Stat 260, Lecture 2

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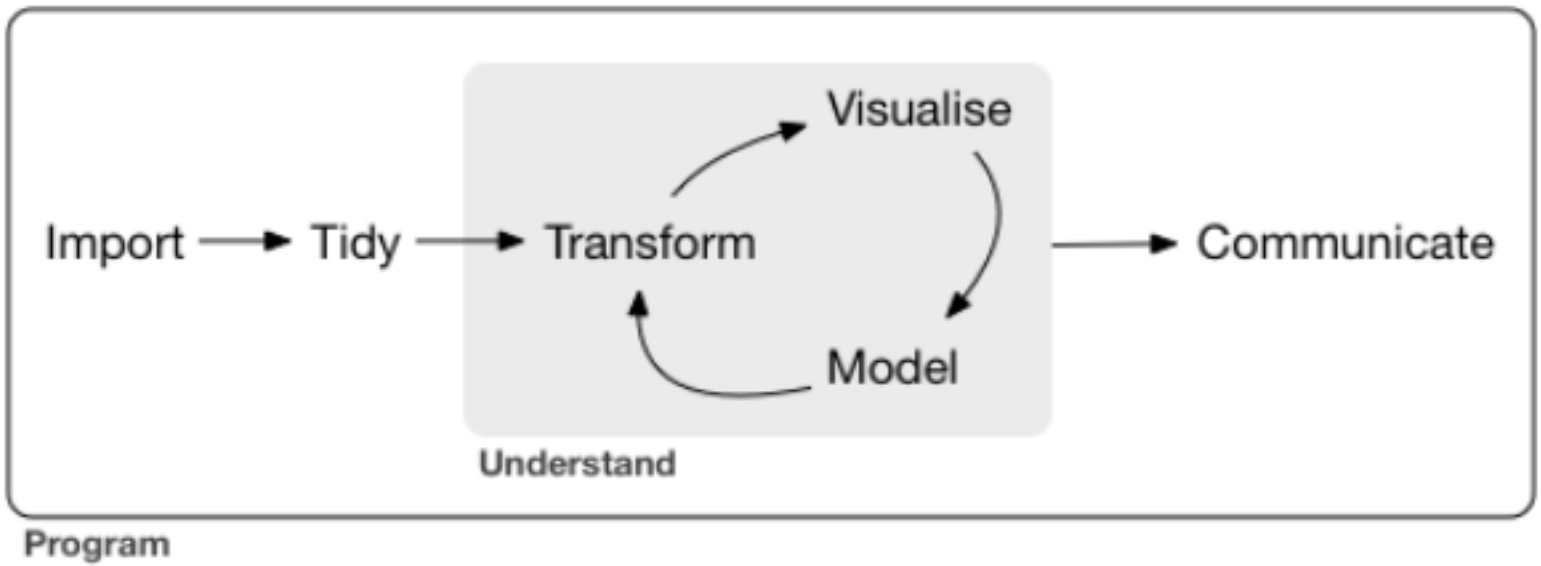
Data Visualization

- Reading: Chapter 1 of the text.
- The key steps of a data analysis are illustrated in the following figure from the text:



- We will jump into the middle of this program and discuss data visualization, because it is often the most interesting.
- We will use the `tidyverse` package `ggplot2` to visualize data.

Loading ggplot2

- Before you start, make sure you install the `tidyverse` collection of R packages. You can do this:
  - With the `Tools -> Install Packages` menu item in RStudio. Type `gapminder, tidyverse` into the text box and click `Install`.
  - By typing `install.packages("tidyverse")` into the R console.
- Install once, load every time with `library()`:

```
library(tidyverse)
```

Example: Car mileage

- Do cars with big engines use more feul that cars with small engines?

```
data(mpg)
head(mpg)
```

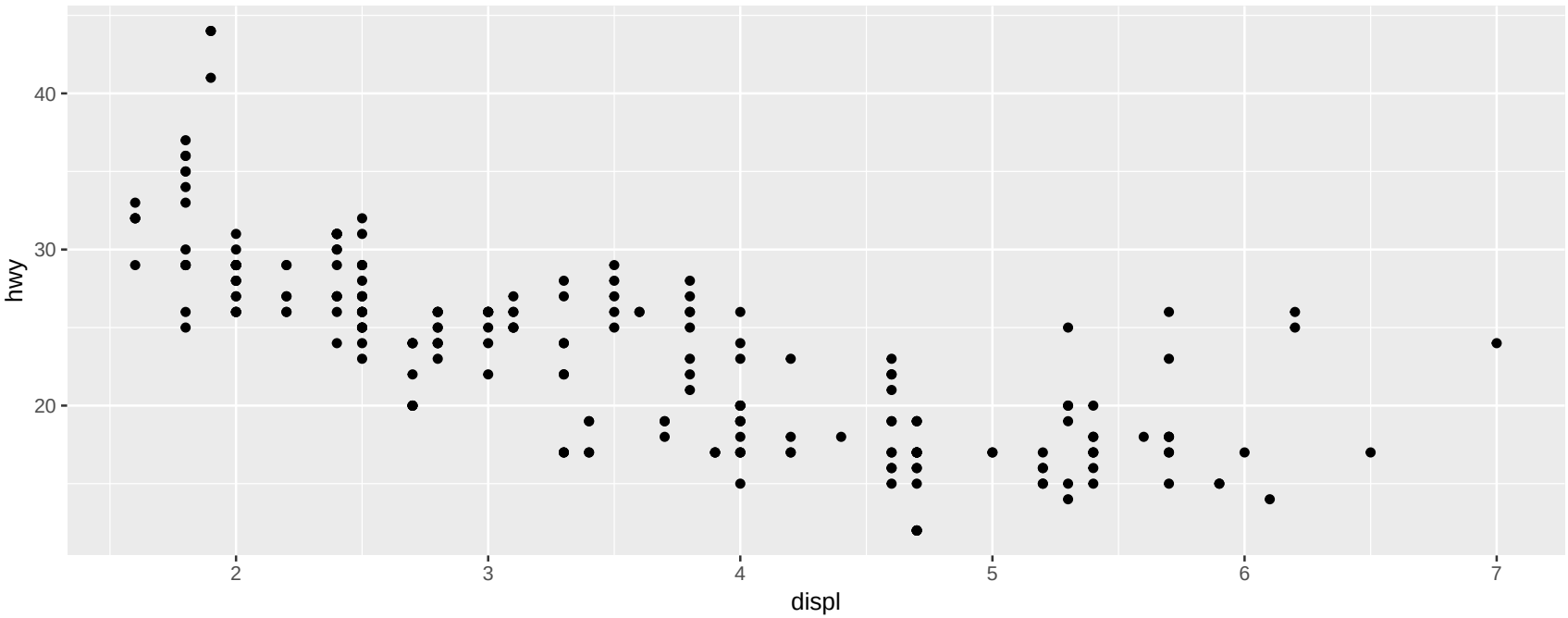
```
## # A tibble: 6 x 11
##   manufacturer model displ  year   cyl trans  drv     cty   hwy fl    class
##   <chr>        <chr> <dbl> <int> <int> <chr>  <chr> <int> <int> <chr> <chr>
## 1 audi         a4      1.8  1999     4 auto(~ f        18    29 p     comp~
## 2 audi         a4      1.8  1999     4 manua~ f        21    29 p     comp~
## 3 audi         a4      2    2008     4 manua~ f        20    31 p     comp~
## 4 audi         a4      2    2008     4 auto(~ f        21    30 p     comp~
## 5 audi         a4      2.8  1999     6 auto(~ f        16    26 p     comp~
## 6 audi         a4      2.8  1999     6 manua~ f        18    26 p     comp~
```

