Class 5: Data Viz with ggplot

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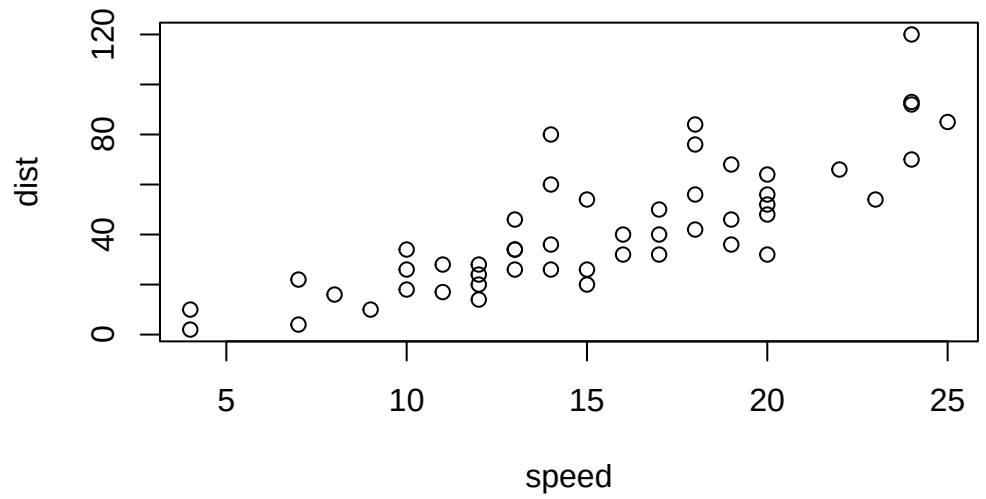
R can make figures and graphs in particular.

One that comes with R out of the box is called **"base" R** - the `plot()` function.

```
plot(cars)
```



A very popular package in this area is called **ggplot2**

Before I can use any add-on package like this, I must install the package with the `install.packages("ggplot2")` command/function

Install the package in the console to avoid downloading the package every time you render your page.

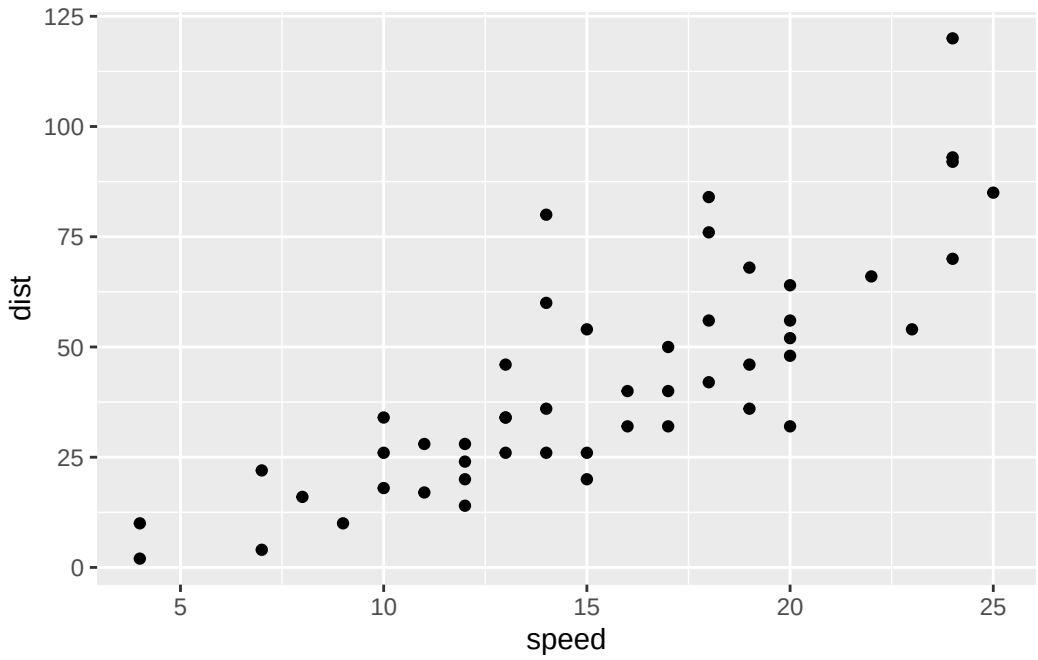
Whenever you need a package, you have to call it from a `library(ggplot2)`

Think of it like you don't want R to download everything on your computer when you start a new project. It'll be really slow. To make it efficient, you have to call the package you want to work with.

Layers of ggplot: 1) data (data.frame you want to plot); 2) aesthetic (graph mechanics); 3) geometry (types of graphs)

To make the plot, you have to call your data with 1) `ggplot()` 2) aesthetic: by adding + next to the and add a subsection code of `aes(x=, y=)`. 3) Geometry: by add another + and new subsection code `geom_point()`.

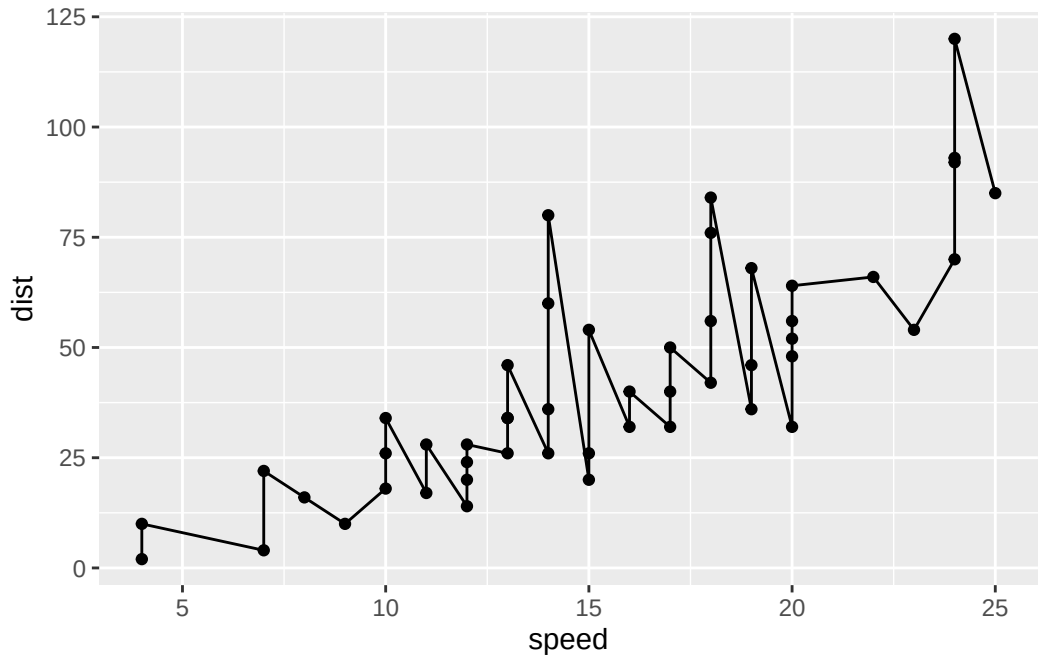
```
library(ggplot2)
ggplot(cars) +
  aes(x=speed, y=dist)+
  geom_point()
```



For "simple" plots like this one, base R code will be much shorter than ggplot code.

Let's fit a model and show it on my plot. 3) line: add +, then `geom_line`. You should see by now that ggplot works with layers.

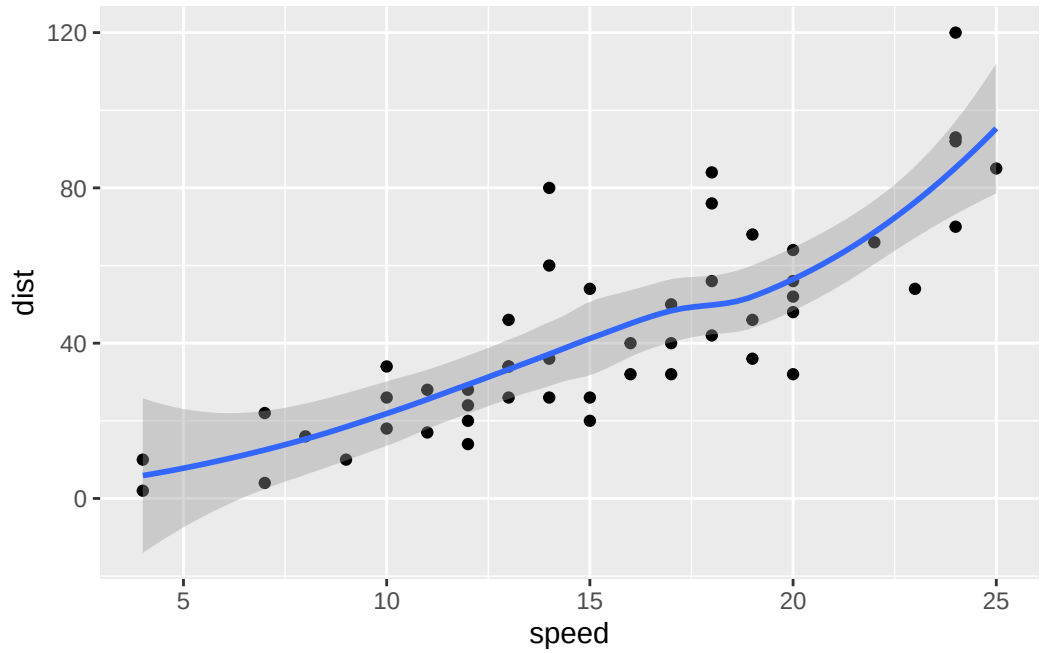
```
library(ggplot2)
ggplot(cars) +
  aes(x=speed, y=dist)+
  geom_point()+
  geom_line()
```



But this is good for a time-series data set, but this isn't that. We want a smooth correlation line. Instead of `geom_line`, use `geom_smooth`

```
library(ggplot2)
ggplot(cars) +
  aes(x=speed, y=dist)+
  geom_point()+
  geom_smooth()
```

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

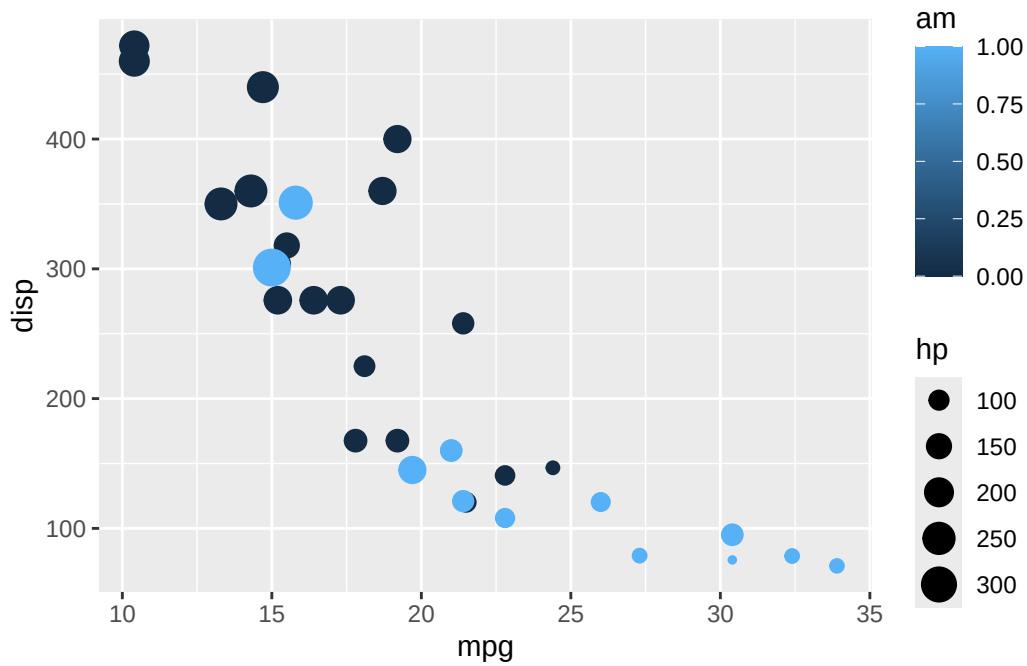


You can also use `geom_col()` for a bar graph

LETS MOVE ON!

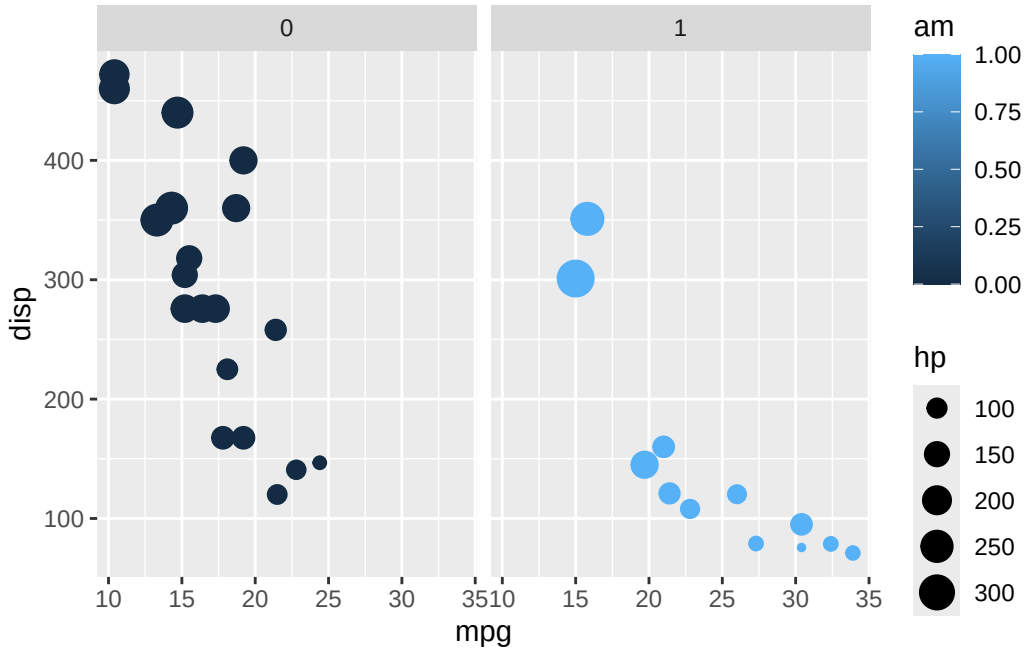
Make a ggplot of `mtcars` data set using `mpg`vs.`disp` AND set the size of the points to the `hp` AND set the color to `am`

```
ggplot(mtcars) +
  aes(x=mpg, y=disp, size=hp, color=am) +
  geom_point()
```



To separate the "ams" into two graphs, add facet_wrap(~am)

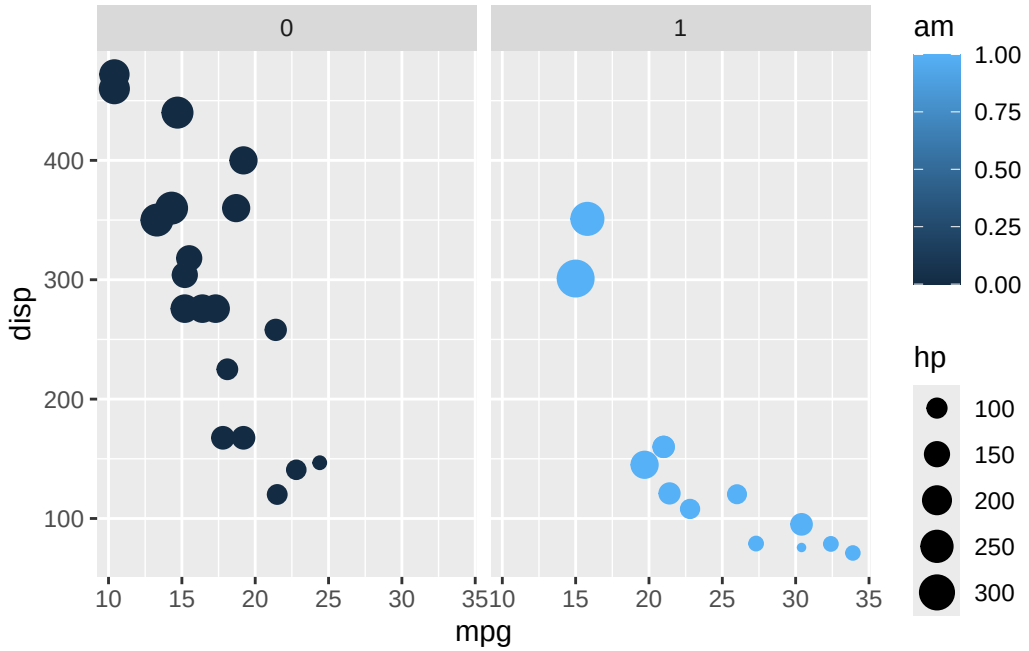
```
ggplot(mtcars) +
  aes(x=mpg, y=disp, size=hp, color=am) +
  geom_point()+
  facet_wrap(~am)
```



If you want labels, instead of the color distrubtion, add label=rownames(mtcars) in the aes() and a new subsection titled geom_label, but all the points will be on top of each other.

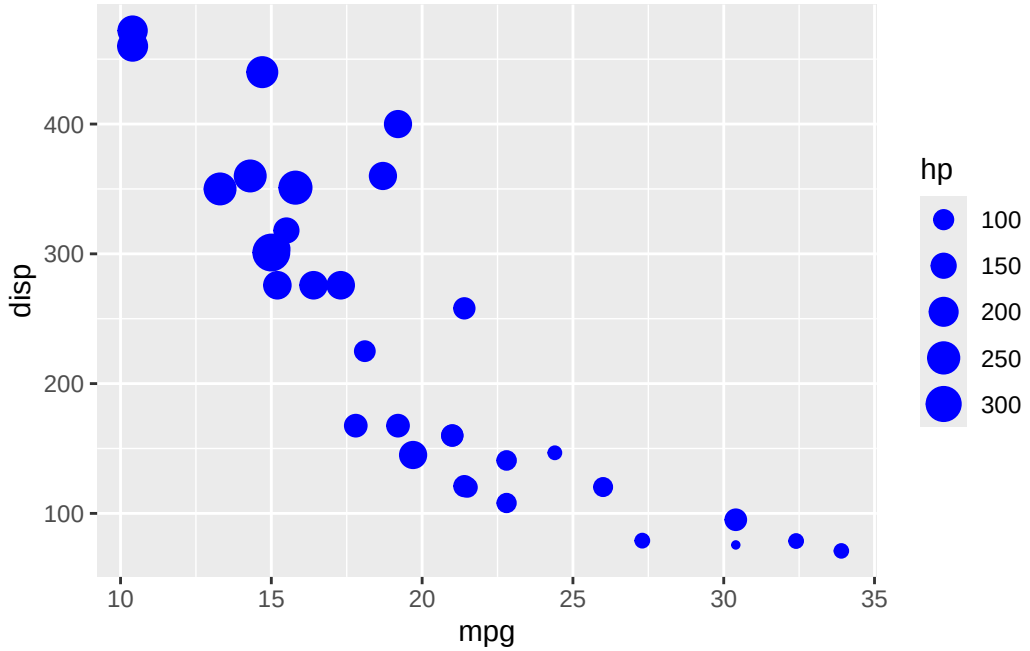
library(ggrepel), will alter the overlap, which is great of graphing gene expression. The new layer code is geom_text_repel()

```
library (ggrepel)

ggplot(mtcars) +
  aes(x=mpg, y=disp, size=hp, col=am, label=rownames(mtcars))+
  geom_point()+
  facet_wrap(~am)
```



Now color all points "blue". You have to put it in `geom_point` because the color blue is not a data-set, it's just a customization. This is a graph customization feature, so you put it in `geom_point`

```
ggplot(mtcars) +
  aes(x=mpg, y=disp, size=hp) +
  geom_point(color="blue")
```



Now lets change data-sets. Lets look at gene expression. Here is the data for this:

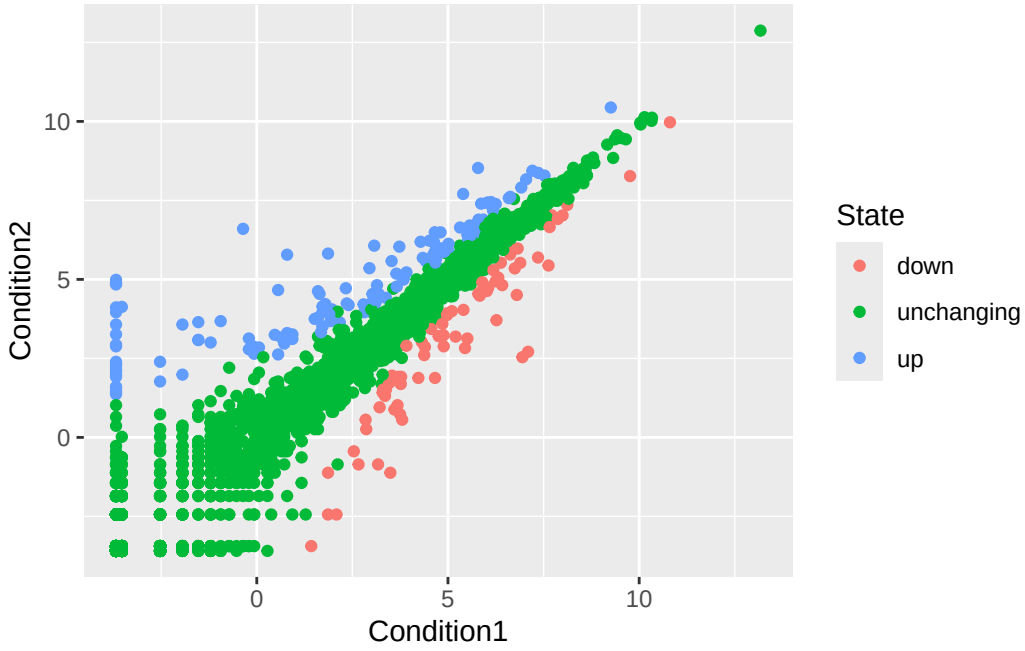
url <- "https://bioboot.github.io/bimm143_S20/class-material/up_down_expression.txt" genes <- read.delim(url) head(genes)

Lets make a graph following the same steps as before, also adding the State column:

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

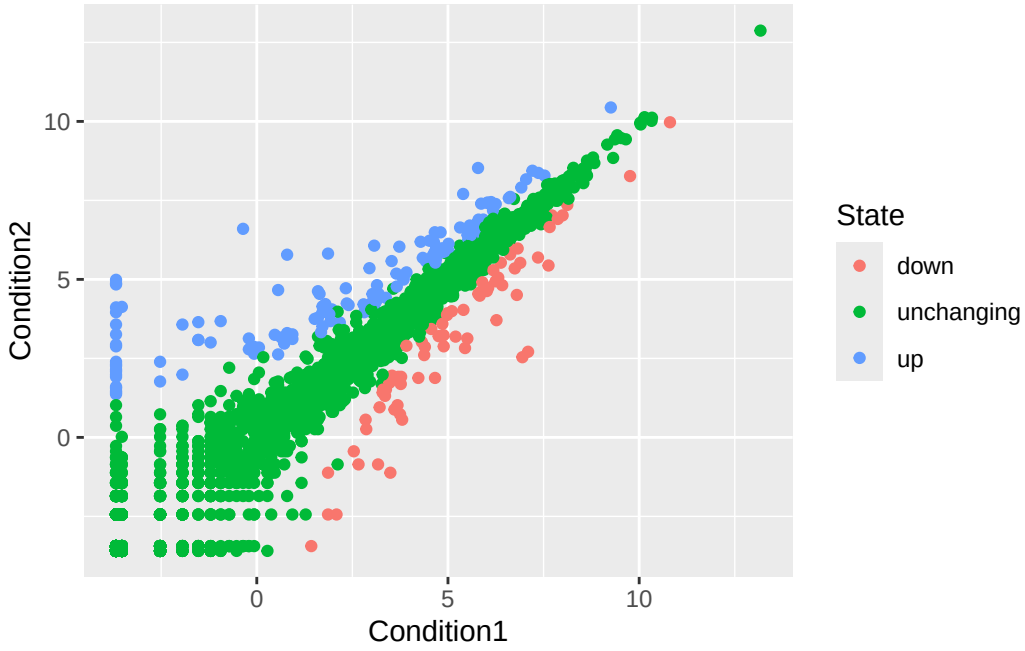
```
        Gene Condition1 Condition2      State
1      A4GNT -3.6808610 -3.4401355 unchanging
2       AAAS  4.5479580  4.3864126 unchanging
3      AASDH  3.7190695  3.4787276 unchanging
4       AATF  5.0784720  5.0151916 unchanging
5       AATK  0.4711421  0.5598642 unchanging
6 AB015752.4 -3.6808610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

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



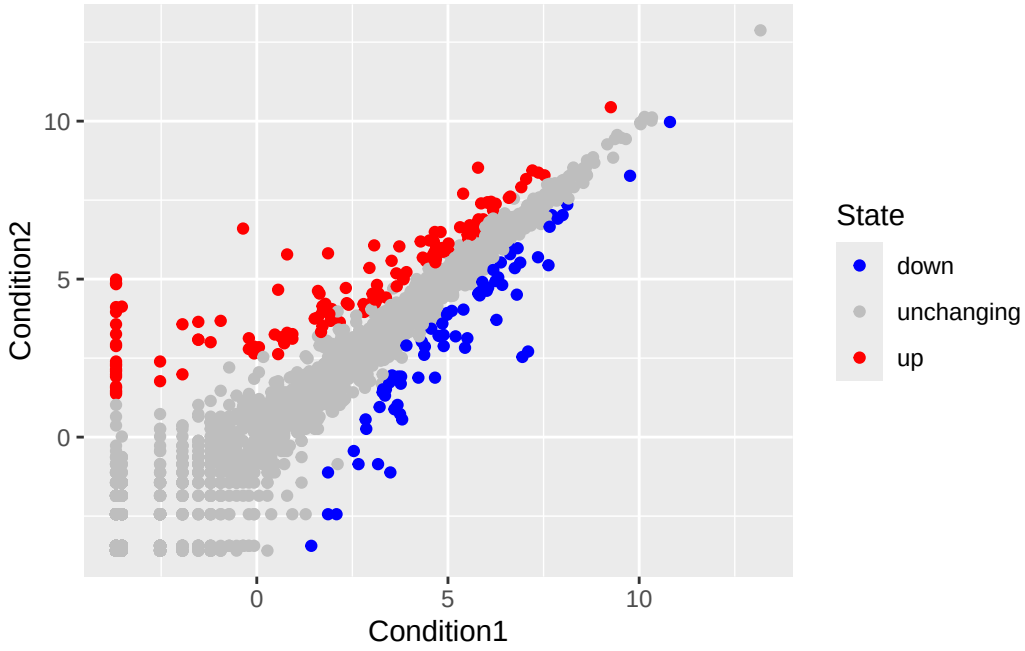
Now let's make this graph a vector to make things easier to customize from now on.

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



To change colors of the up, down, and unchanging states, lets use `scale_colour_manual( values=c("blue","gray","red") )`

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



Going Further

Now let's work with another data set. This data contains the economic and demographic data about various countries since 1952.

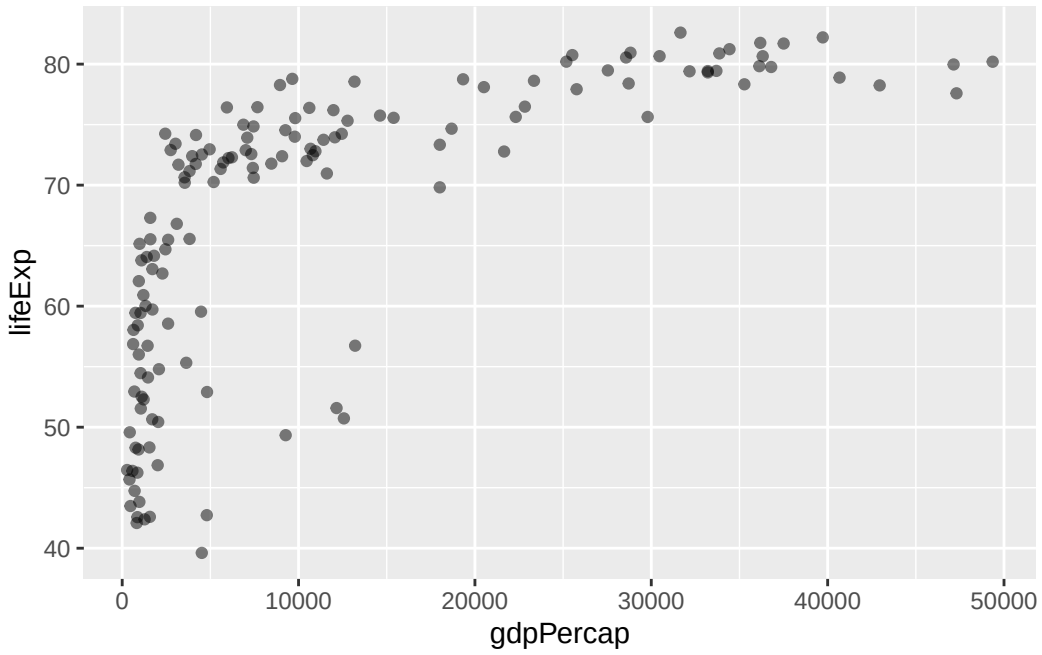
The data set covers many years and many countries. Let's use **dplyr** code to focus on a single year. `# install.packages("dplyr")`

```
library(gapminder)
```

```
library(dplyr)
```

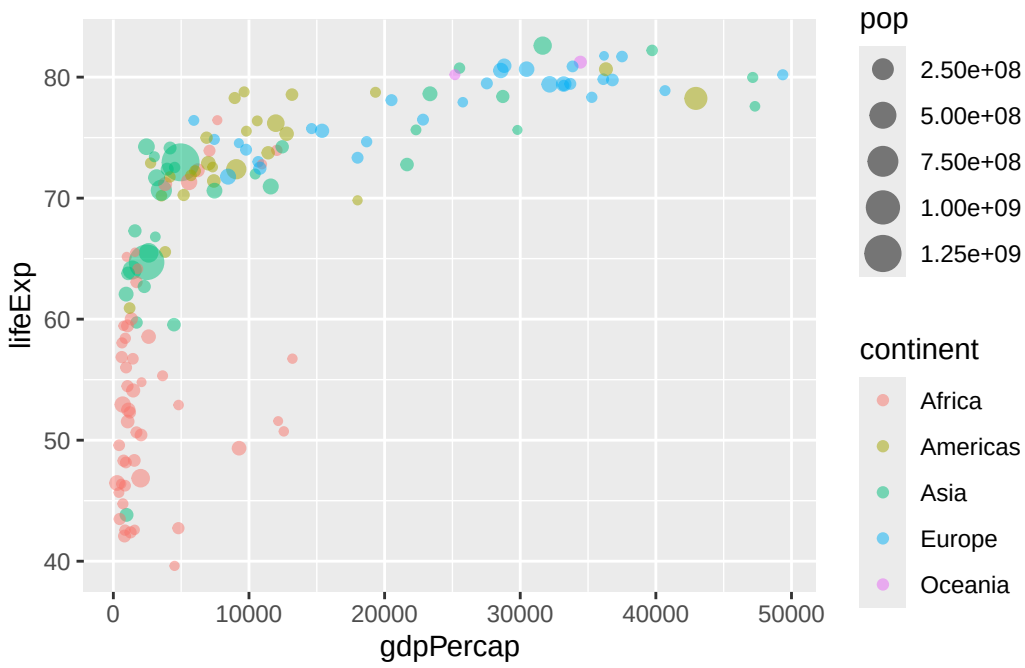
```
Attaching package: 'dplyr'

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)

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



Now lets add the color=continent, size=population. This will obtain a much richer plot.

