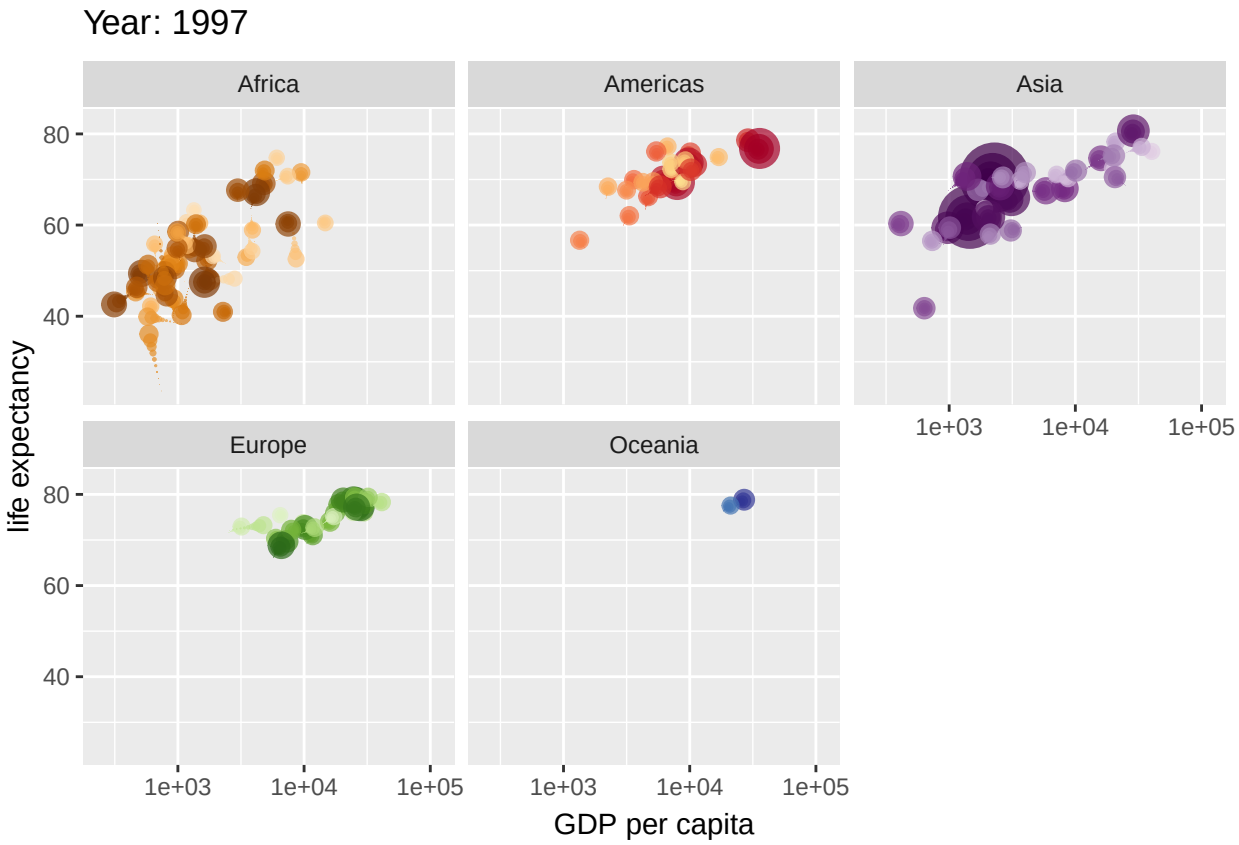
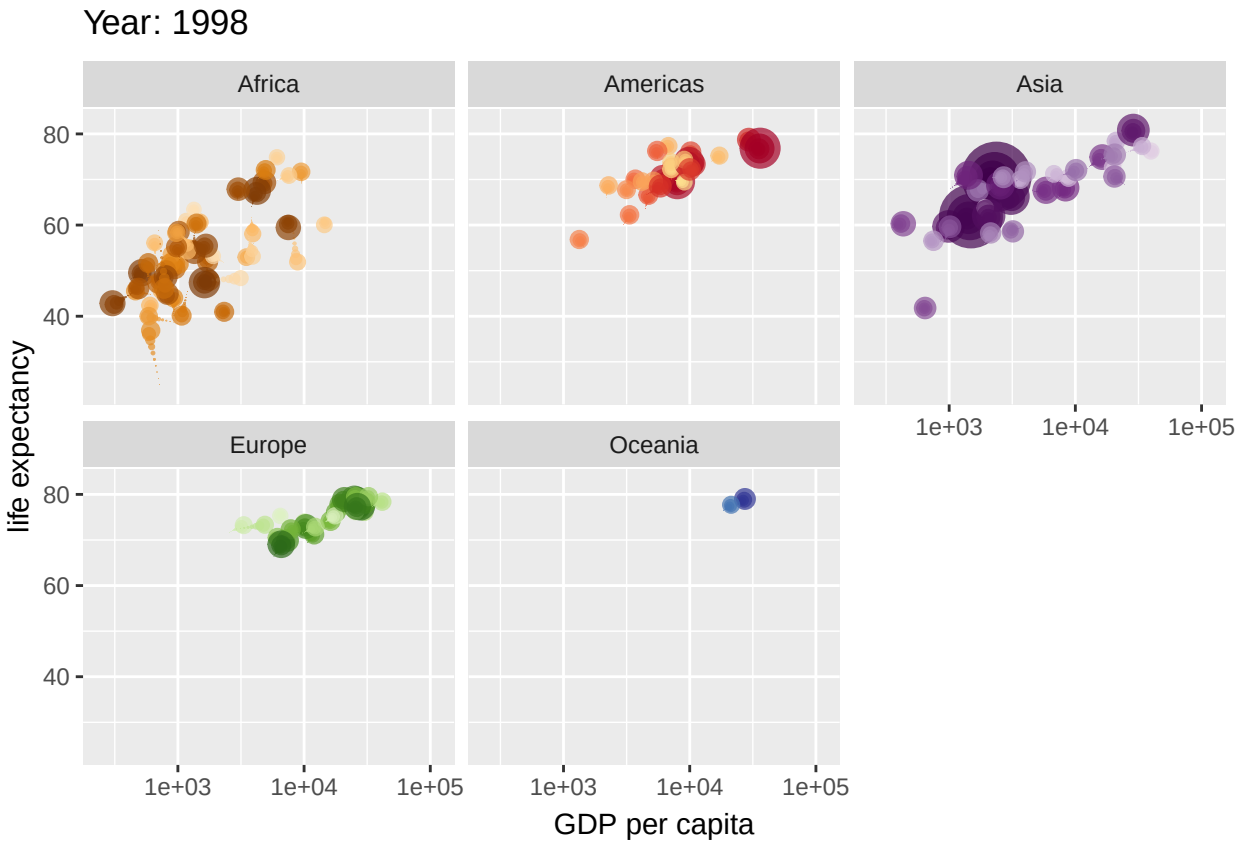
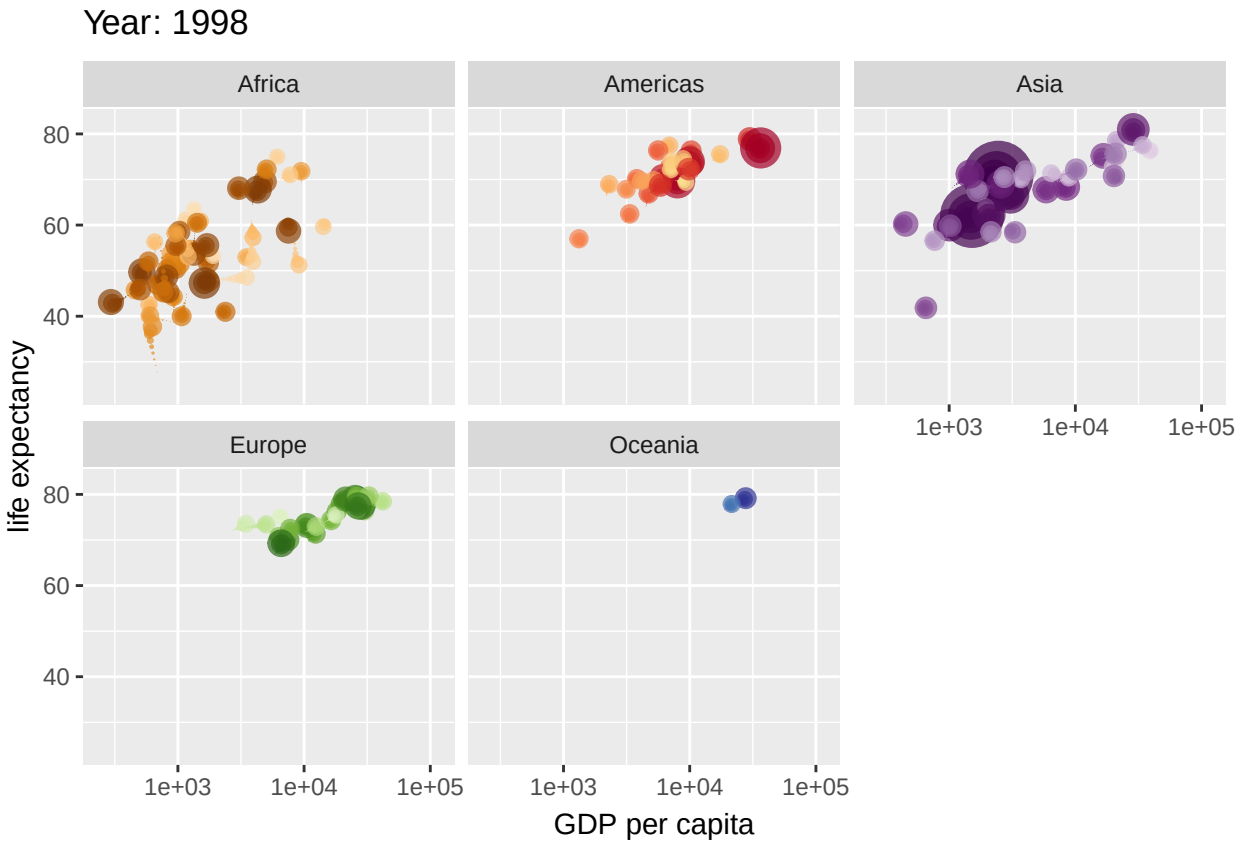