- Type `View(mpg)` to view the dataset and `?mpg` for details on the variables.

First ggplot

- `displ` is the engine displacement in litres and `hwy` is the highway mileage in miles per gallon.
- We can plot `hwy` *versus* `displ` as follows:

```
ggplot(data=mpg) + geom_point(mapping = aes(x=displ,y=hwy))
```

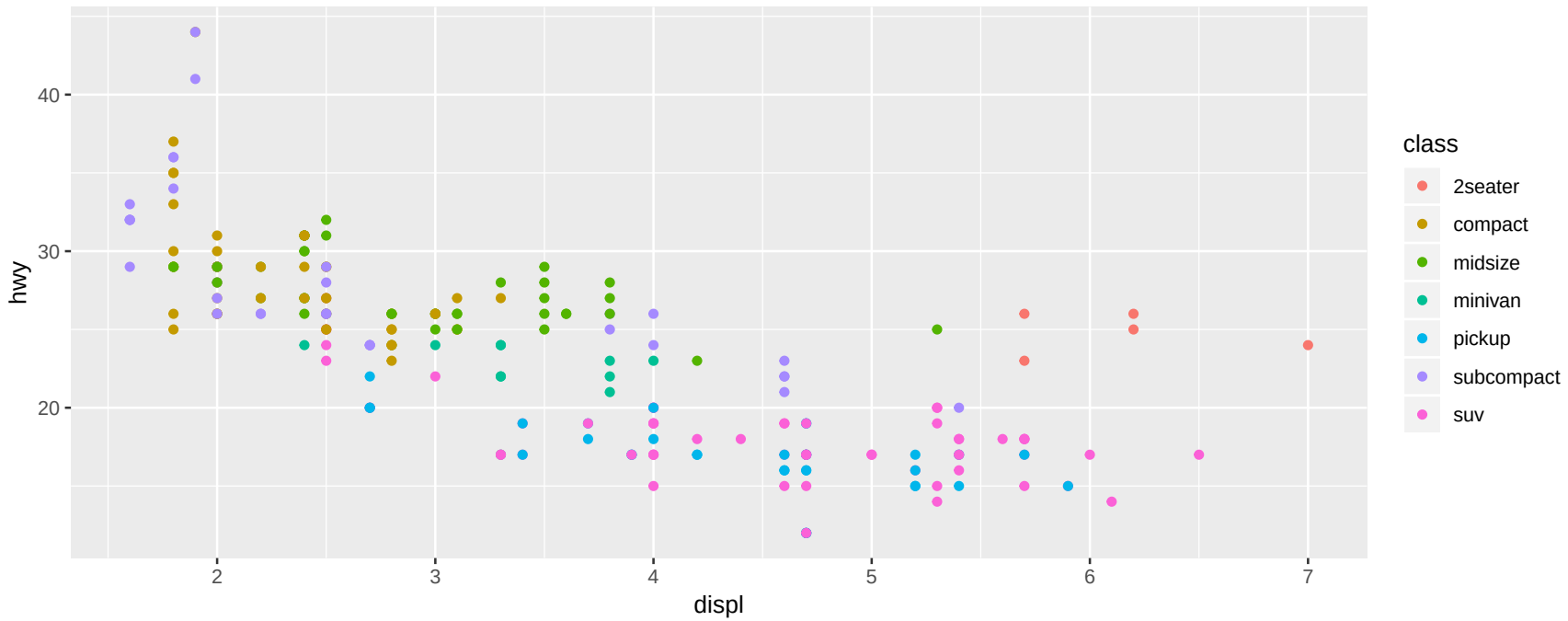


- Generally a negative linear trend, though there are some cars with large engines that get better-than-expected mileage.

Second ggplot

- We can plot `hwy` *versus* `displ` with colors to represent different kinds of cars:

```
ggplot(data=mpg) + geom_point(mapping = aes(x=displ,y=hwy,color=class))
```



- The `2seaters` are sports cars, with large engines but light bodies.
- **Exercise:** Redo the above scatterplot but using the aesthetic `shape=class` to plot different shapes for different kinds of cars.