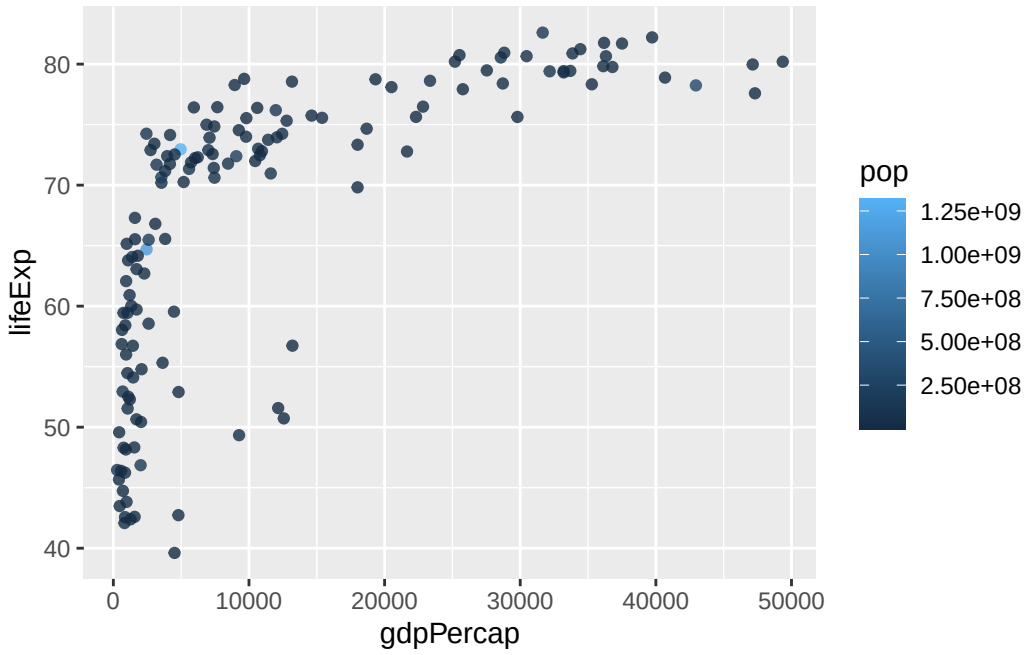
```
ggplot(gapminder_2007) +
  aes(x=gdpPercap, y=lifeExp, color=continent, size=pop) +
  geom_point(alpha=0.5)
```



Here each new aesthetic we add results in a new dimension to our scatter plot. We see that in the resulting plot each point is colored differently based on the continent of each country. ggplot uses the coloring scheme based on the categorical data type of the variable continent.

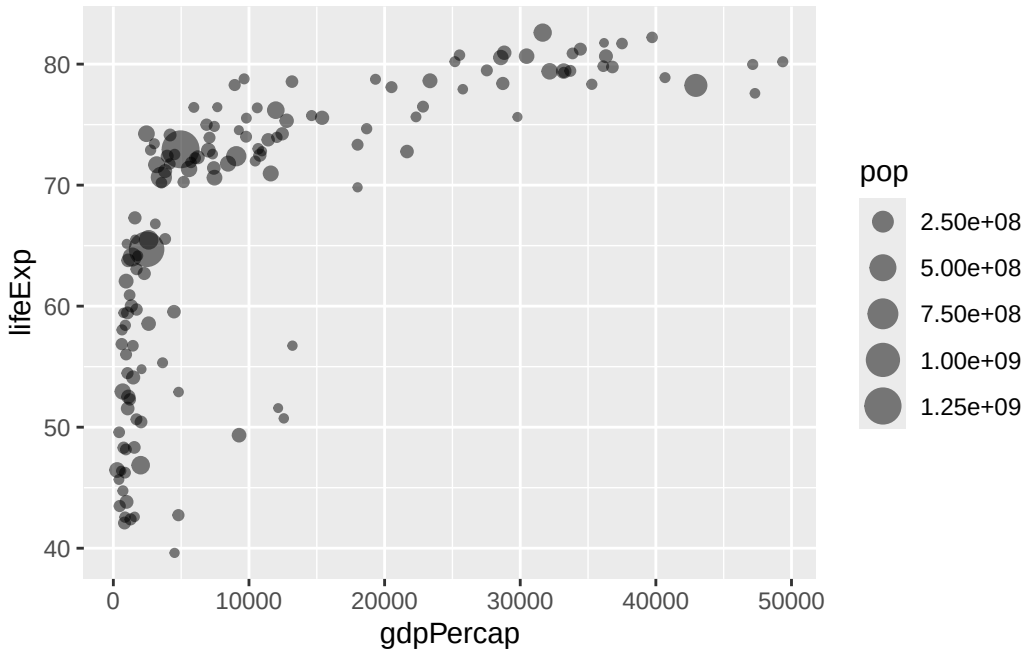
By contrast, let's see how the plot looks like if we color the points by the numeric variable population pop:

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



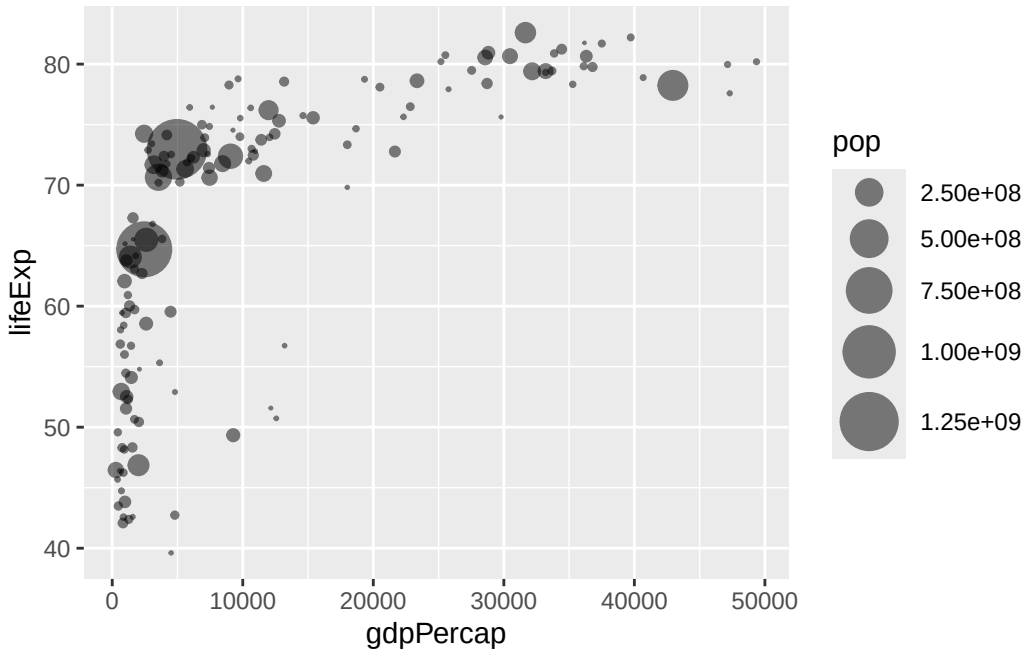
For the gapminder_2007 dataset we can plot the GDP per capita (x=gdpPercap) vs. the life expectancy (y=lifeExp) and set the point size based on the population (size=pop) of each country we can use:

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



However, if you look closely we see that the point sizes in the plot above do not clearly reflect the population differences in each country. If we compare the point size representing a population of 250 million people with the one displaying 750 million, we can see, that their sizes are not proportional. Instead, the point sizes are binned by default. To reflect the actual population differences by the point size we can use the scale_size_area() function instead. The scaling information can be added like any other ggplot object with the + operator:

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

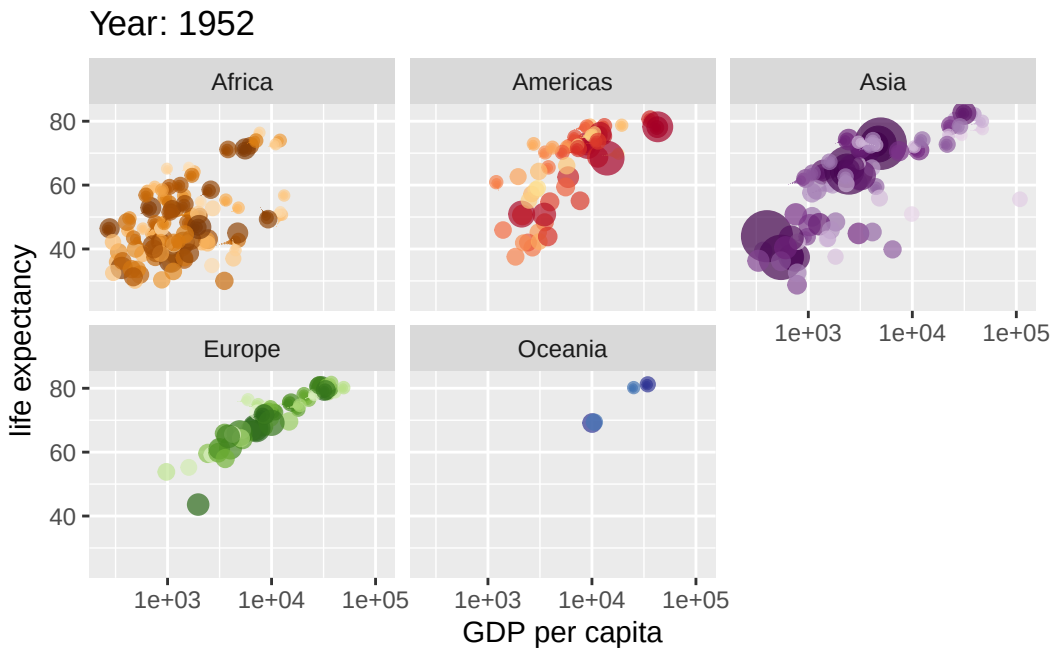


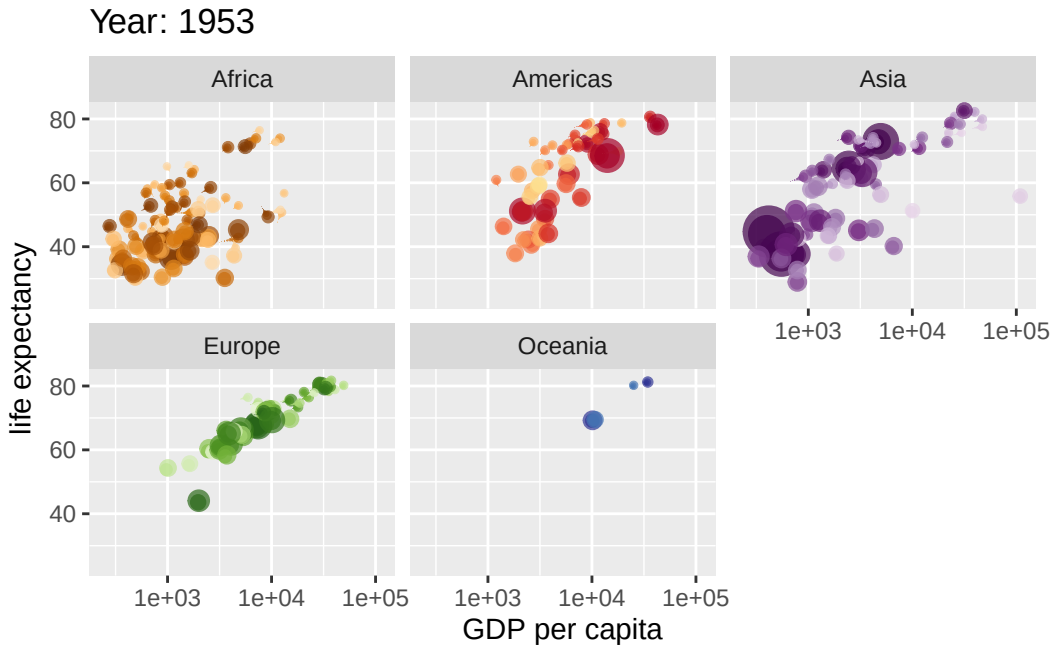
In a bar graph, you can reorder by a certain visualization by `aes(x=reorder(country, -pop))` A new graph function is `coord_flip()`, which will rotate your plots to enable a clear visualization. If it's too clutters, combine `geom_point` and `geom_segment`

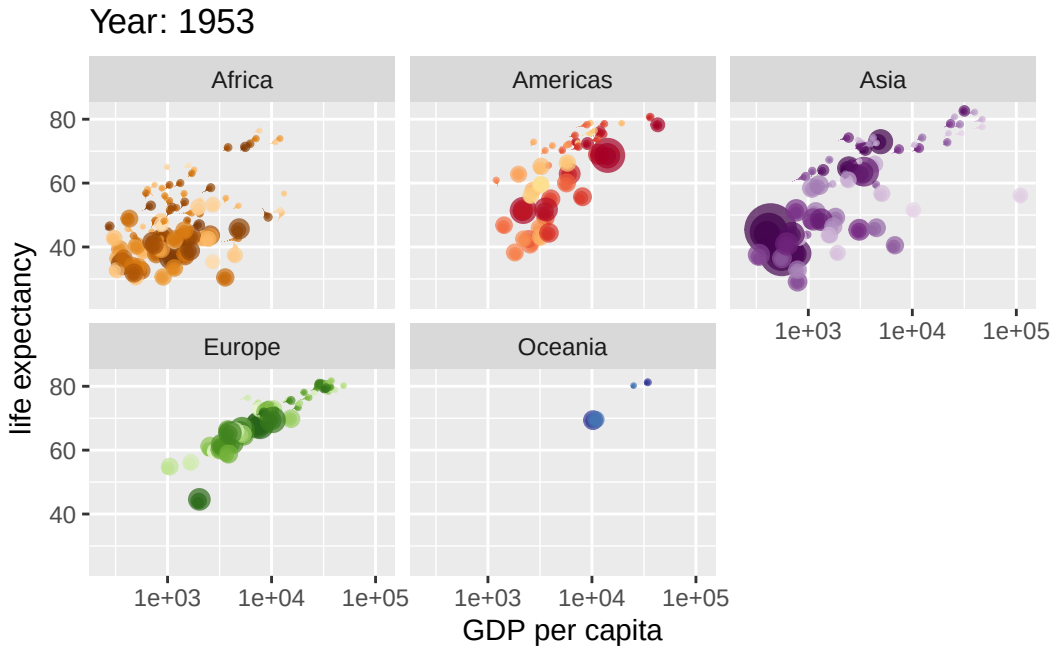
NOW LETS ANIMATE!!!!!

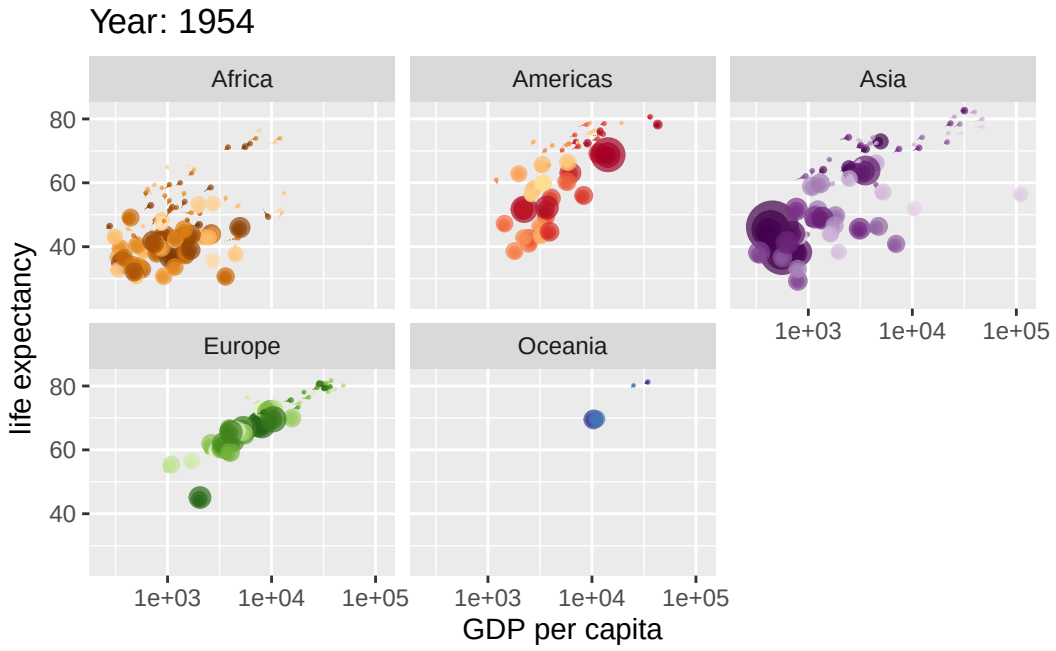
```
library(gapminder)
library(gganimate)

# Setup nice regular ggplot of the gapminder data
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() +
  # Facet by continent
  facet_wrap(~continent) +
  # Here comes the gganimate specific bits
  labs(title = 'Year: {frame_time}', x = 'GDP per capita', y = 'life expectancy') +
  transition_time(year) +
  shadow_wake(wake_length = 0.1, alpha = FALSE)
```

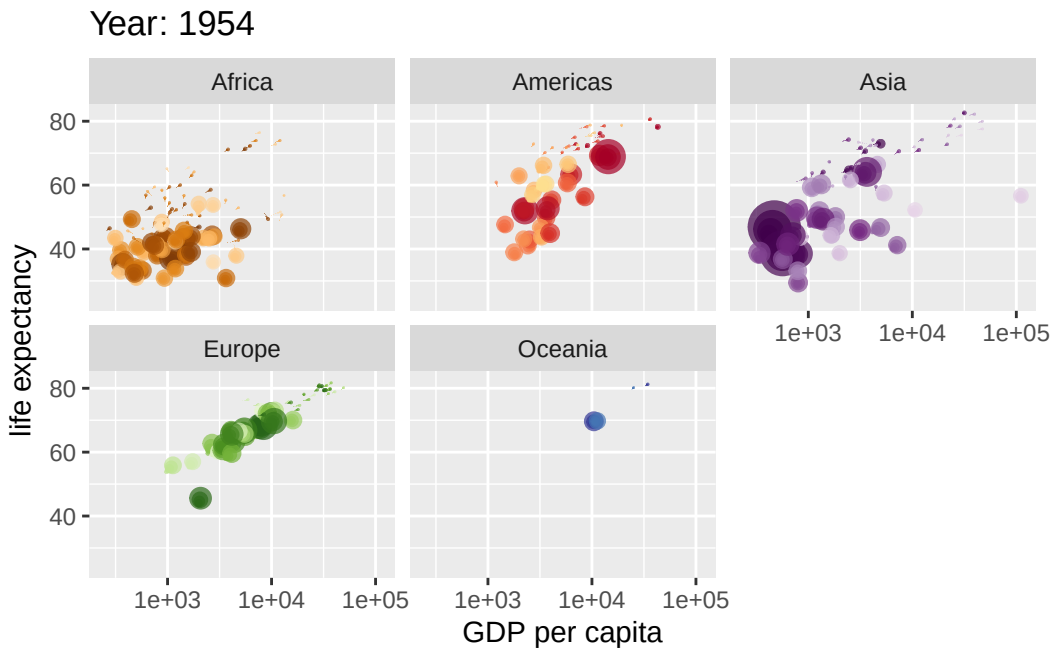
```
Warning in formals(fun): argument is not a function
```