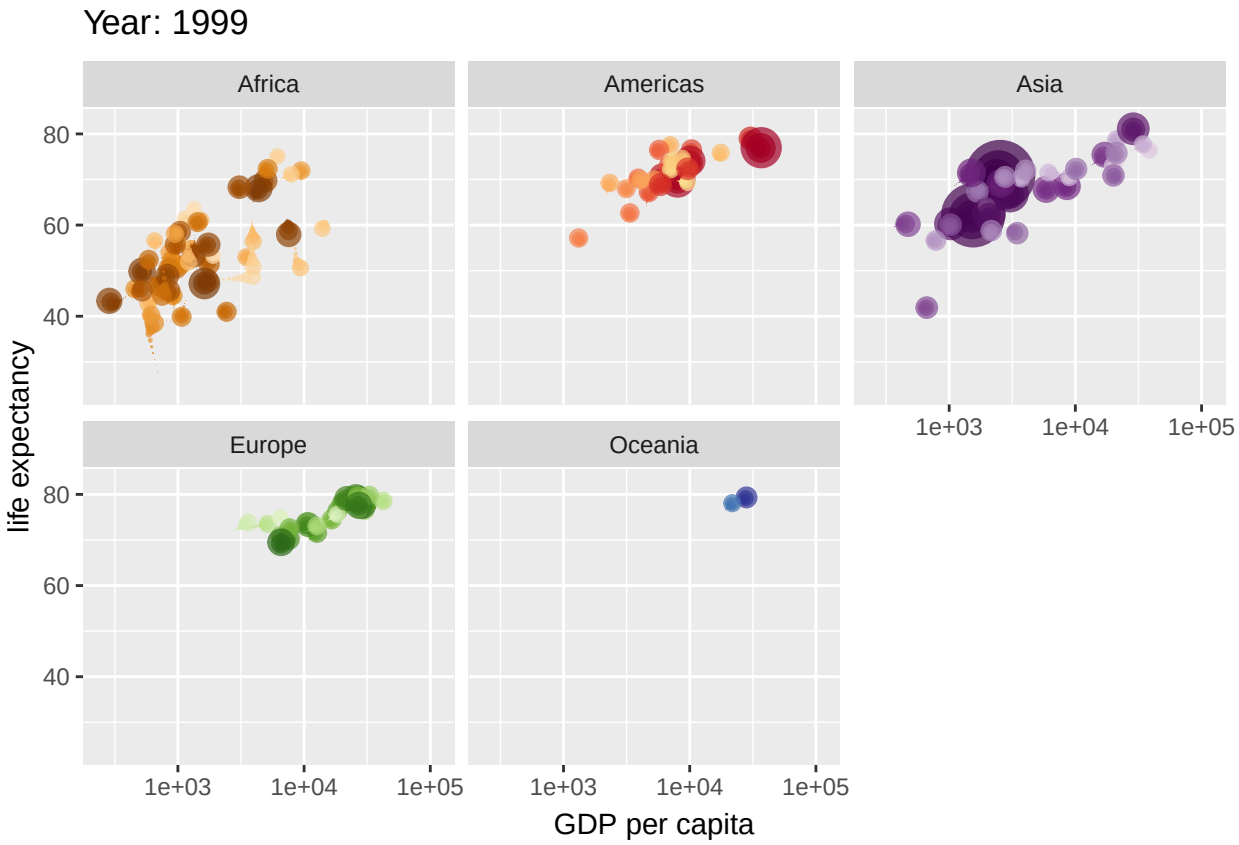
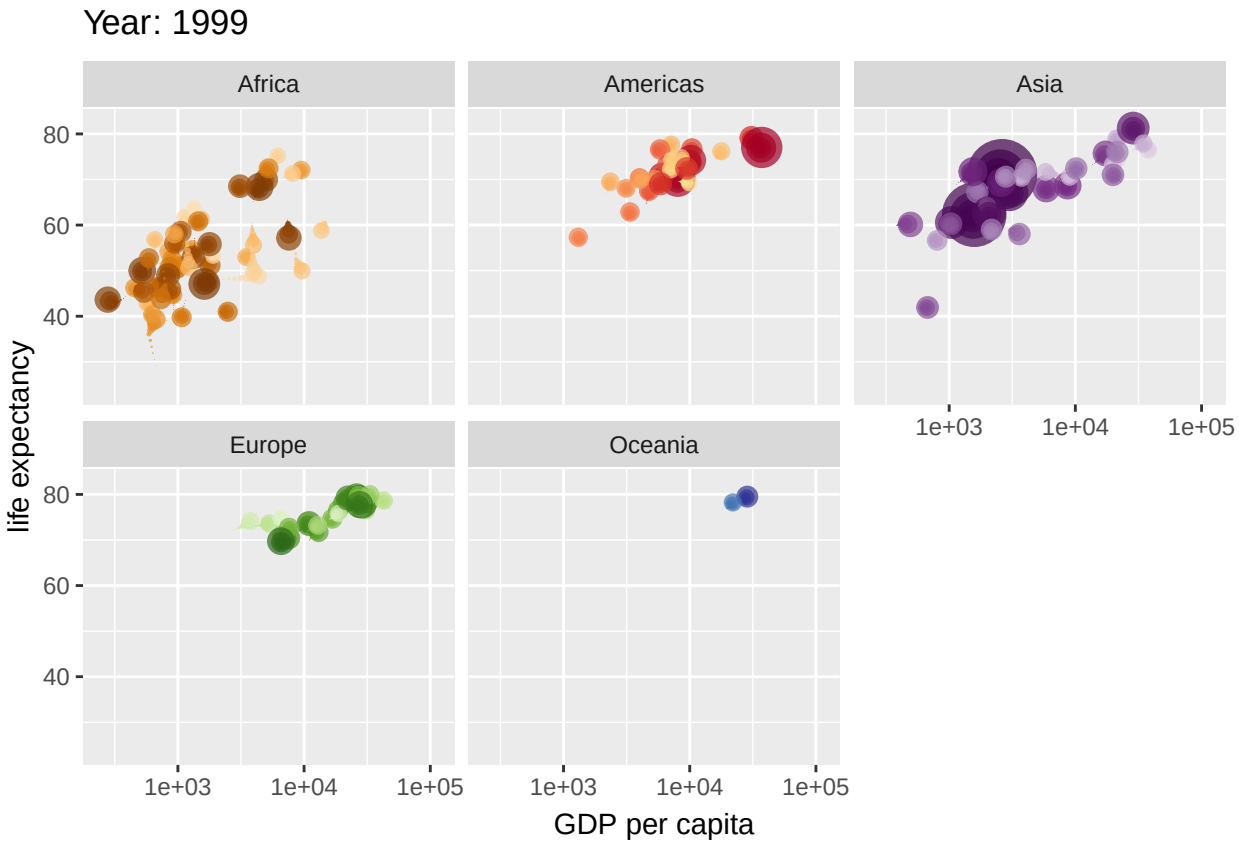
40
1e+03
1e+04
1e+05
GDP per capita