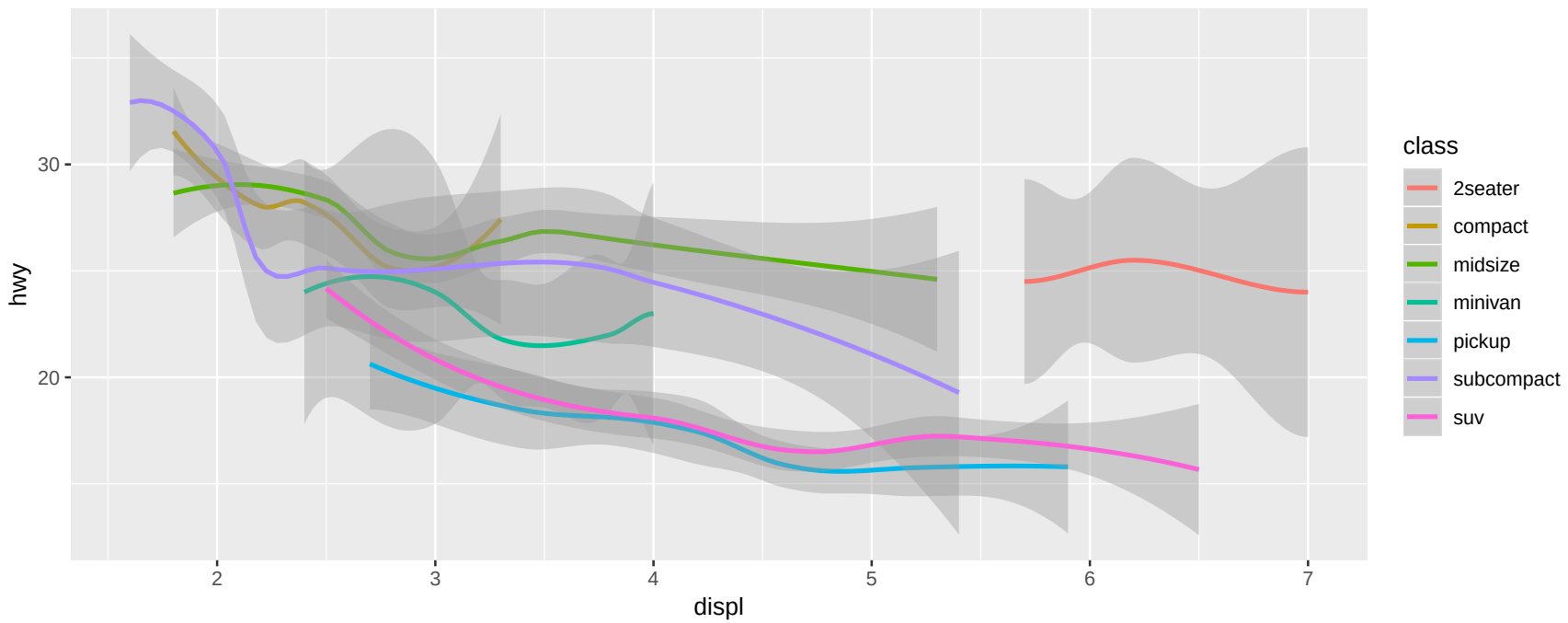
Components of our `ggplot`

- Our plot requires a dataset, objects to plot for each observation in the dataset, and a mapping of the variables in that dataset to features of the plot.
- In `ggplot(data = mpg)` we use the dataset `mpg`,
- we plot points for each observation in the dataset with `geom_point()`,
- and `mapping = aes(x=displ,y=hwy,color=class)` maps engine displacement to the x-axis, highway mileage to the y-axis and vehicle class to the color of each point.

Geometric objects

- The geometric objects to plot, or "geoms" are specified by the functions `geom_XXX()`.
- Example: scatterplot smooths for each class of car.

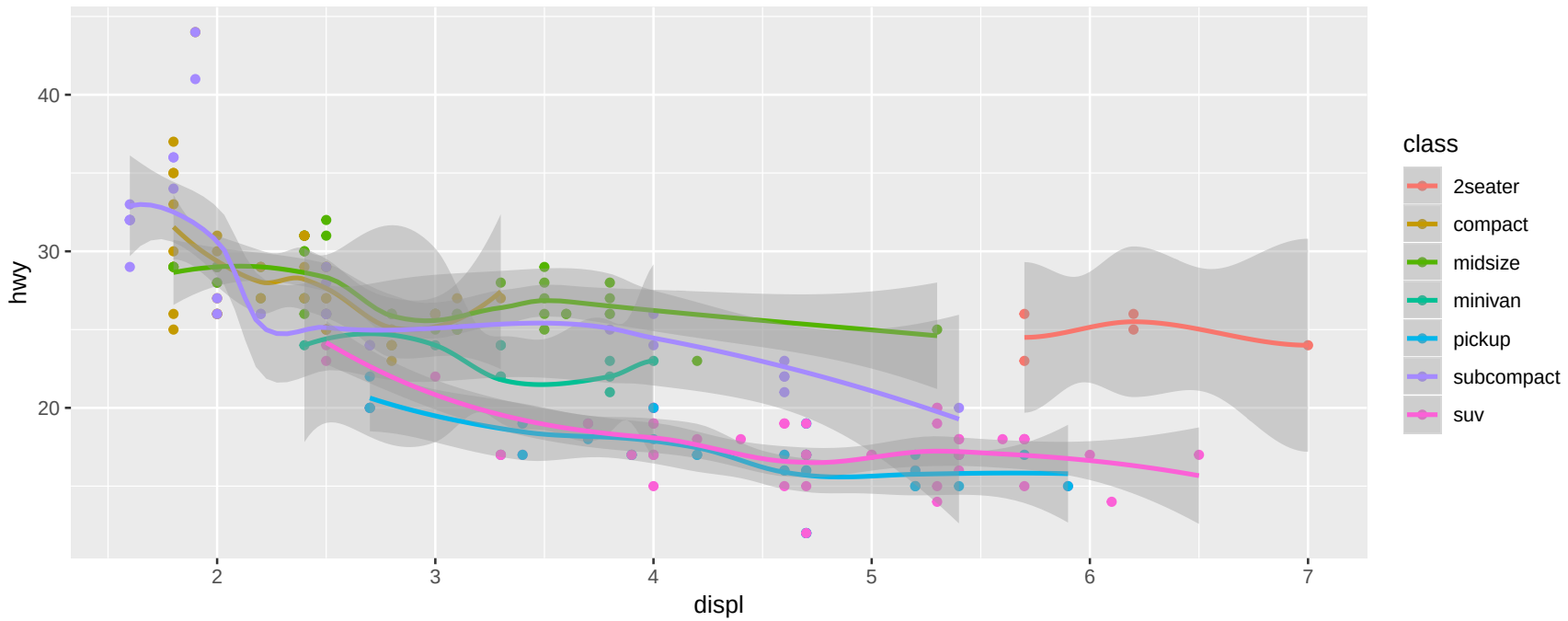
```
ggplot(data=mpg) + geom_smooth(mapping = aes(x=displ,y=hwy,color=class))
```



Multiple geoms

- Scatterplot smooths are more often plotted over top of points, as a summary of the trend.
- In the following we specify a default aesthetic mapping that is used by both the points and smooth.