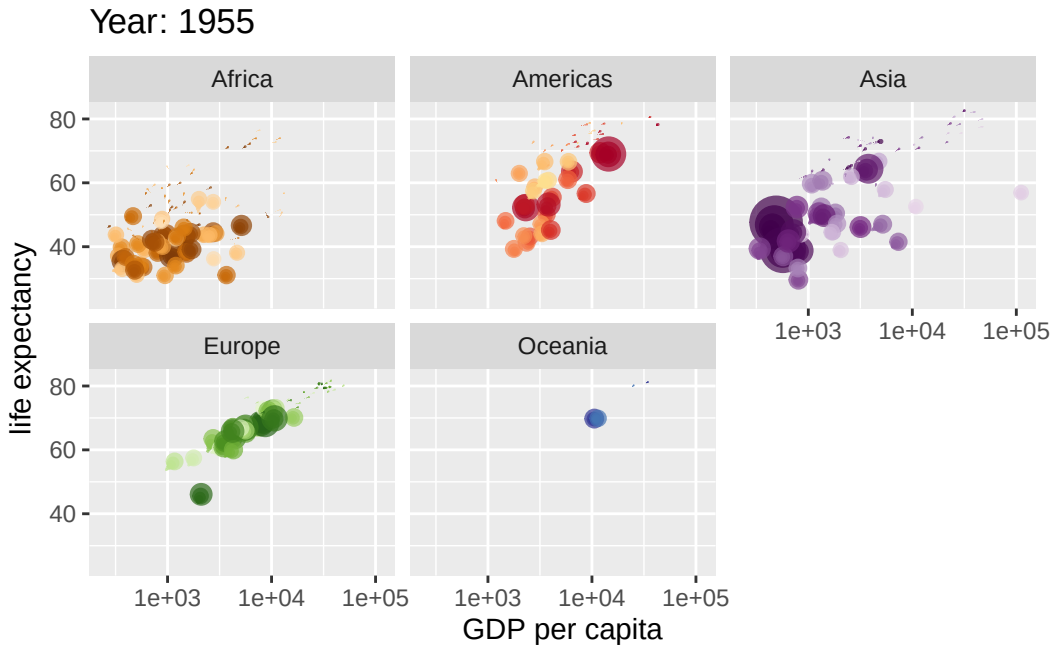

Year: 1952
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

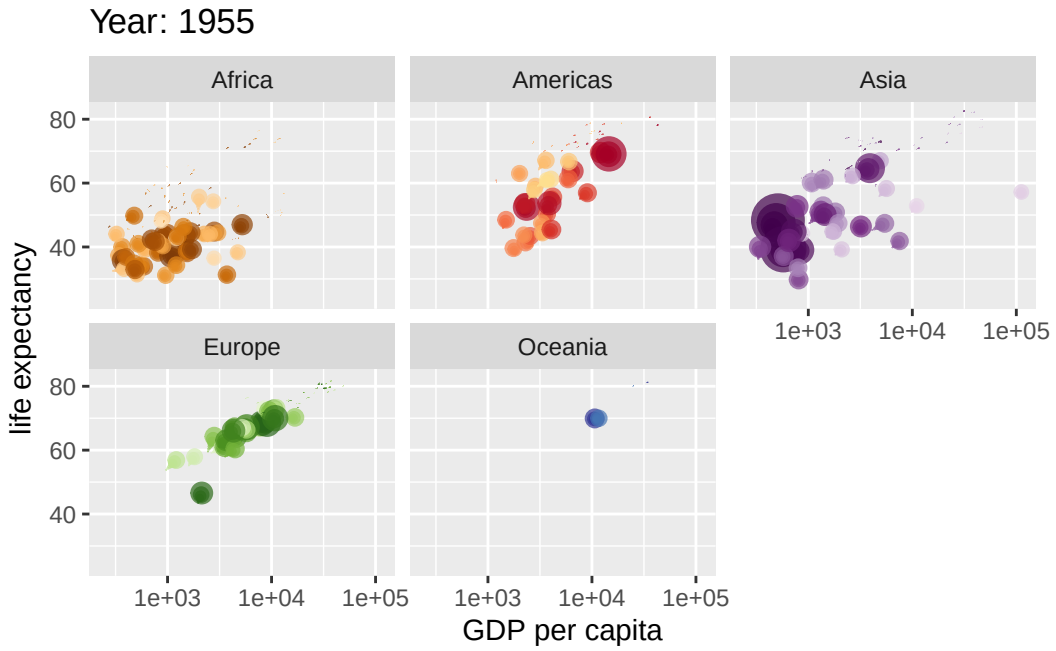

Year: 1953
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

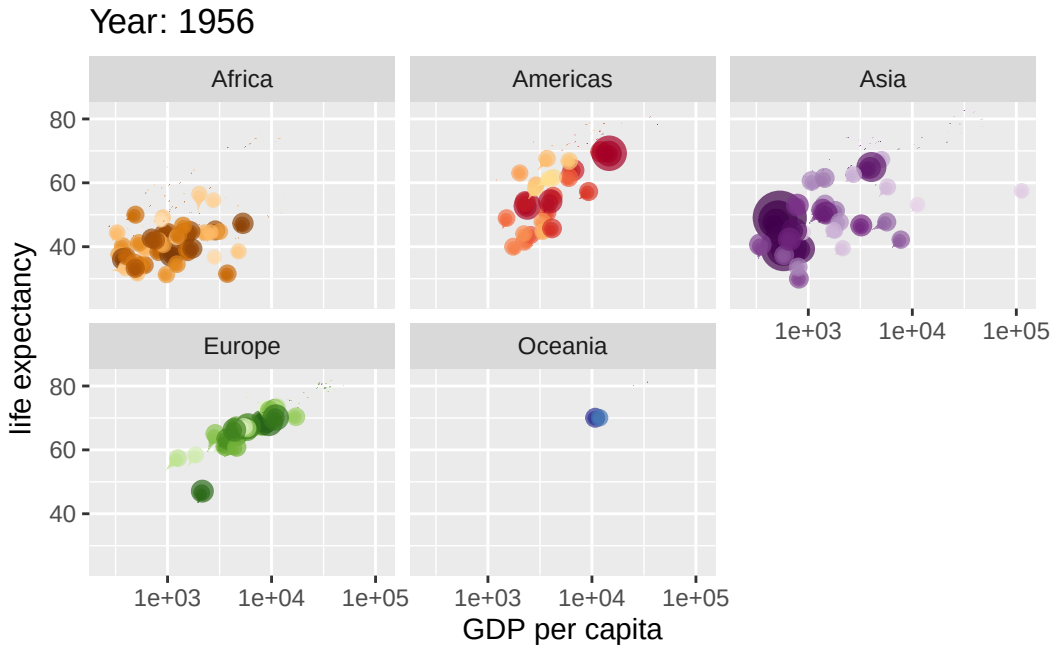

Year: 1953
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

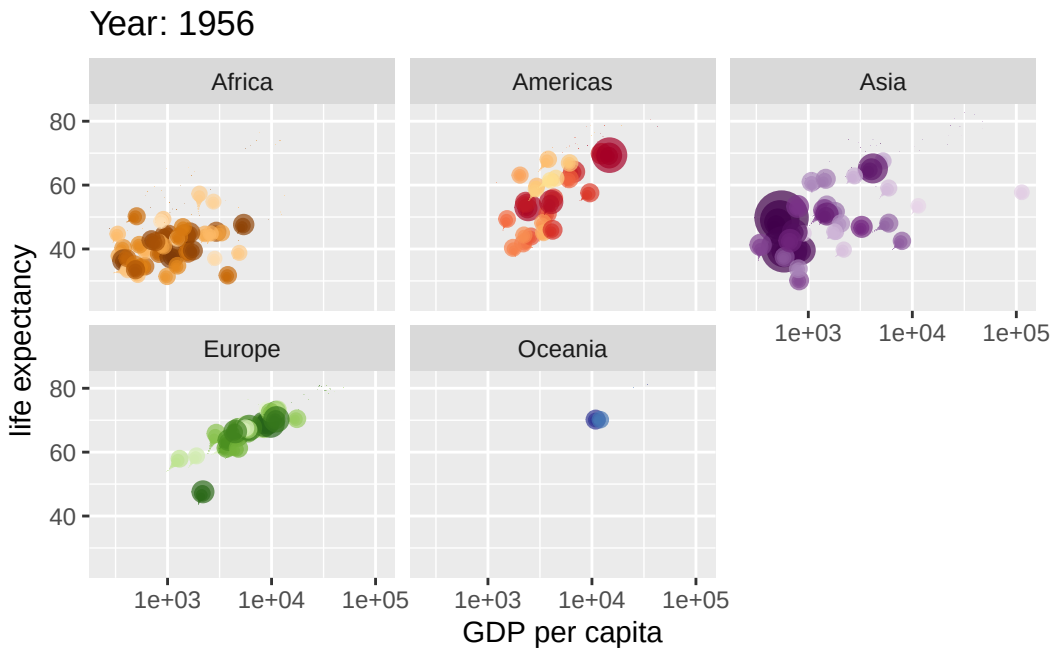

Year: 1954
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

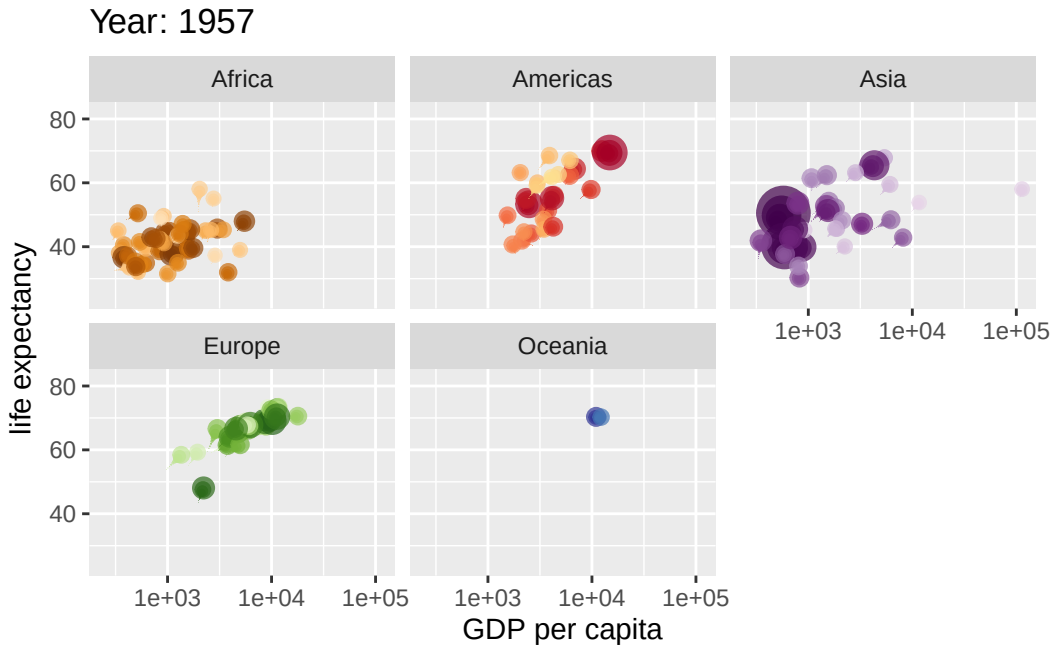

Year: 1954
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

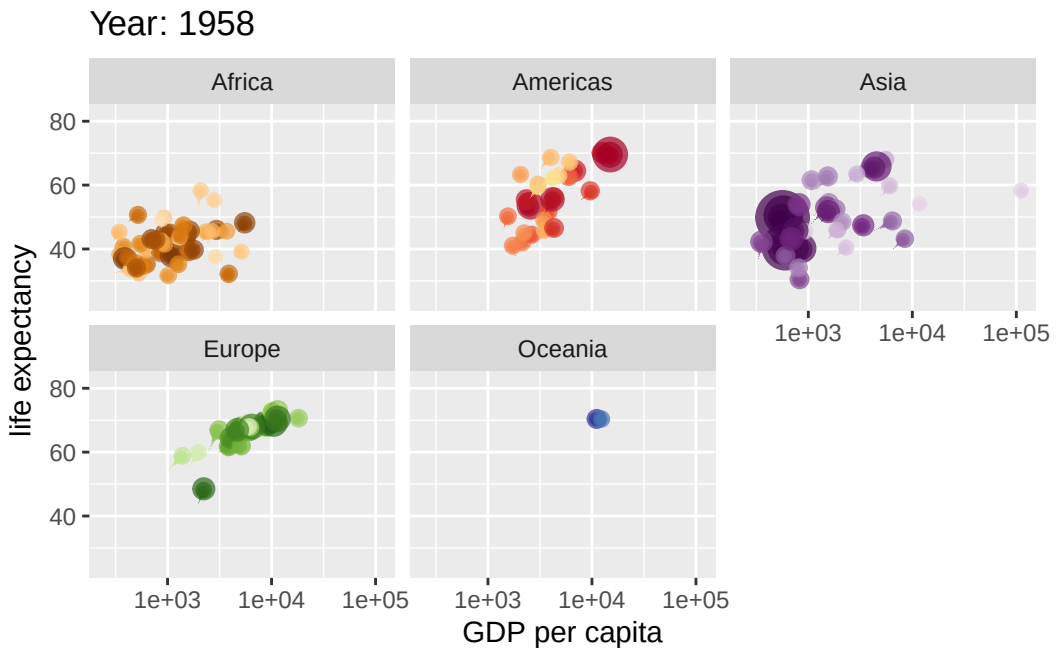

Year: 1955
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

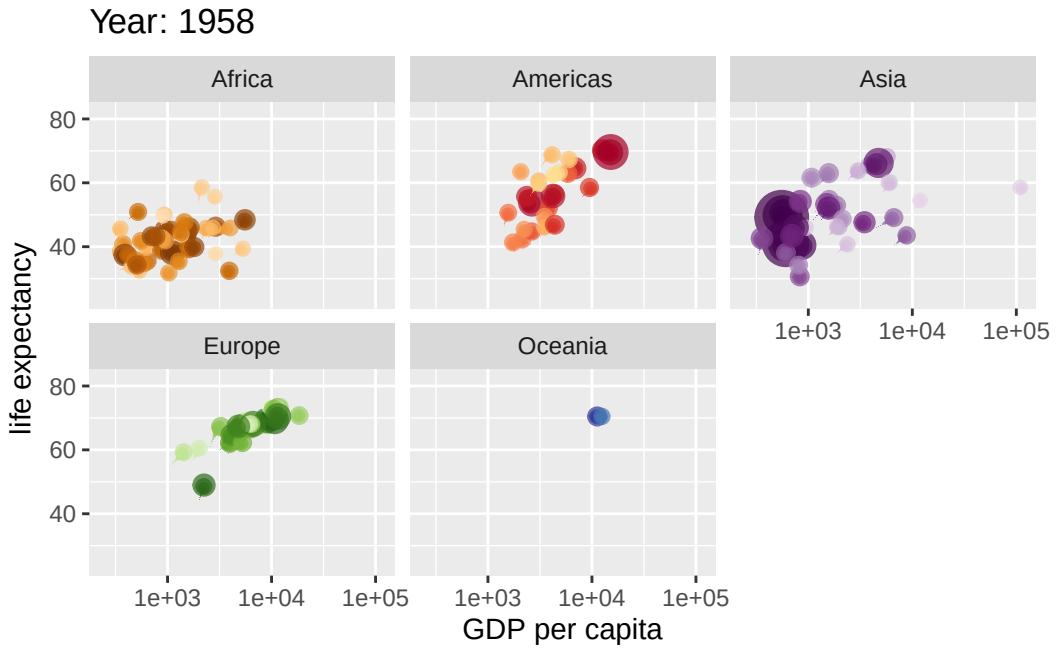

Year: 1955
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

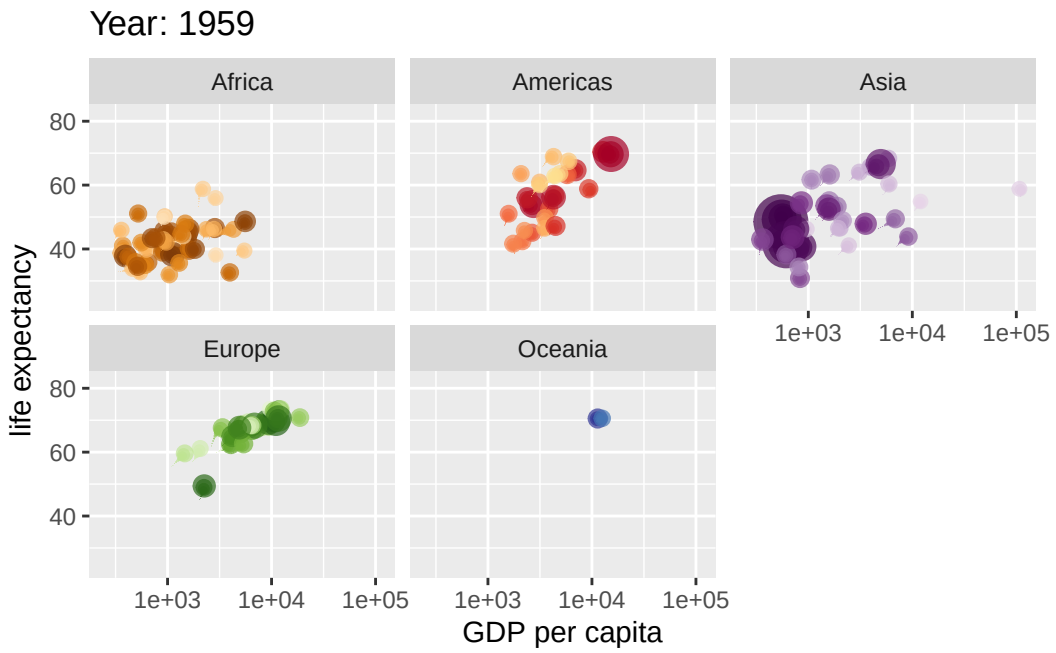

Year: 1956
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

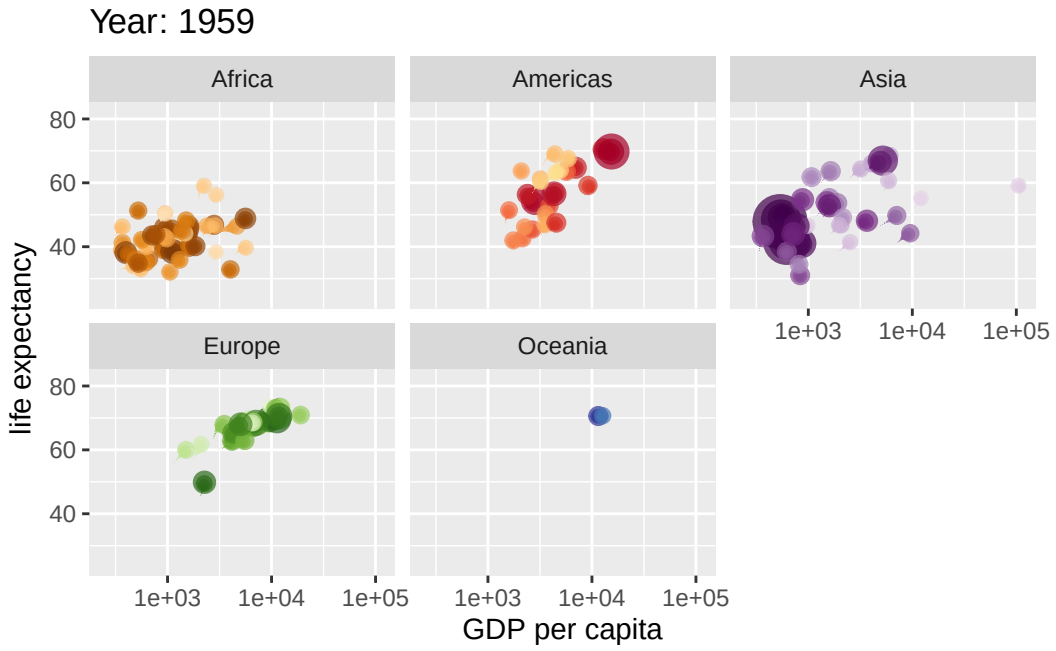

Year: 1956
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

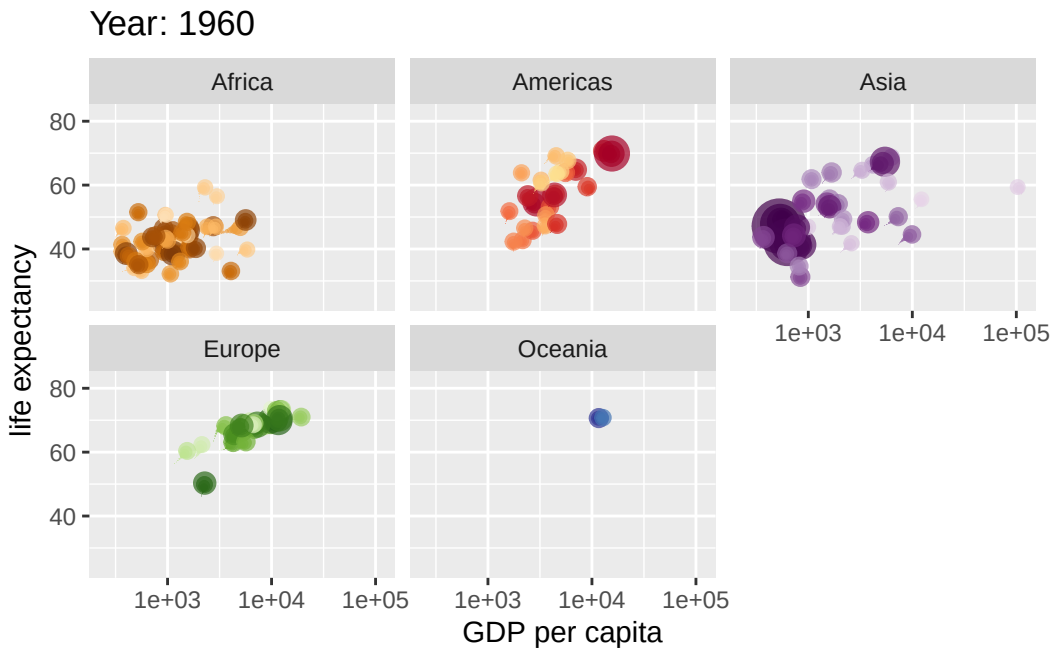

Year: 1957
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

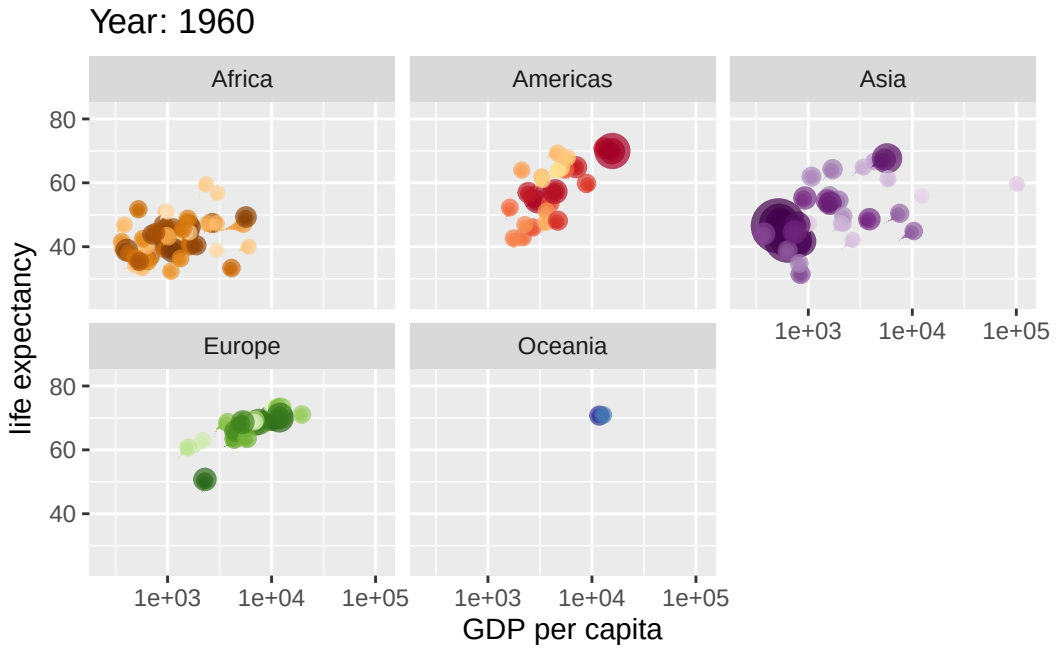

Year: 1958
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

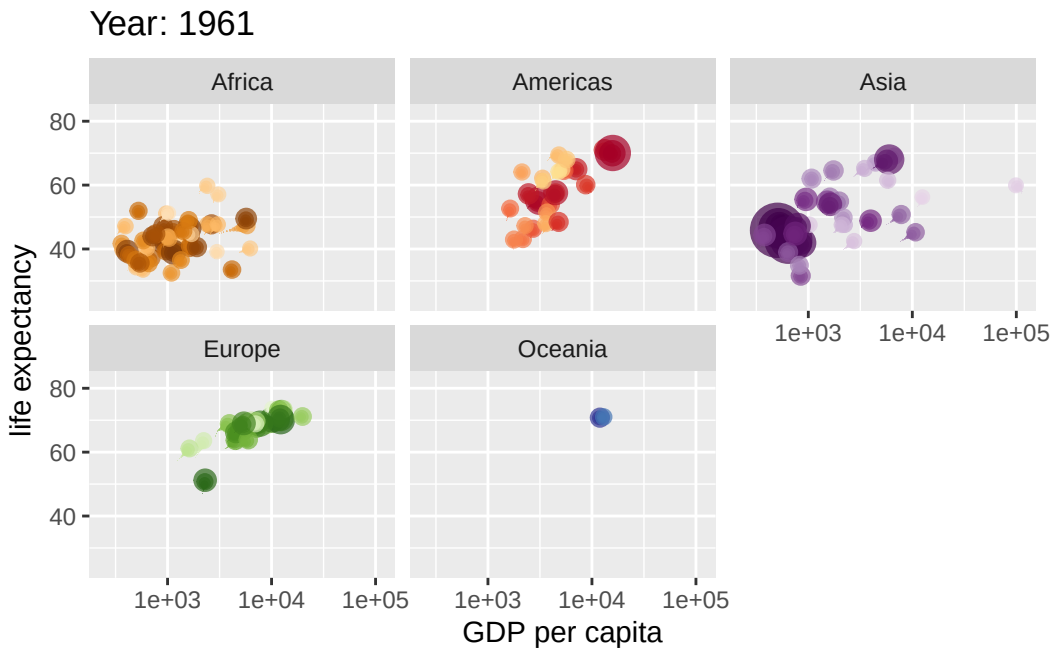

Year: 1958
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita

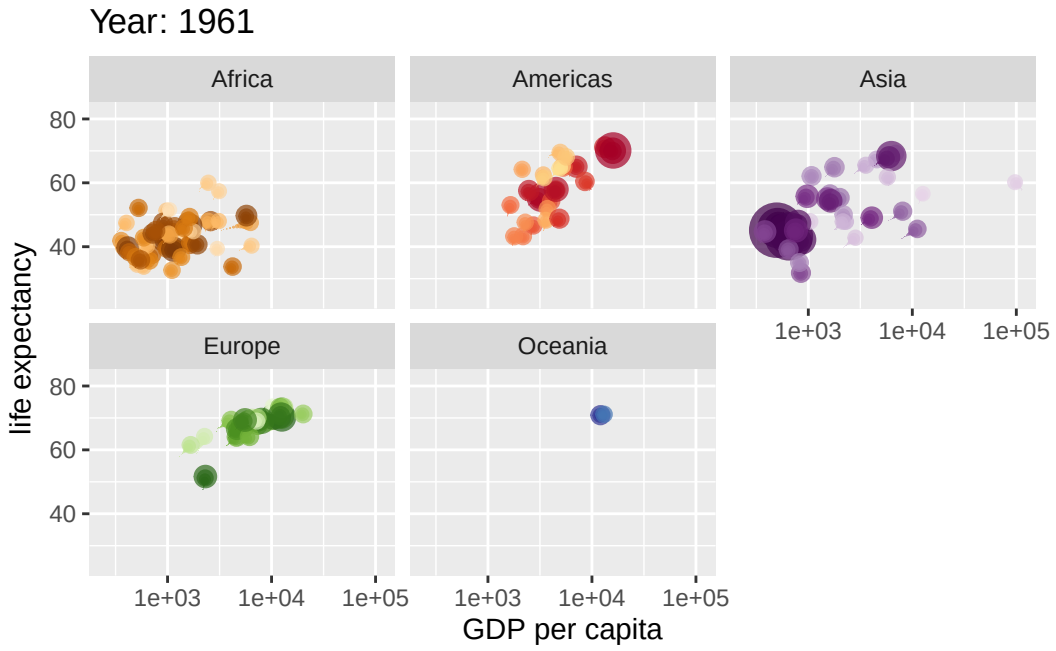

Year: 1959
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1959
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
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: 1961
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


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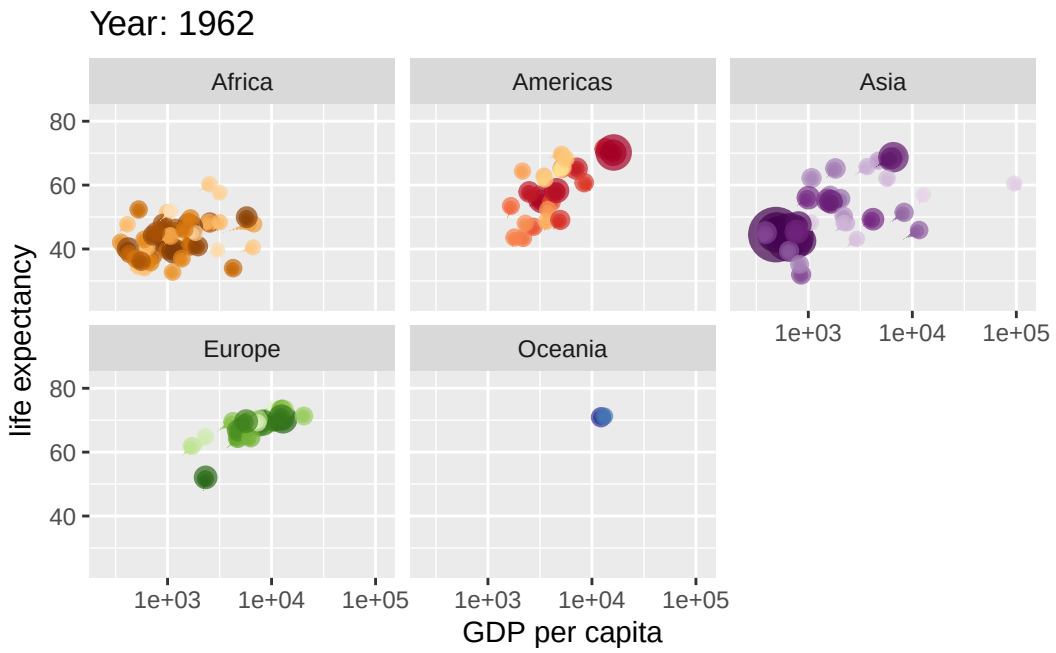
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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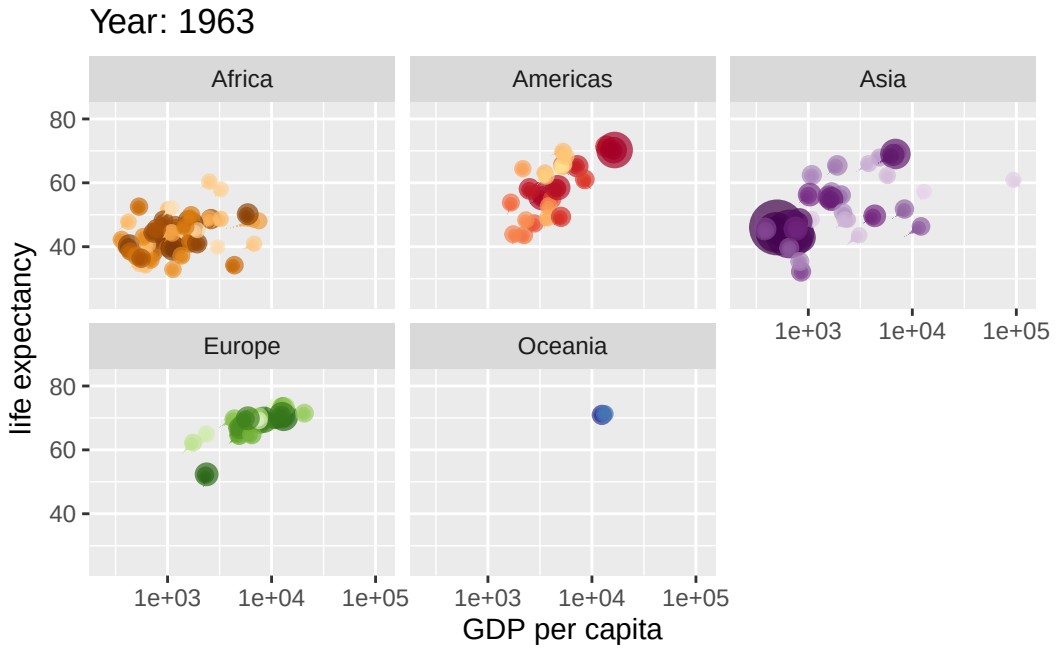
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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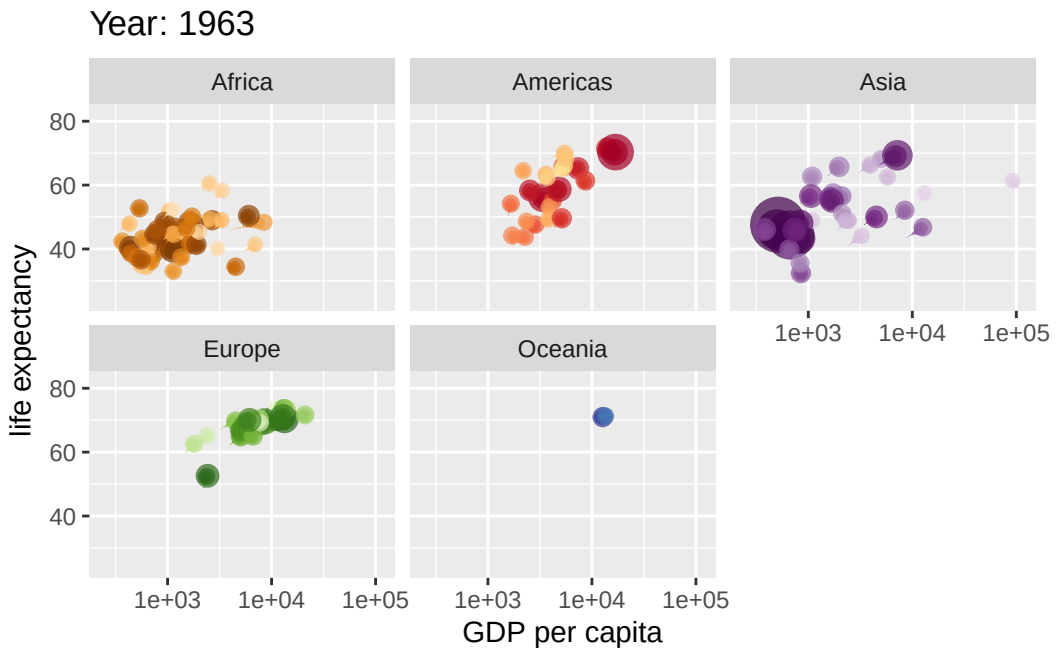
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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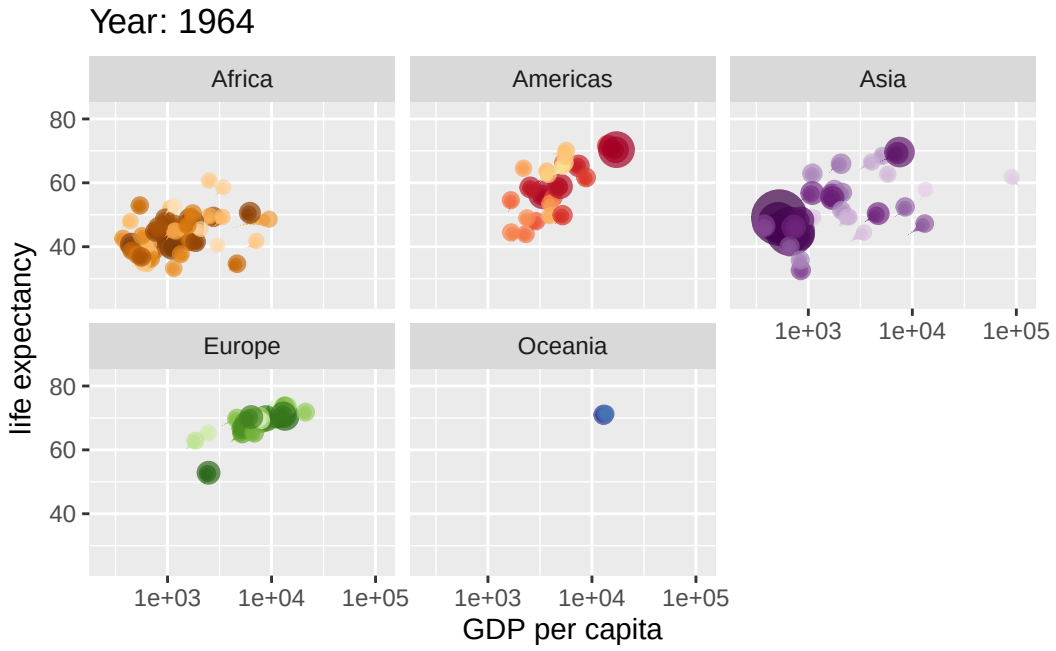
60
40
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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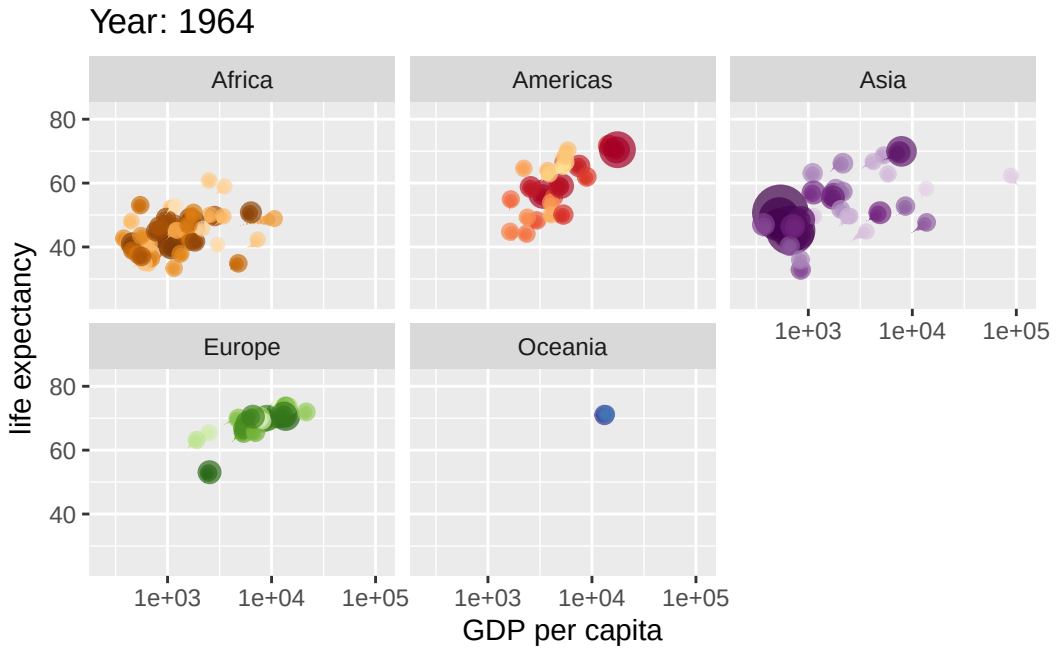
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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60
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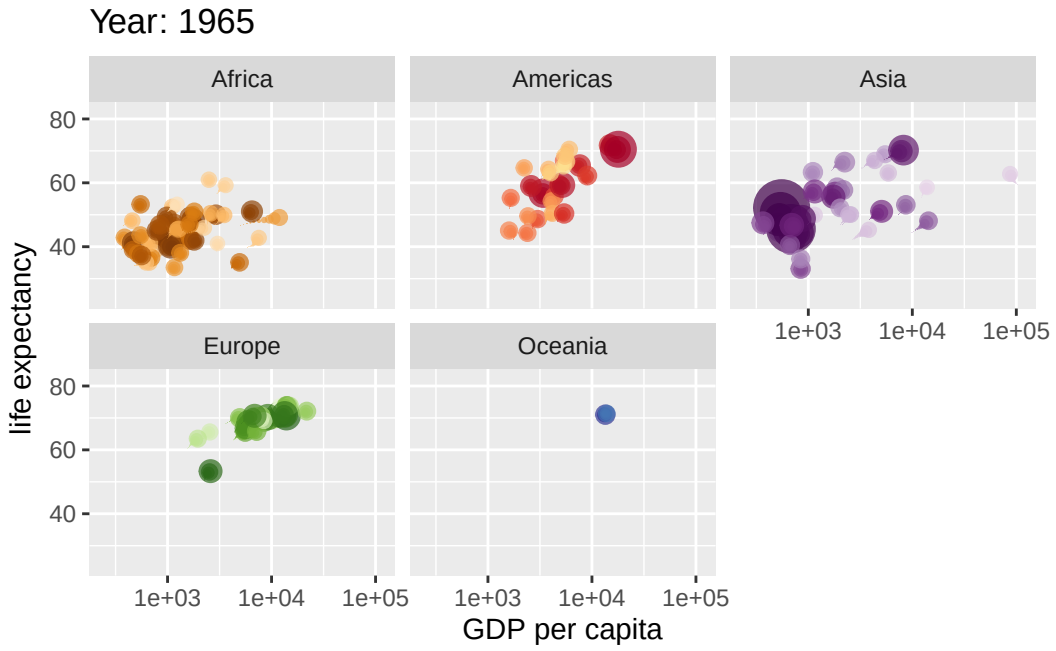
1e+03
1e+04
1e+05
GDP per capita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Africa
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Europe
Oceania
life expectancy
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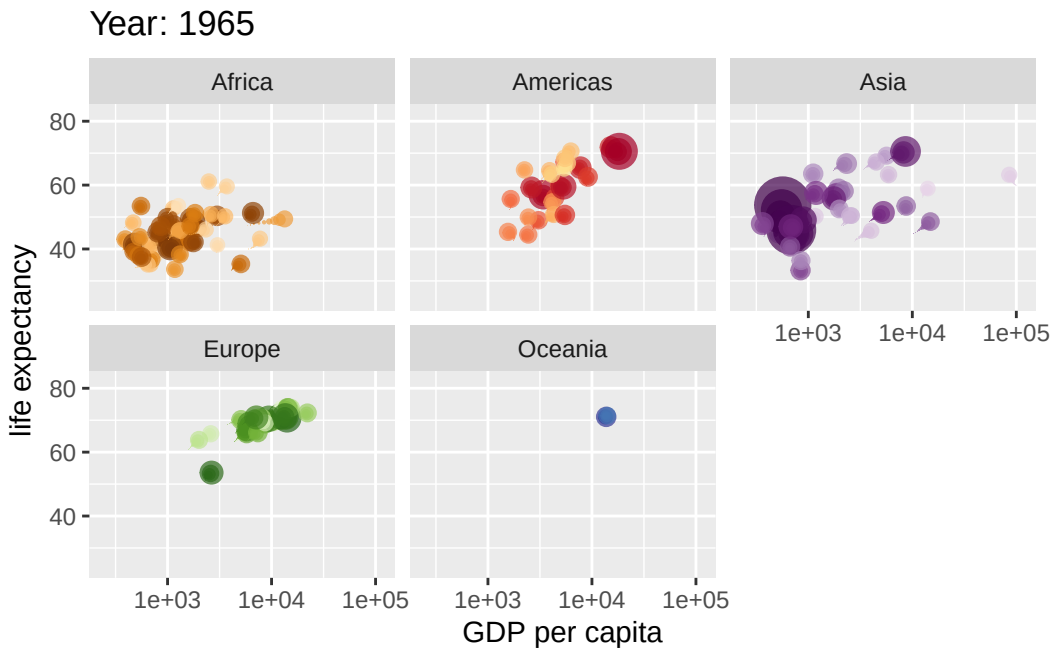
1e+03
1e+04
1e+05
GDP per capita


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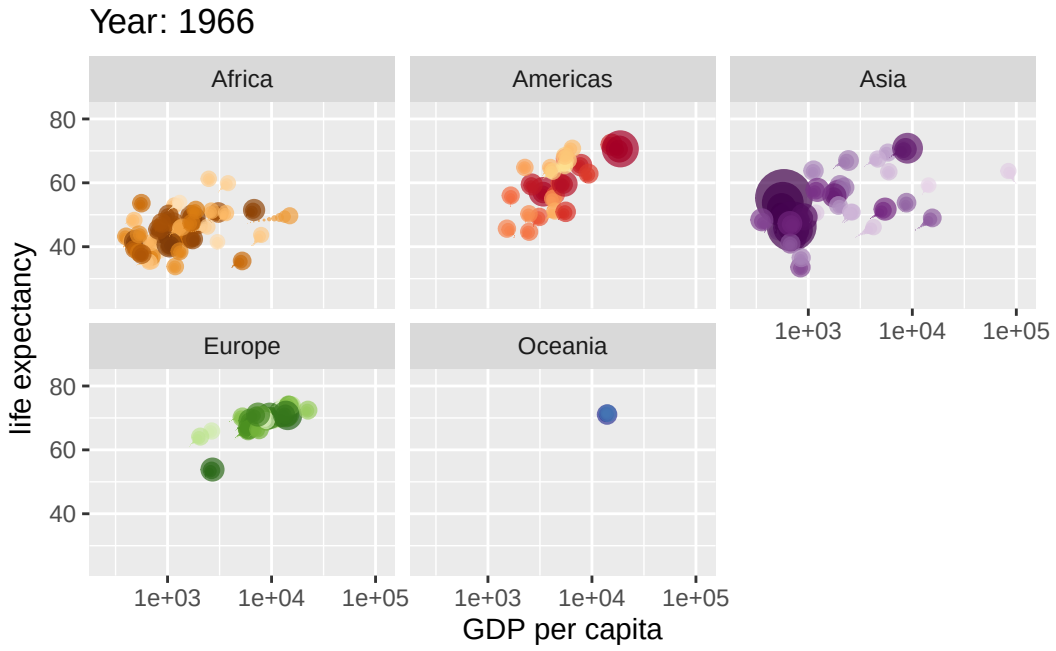
1e+03
1e+04
1e+05
GDP per capita