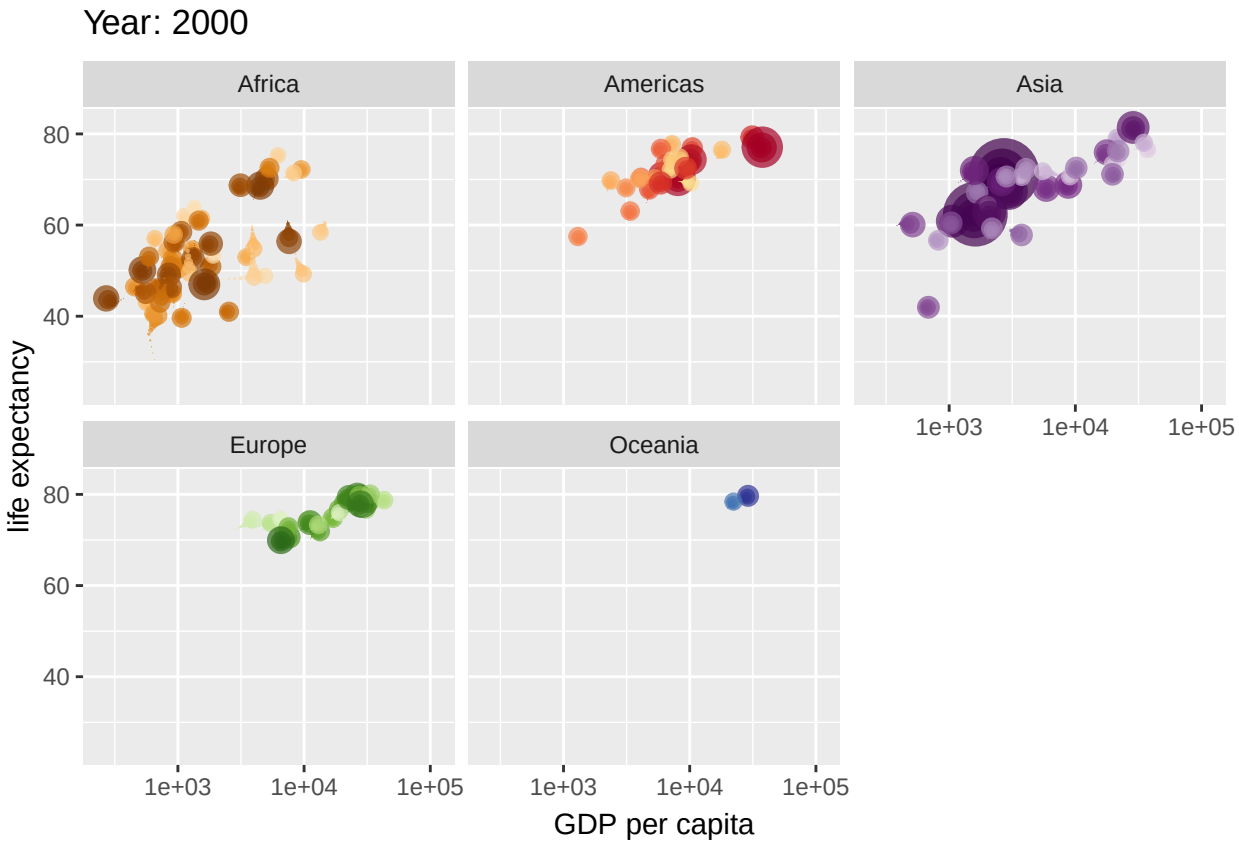

Year: 1997
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

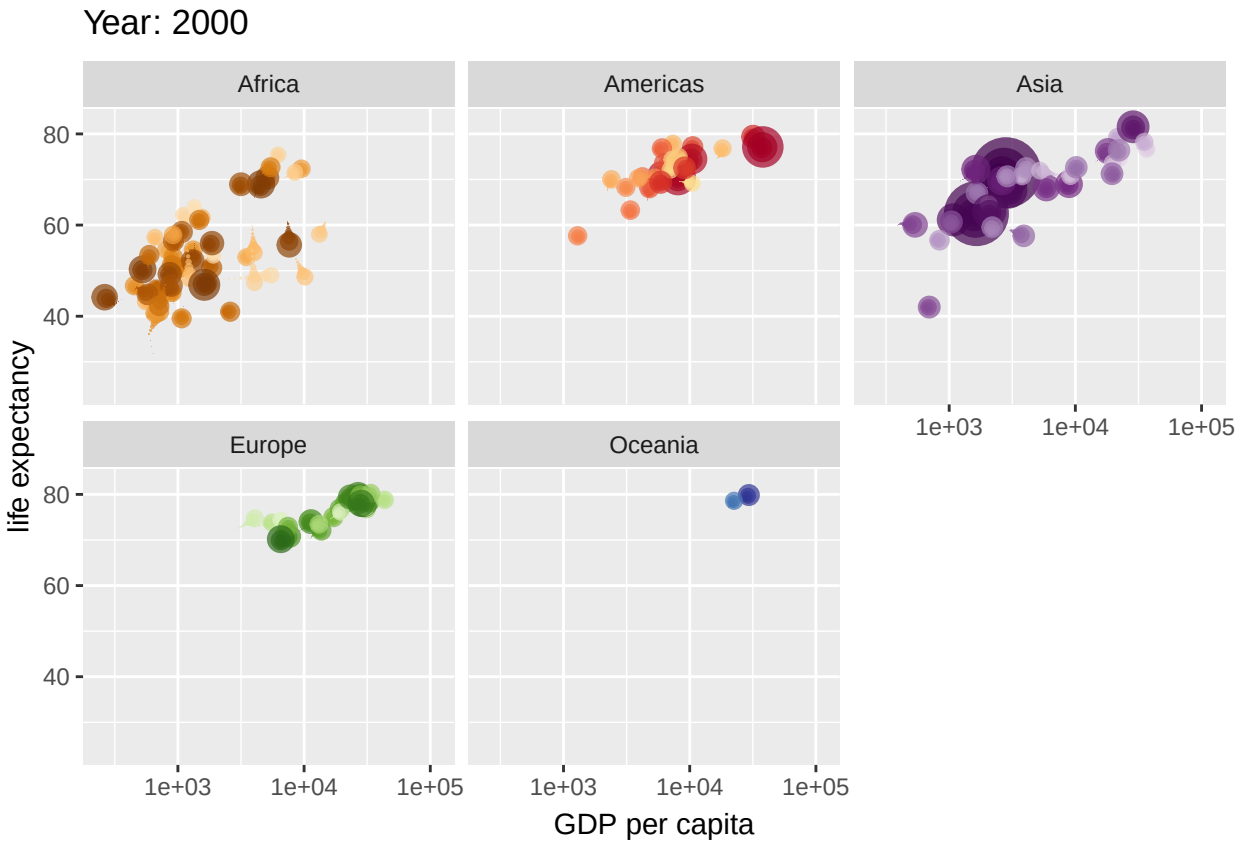

Year: 1998
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

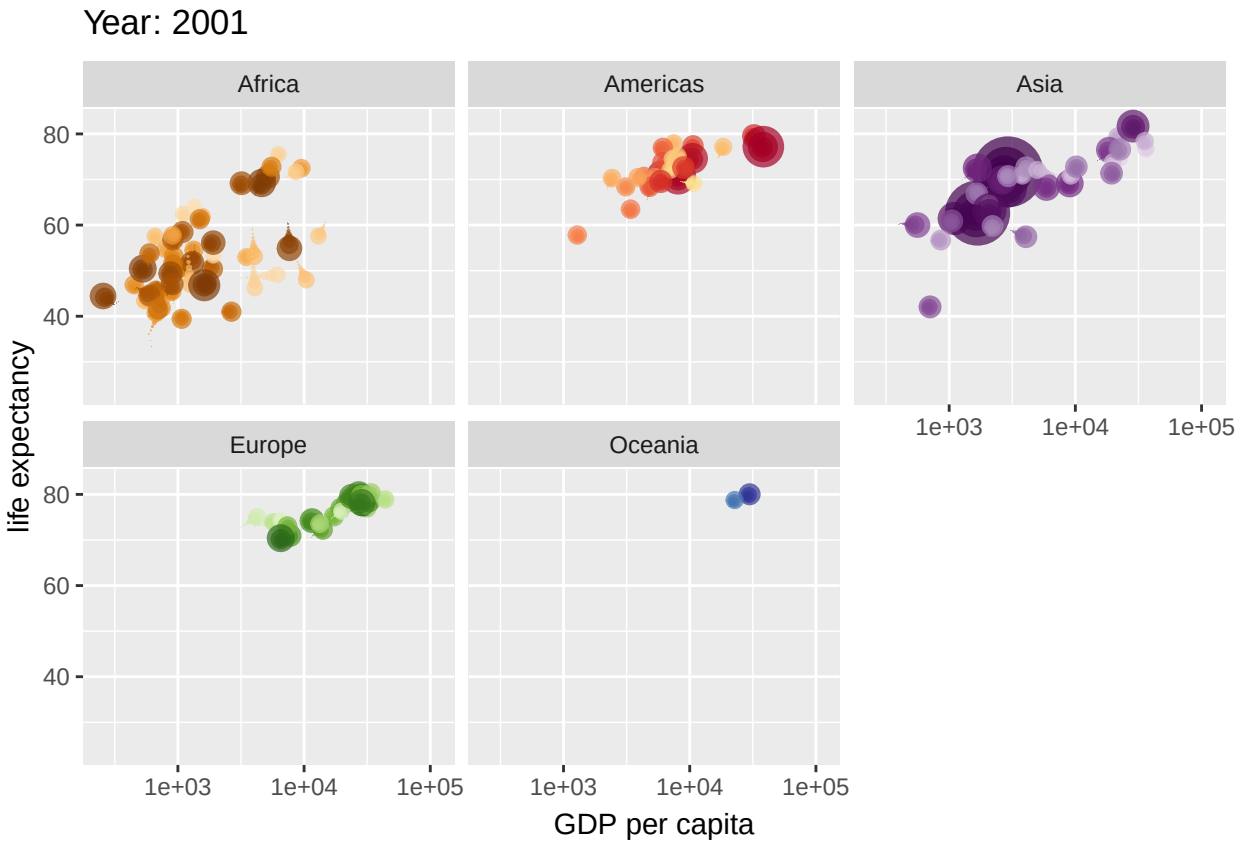

Year: 1998
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

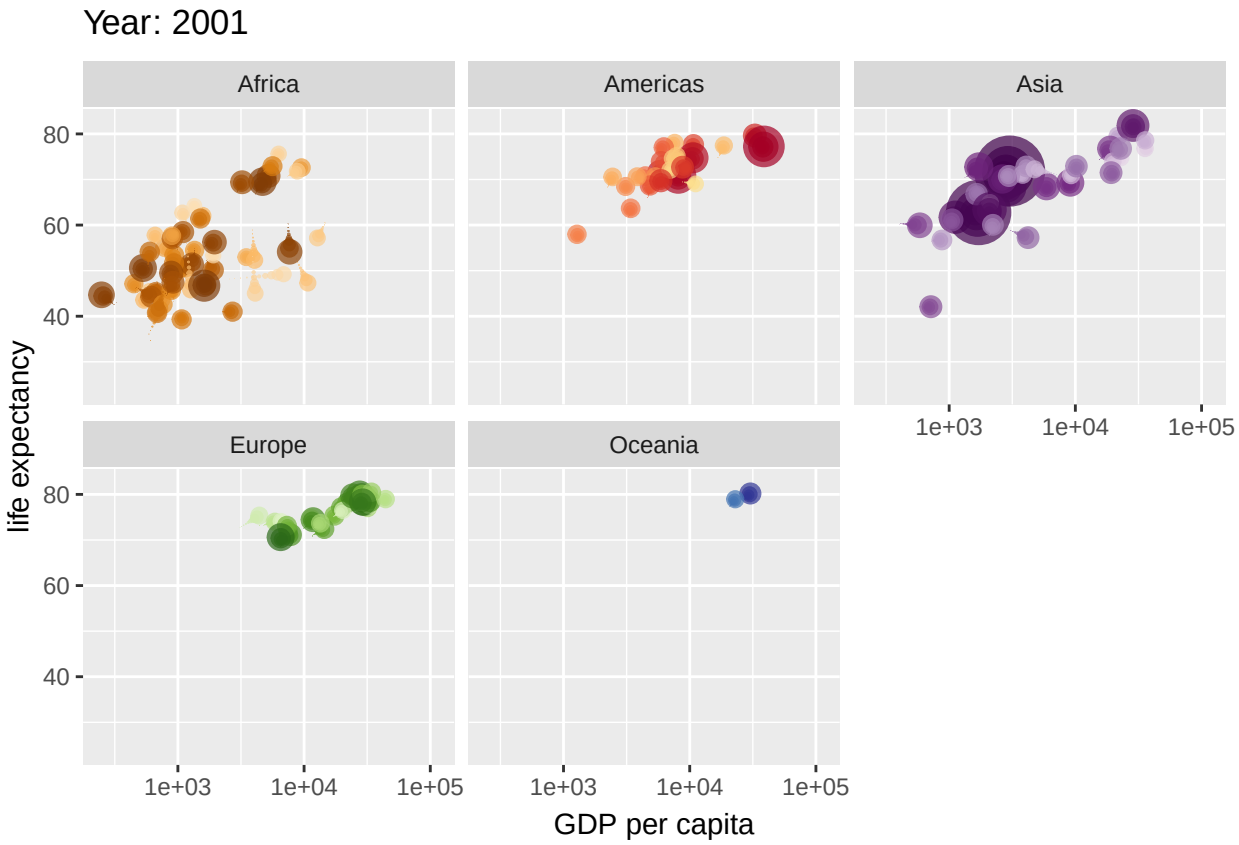

Year: 1999
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