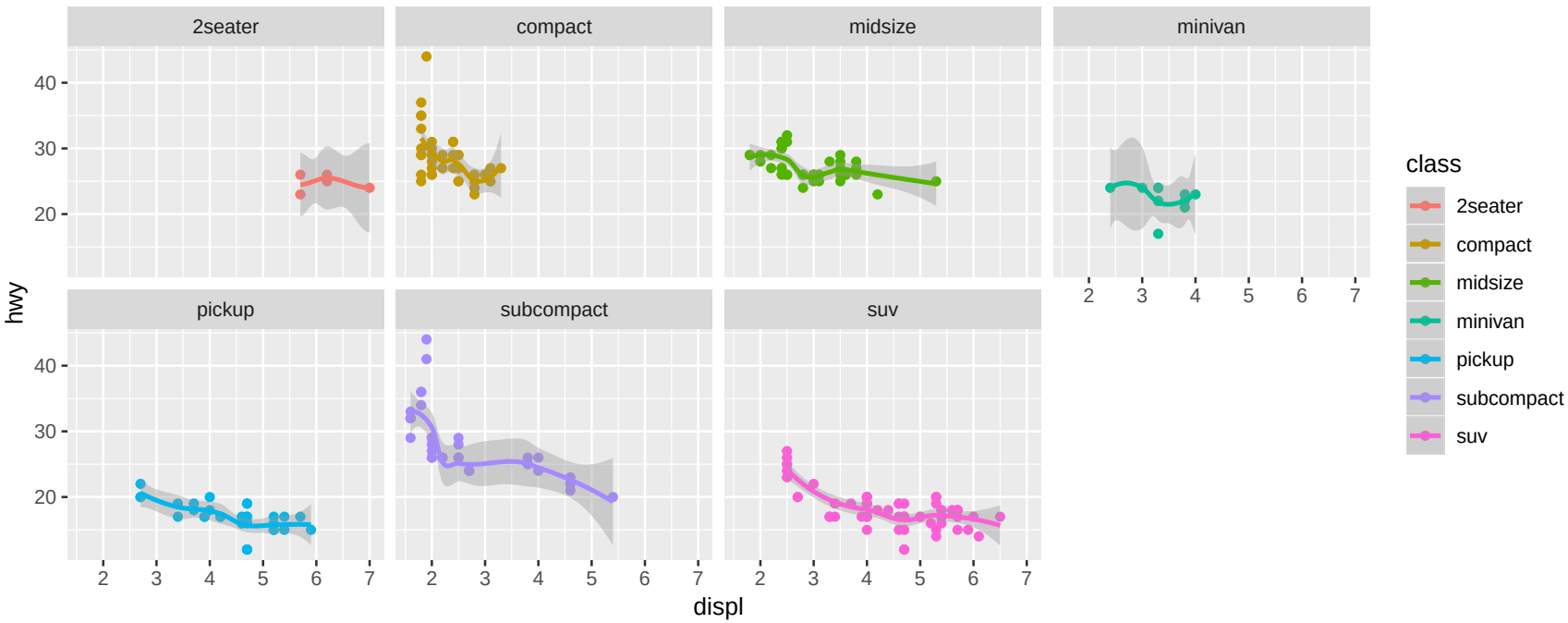
```
ggplot(data=mpg, mapping = aes(x=displ,y=hwy,color=class)) +
  geom_point() +
  geom_smooth()
```



Facets

- Instead of using colors to distinguish car class on one scatterplot, we can split into multiple scatterplots or "facets".

```
ggplot(data=mpg, mapping = aes(x=displ,y=hwy,color=class)) +
  geom_point() + geom_smooth() +
  facet_wrap(~ class,nrow=2)
```



- (The colors are no longer necessary, but are included to emphasize how our earlier scatterplot has been split.)

