R package ggplot2

STAT 133

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ggplot2

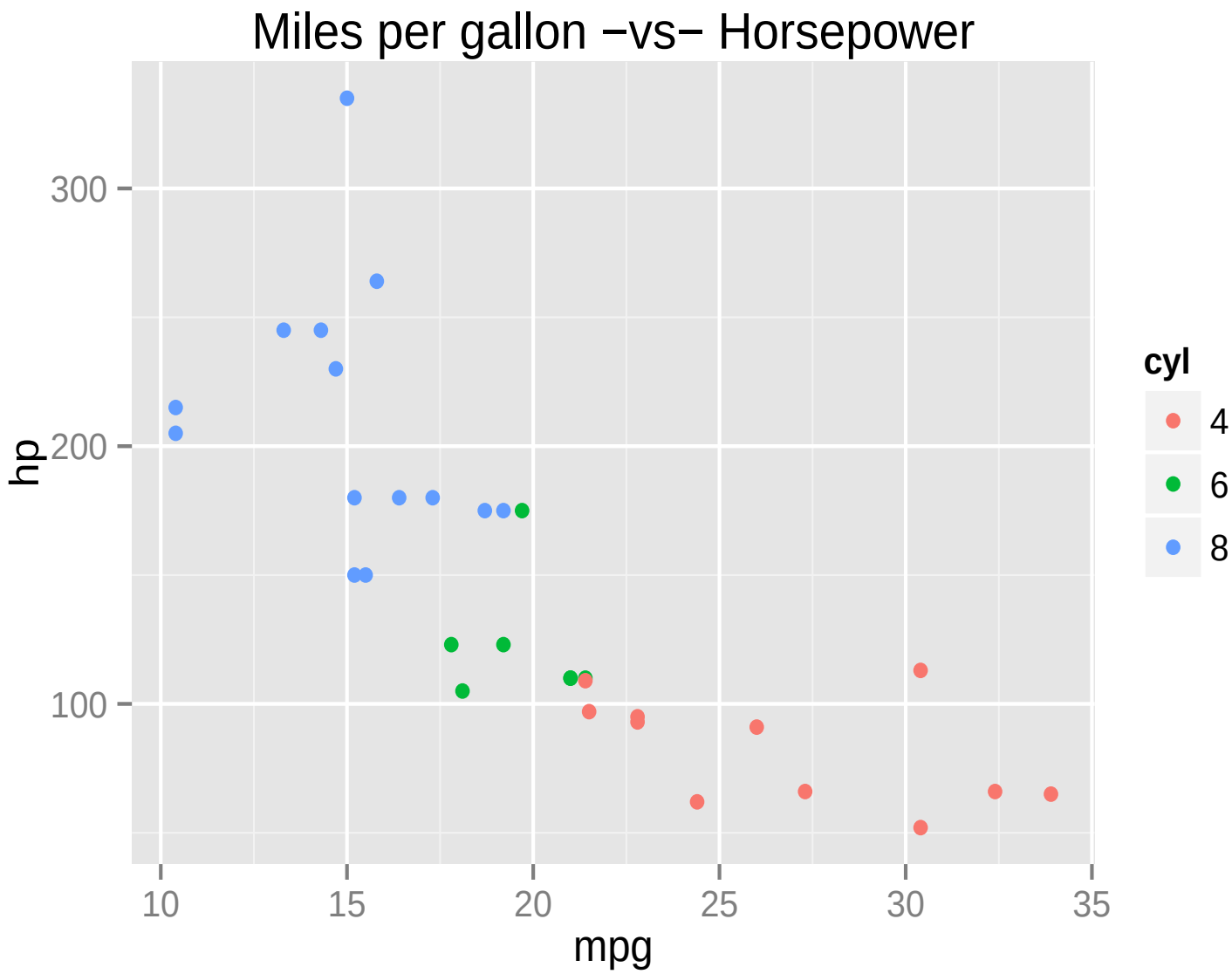
Resources for "ggplot2"

- Documentation: http://docs.ggplot2.org/
- Book: **ggplot2: Elegant Graphics for Data Analysis** (by Hadley Wickham)
- Book: **R Graphics Cookbook** (by Winston Chang)

```
install.packages("ggplot2")
library(ggplot2)
```

About "ggplot2"

- "ggplot2" (by Hadley Wickham) is an R package for producing statistical graphics
- It provides a framework based on Leland Wilkinson's **Grammar of Graphics**
- "ggplot2" provides beautiful plots while taking care of fiddly details like legends, axes, colors, etc.
- "ggplot2" is built on the R graphics package "grid"
- Underlying philosophy is to describe a wide range of graphics with a compact syntax and independent components