Year: 1966
Africa
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Asia
Europe
Oceania
life expectancy
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60
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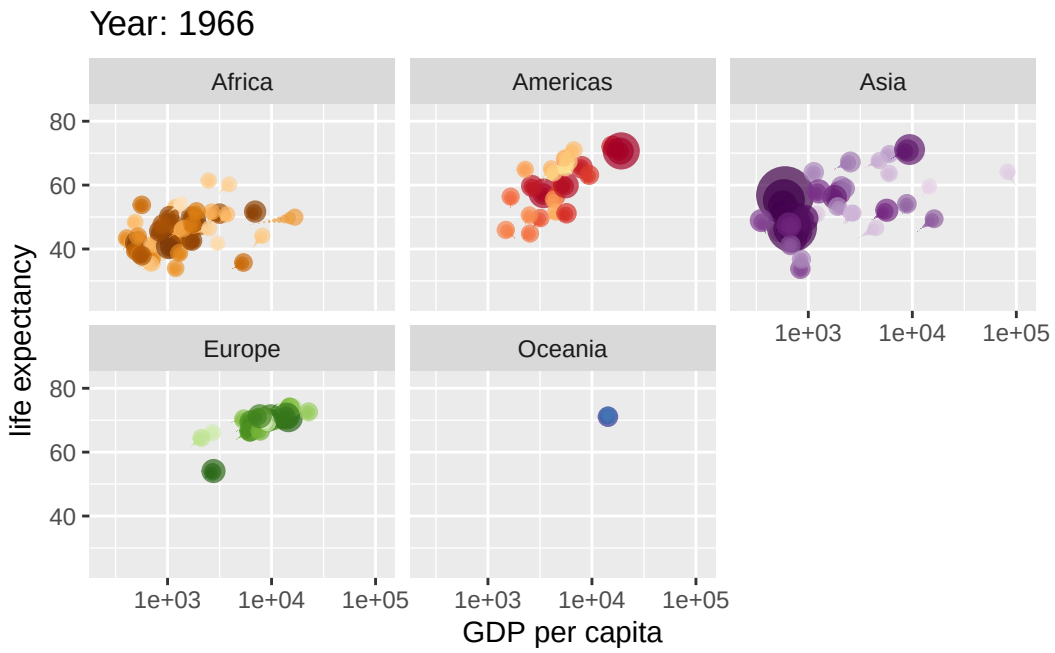
1e+03
1e+04
1e+05
GDP per capita


Year: 1966
Africa
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Asia
Europe
Oceania
life expectancy
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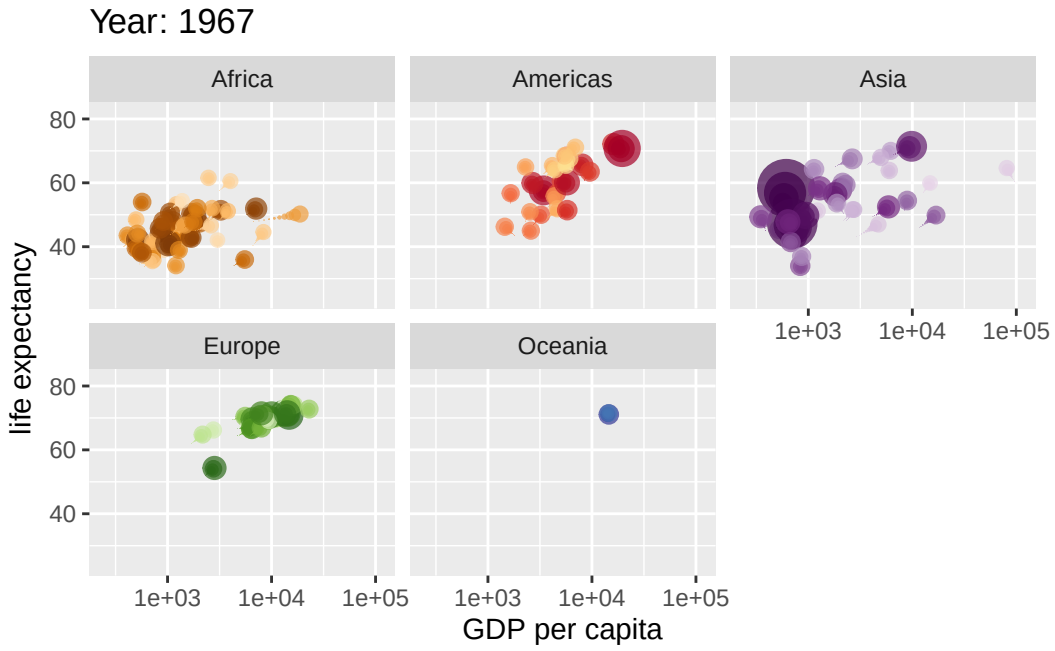
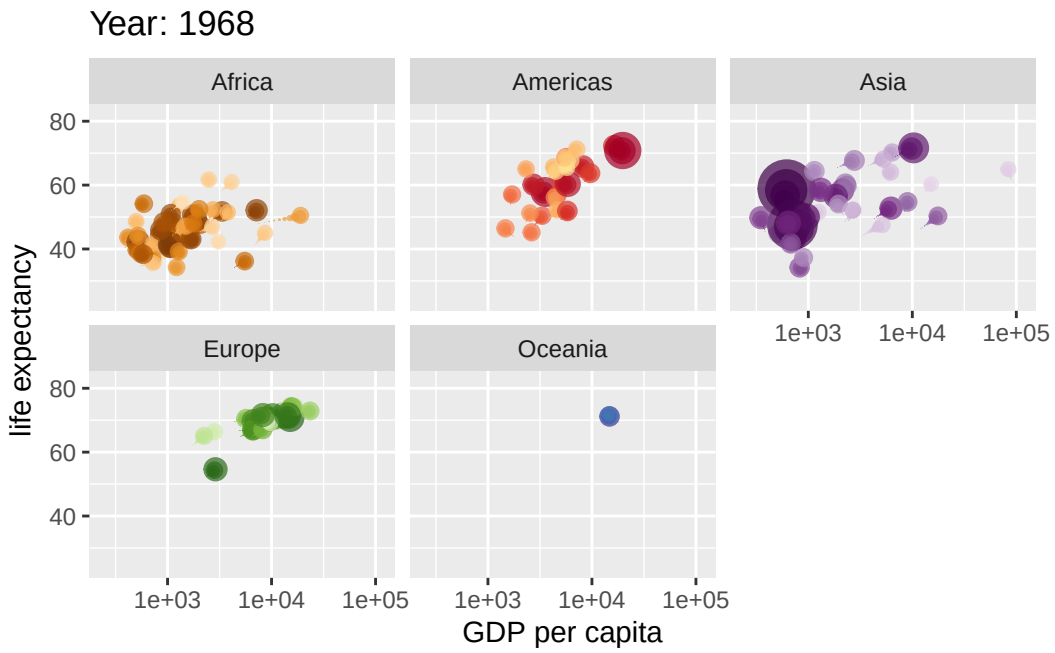
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1967
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
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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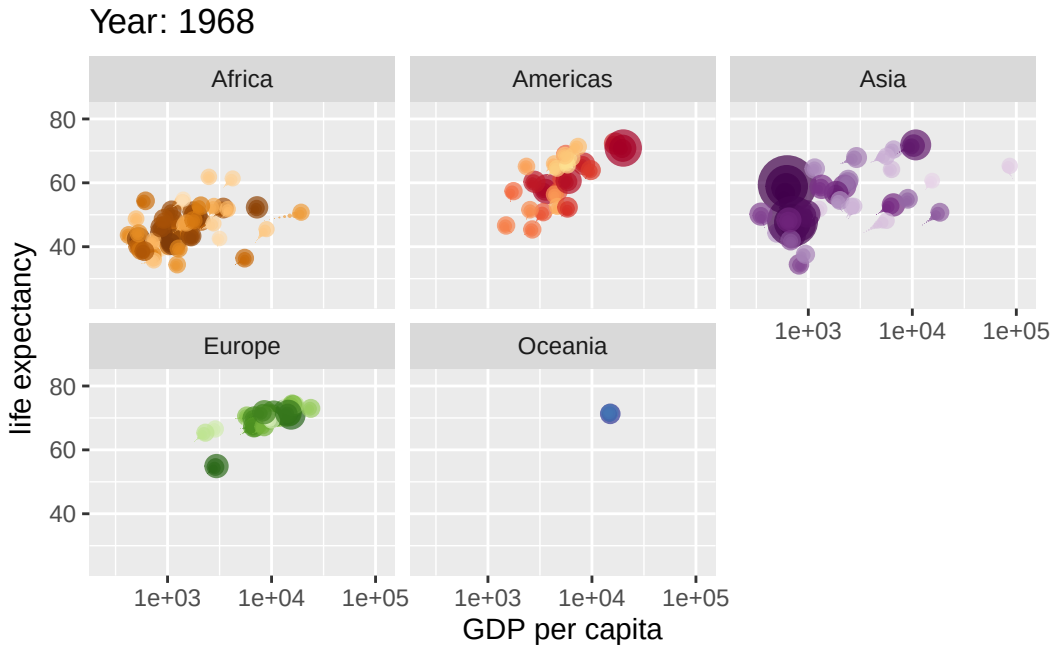
1e+03
1e+04
1e+05
GDP per capita


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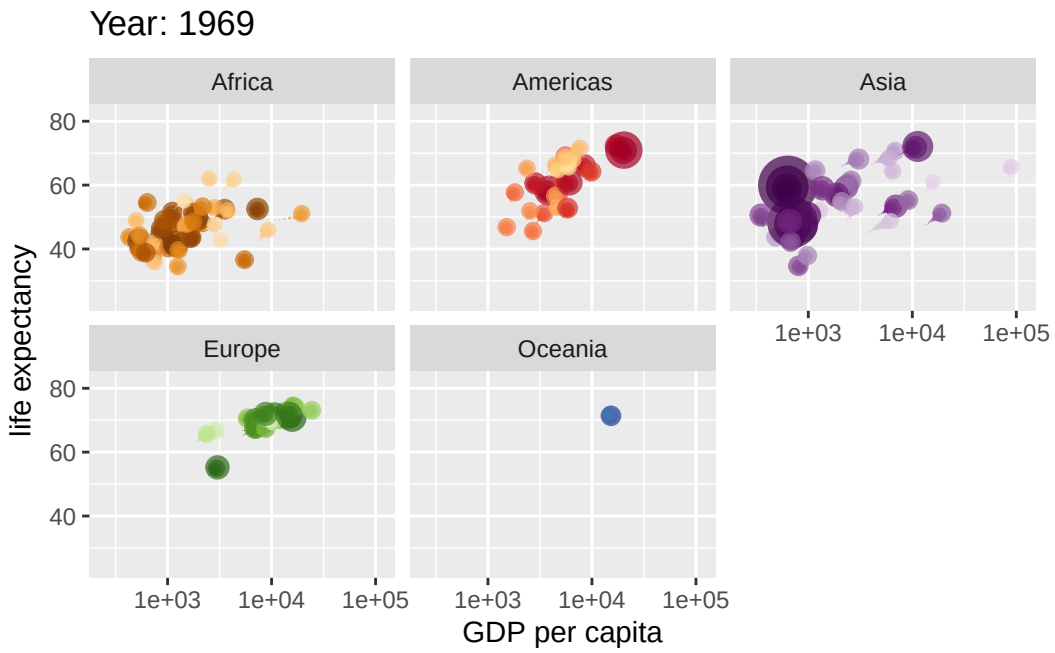
1e+03
1e+04
1e+05
GDP per capita


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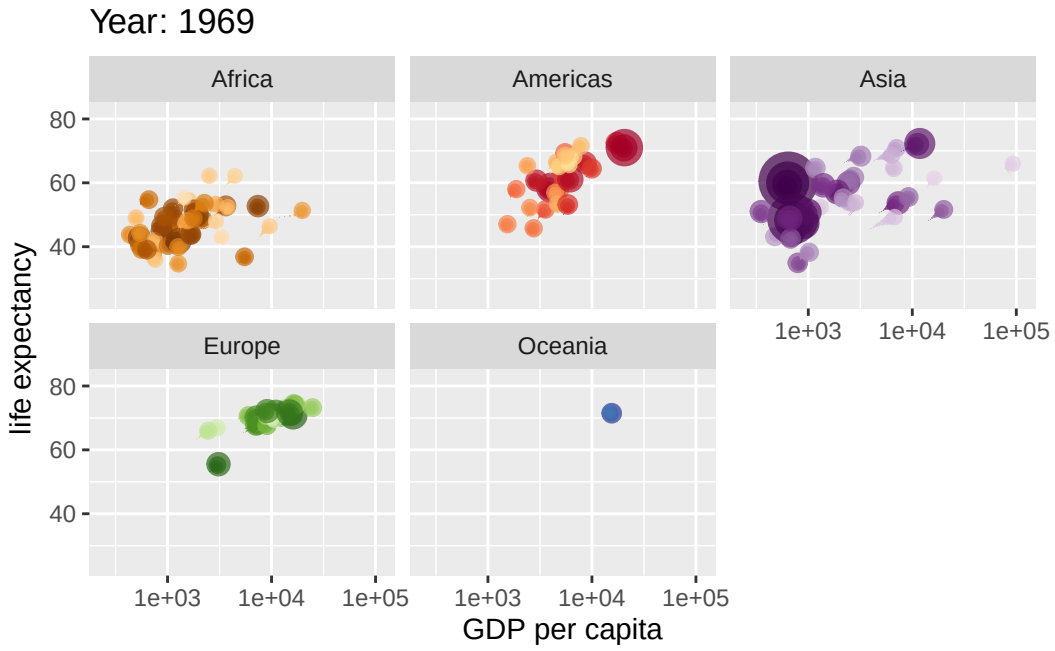
1e+03
1e+04
1e+05
GDP per capita


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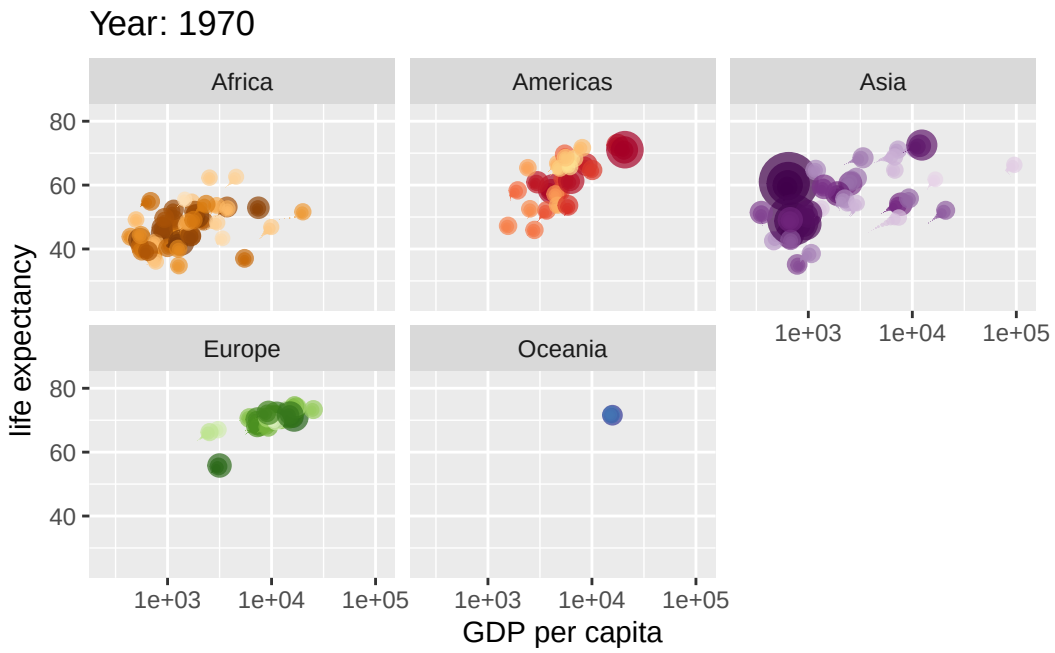
1e+05
GDP per capita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Africa
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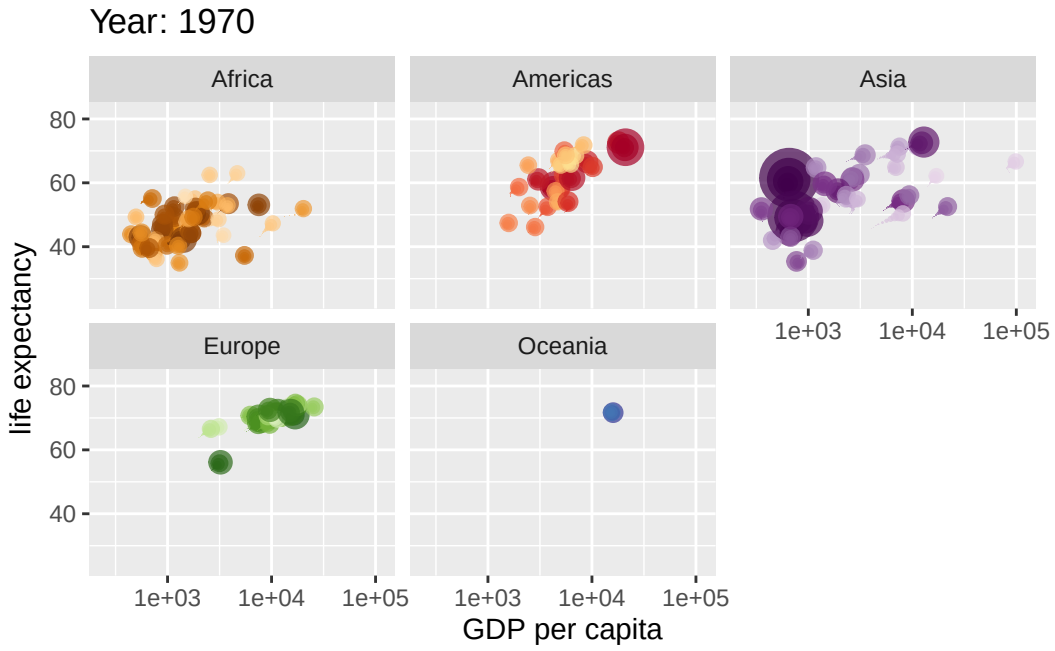
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


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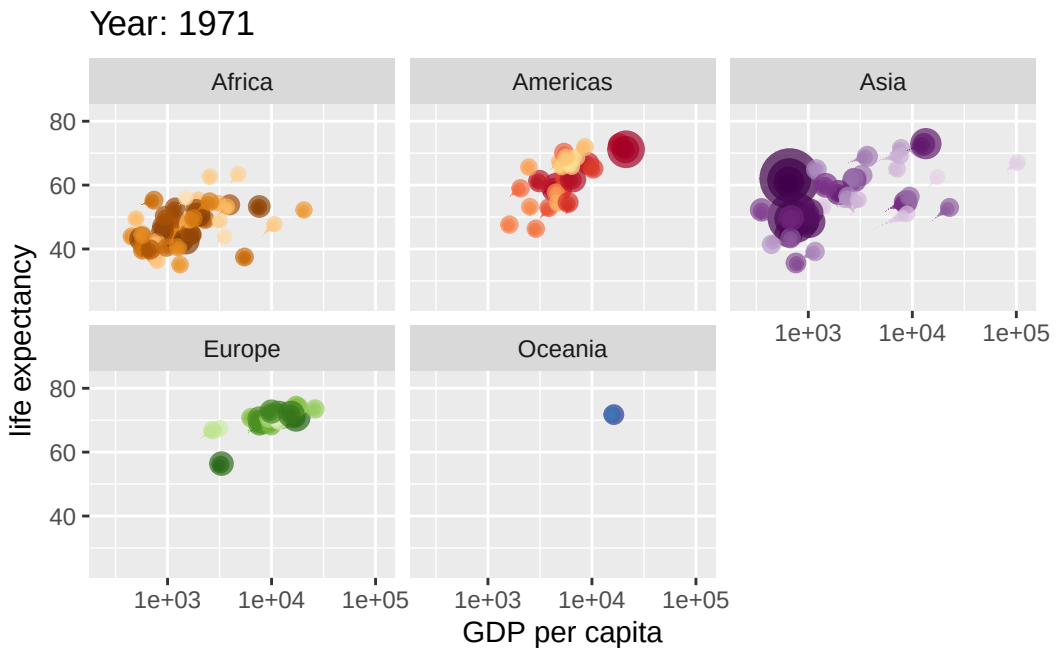
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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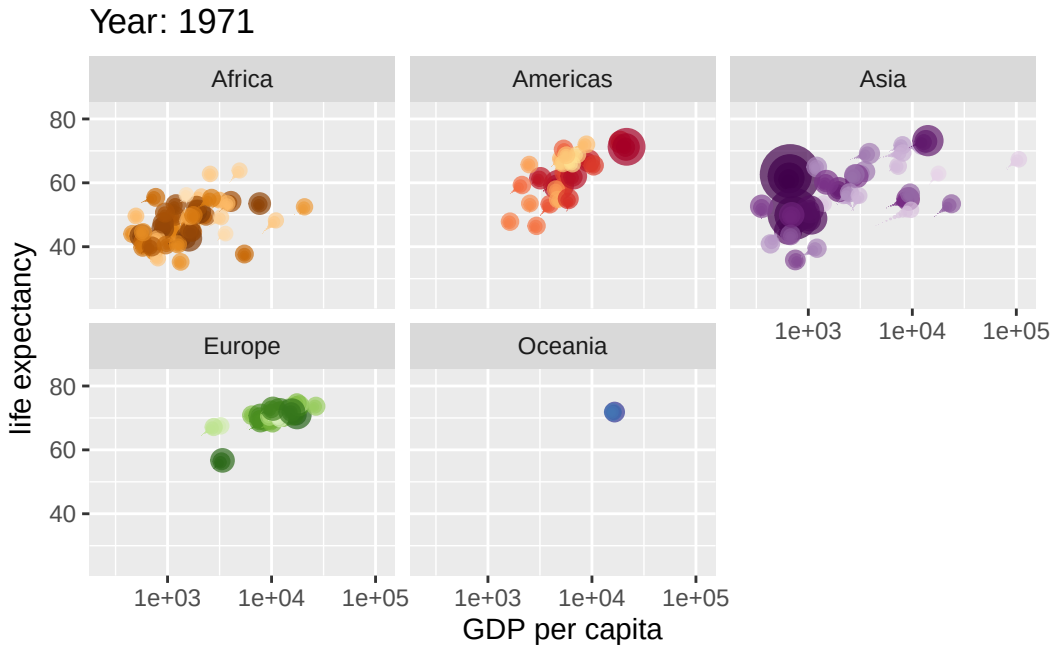
1e+03
1e+04
1e+05
GDP per capita


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


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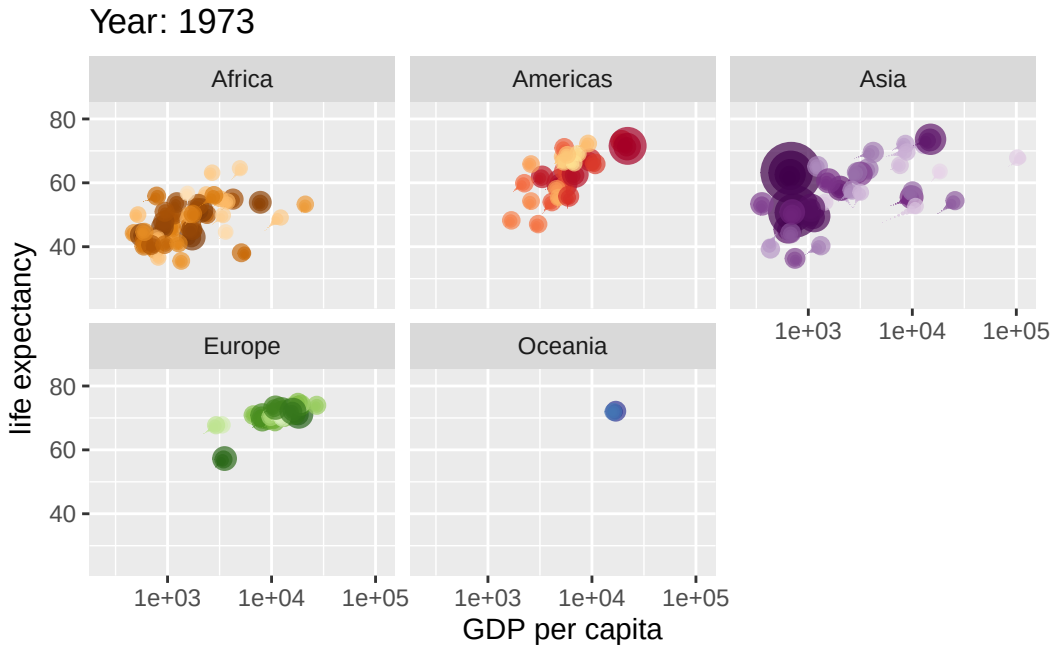
1e+03
1e+04
1e+05
GDP per capita


Year: 1973
Africa
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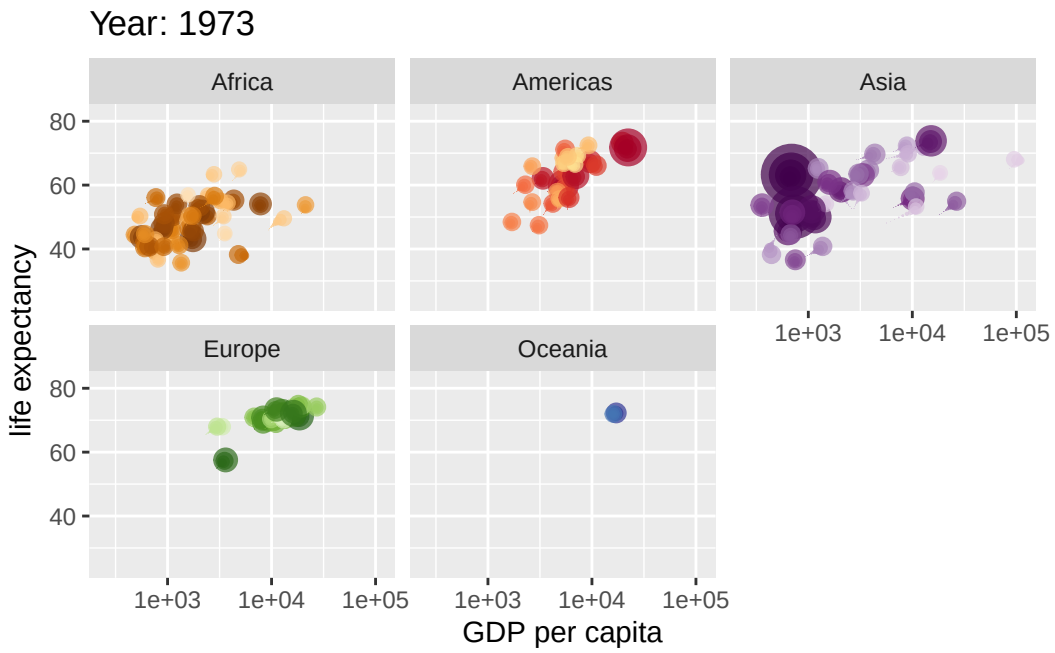
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


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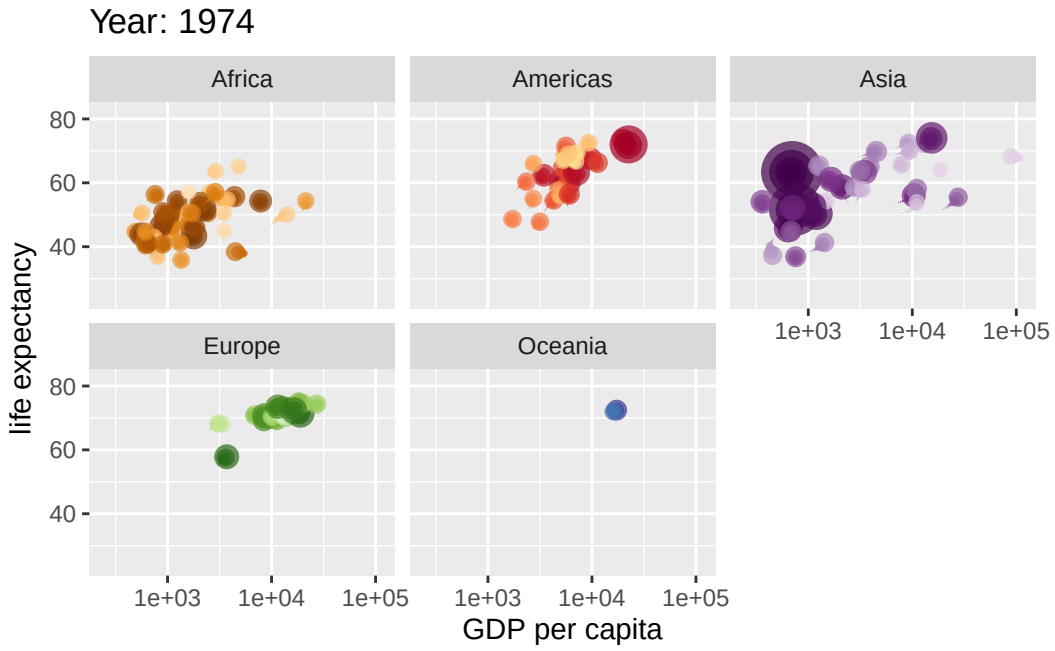
1e+03
1e+04
1e+05
GDP per capita


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


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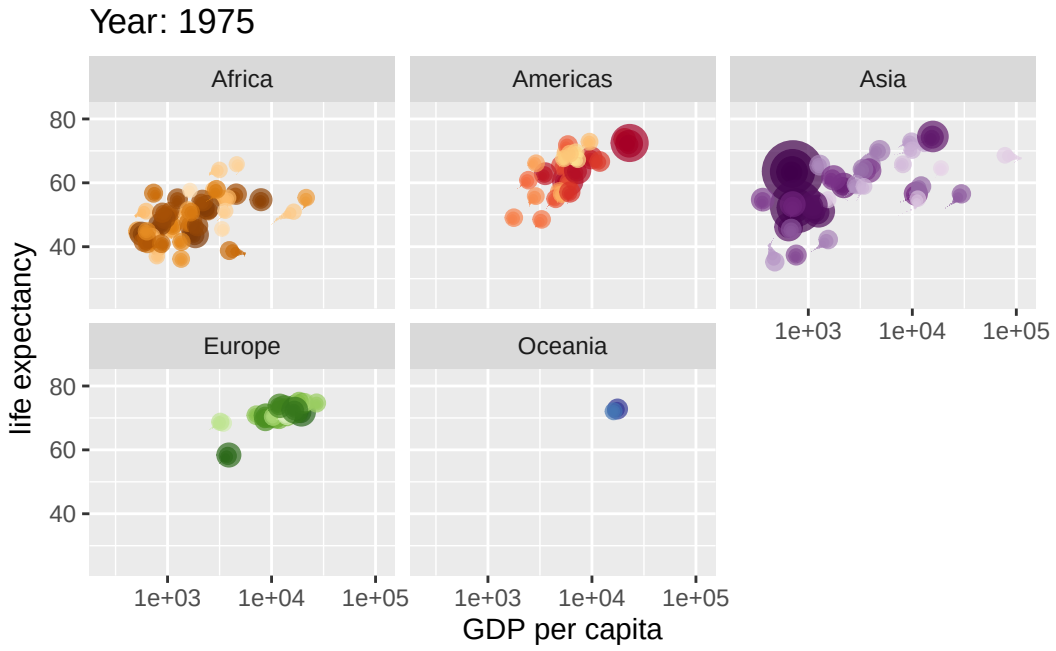
1e+03
1e+04
1e+05
GDP per capita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life expectancy
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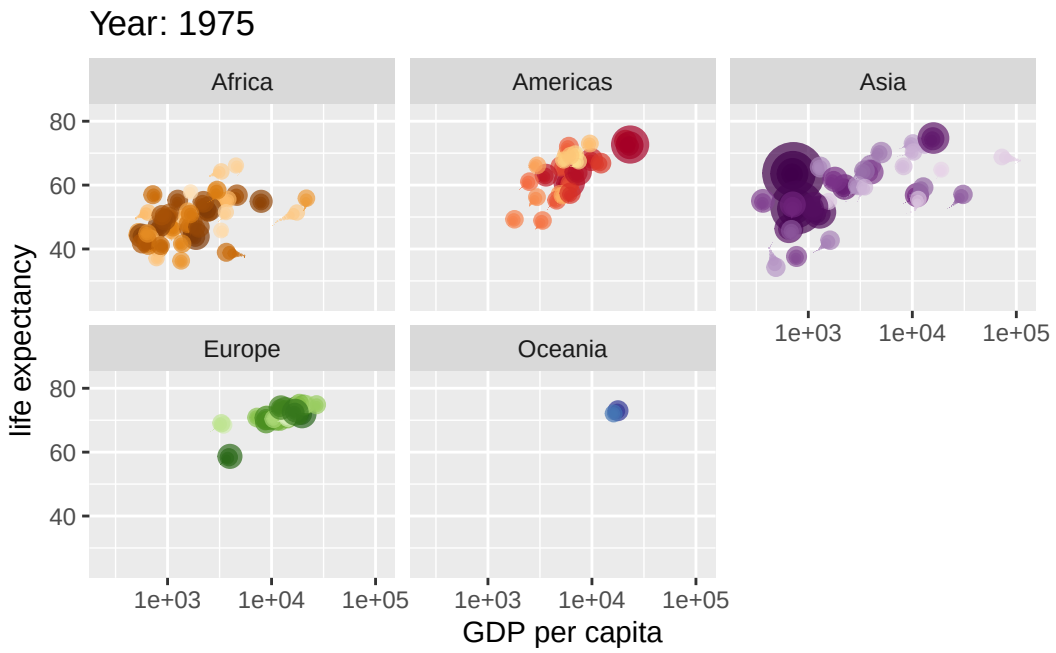
1e+05
GDP per capita