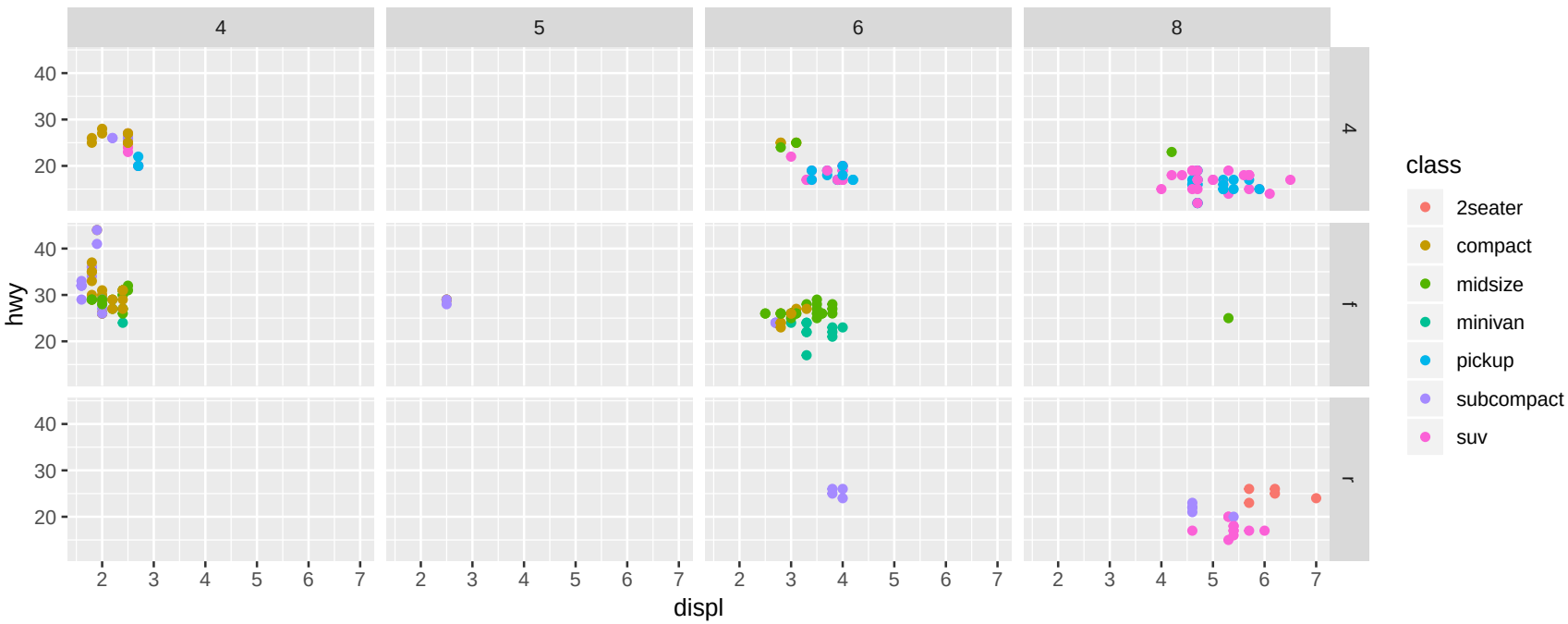
Faceting

- The facets by car class were added with `facet_wrap()`.
  - The variable to facet on was given in the "formula" `~ class`. Formulas will make more sense in the next faceting example.
  - `facet_wrap()` would have put made three rows in this example. We force two with `nrow=2`.
- **Exercise:** Repeat the above example, but omit the `nrow=2` argument to `facet_wrap()`.

Faceting on two variables.

- The variable `drv` is 4-, front- or rear-wheel drive.
- The variable `cyl` is the number of cylinders.

```
ggplot(data=mpg) +
  geom_point(mapping = aes(x=displ,y=hwy,color=class)) +
  facet_grid(drv ~ cyl)
```



ggplot layers

- The g's stand for Grammar of Graphics.
  - Like English grammar is the way in which words are put together to form sentences, a grammar of graphics is a way to put together basic graphical elements to make a graph.
- ggplots are built in layers, comprised of **data** a **mapping**, a **geom** and optionally **stats**, such as a scatterplot smoother.
- The layers are arranged and labelled on the graph by **scale**s and **coord**s (next lecture).
- The data can also be broken into subsets and displayed in separate graphs by a **facet** specification.

Another example: The gapminder data

- The gapminder dataset contains life expectancy, population size and GDP per capita for countries throughout the world from 1952 to 2007 in seven-year intervals.

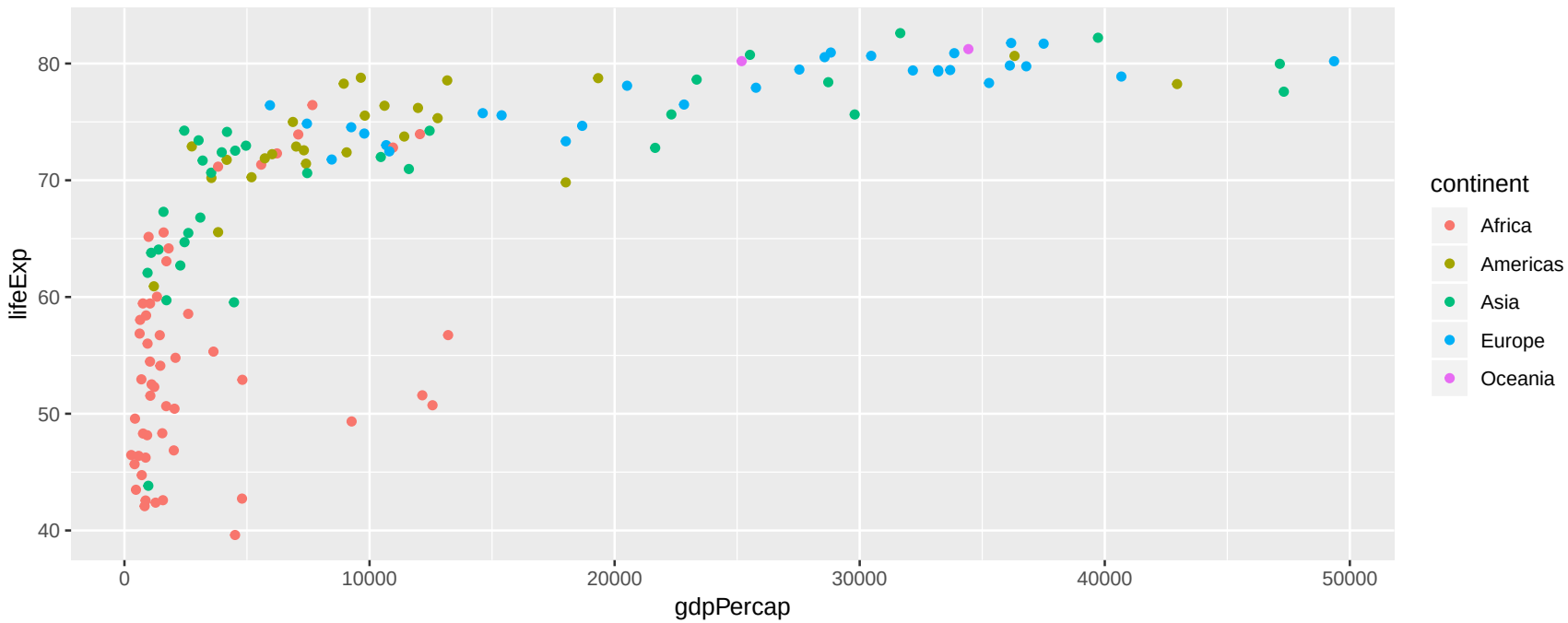
```
library(gapminder)
data(gapminder)
head(gapminder)
```

```
## # A tibble: 6 x 6
##   country     continent  year lifeExp      pop gdpPercap
##   <fct>       <fct>     <int>   <dbl>    <int>     <dbl>
## 1 Afghanistan Asia       1952    28.8  8425333      779.
## 2 Afghanistan Asia       1957    30.3  9240934      821.
## 3 Afghanistan Asia       1962    32.0 10267083      853.
## 4 Afghanistan Asia       1967    34.0 11537966      836.
## 5 Afghanistan Asia       1972    36.1 13079460      740.
## 6 Afghanistan Asia       1977    38.4 14880372      786.
```

Subsetting the gapminder data

- Plot life expectancy *versus* GDP per capita for 2007.
  - Need to subset, or "filter" the data to observations from 2007.