Miles per gallon −vs− Horsepower
hp
300
200
100
10
15
20
25
30
35
mpg
cyl
4
6
8

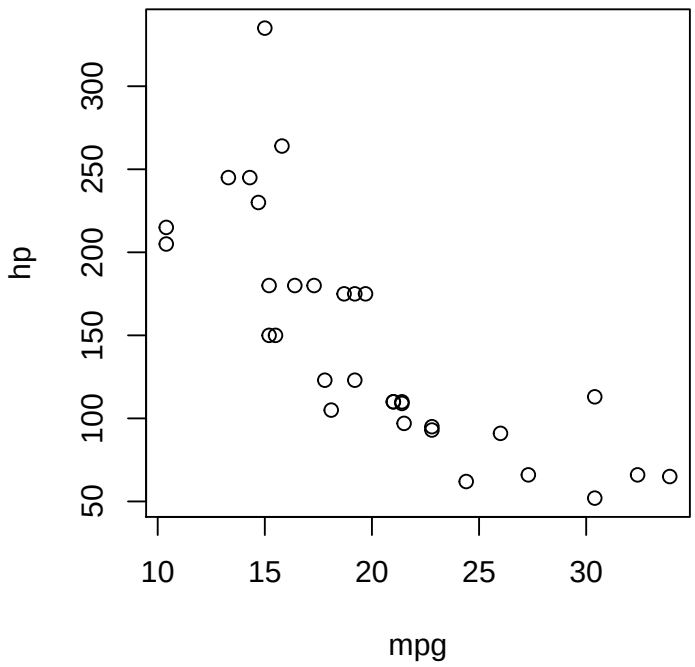
R package "ggplot2"

About "ggplot2"

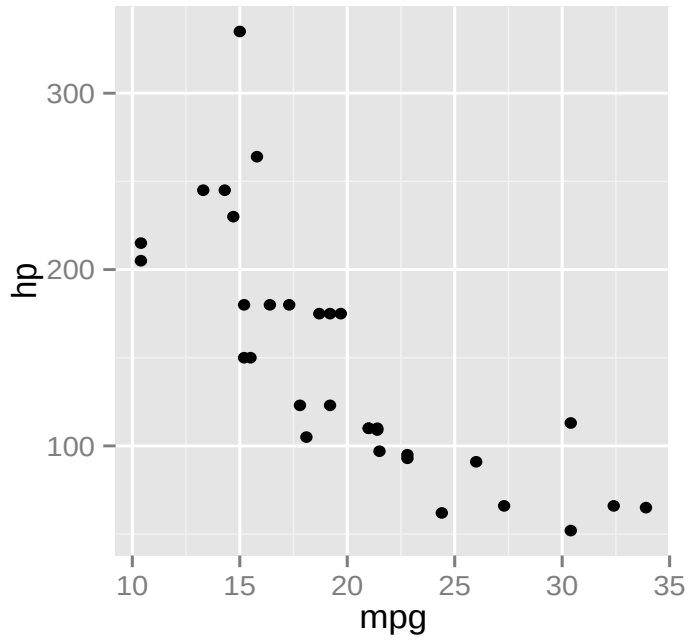
- Default appearance of plots carefully chosen
- Designed with visual perception in mind
- Inclusion of some components, like legends, are automated
- Great flexibility for annotating, editing, and embedding output

Base graphics -vs- "ggplot2"