Year: 1975
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life expectancy
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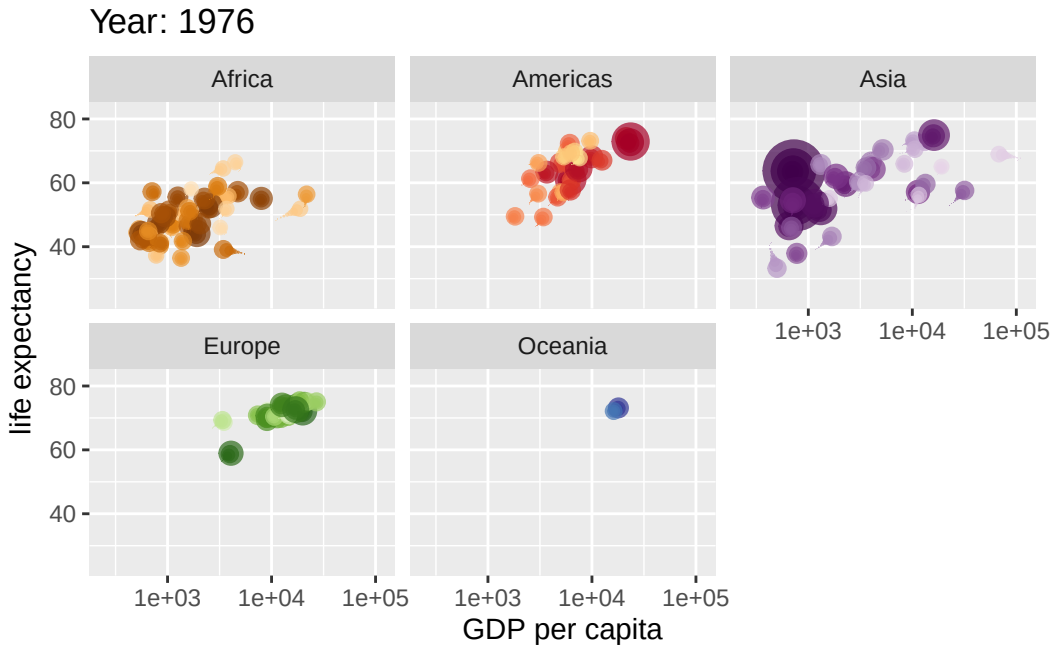
GDP per capita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life expectancy
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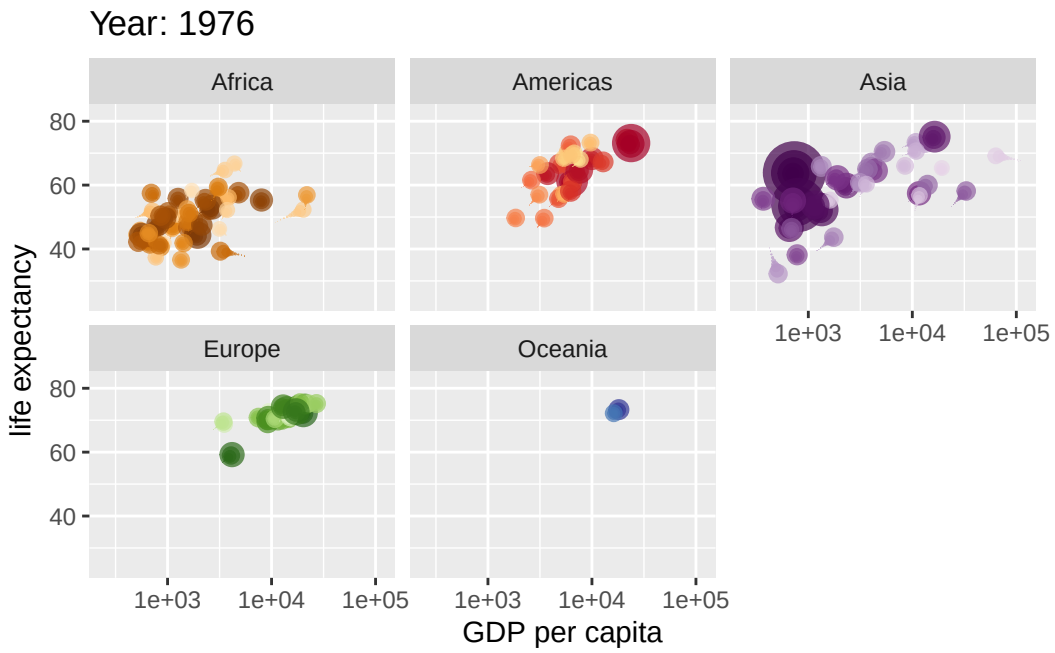
1e+04
1e+05
GDP per capita


Year: 1976
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life expectancy
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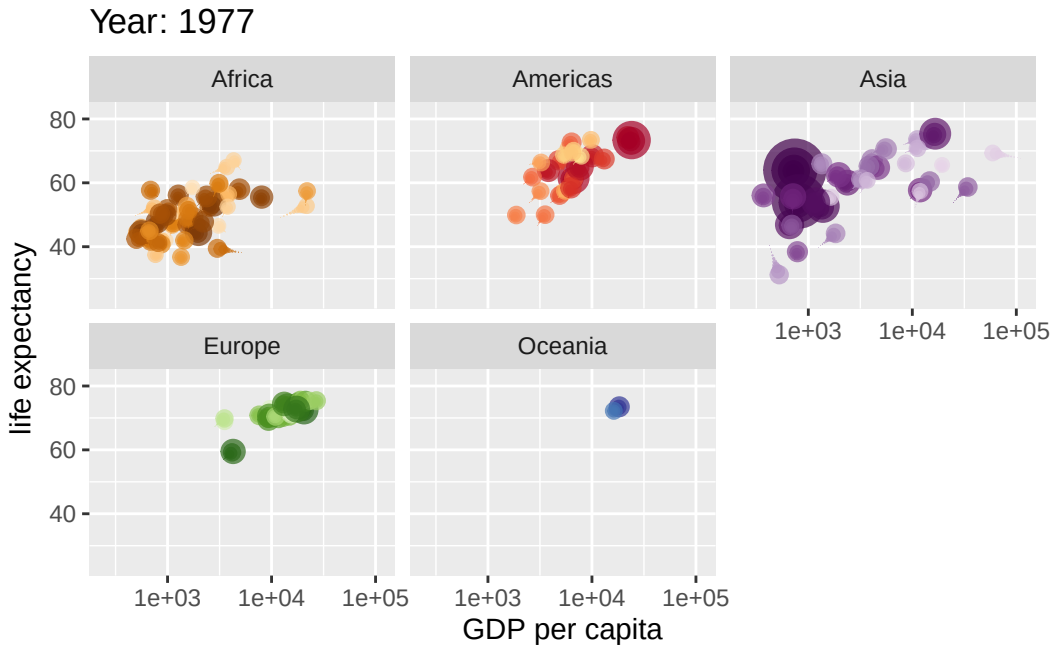
GDP per capita


Year: 1977
Africa
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Oceania
life expectancy
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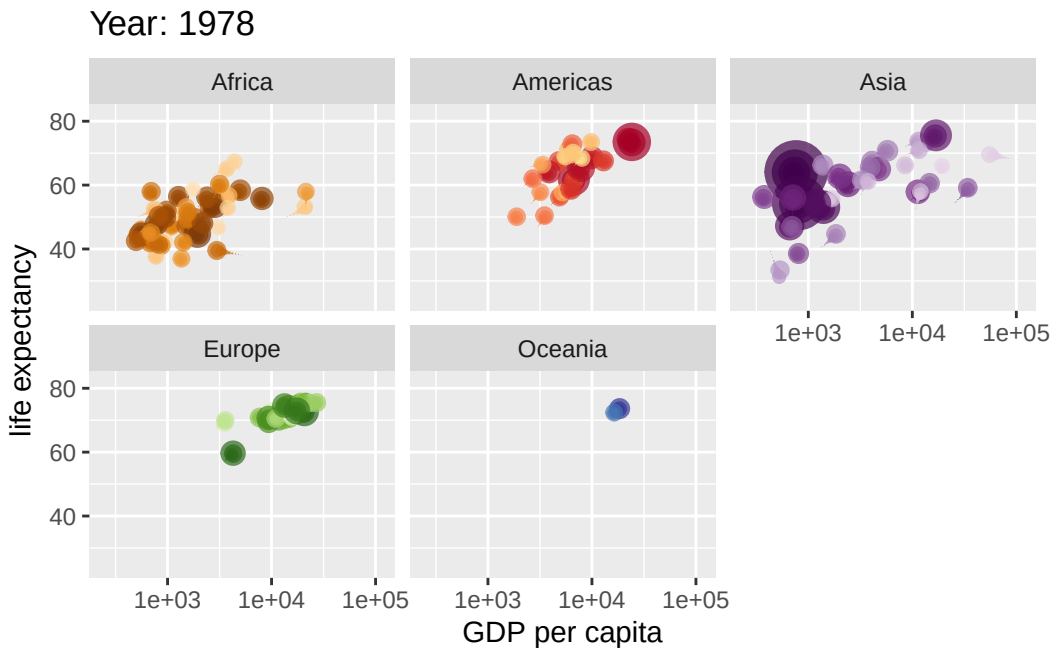
GDP per capita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Africa
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life expectancy
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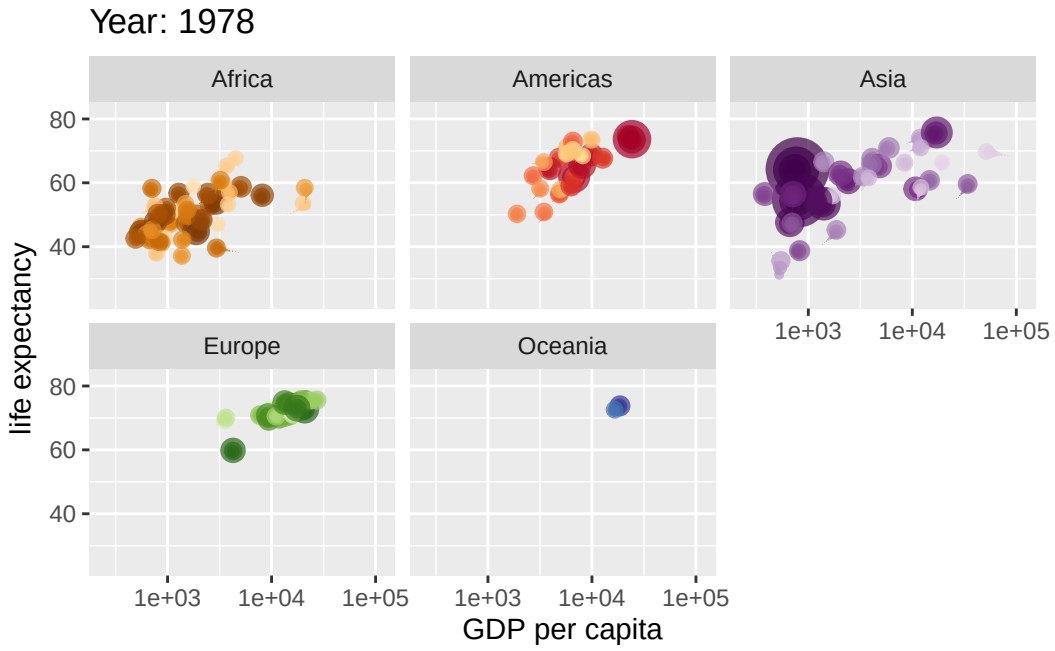
1e+03
1e+04
1e+05
GDP per capita


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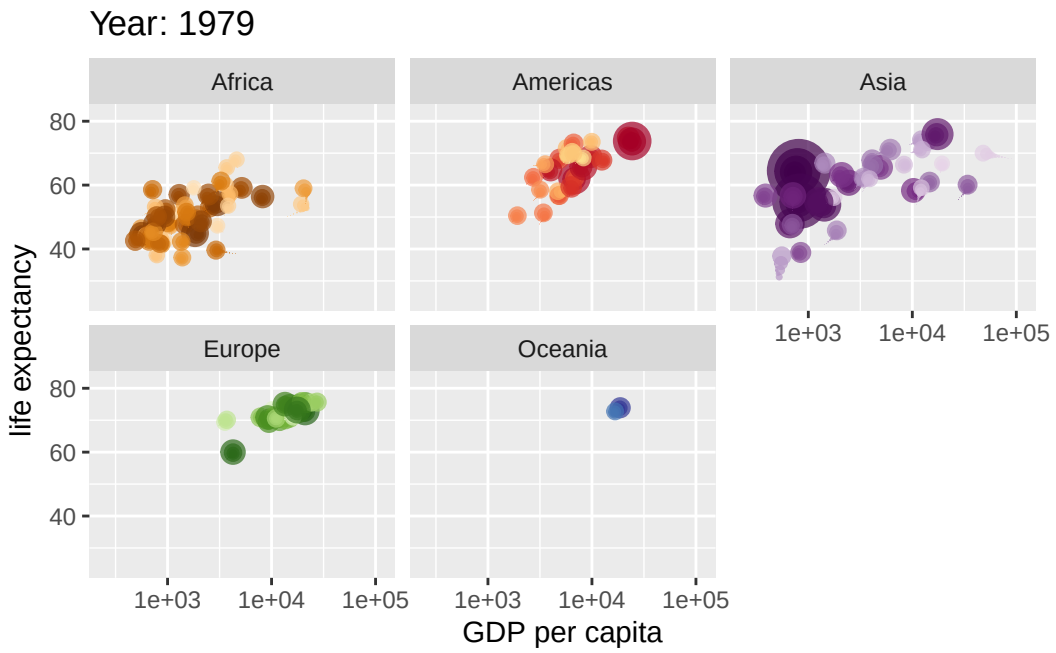
1e+03
1e+04
1e+05
GDP per capita


Year: 1979
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Oceania
life expectancy
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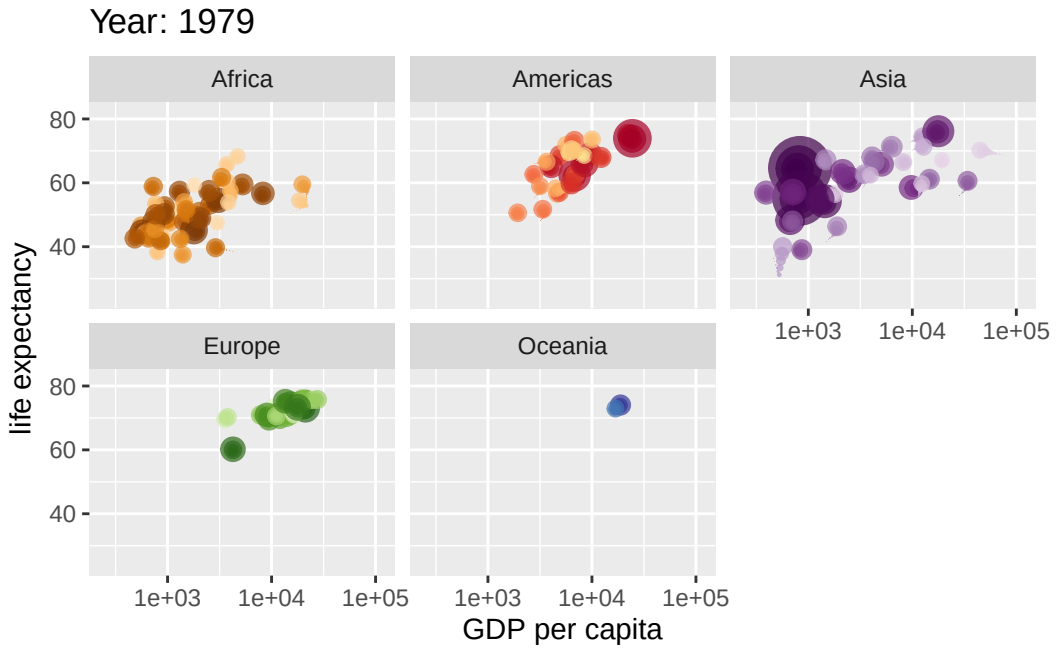
1e+03
1e+04
1e+05
GDP per capita


Year: 1979
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Europe
Oceania
life expectancy
80
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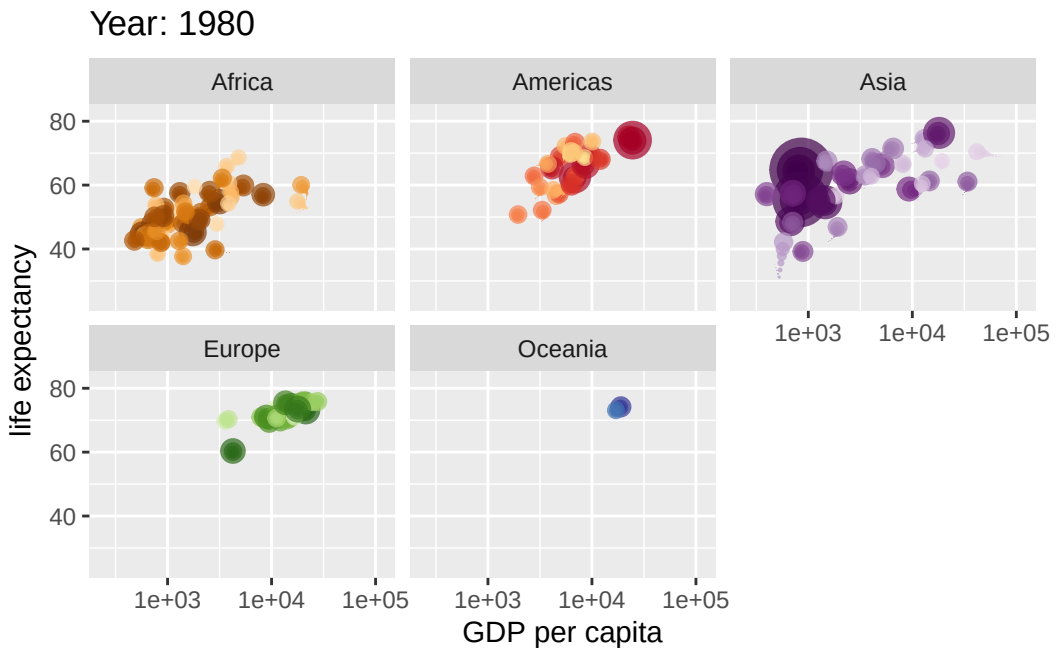
1e+03
1e+04
1e+05
GDP per capita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Asia
Europe
Oceania
life expectancy
80
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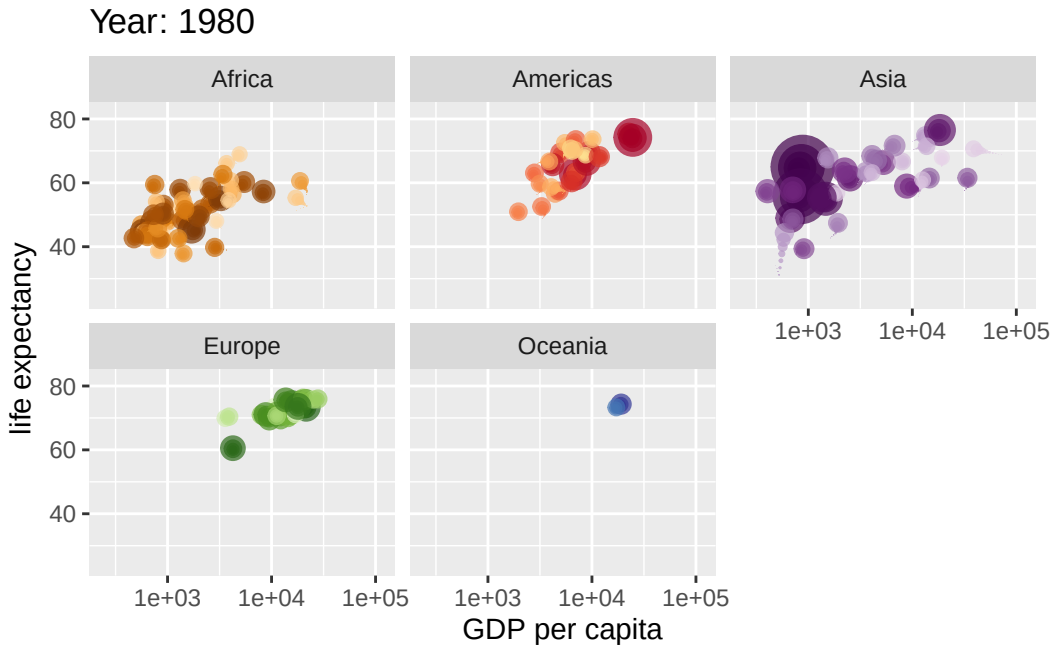
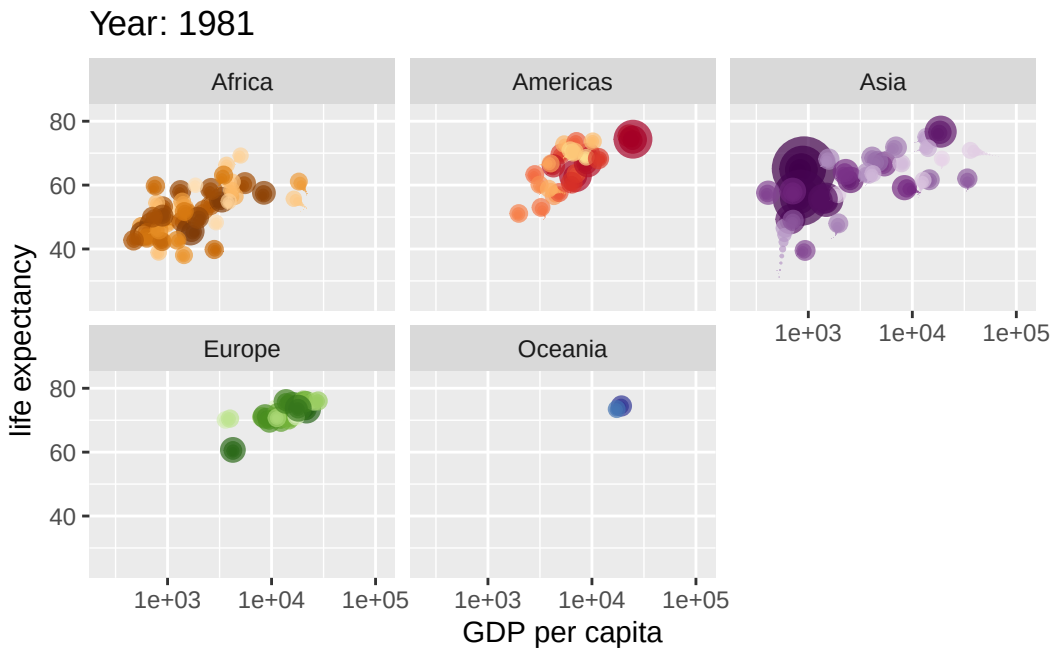
1e+03
1e+04
1e+05
GDP per capita