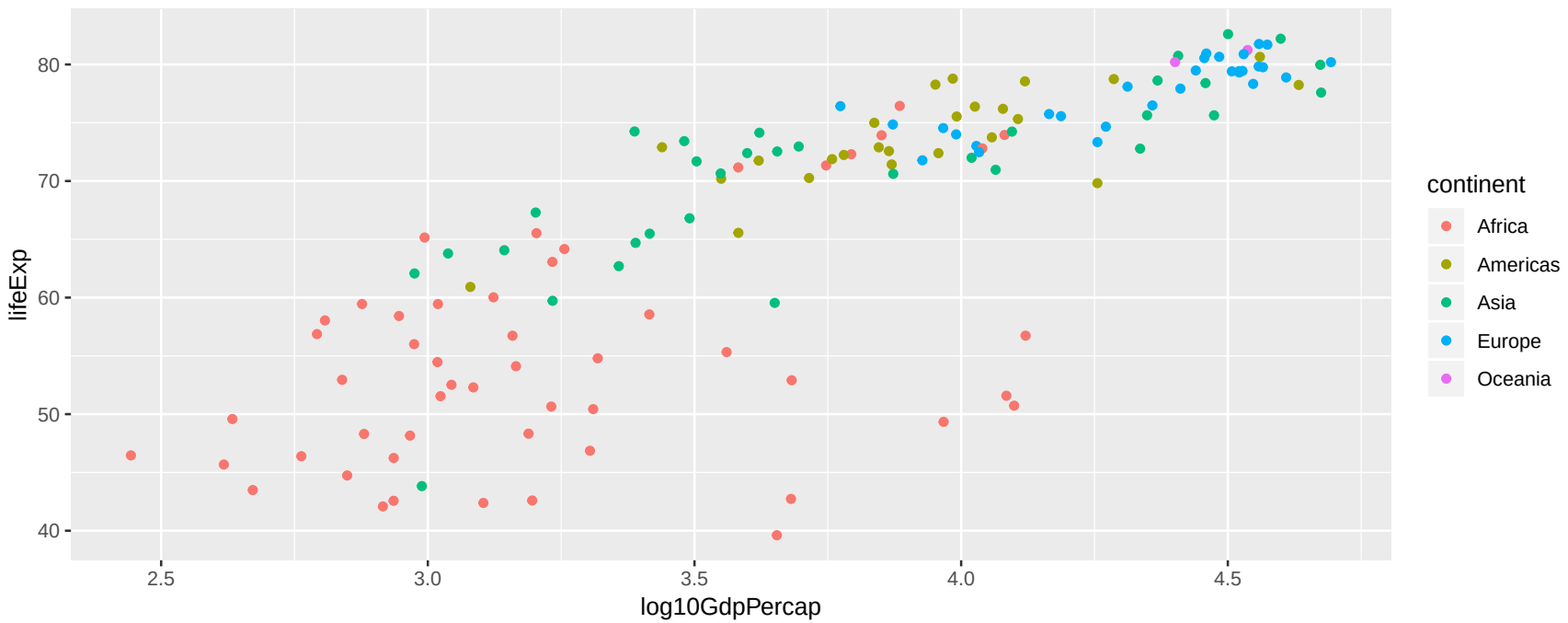
```
gm07 <- filter(gapminder,year==2007)
ggplot(gm07, aes(x=gdpPercap,y=lifeExp,color=continent)) +
  geom_point()
```



Transform GDP per capita

- GDP per capita differs by several orders of magnitude across countries. For such explanatory variables, the log scale may be more appropriate.

```
gm07 <- mutate(gm07,log10GdpPercap = log10(gdpPercap))
ggplot(gm07, aes(x=log10GdpPercap,y=lifeExp,color=continent)) +
  geom_point()
```



Build a plot by layer

- In this example we build the plot by layer and do not show the plot until all layers are added.
- Our plot will be for the entire `gampinder` dataset.
- Set the mapping:

```
gapminder <- mutate(gapminder, log10GdpPercap = log10(gdpPercap))
p <- ggplot(gapminder, aes(x=log10GdpPercap,y=lifeExp,color=continent))
```

Add the geoms

- Overplotting means we can't tell how many points per area of the plot.
- Set a transparency, or "alpha" value to make points semi-transparent. Then many points will add up to solid, and few points will show as semi-transparent.