base graphics



ggplot2



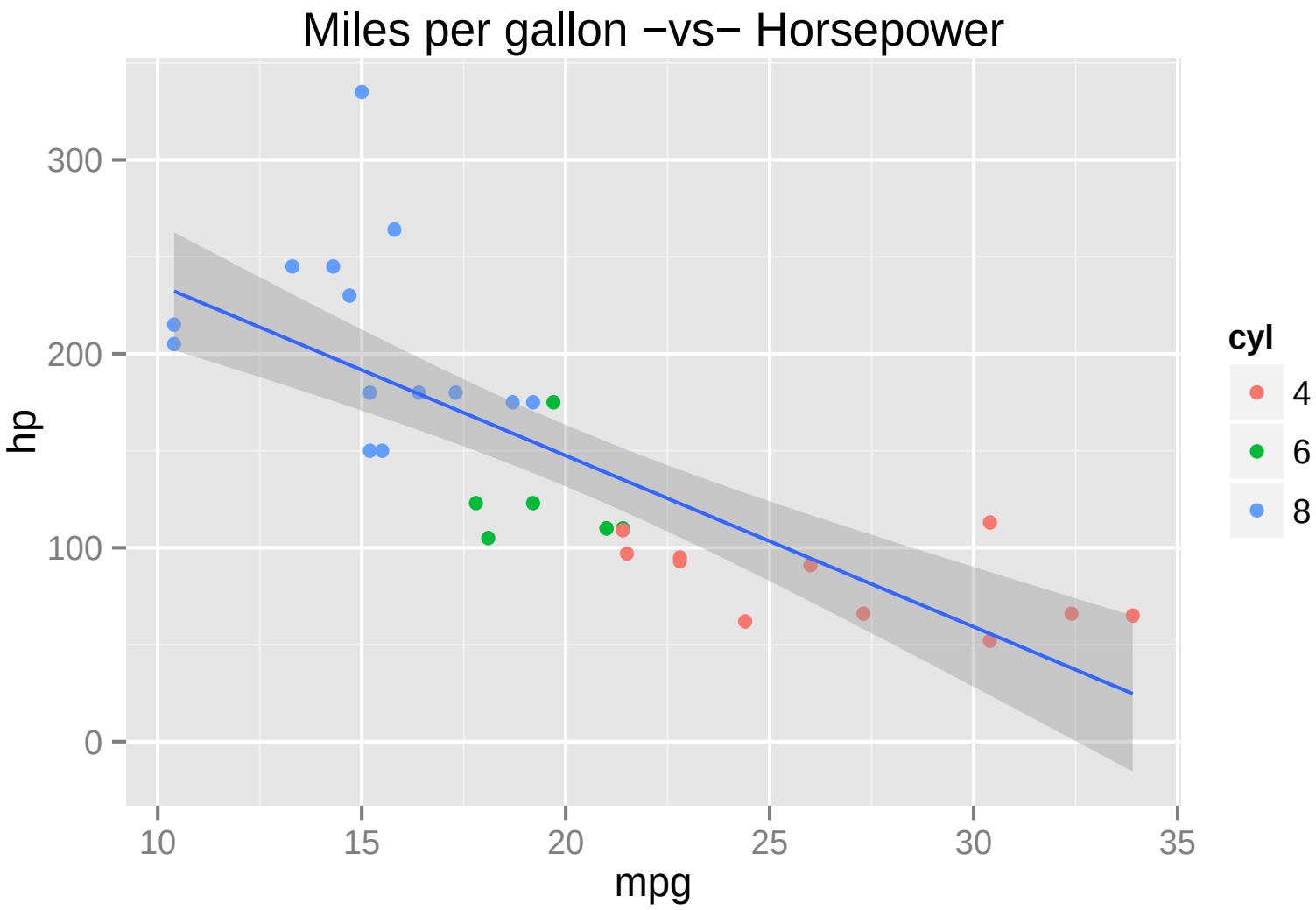
Preliminary Concepts

Grammar of Graphics

About `"ggplot2"`

- The gg in `"ggplot2"` stands for *Grammar of Graphics*
- `"ggplot2"` has a deep underlying grammar
- inspired in the **Grammar of Graphics** by Lee Wilkinson
- Grammar of Graphics describes the features that underlie all statistical graphics

What is a statistical graphic?



What is a statistical graphic?

```
##                    mpg   hp  cyl
## Mazda RX4         21.0  110    6
## Mazda RX4 Wag     21.0  110    6
## Datsun 710        22.8   93    4
## Hornet 4 Drive    21.4  110    6
## Hornet Sportabout 18.7  175    8
## Valiant           18.1  105    6
## Duster 360        14.3  245    8
## Merc 240D         24.4   62    4
## Merc 230          22.8   95    4
## Merc 280          19.2  123    6
```

What is a statistical graphic?

Simply put, a statistical graphic is:

- A mapping from data to aesthetic attributes (color, shape, size) of geometric objects (points, lines, bars)
- A plot may also contain statistical transformations of the data
- A plot is drawn on a specific coordinate system
- Sometimes faceting can be used to get the same plot for different subsets of the dataset

What is a statistical graphic?

Simply put, a statistical graphic is:

A mapping from **data** to **aesthetic attributes** (color, shape, size) of **geometric objects** (points, lines, bars)

What is a statistical graphic?

Simply put, a statistical graphic is:

A mapping from **data** to **aesthetic attributes** (color, shape, size) of **geometric objects** (points, lines, bars)

- `ggplot(data, ...)`
- `aes()`
- `geom_objects()`

Starting with "ggplot2"