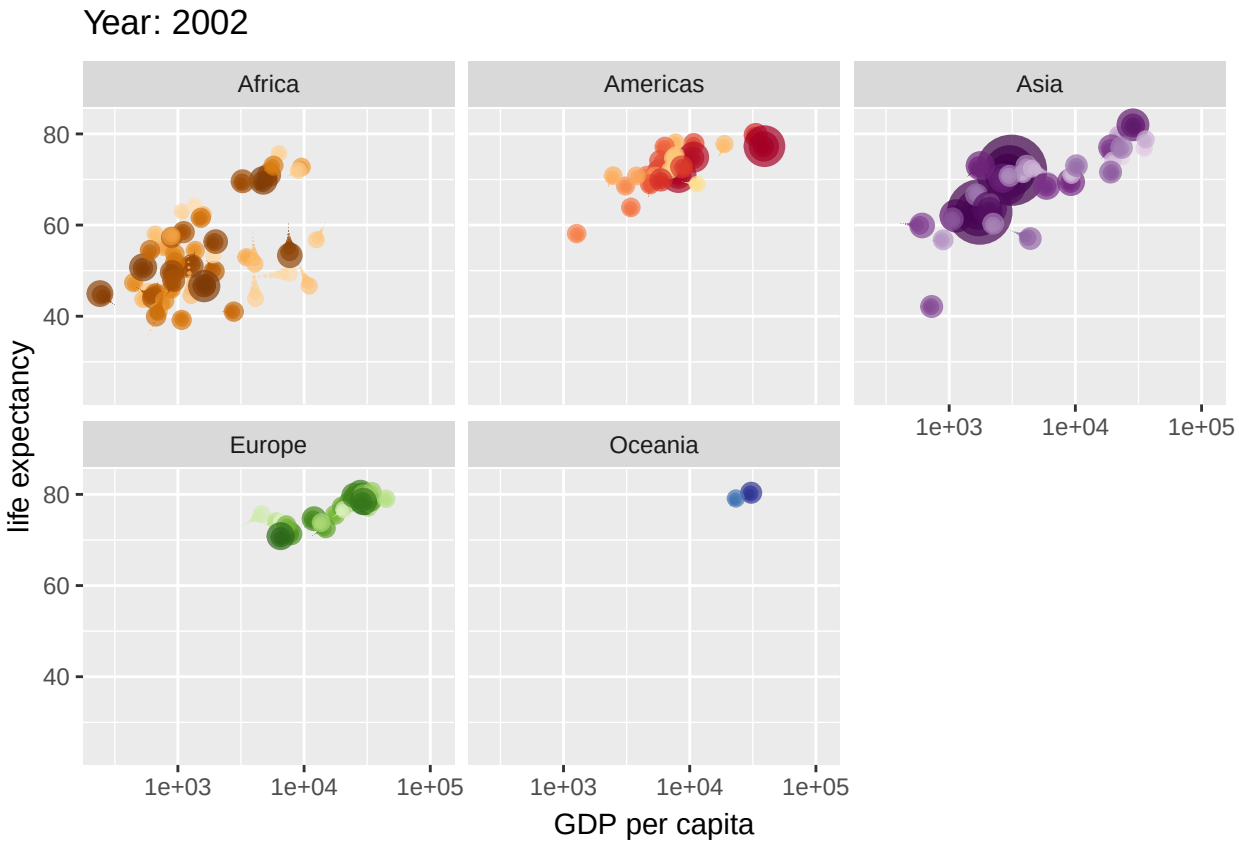

Year: 1999
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

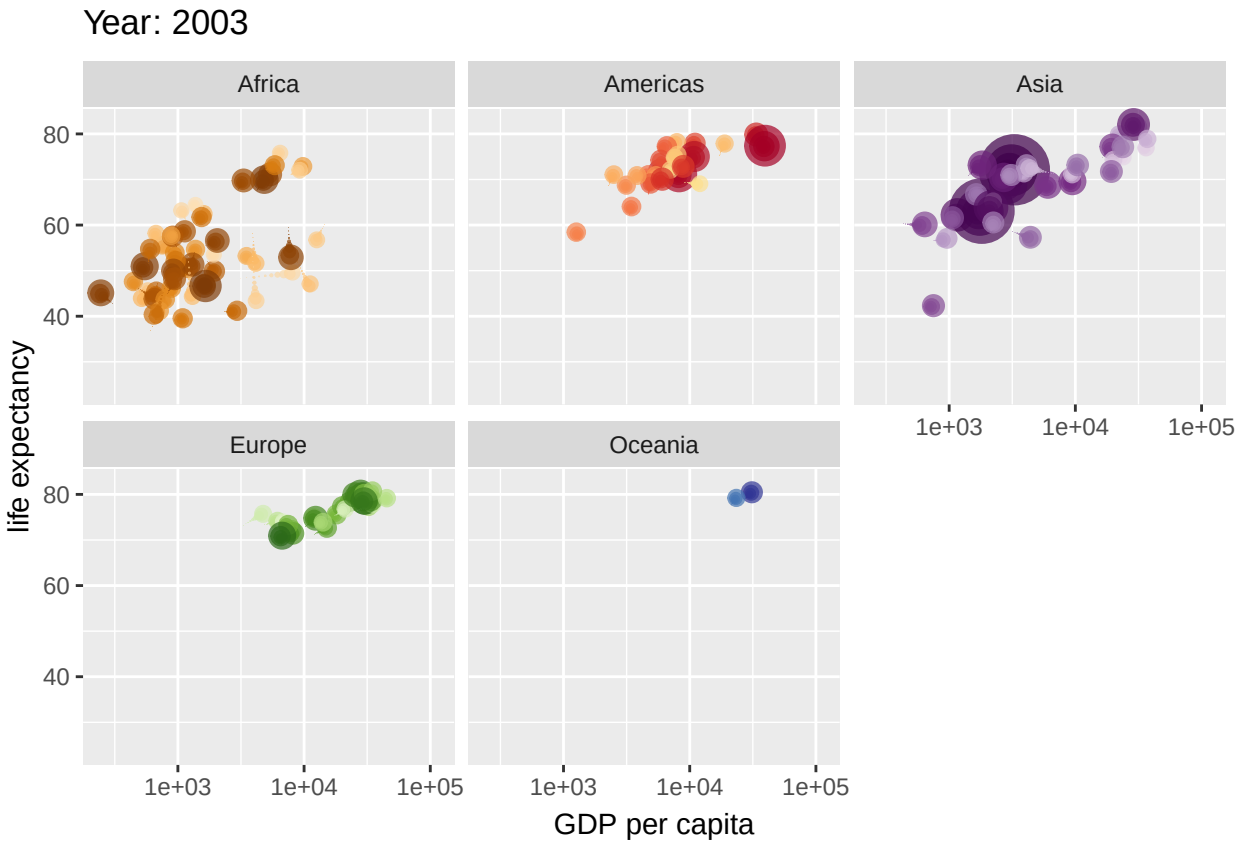

Year: 2000
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

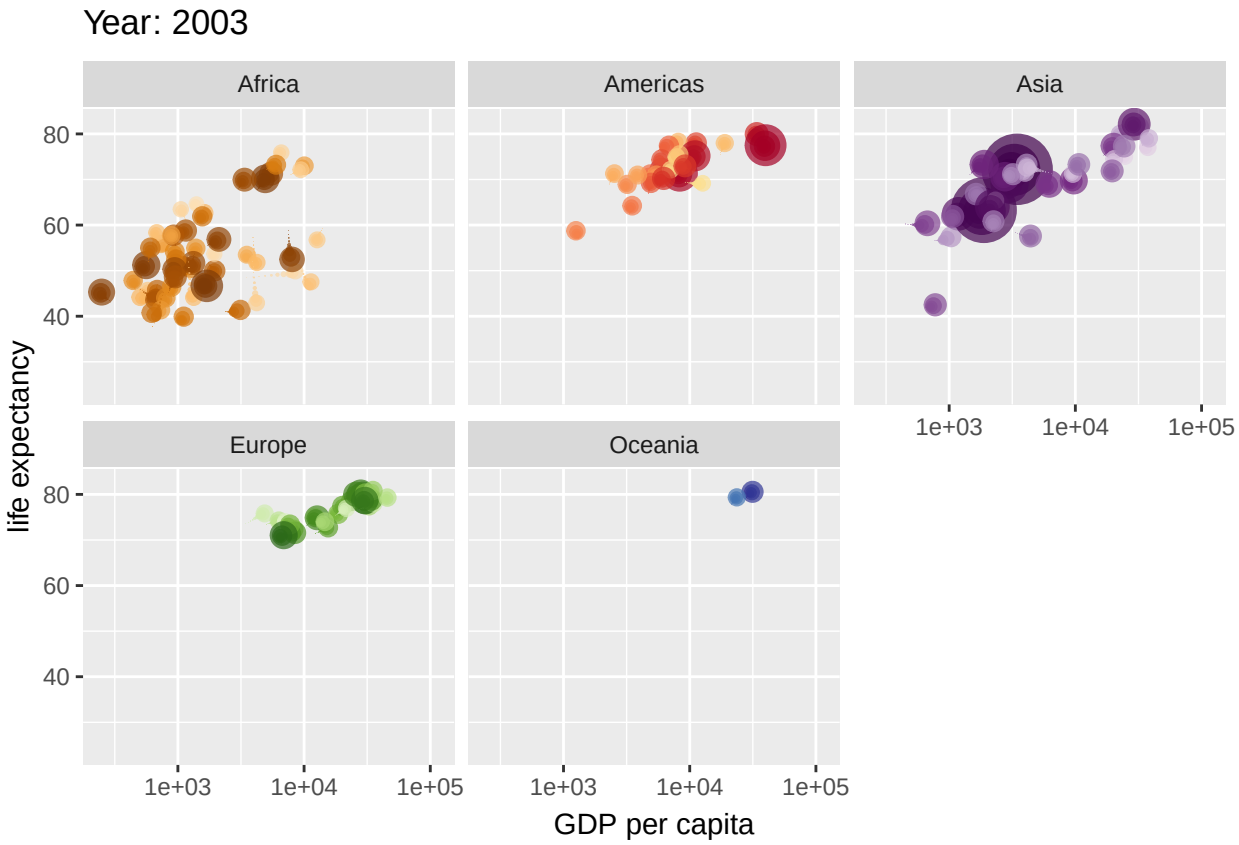

Year: 2000
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

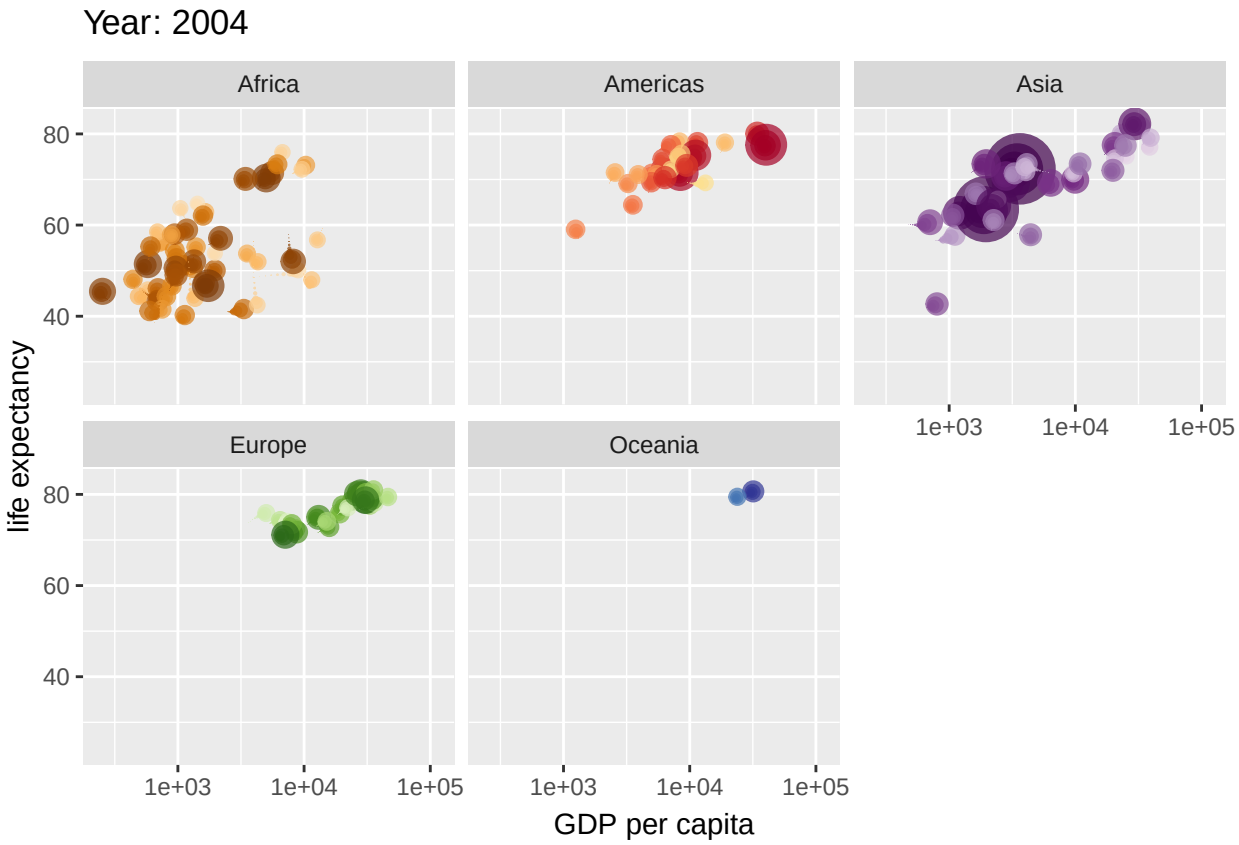

Year: 2001