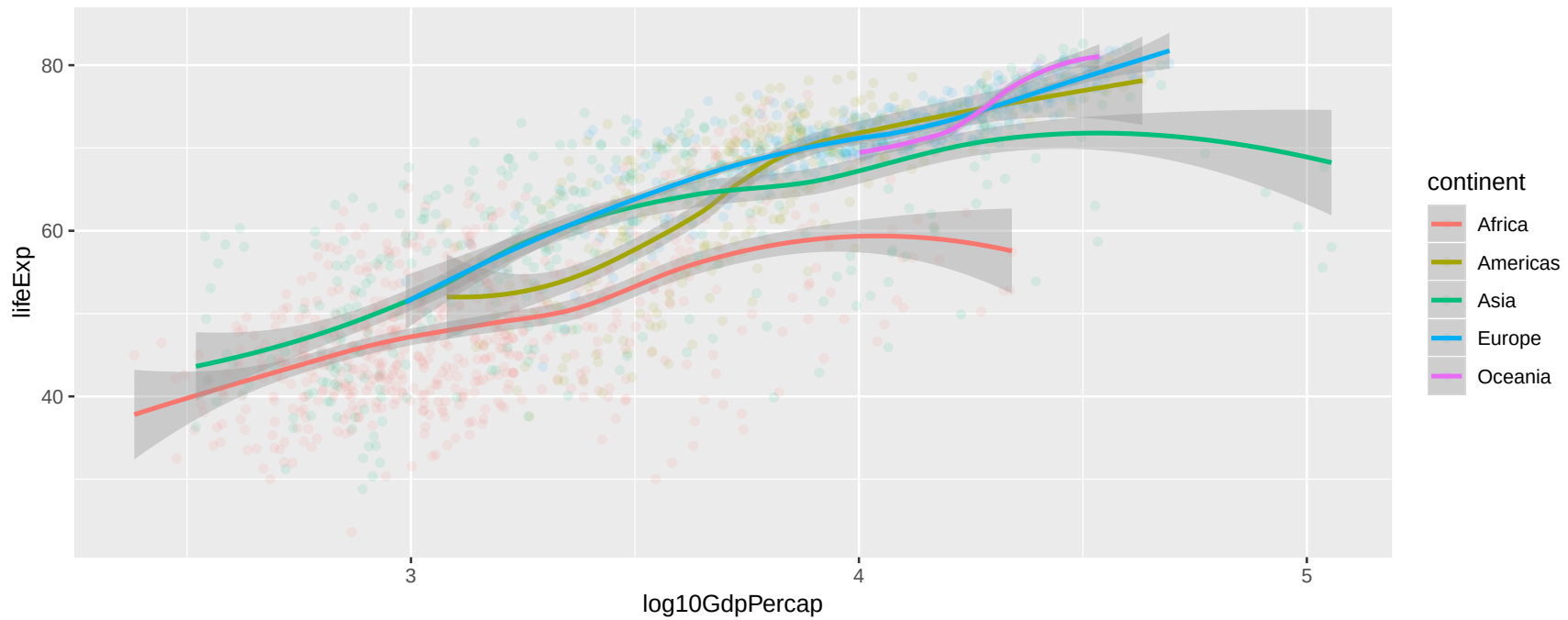
```
p2 <- p + geom_point(alpha=0.1)
```

- alpha is the transparency aesthetic, between 0 and 1, best applied directly to the geom.

Add statistical transformations

- Statistical transformations or **stats** summarize the data; e.g., a scatterplot smoother

```
p2 + stat_smooth()
```



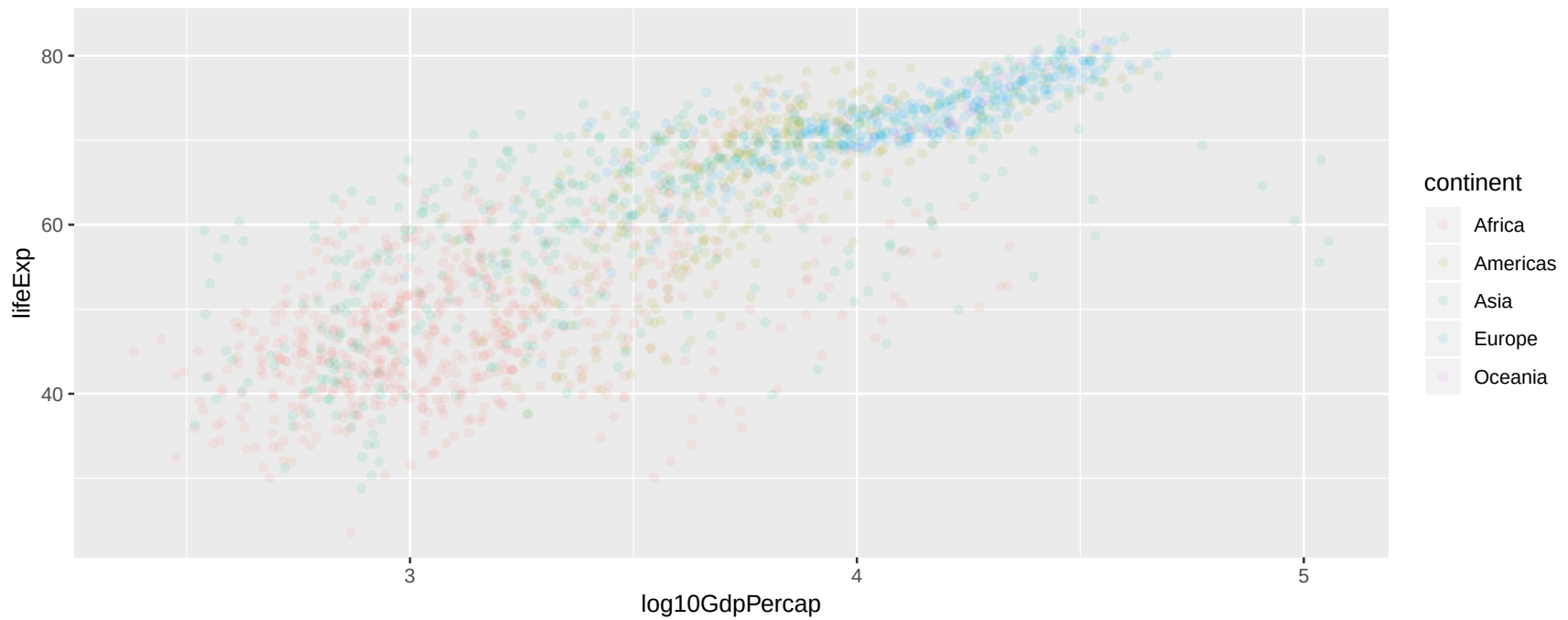
Exercise:

- The variable `year` is quantitative, but can still be used as a grouping variable. Do scatterplots of `lifeExp` versus `log10GdpPercap` with points colored by `year`. Add a scatterplot smoother with (i) no grouping variable and (ii) `year` as the grouping variable. Set the SE to FALSE for your smoothers.

ggplot scales

- The **scales** are mappings from the data to the graphics device
  - domain of `continent` is the five continents, range is the hexidecimal of the five colors represented on the graph
  - domain of `lifeExp` is 23.599 to 82.603, range is [0,1], which `grid` converts to a range of vertical pixels on the graph.
  - legends and axes provide the inverse mapping