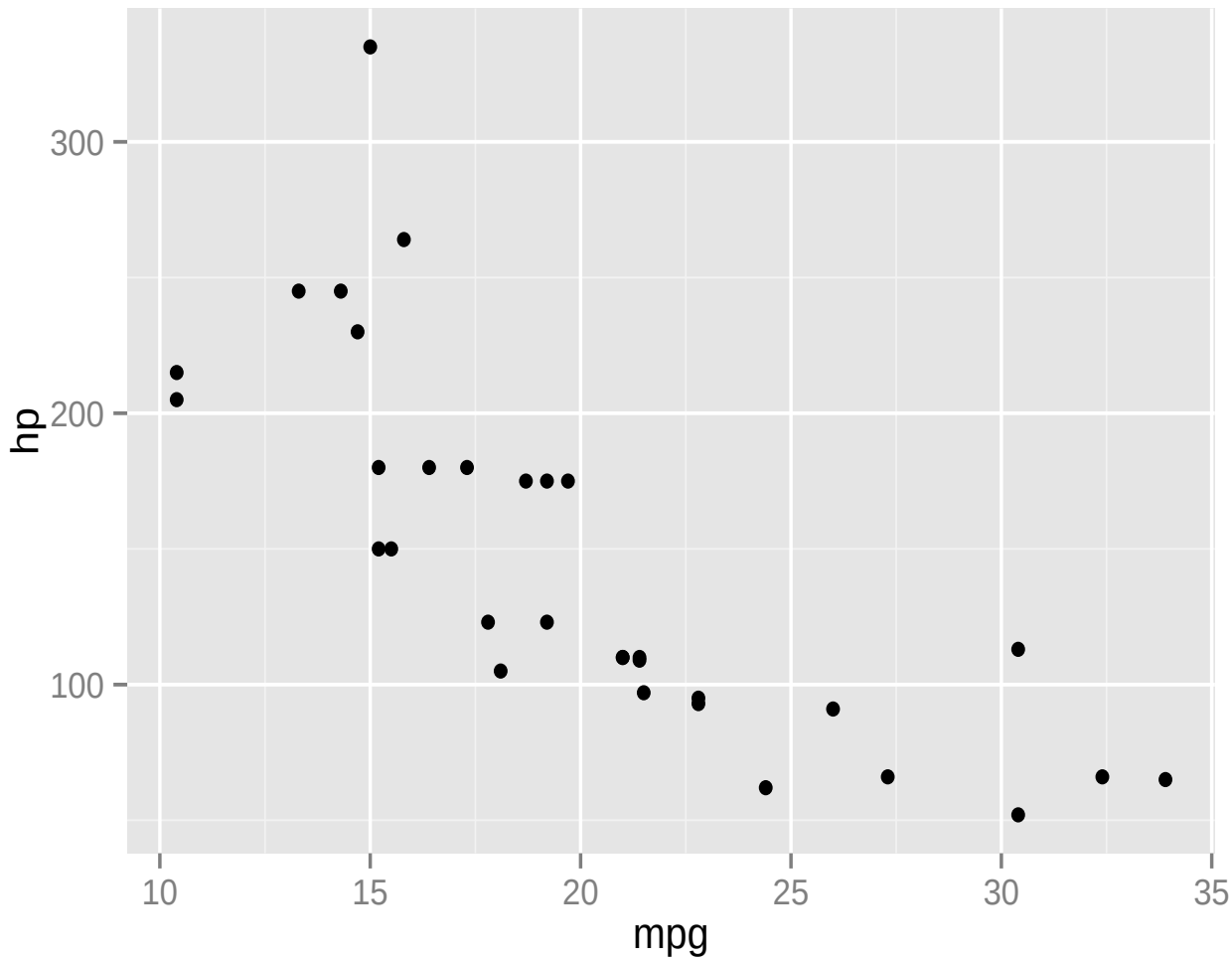
mtcars dataset

```
head(mtcars, n = 10)
```

```
##                    mpg cyl  disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4         21.0   6 160.0 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag     21.0   6 160.0 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710        22.8   4 108.0  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive    21.4   6 258.0 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
## Valiant           18.1   6 225.0 105 2.76 3.460 20.22  1  0    3    1
## Duster 360        14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
## Merc 240D         24.4   4 146.7  62 3.69 3.190 20.00  1  0    4    2
## Merc 230          22.8   4 140.8  95 3.92 3.150 22.90  1  0    4    2
## Merc 280          19.2   6 167.6 123 3.92 3.440 18.30  1  0    4    4
```

Scatter plot (Option 1)