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

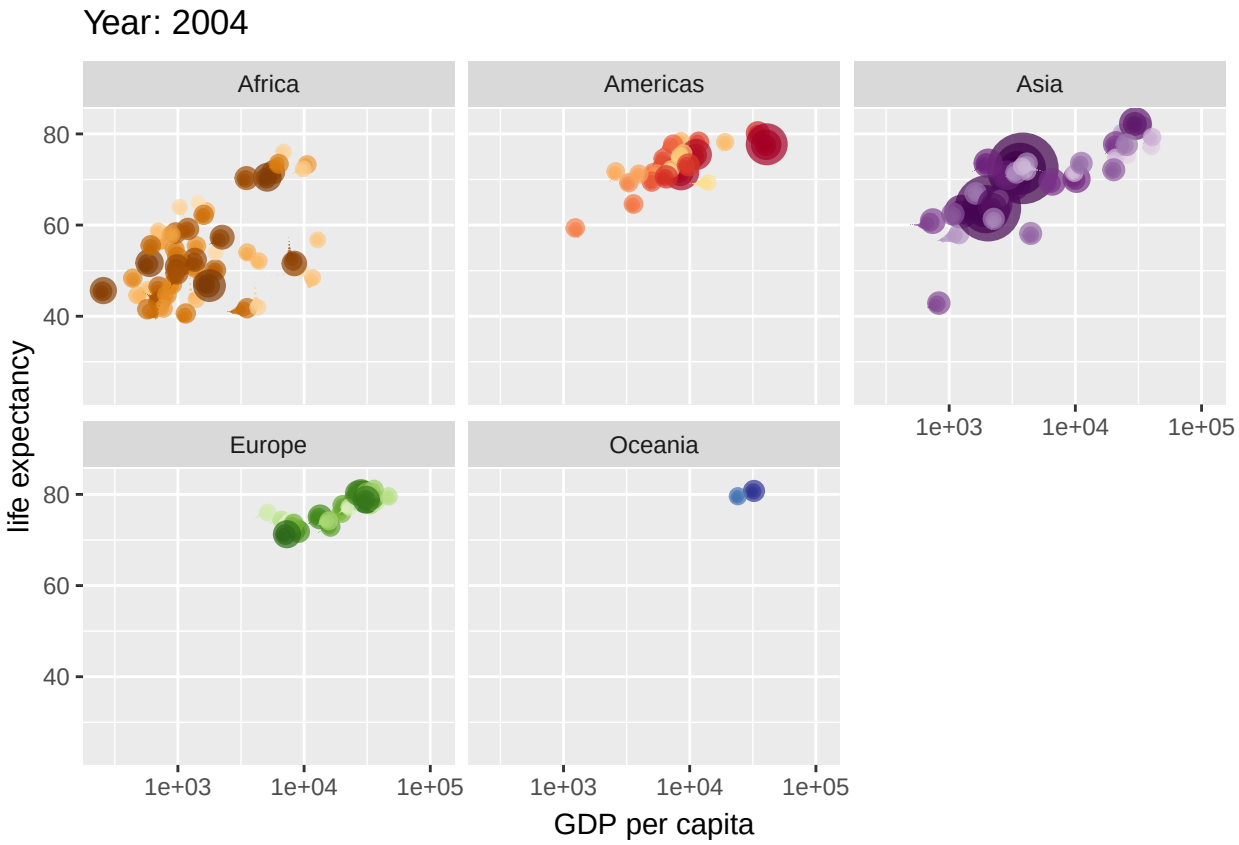

Year: 2001
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

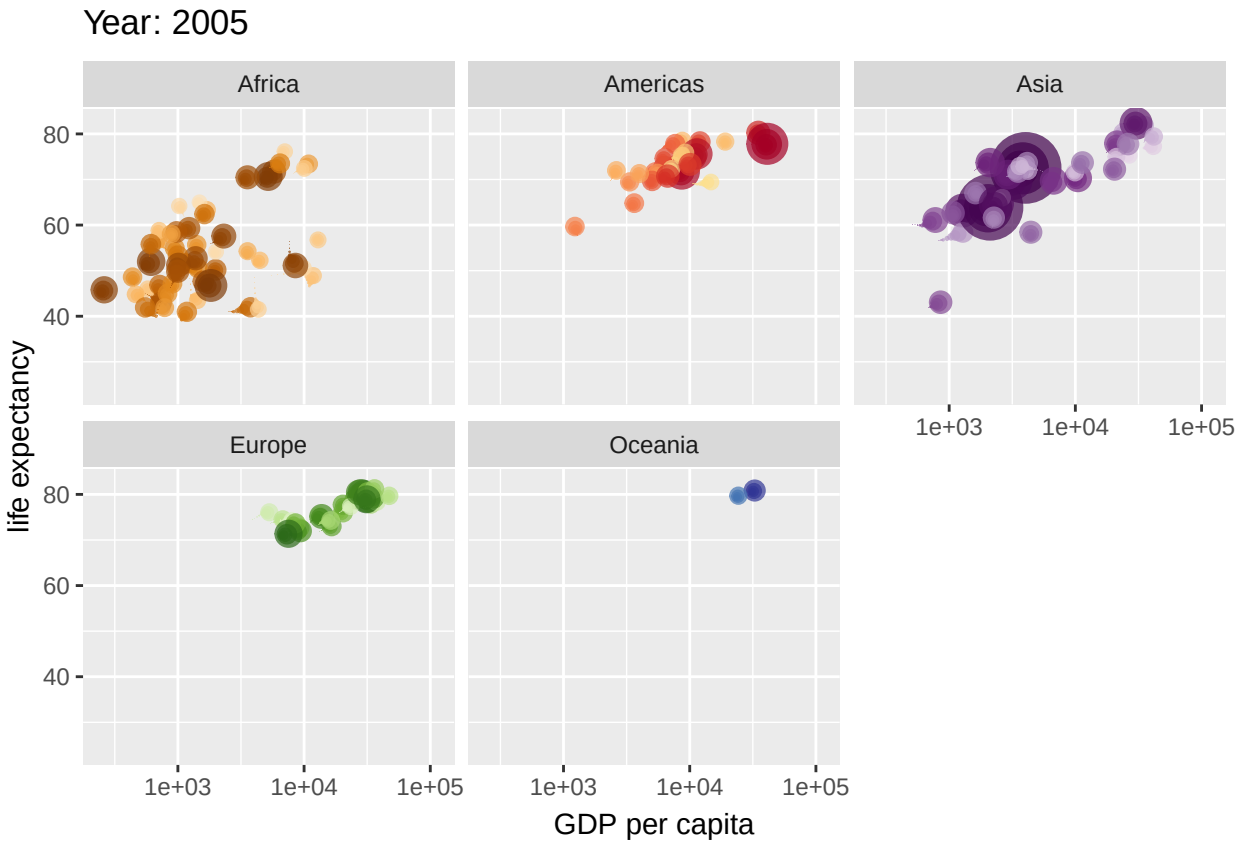

Year: 2002
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

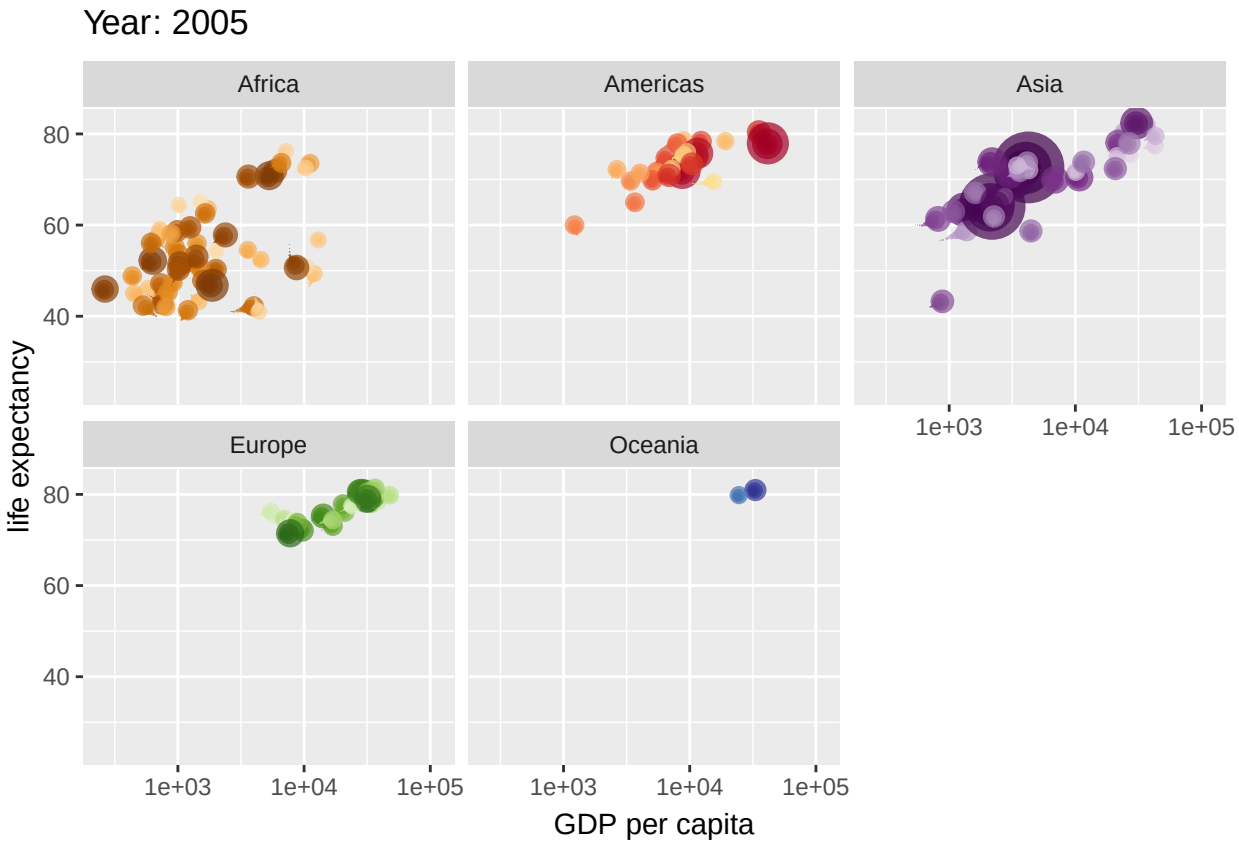

Year: 2003
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

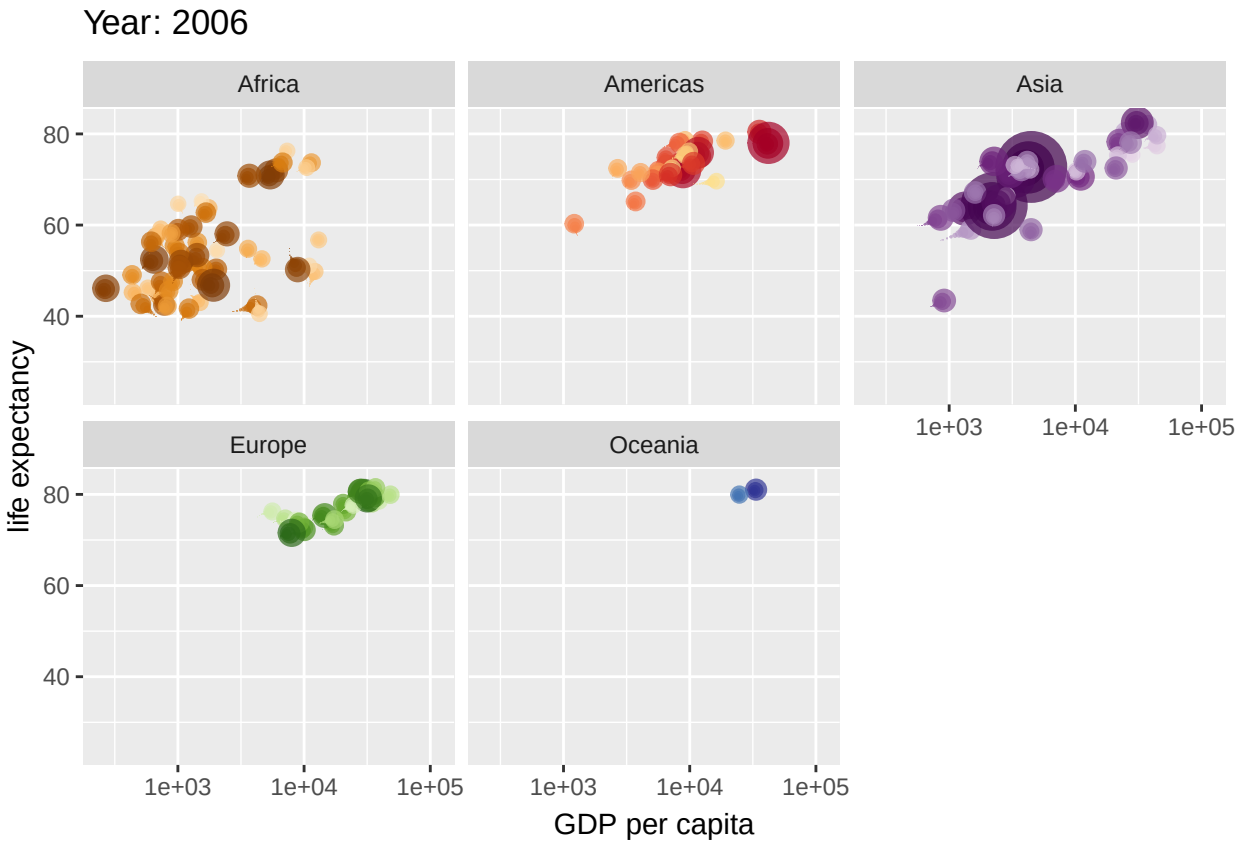