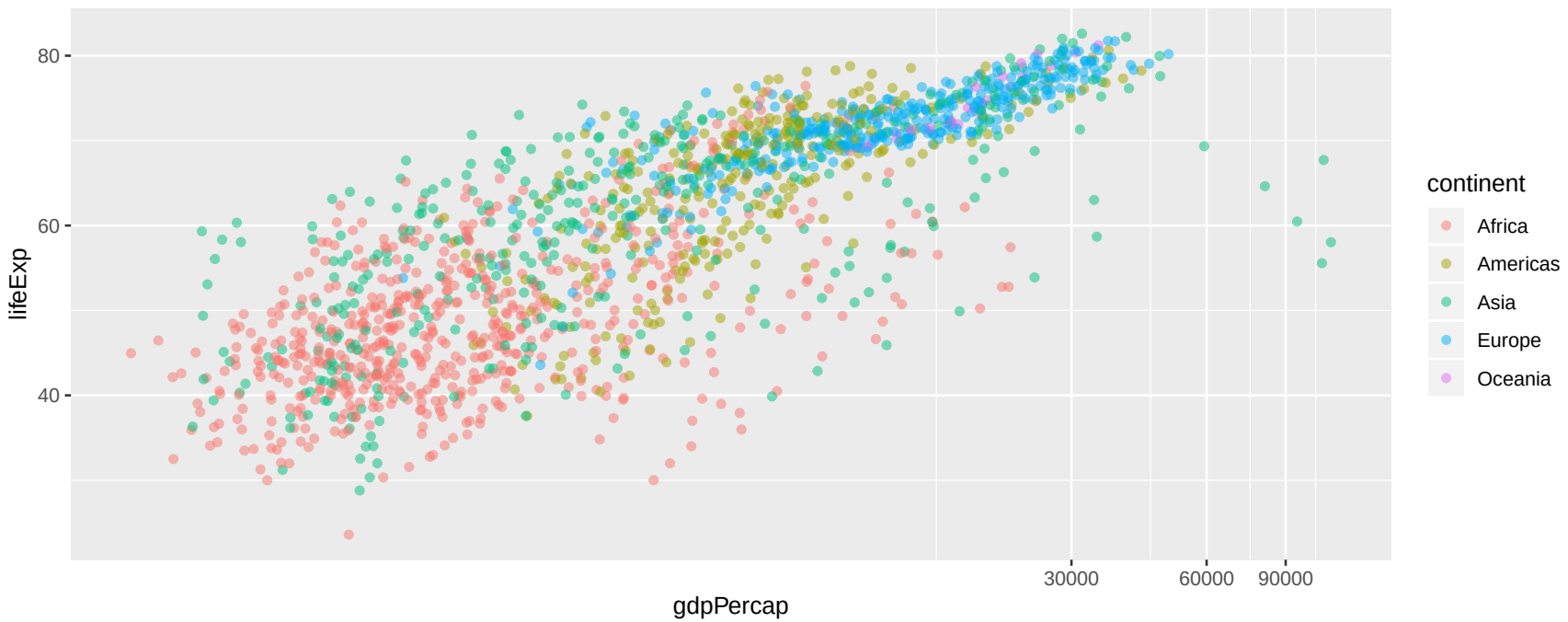
```
p2
```



ggplot coodinate system

- The coordinate system is another layer in how the data get mapped to the graphics device.
  - Usually Cartesian, but could be, e.g., polar coordinates, or a transformation.

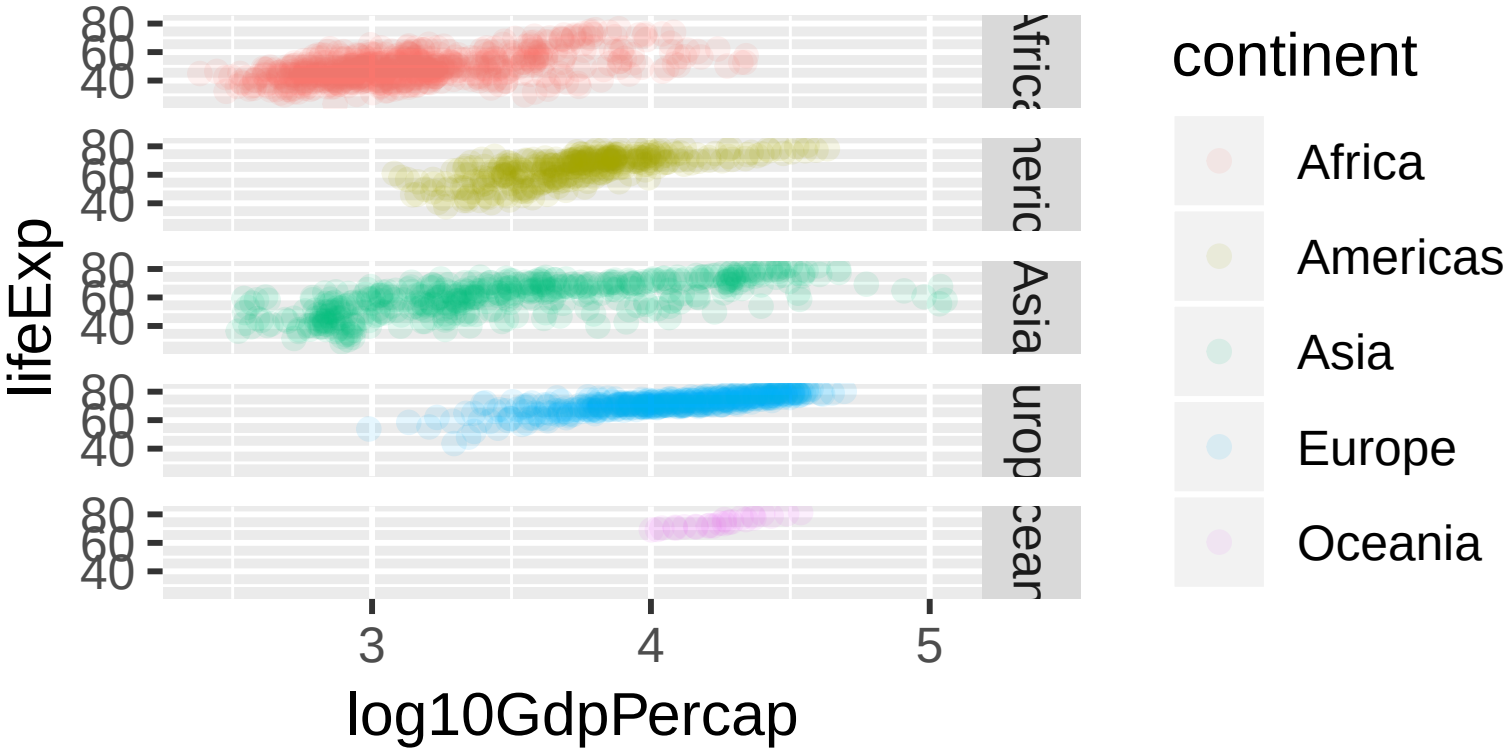
```
ggplot(gapminder,aes(x=gdpPercap,y=lifeExp,color=continent)) +
  geom_point(alpha=0.5) + coord_trans(x="log10")
```



ggplot faceting

- How to break up the data into subsets and arrange multiple plots on the graphics device.

```
p2 +  facet_grid(continent ~ .)
```



Why so many components?

- A framework for the components of a graph.
- Gives the user the ability to change indvidual components one at a time.