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point()
```



How does it work?

We specify the data and variables inside the function `ggplot()`. Note the use of the internal function `aes()` to *map* `x` to `mpg`, and `y` to `hp`.

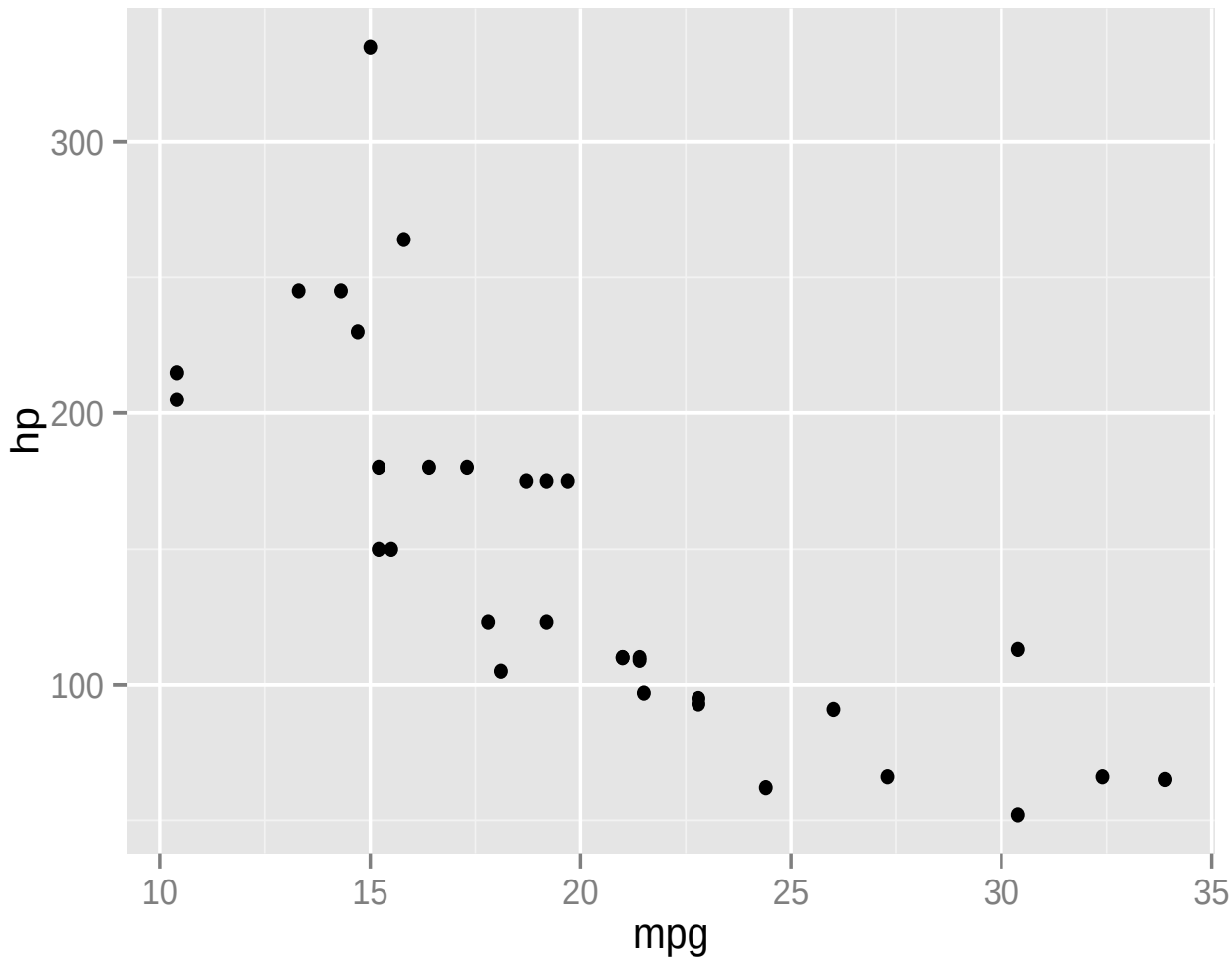
```
ggplot(data = mtcars, aes(x = mpg, y = hp))
```

Then we add a layer of geometric objects: points in this case. Note the use of `"+"` to **add** the layer to the plot

```
+ geom_point()
```

Scatter plot (Option 2)