Year: 2003
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

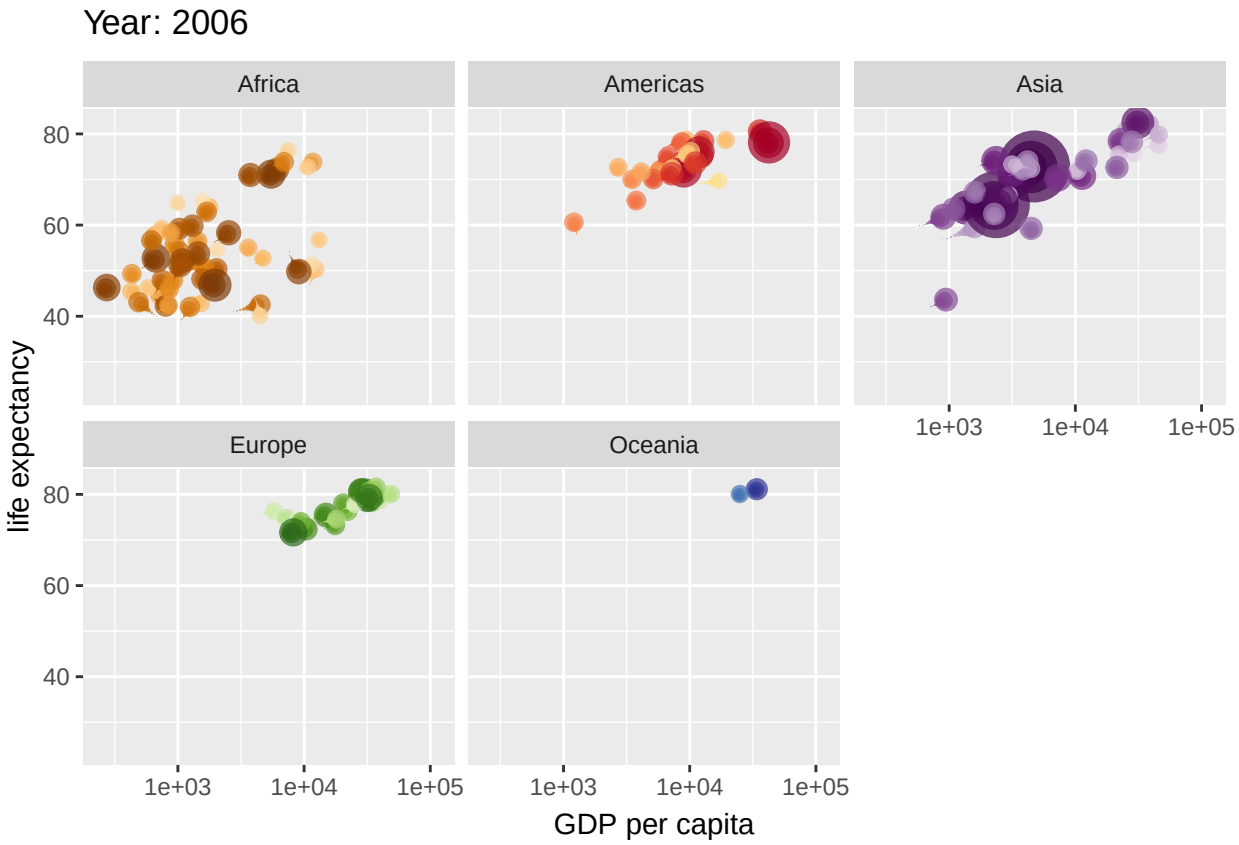

Year: 2004
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

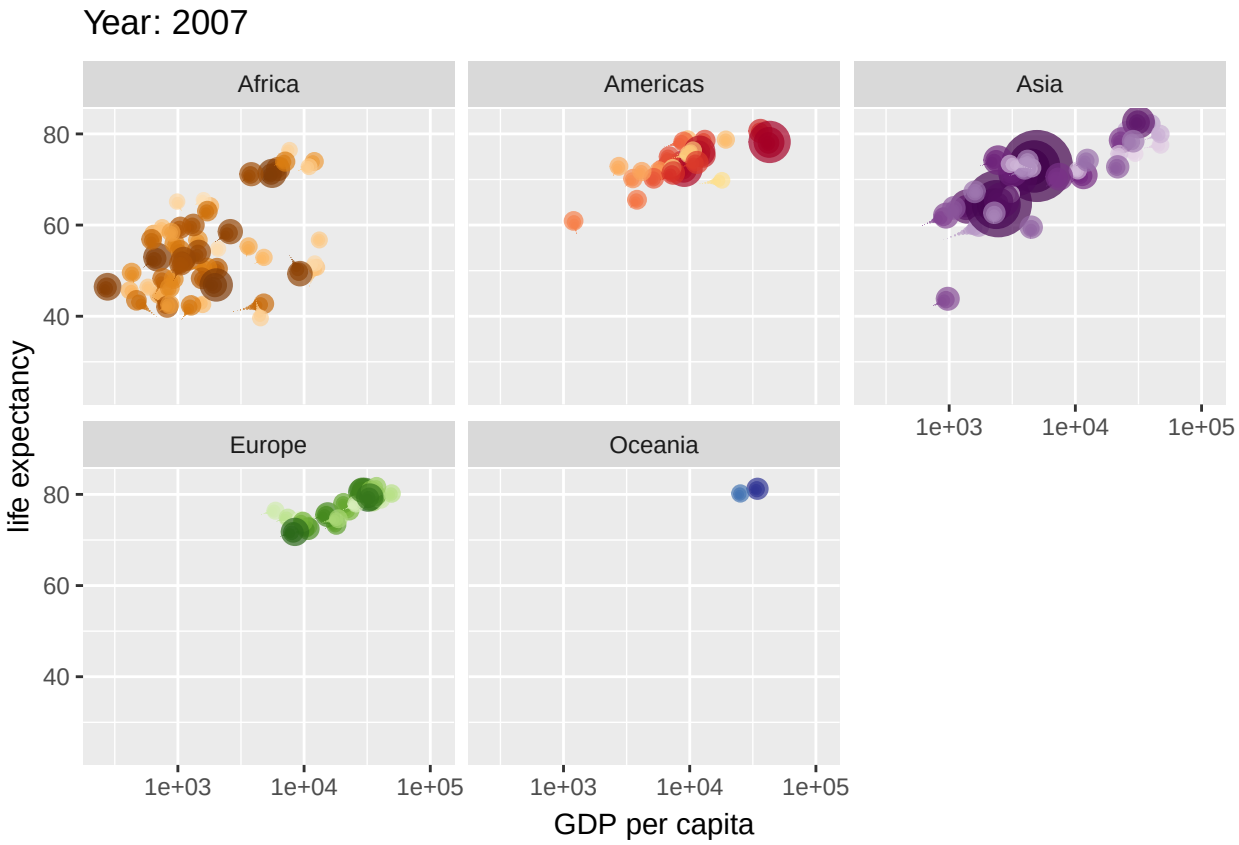

Year: 2004
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2005
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2005
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2006