Year: 1980
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1981
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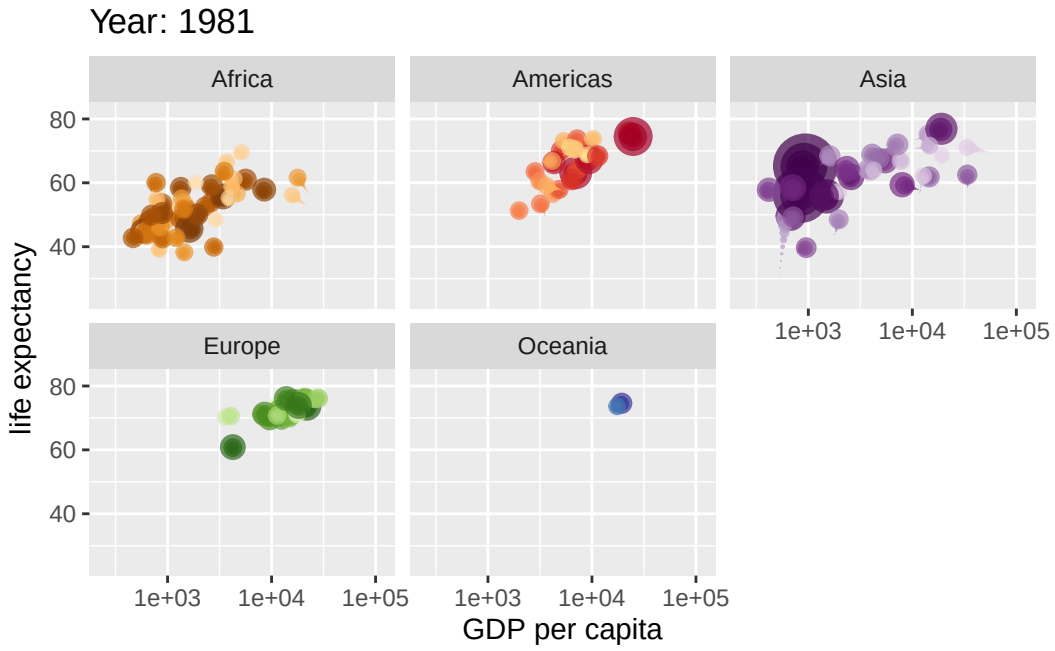
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1981
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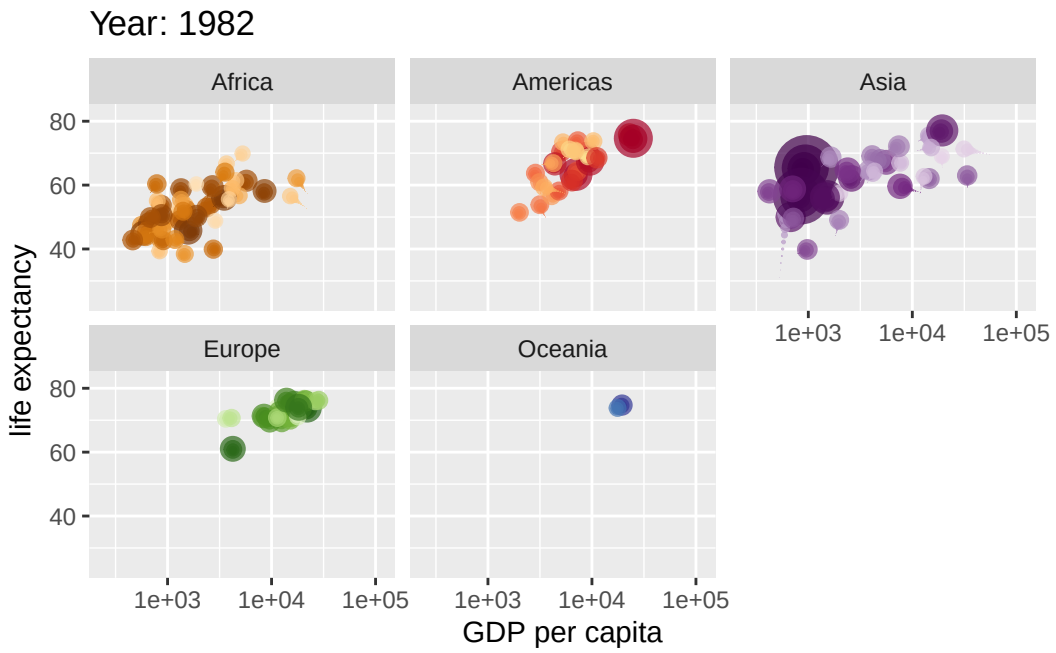
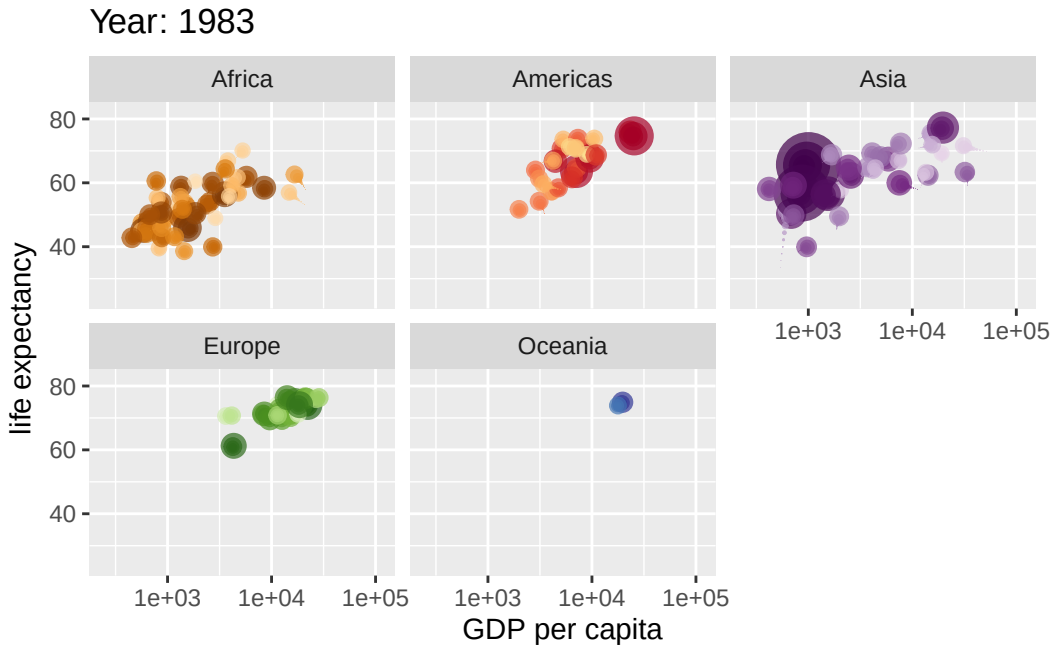
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1982
Africa
Americas
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1983
Africa
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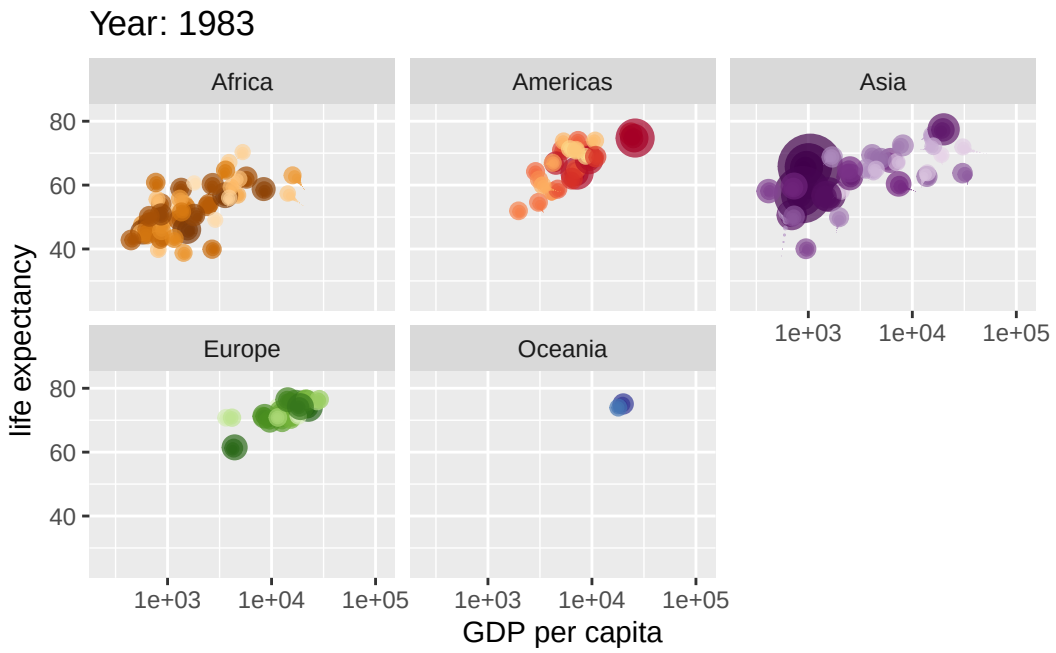
Asia
Europe
Oceania
life expectancy
80
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 1983
Africa
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Asia
Europe
Oceania
life expectancy
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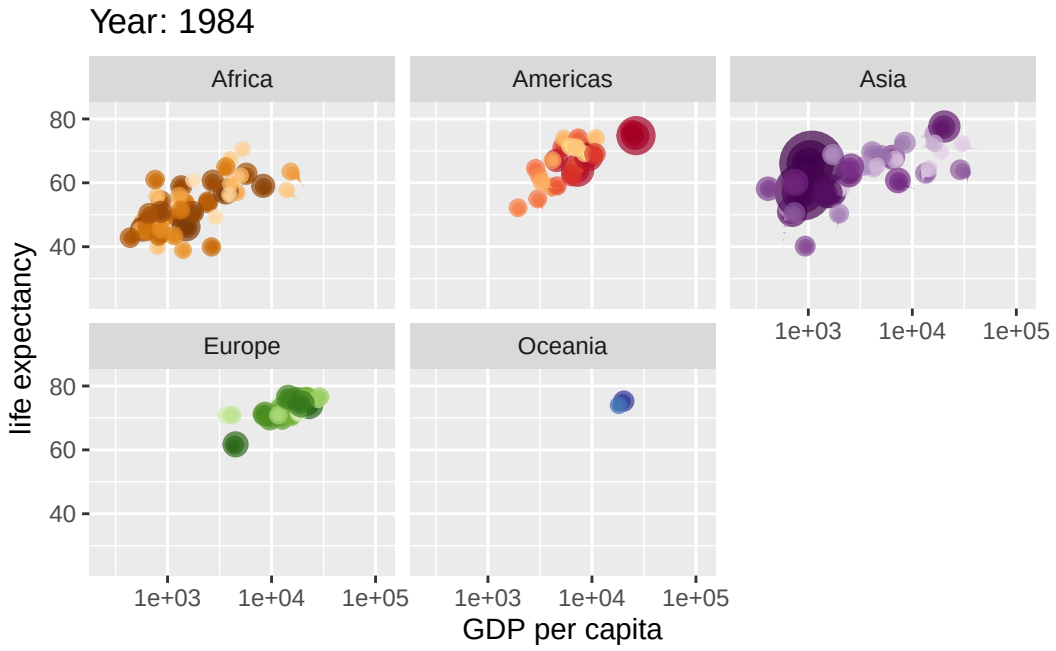
60
40
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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60
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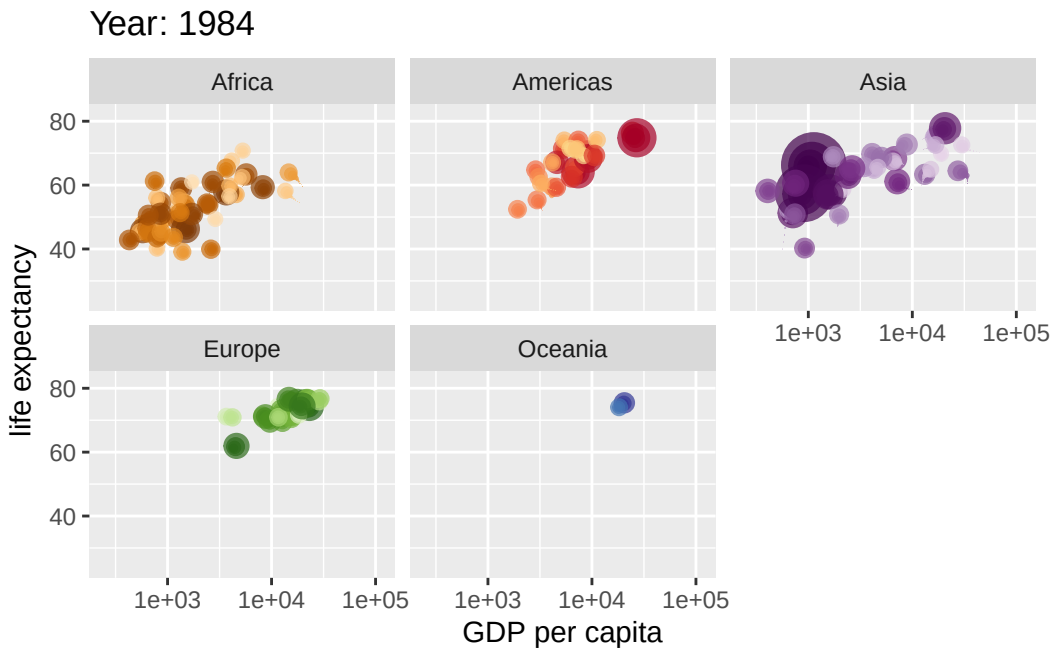
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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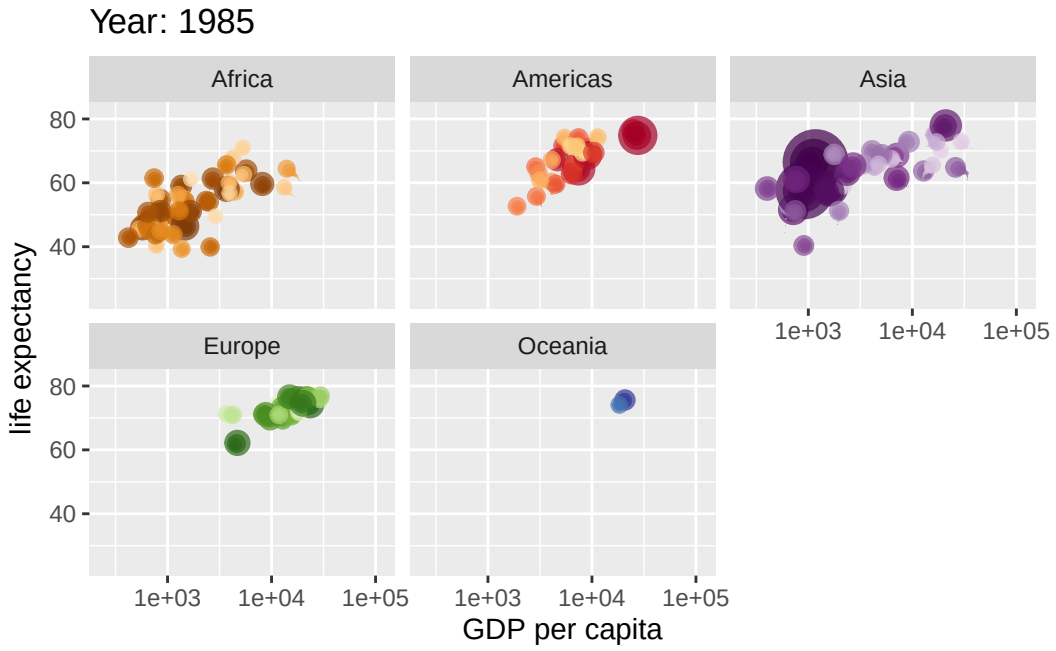
1e+05
GDP per capita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life expectancy
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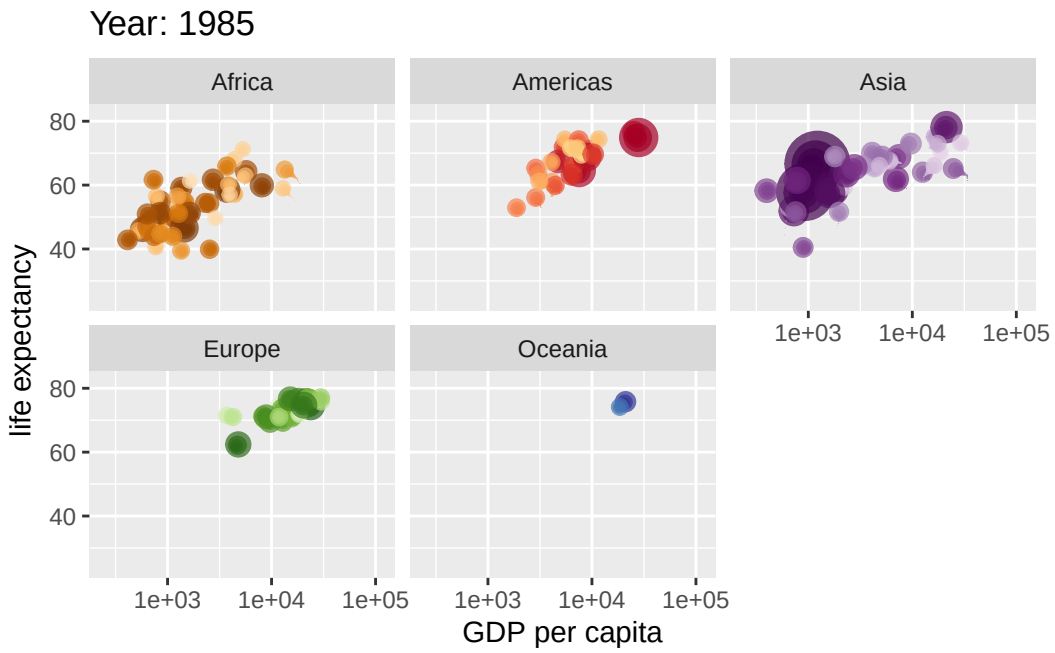
1e+05
GDP per capita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life expectancy
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1e+03
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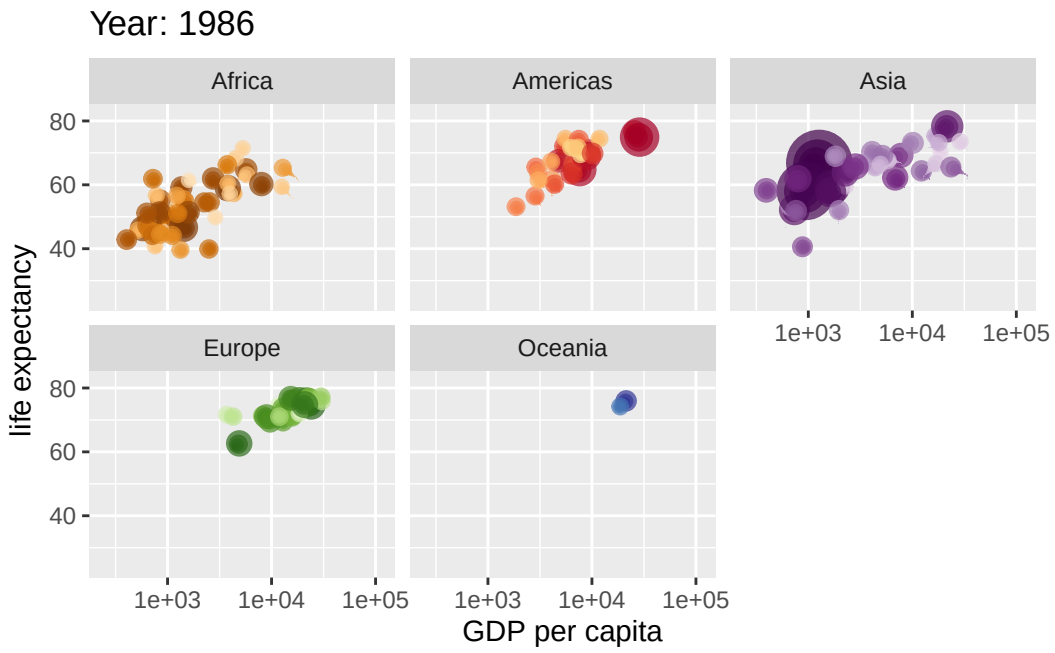
1e+05
GDP per capita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Oceania
life expectancy
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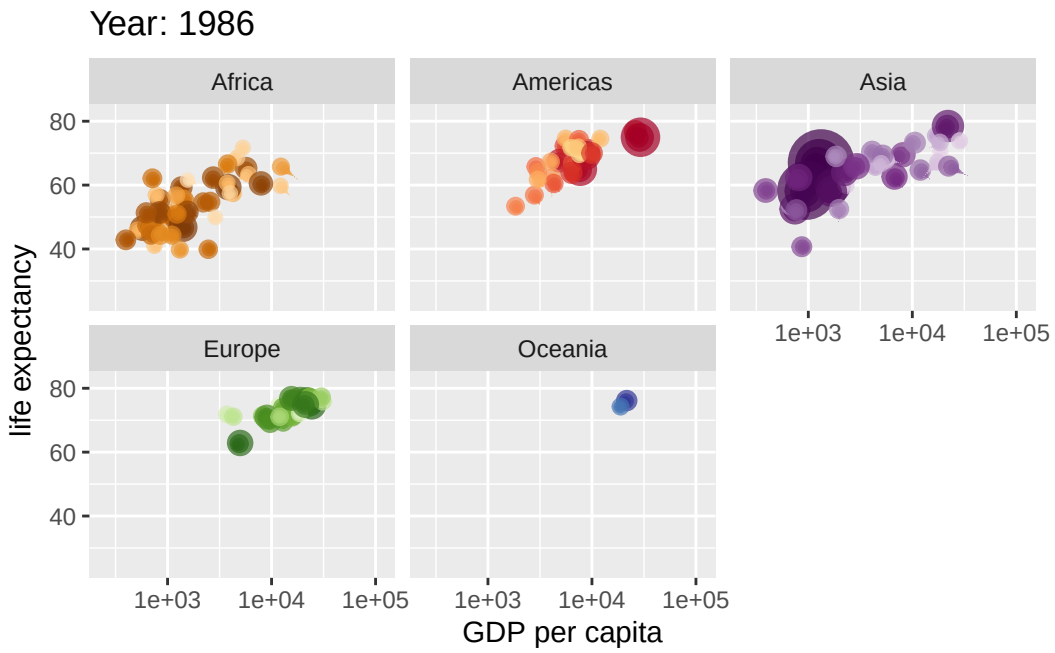
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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1e+03
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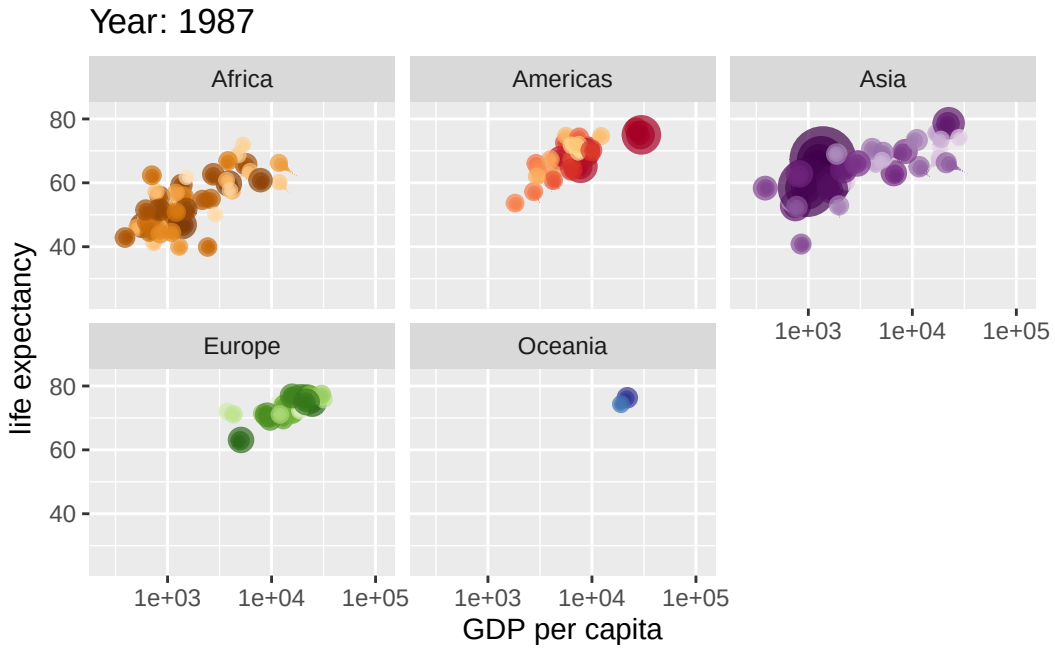
1e+05
GDP per capita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Europe
Oceania
life expectancy
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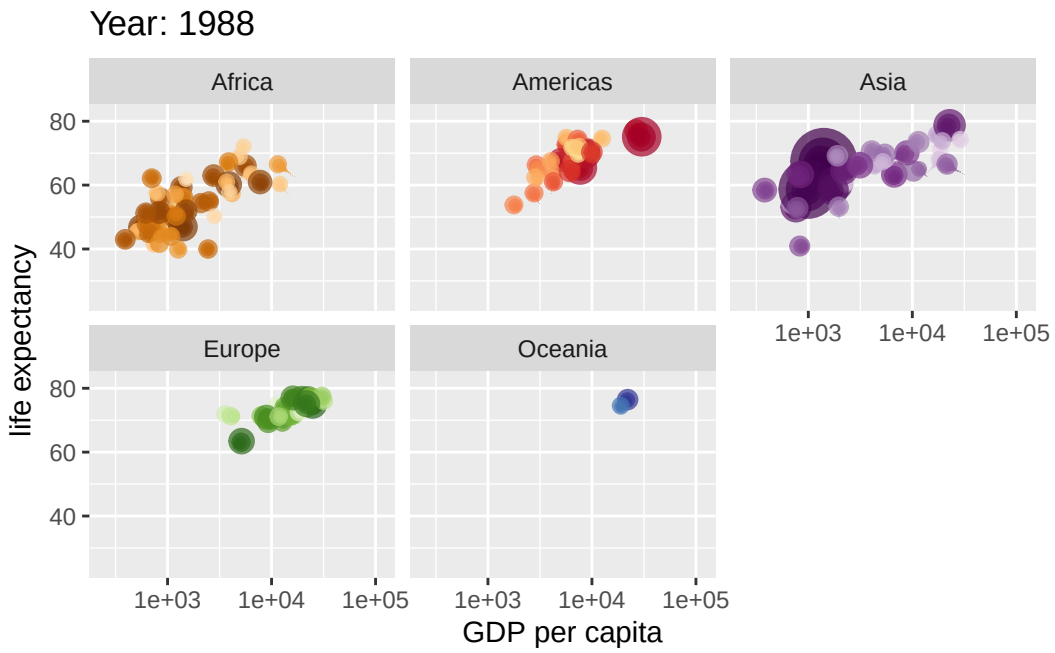
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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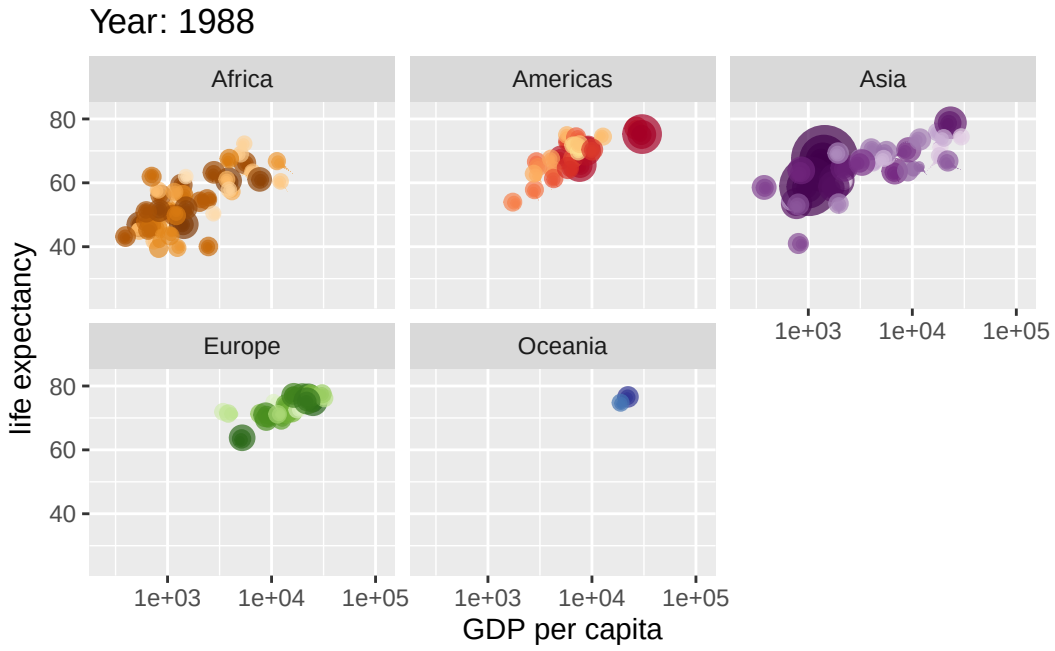
1e+03
1e+04
1e+05
GDP per capita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life expectancy
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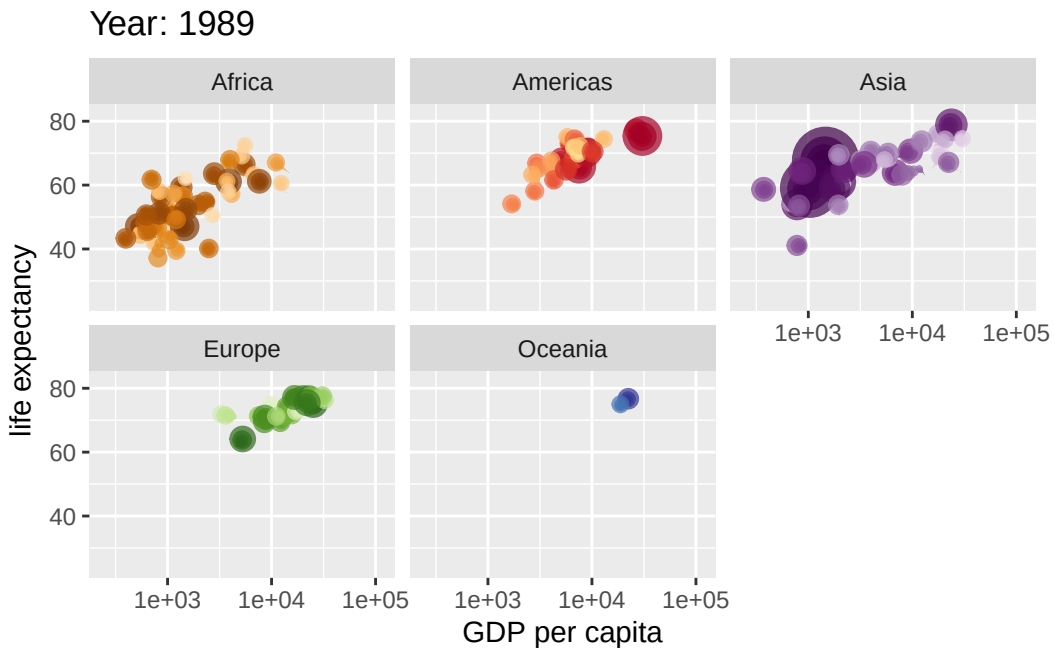
1e+03
1e+04
1e+05
GDP per capita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Africa
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Europe
Oceania
life expectancy
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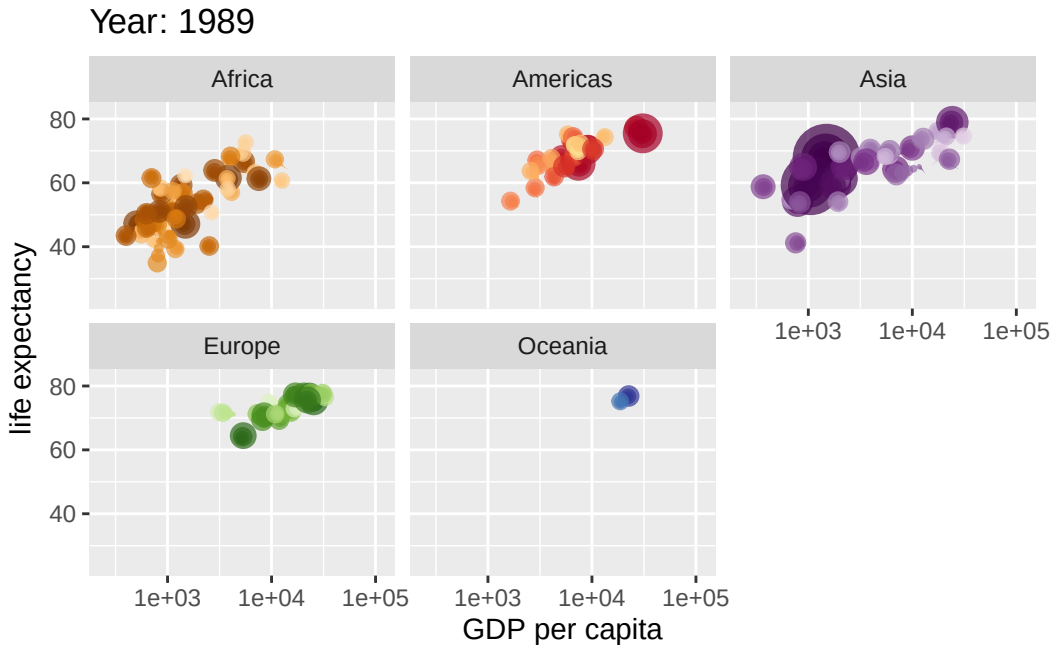
1e+03
1e+04
1e+05
GDP per capita


Year: 1989
Africa
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Europe
Oceania
life expectancy
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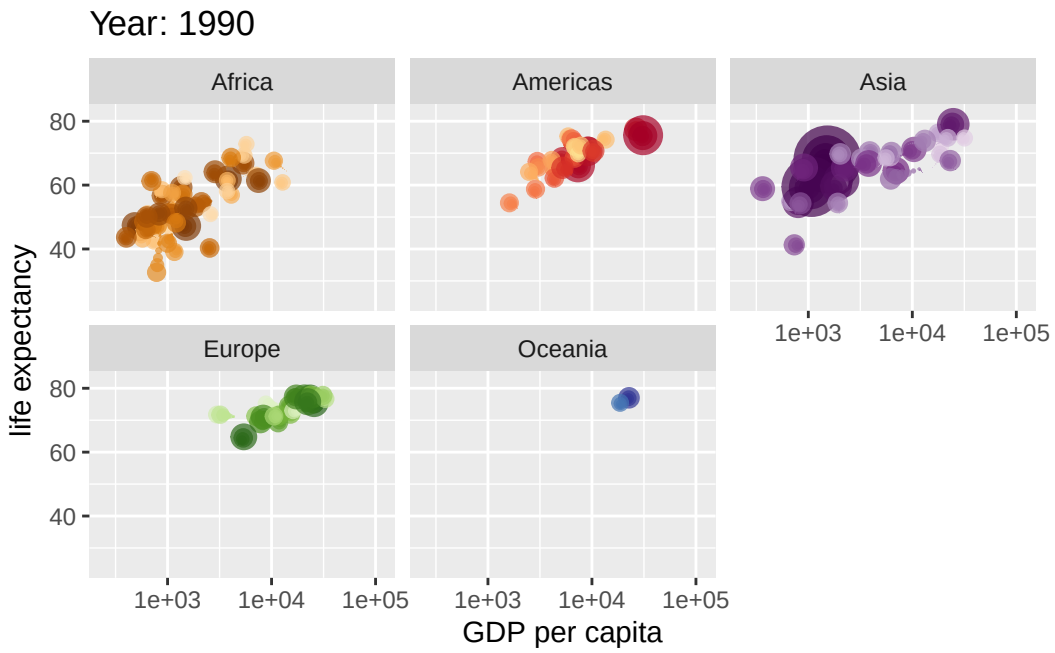
1e+03
1e+04
1e+05
GDP per capita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Africa
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Asia
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Oceania
life expectancy
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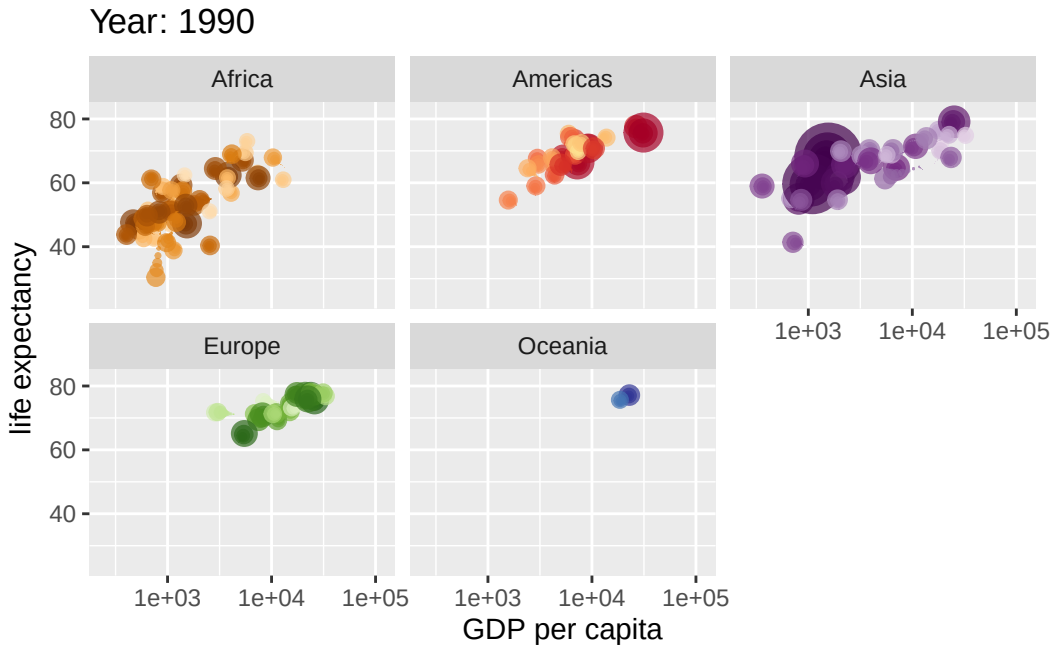
1e+03
1e+04
1e+05
GDP per capita


Year: 1990
Africa
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Europe
Oceania
life expectancy
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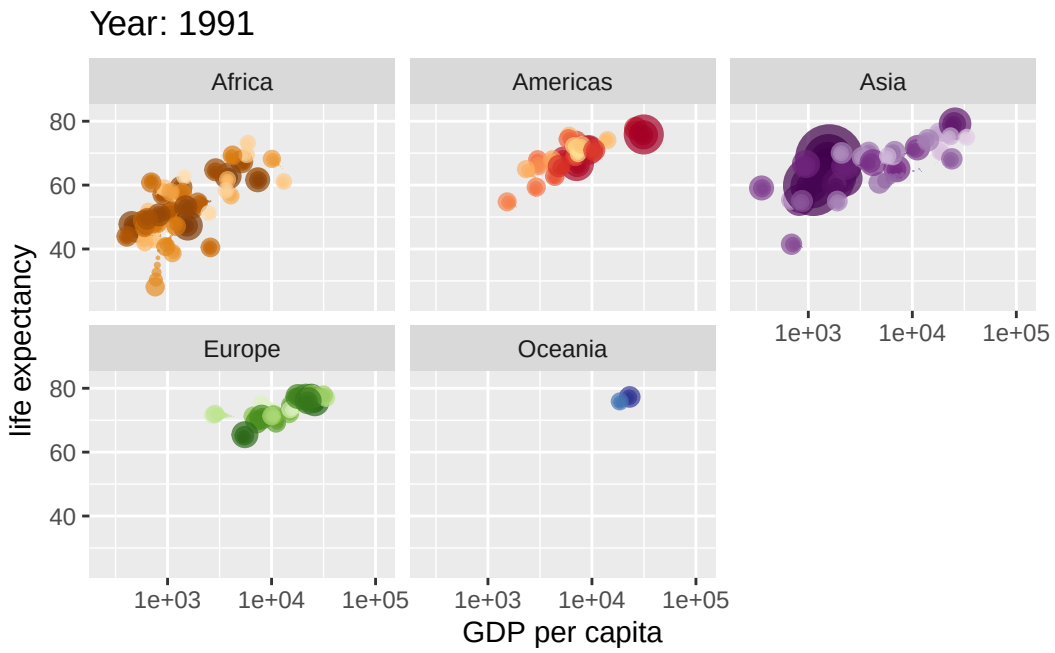
1e+03
1e+04
1e+05
GDP per capita