```
ggplot(data = mtcars) +
  geom_point(aes(x = mpg, y = hp))
```



"ggplot2" basics

- The data must be in a `data.frame`
- Variables are mapped to aesthetic attributes
- Aesthetic attributes belong to geometric objects **geoms** (points, lines, polygons)

Basic Terminology

- **ggplot()** - The main function where you specify the dataset and variables to plot
- **geoms** - geometric objetcs
  - `geom_point()`, `geom_bar()`, `geom_line()`, `geom_density()`
- **aes** - aesthetics
  - shape, color, fill, linetype

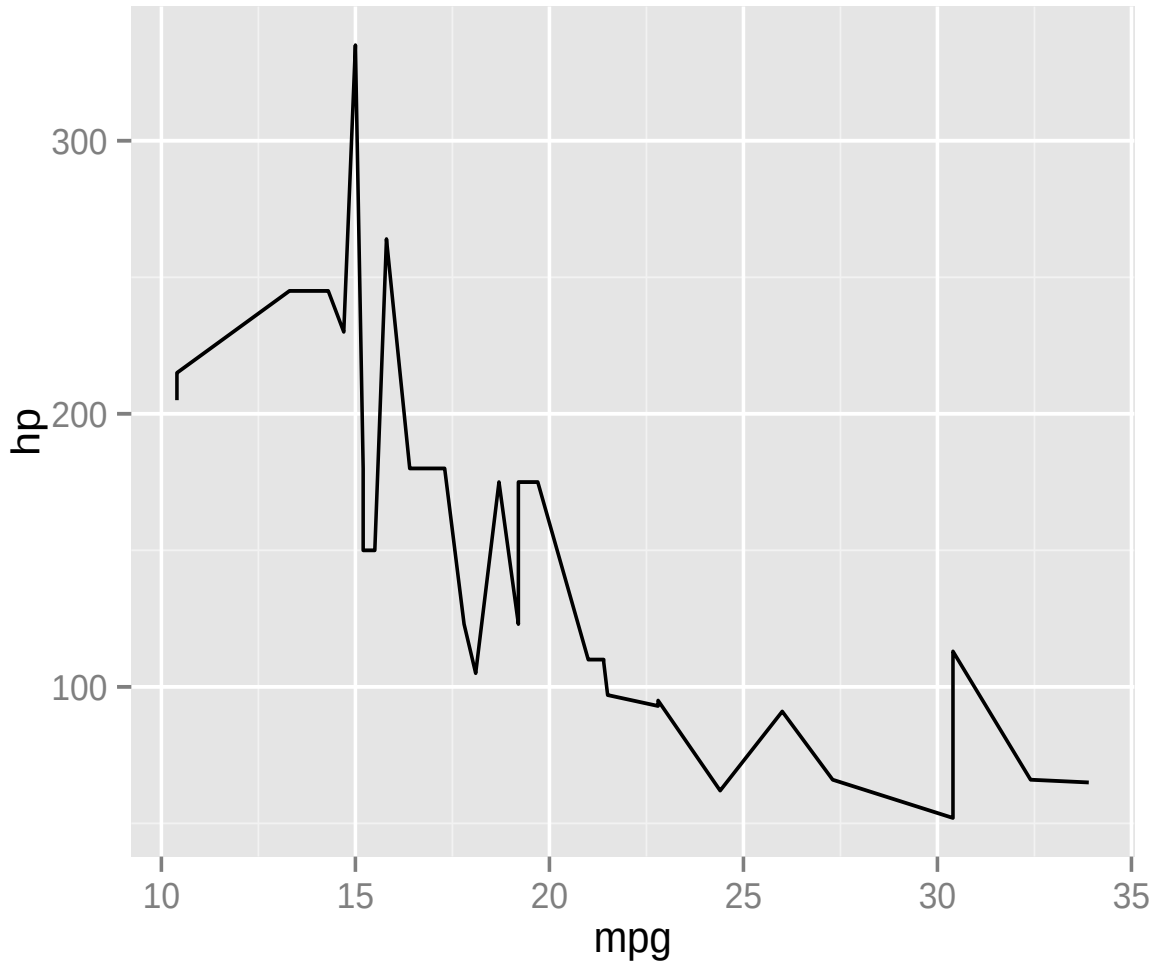
Warning

"ggplot2" comes with the function `qplot()` (i.e. *quick plot*). Avoid using it!

As Karthik Ram says: "you'll end up unlearning and relearning a good bit"

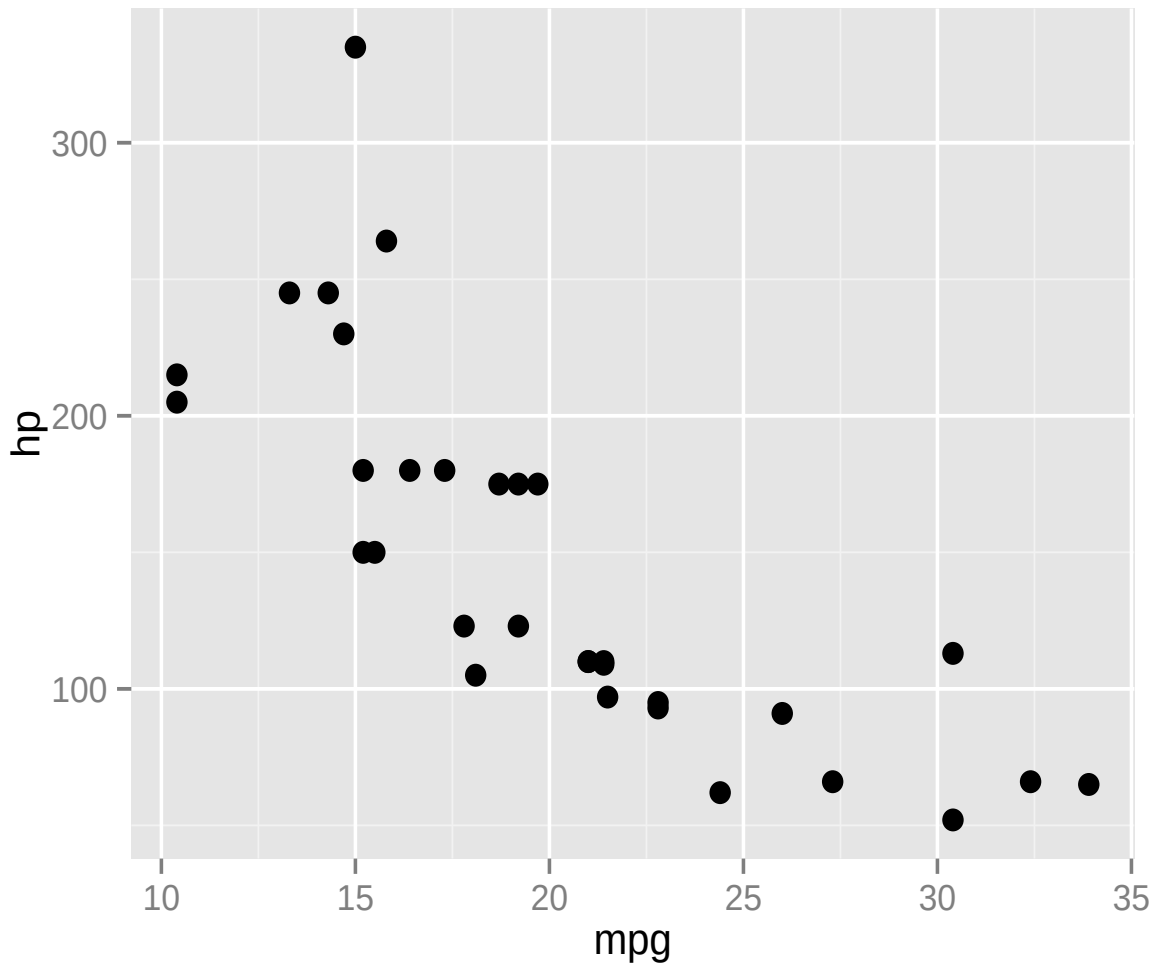
Another geom

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_line()
```