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2006
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita



Section 9: Combining Plots

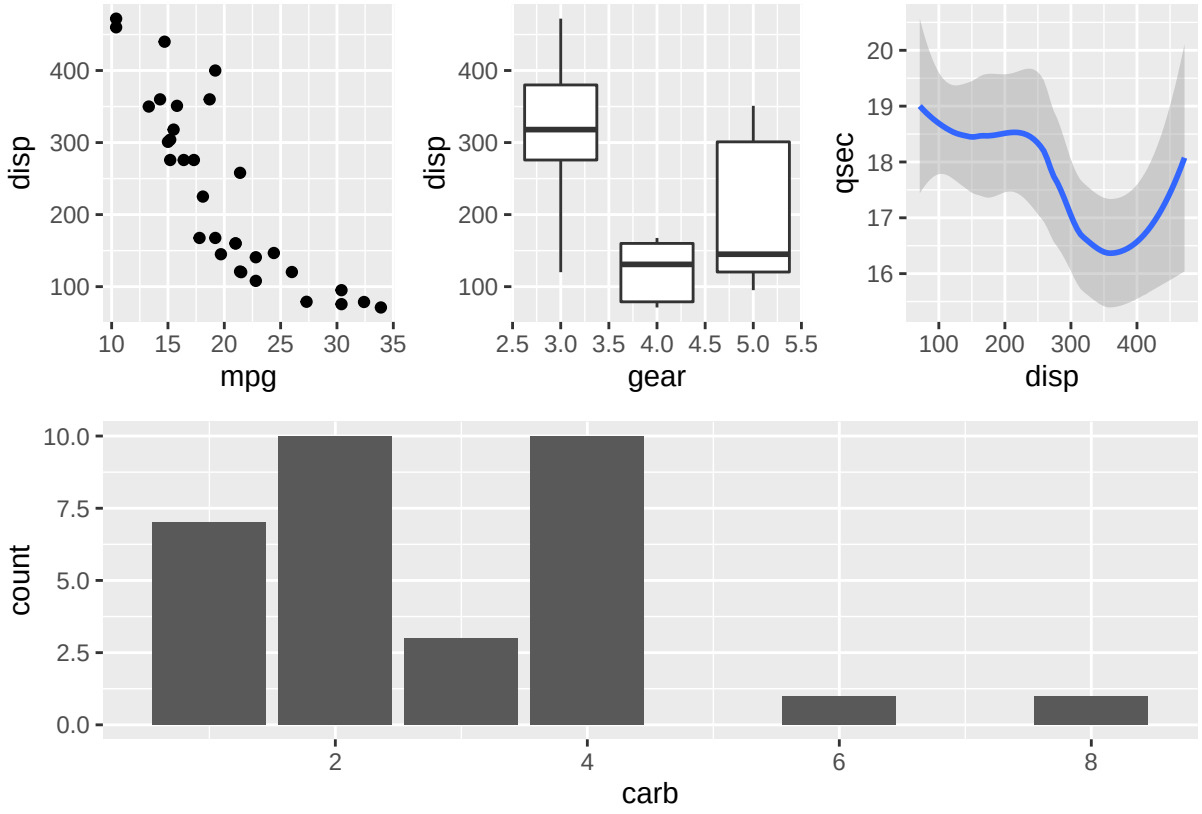
```
#install.packages("patchwork") ## un-comment to install if needed
```

```
library(patchwork)

# These are example plots
p1 <- ggplot(mtcars) + geom_point(aes(mpg, disp))
p2 <- ggplot(mtcars) + geom_boxplot(aes(gear, disp, group = gear))
p3 <- ggplot(mtcars) + geom_smooth(aes(disp, qsec))
p4 <- ggplot(mtcars) + geom_bar(aes(carb))

# This part is for pathcwork
(p1 | p2 | p3) /p4
```

```
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```


disp
400
300
200
100
10
15
20
25
30
35
mpg
disp
400
300
200
100
2.5
3.0
3.5
4.0
4.5
5.0
5.5
gear
qsec
20
19
18
17
16
100
200
300
400
disp
count
10.0
7.5
5.0
2.5
0.0
2
4
6
8
carb