Year: 1991
Africa
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Asia
Europe
Oceania
life expectancy
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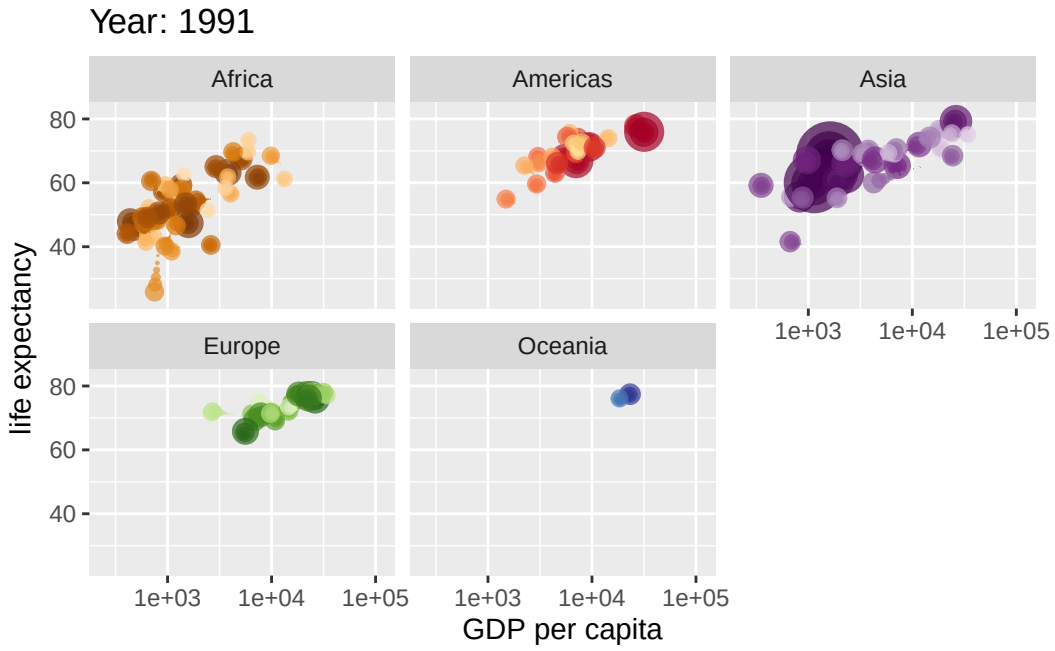
1e+03
1e+04
1e+05
GDP per capita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Africa
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Europe
Oceania
life expectancy
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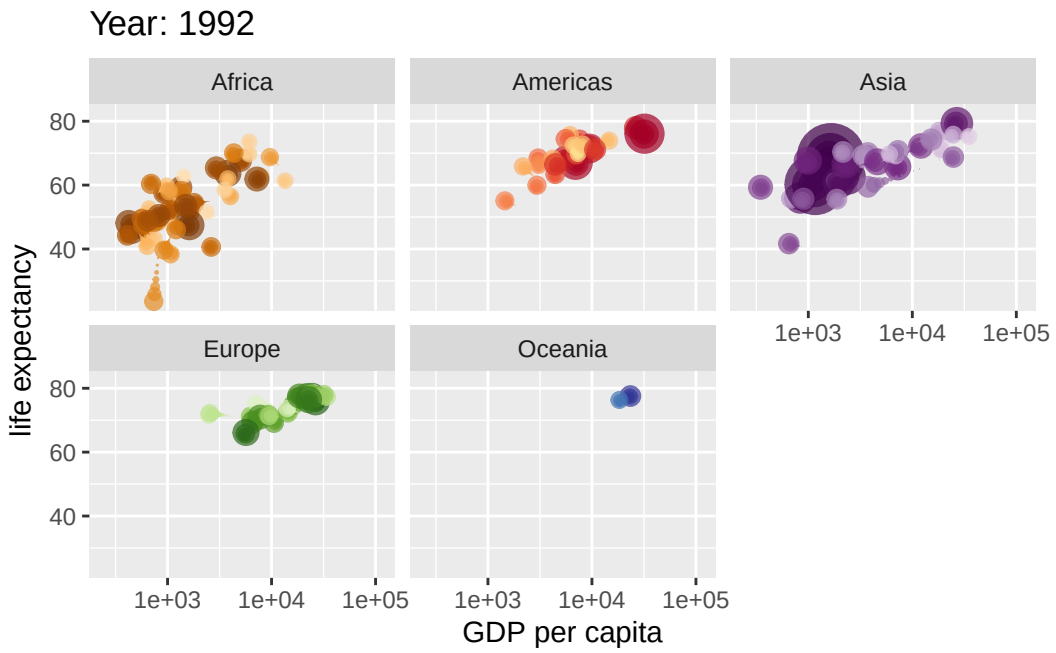
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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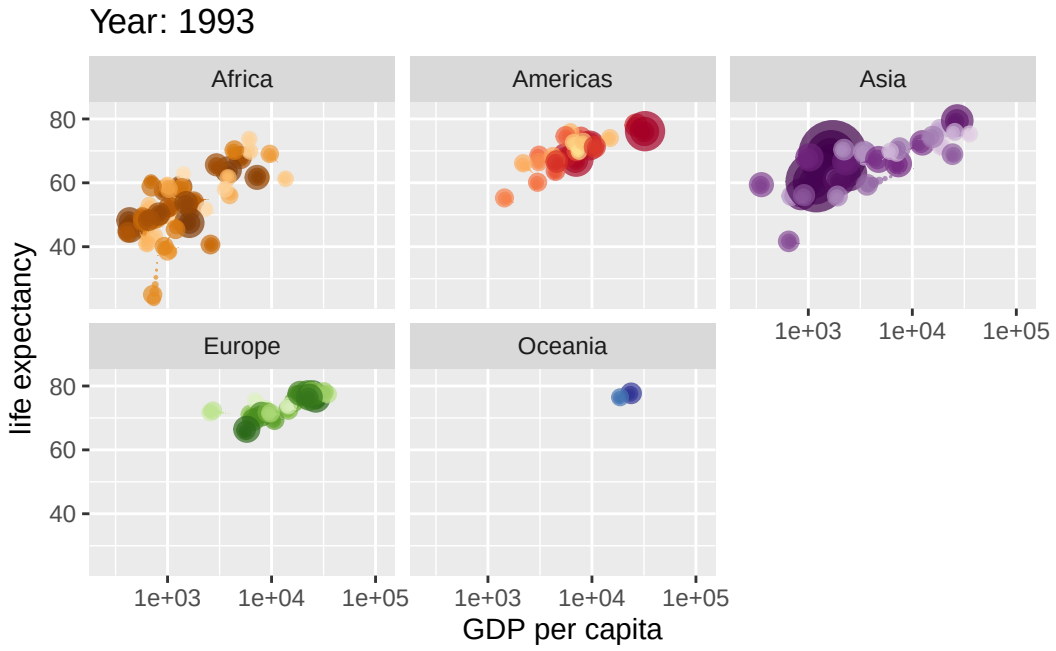
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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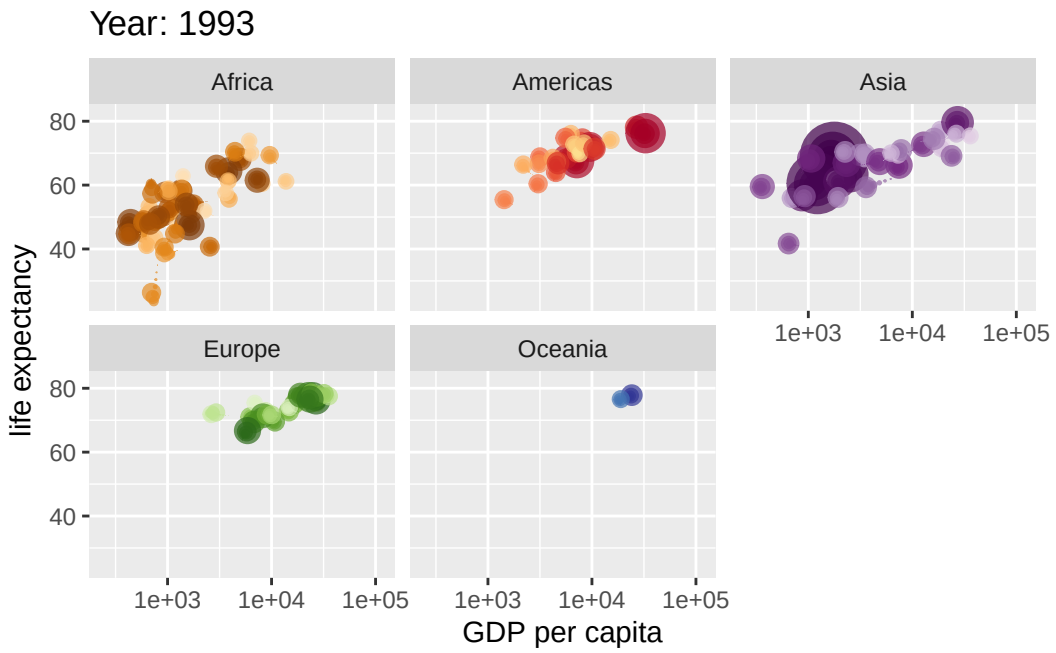
1e+03
1e+04
1e+05
GDP per capita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Africa
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Oceania
life expectancy
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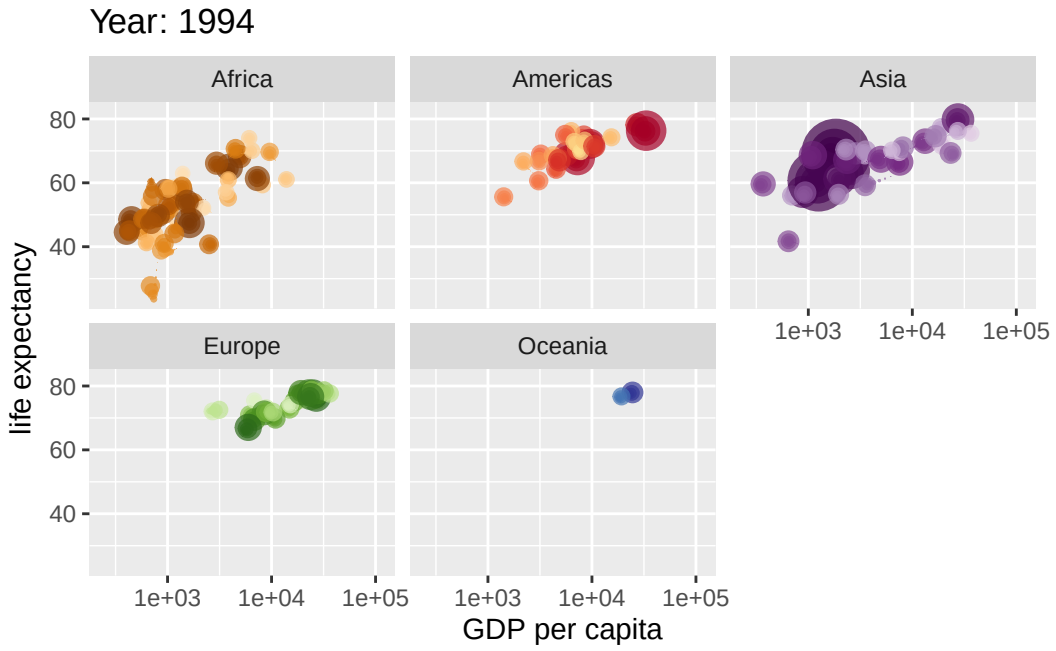
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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1e+03
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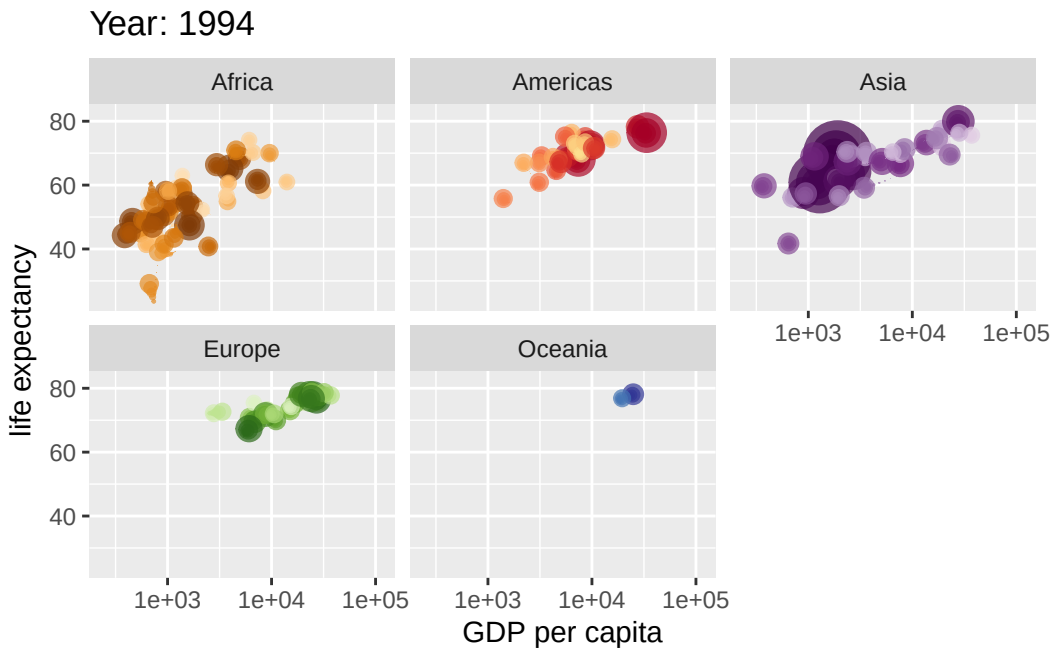
1e+05
GDP per capita


Year: 1994
Africa
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Oceania
life expectancy
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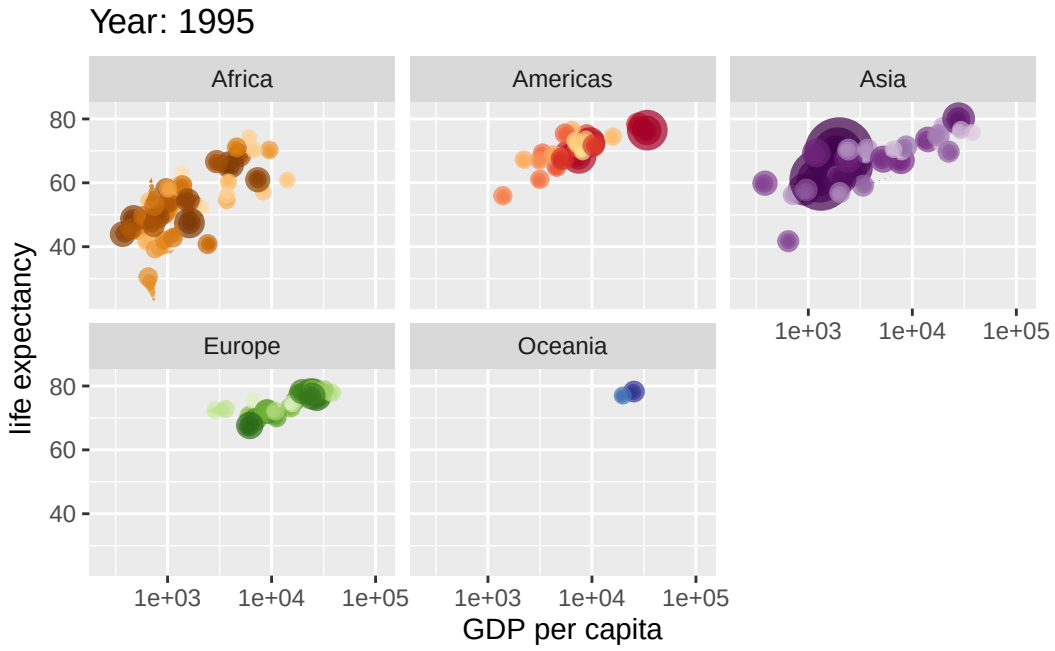
1e+03
1e+04
1e+05
GDP per capita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Oceania
life expectancy
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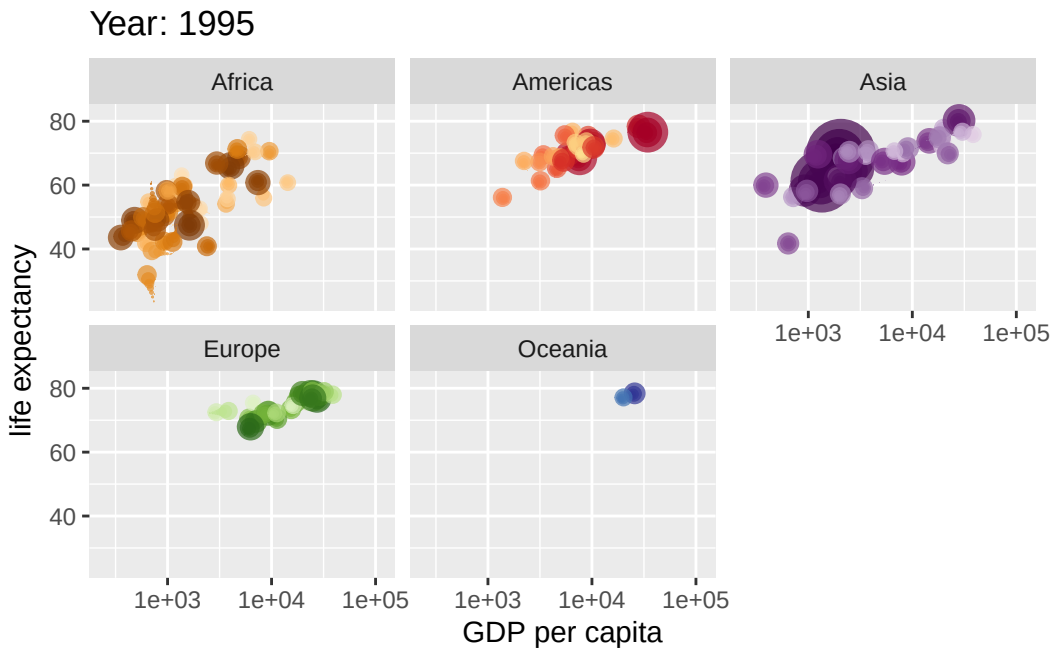
1e+04
1e+05
GDP per capita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Africa
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Asia
Europe
Oceania
life expectancy
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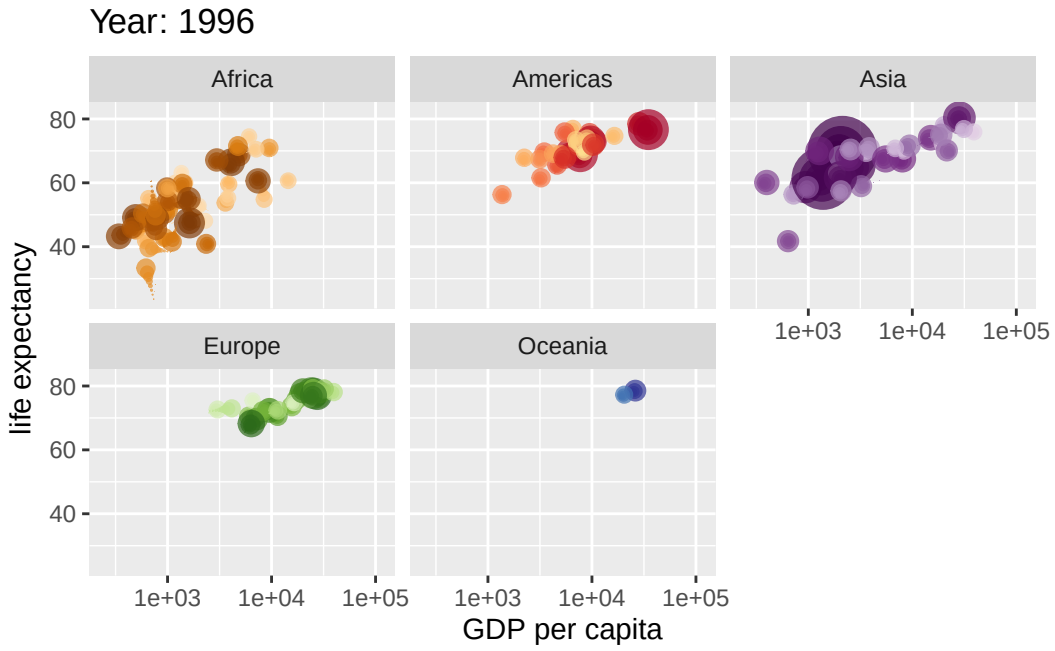
1e+05
GDP per capita


Year: 1996
Africa
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Oceania
life expectancy
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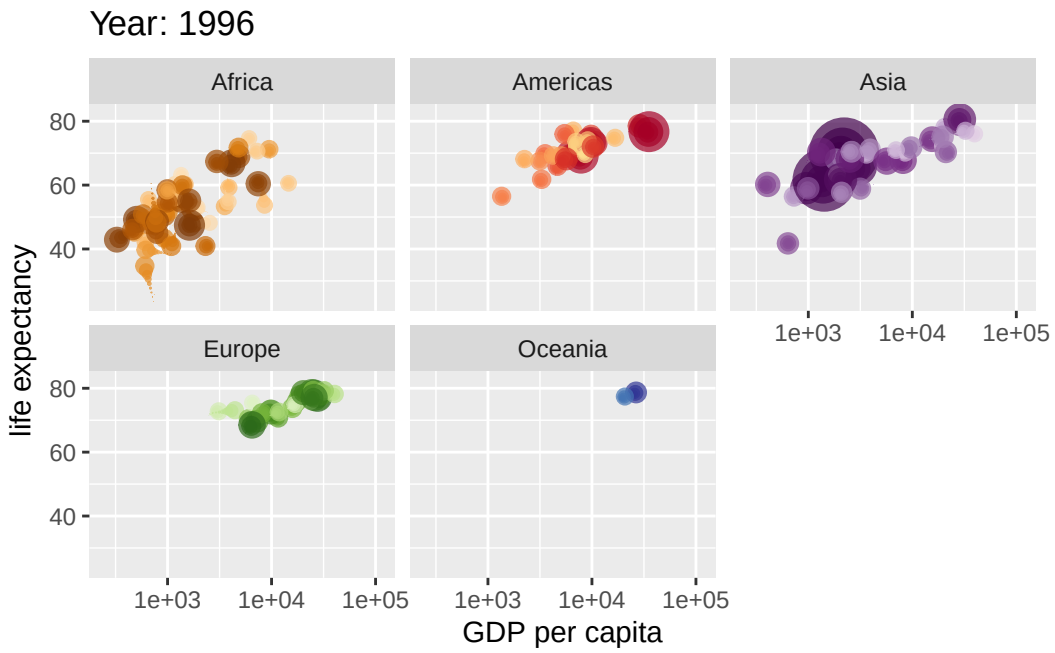
1e+05
GDP per capita


Year: 1996
Africa
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life expectancy
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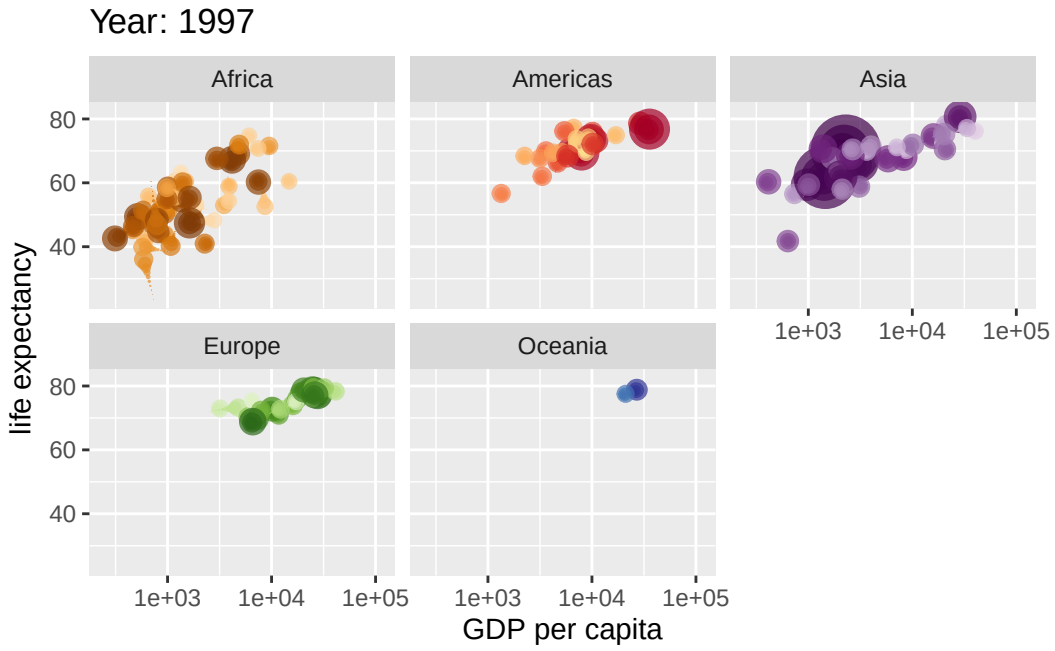
1e+05
GDP per capita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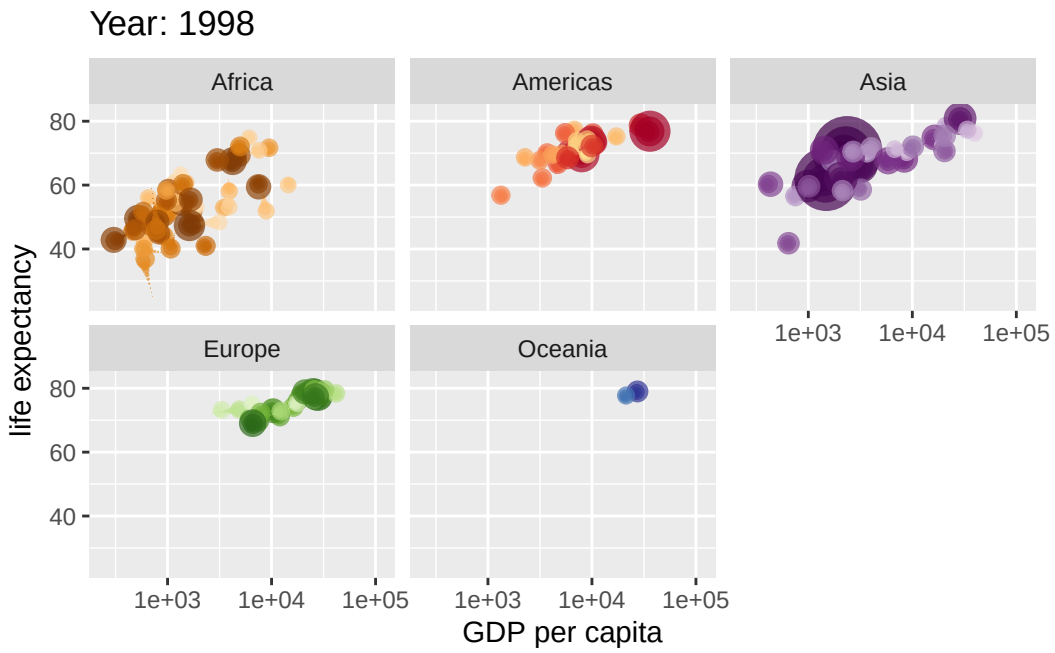
1e+05
GDP per capita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Oceania
life expectancy
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1e+03
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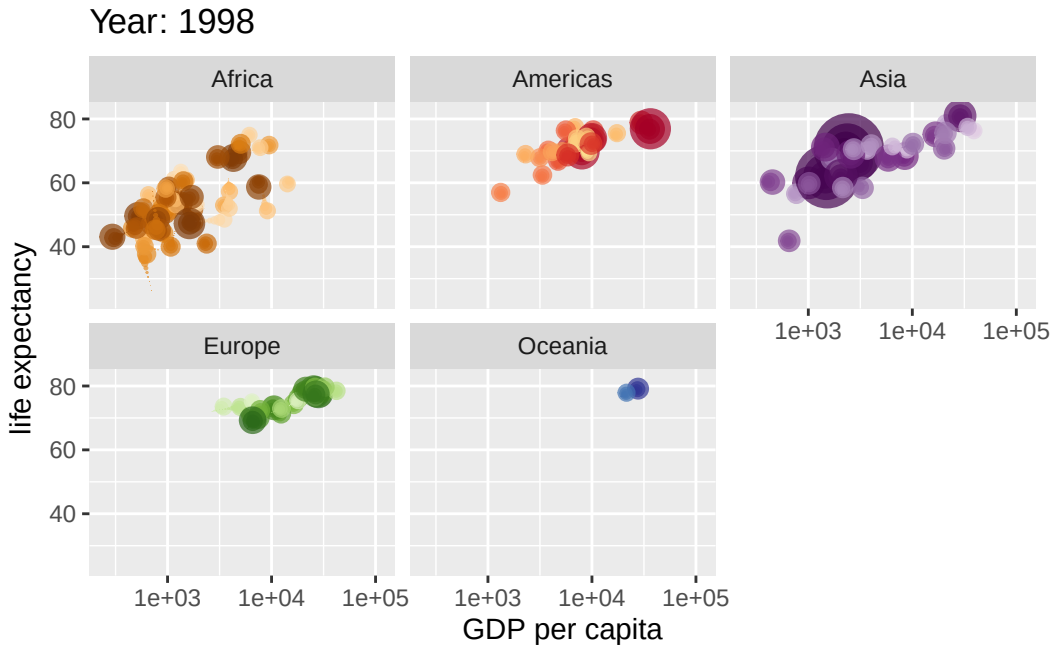
1e+05
GDP per capita


Year: 1998
Africa
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Europe
Oceania
life expectancy
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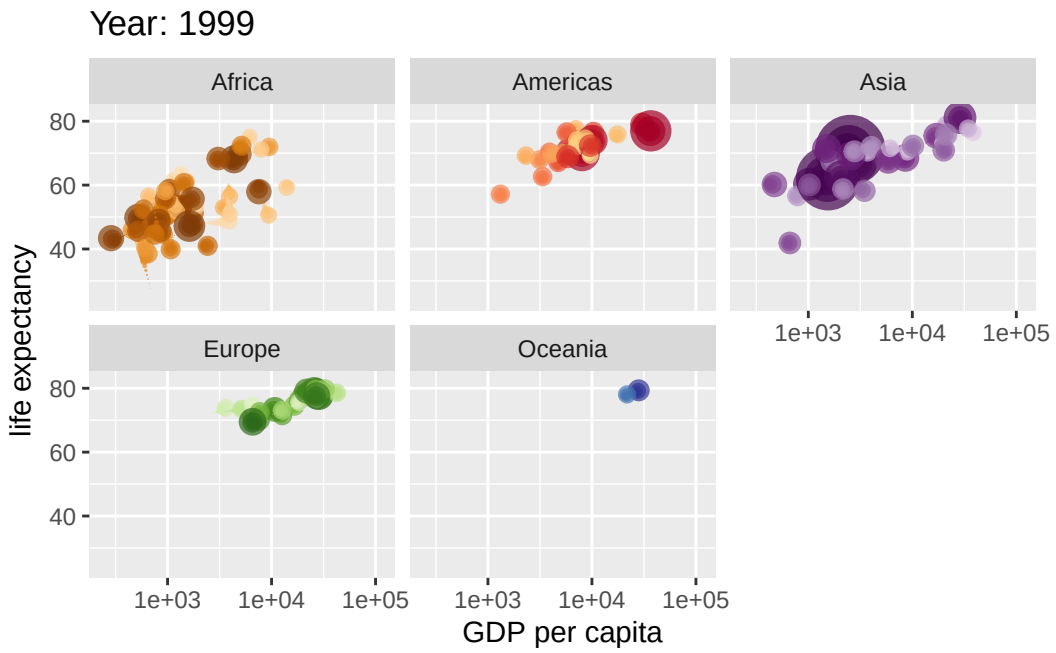
1e+03
1e+04
1e+05
GDP per capita


Year: 1999
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Oceania
life expectancy
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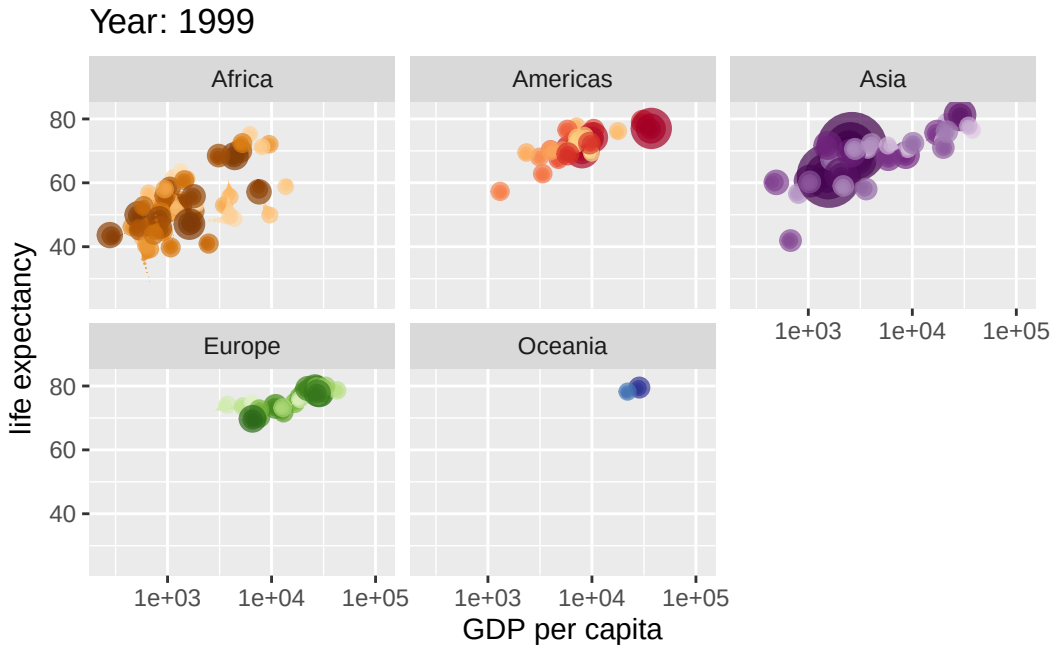
1e+03
1e+04
1e+05
GDP per capita