Increase size of points

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3)
```



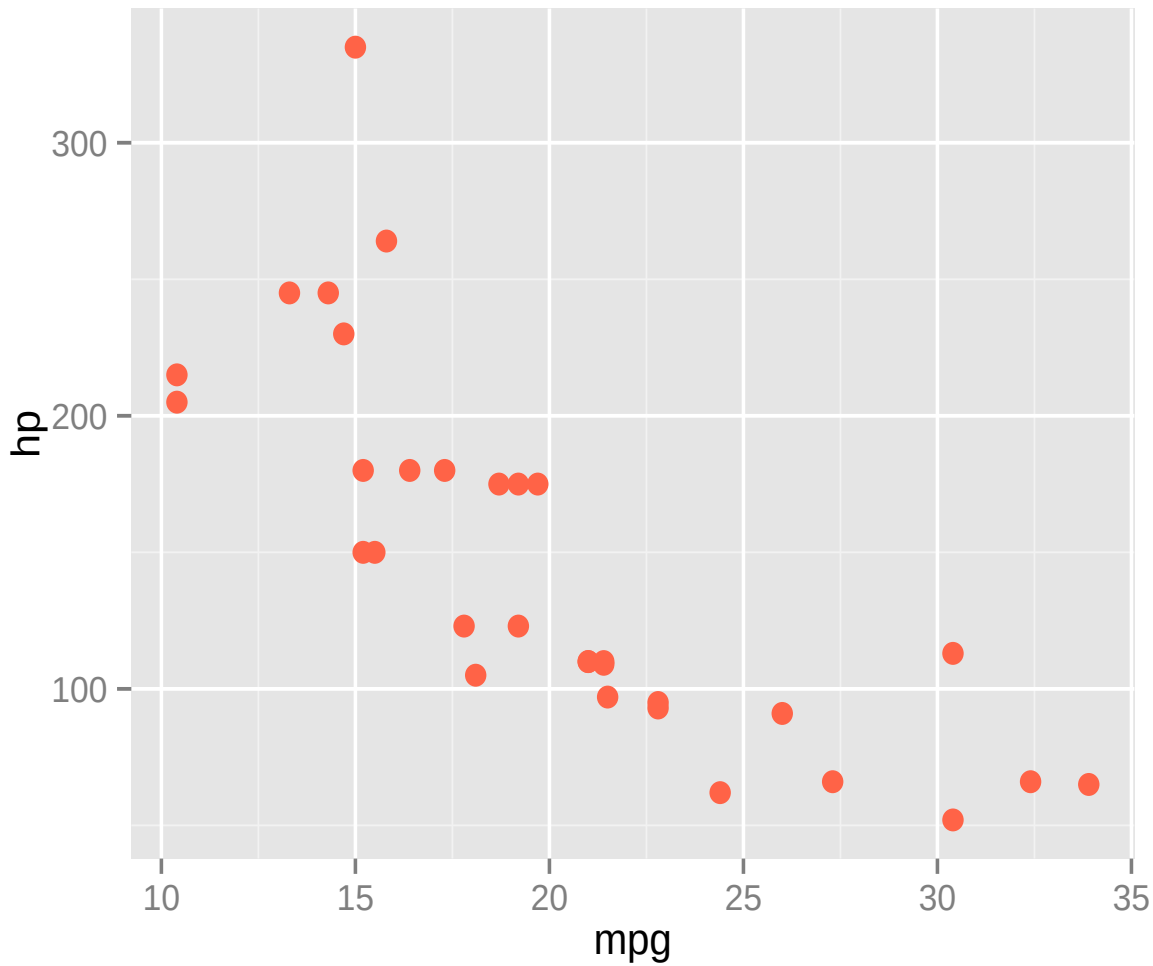
How does it work?

To increase the size of points, we **set** the aesthetic `size` to a constant value of 3 (inside the *geoms* function):