Year: 1999
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life expectancy
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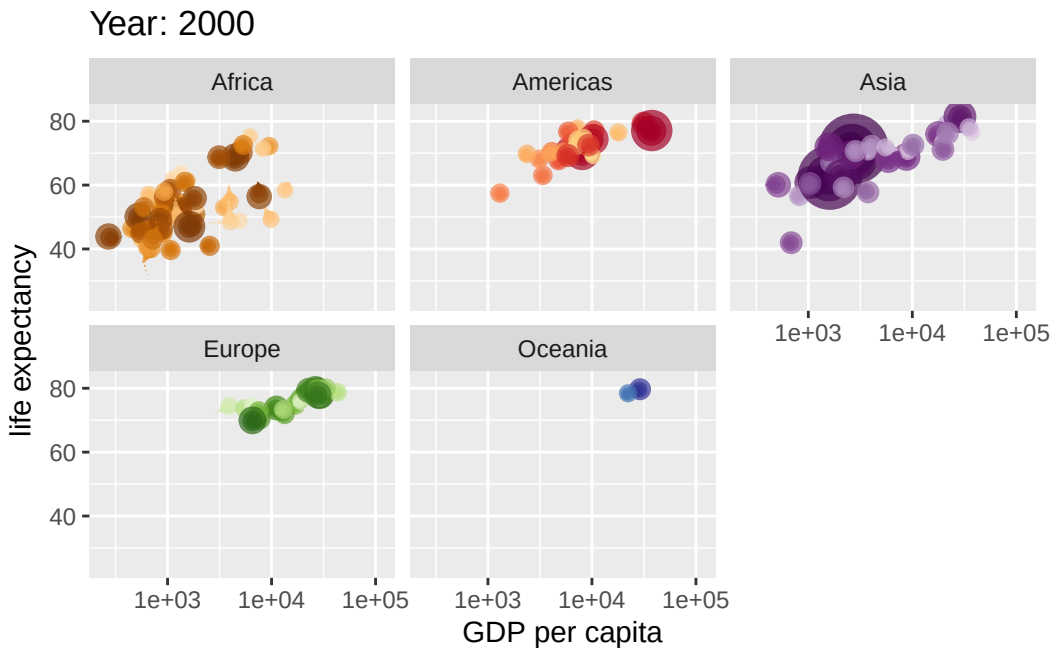
1e+04
1e+05
GDP per capita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Europe
Oceania
life expectancy
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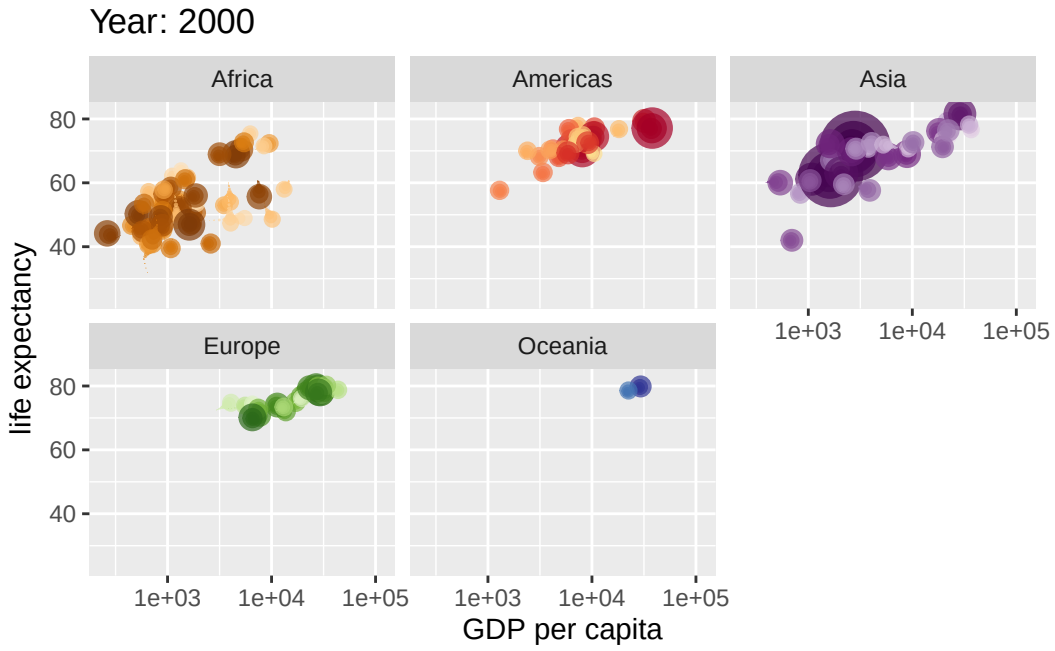
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2000
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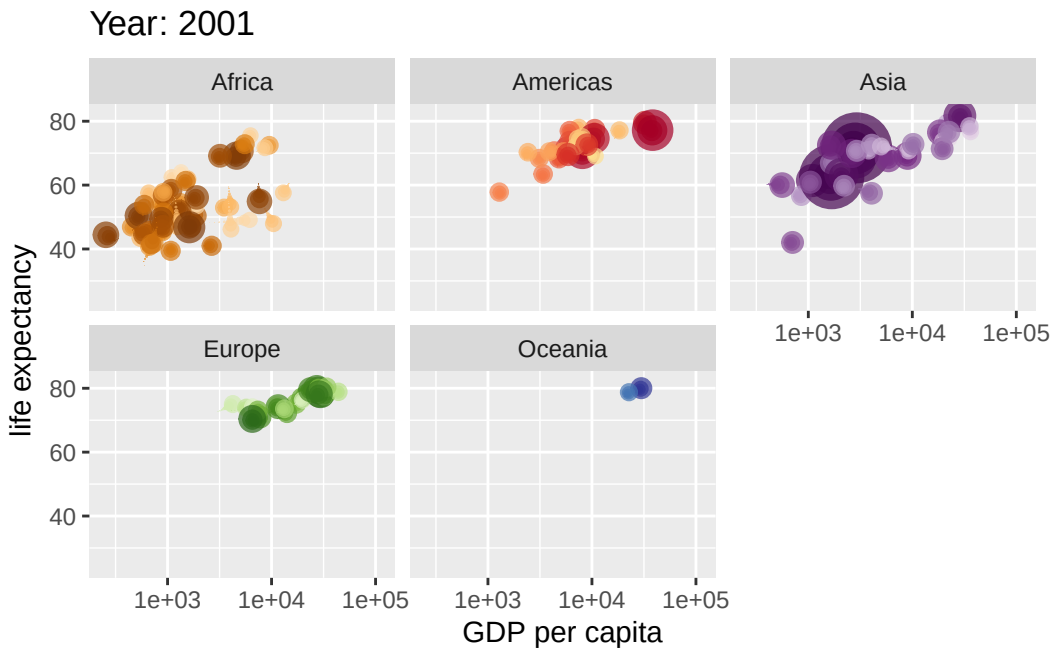
GDP per capita


Year: 2001
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Europe
Oceania
life expectancy
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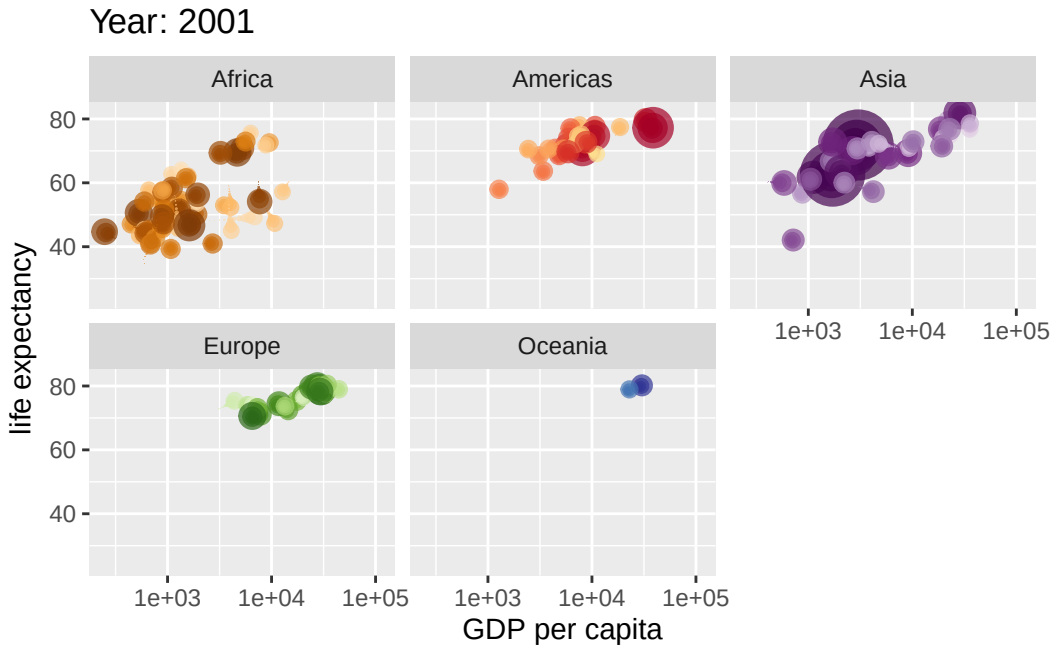
1e+04
1e+05
GDP per capita


Year: 2001
Africa
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Oceania
life expectancy
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60
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1e+03
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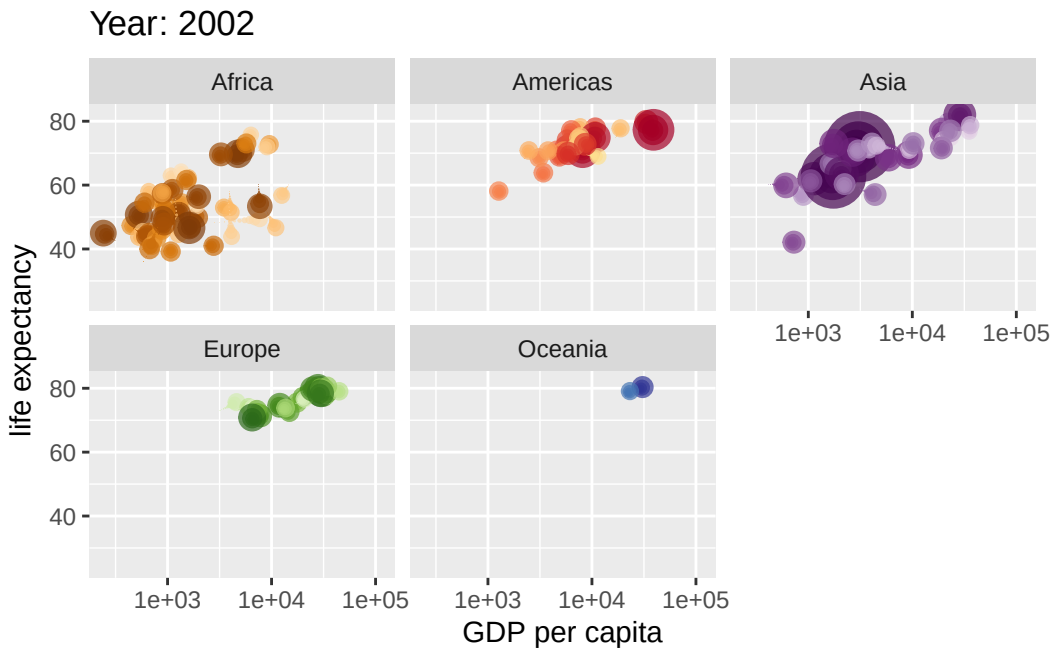
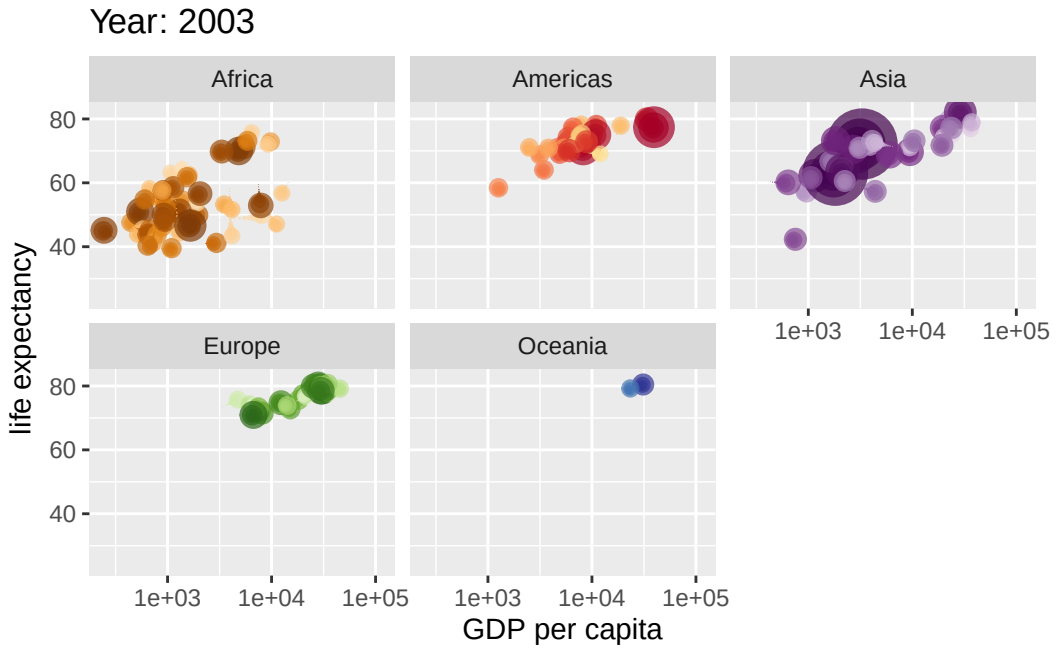
1e+05
GDP per capita


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


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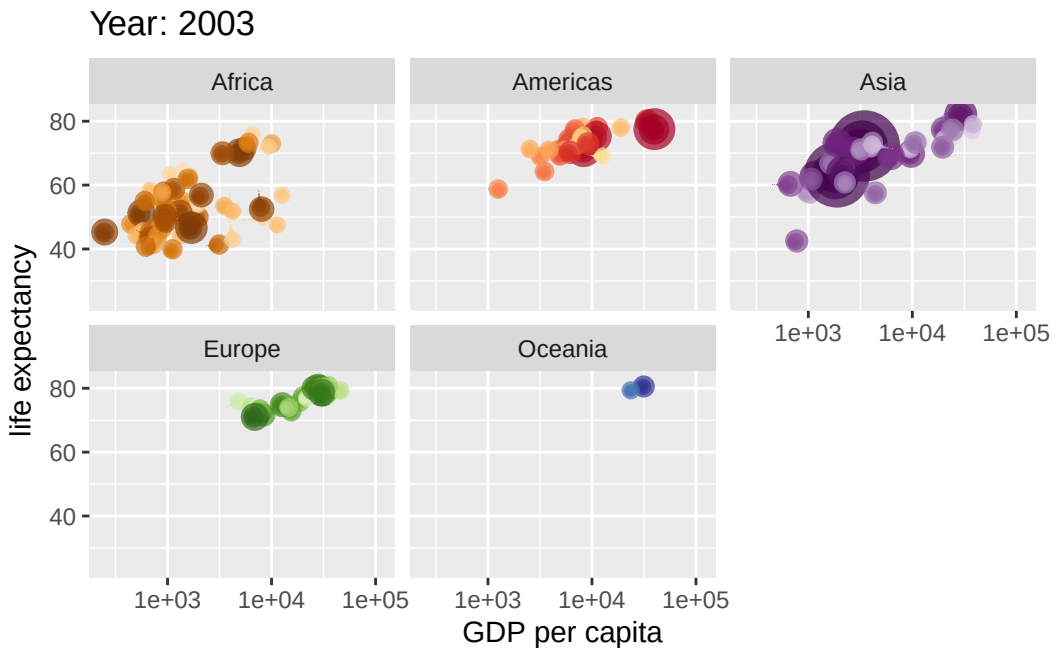
60
40
1e+03
1e+04
1e+05
GDP per capita


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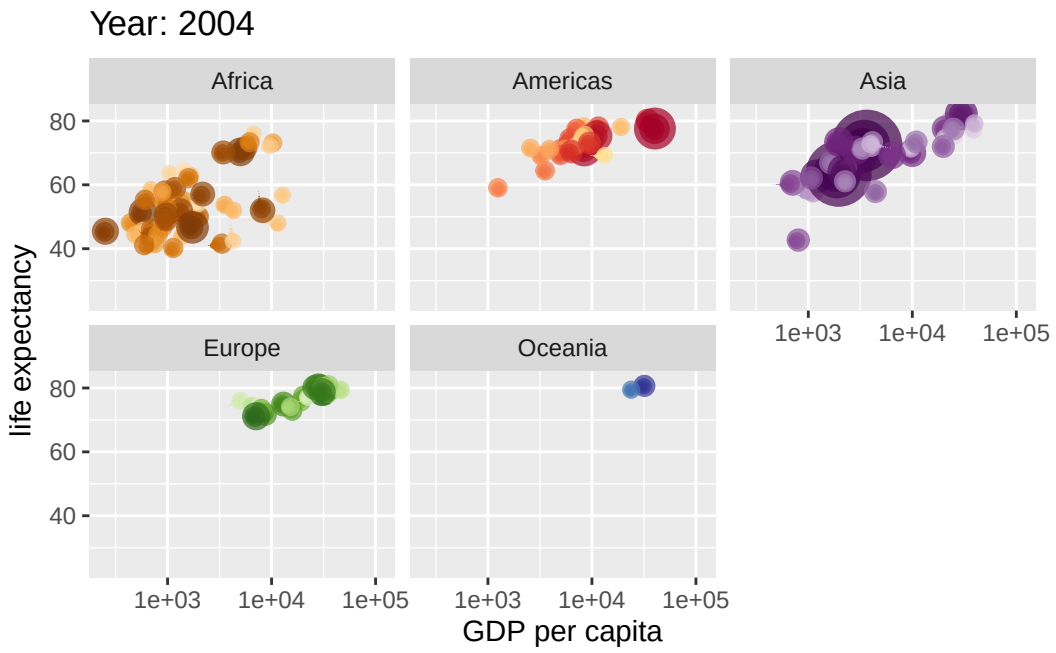
60
40
1e+03
1e+04
1e+05
GDP per capita


Year: 2004
Africa
Americas
Asia
Europe
Oceania
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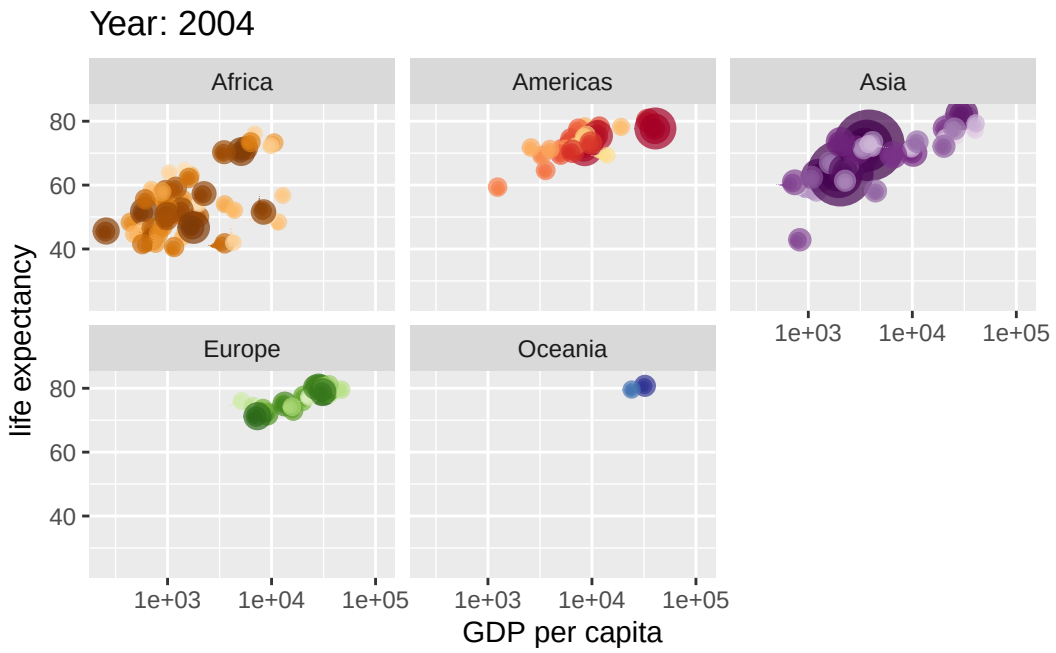
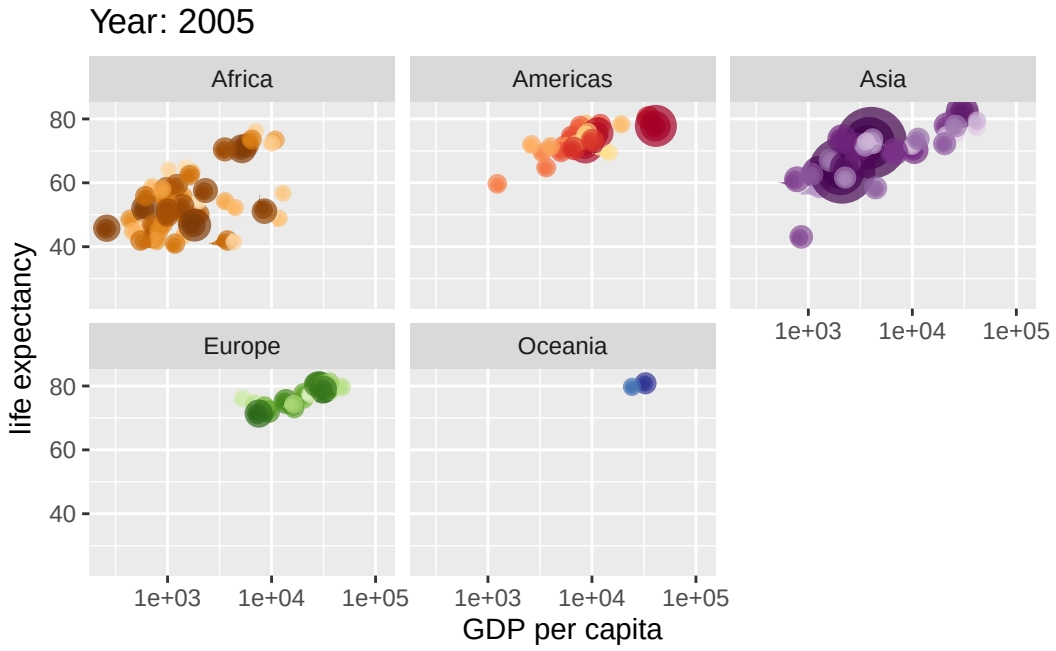
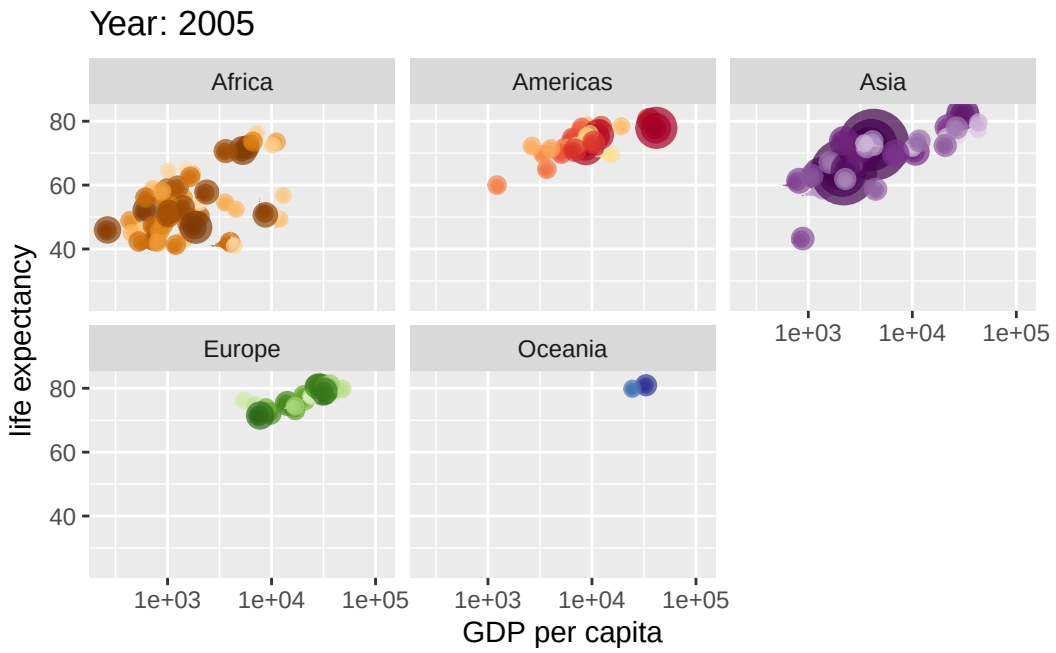
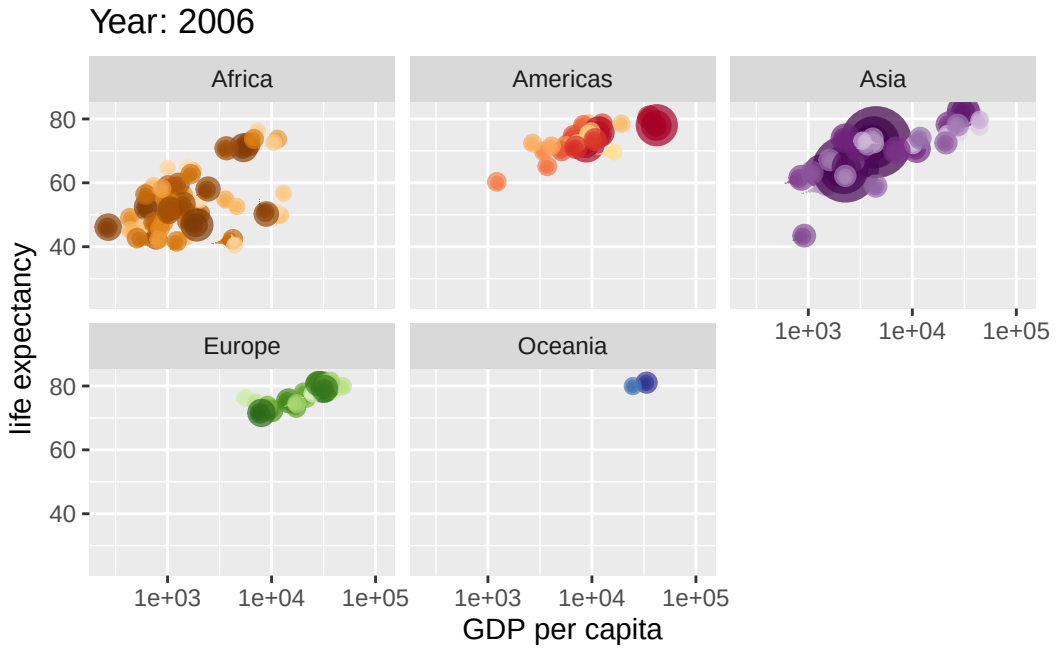
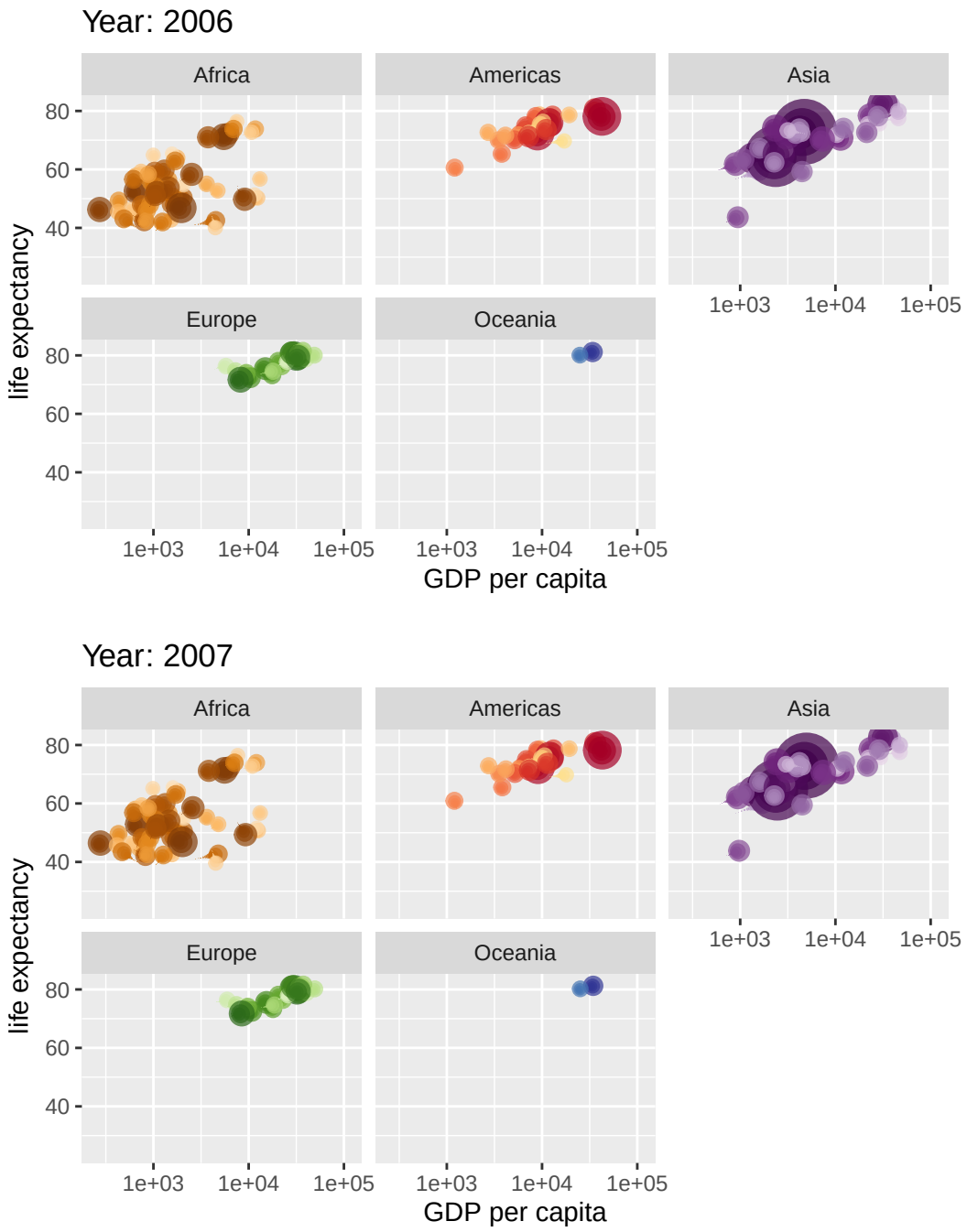
1e+03
1e+04
1e+05
GDP per capita


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



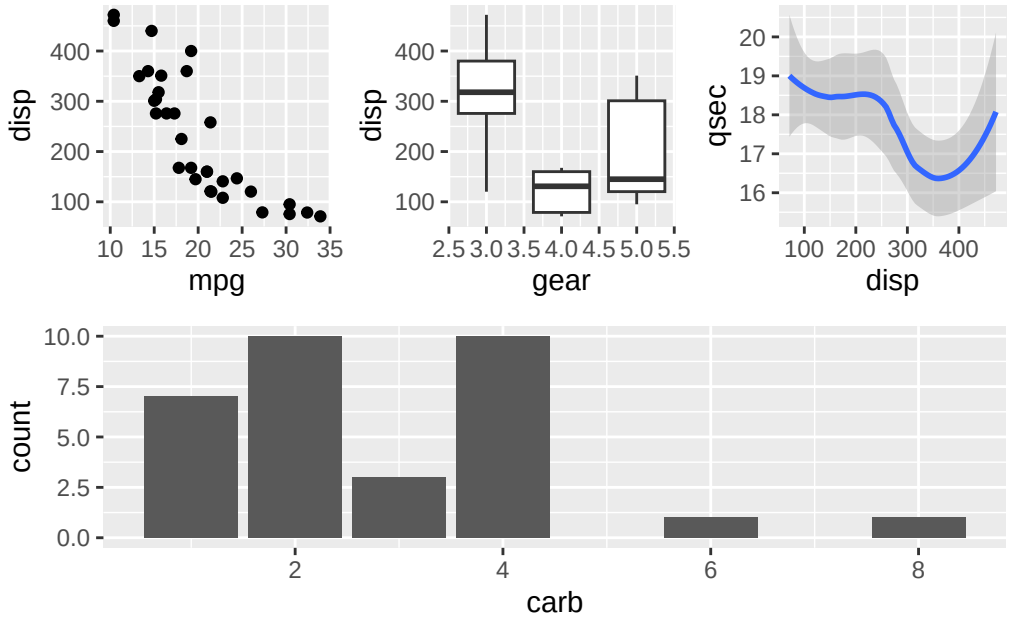
NOW LET'S COMBINE PLOTS Another excellent package extending ggplot is patchwork that is useful for combining plots to make an all-in-one multi-panel figure. For example:

```
library(patchwork)

# Setup some 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))

# Use patchwork to combine them here:
(p1 | p2 | p3) /
      p4
```

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



to save use ggsave("title.pdf)