```
+ geom_point(size = 3)
```

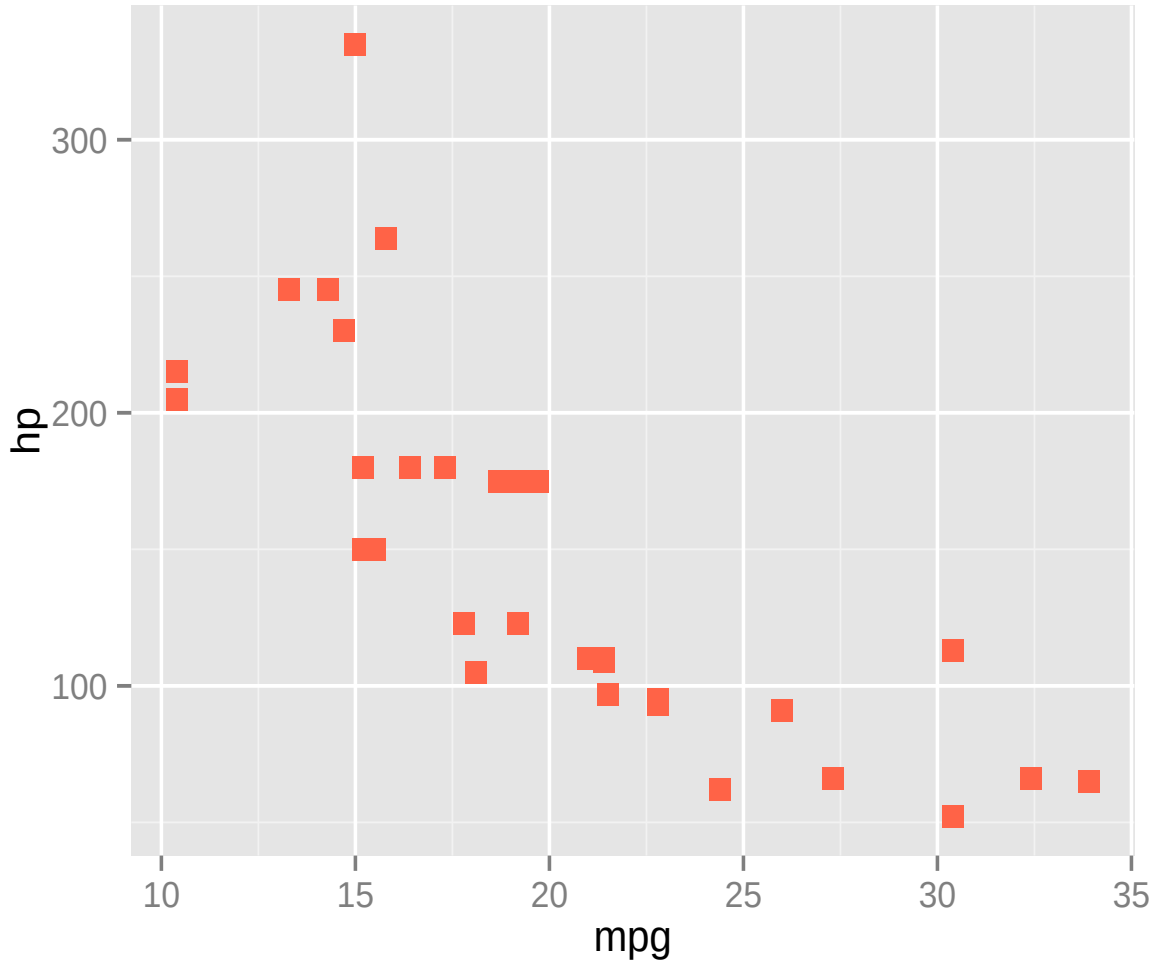
Adding color

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "tomato")
```



Changing points shape

```
# 'shape' accepts 'pch' values
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "tomato", shape = 15)
```



Setting and Mapping

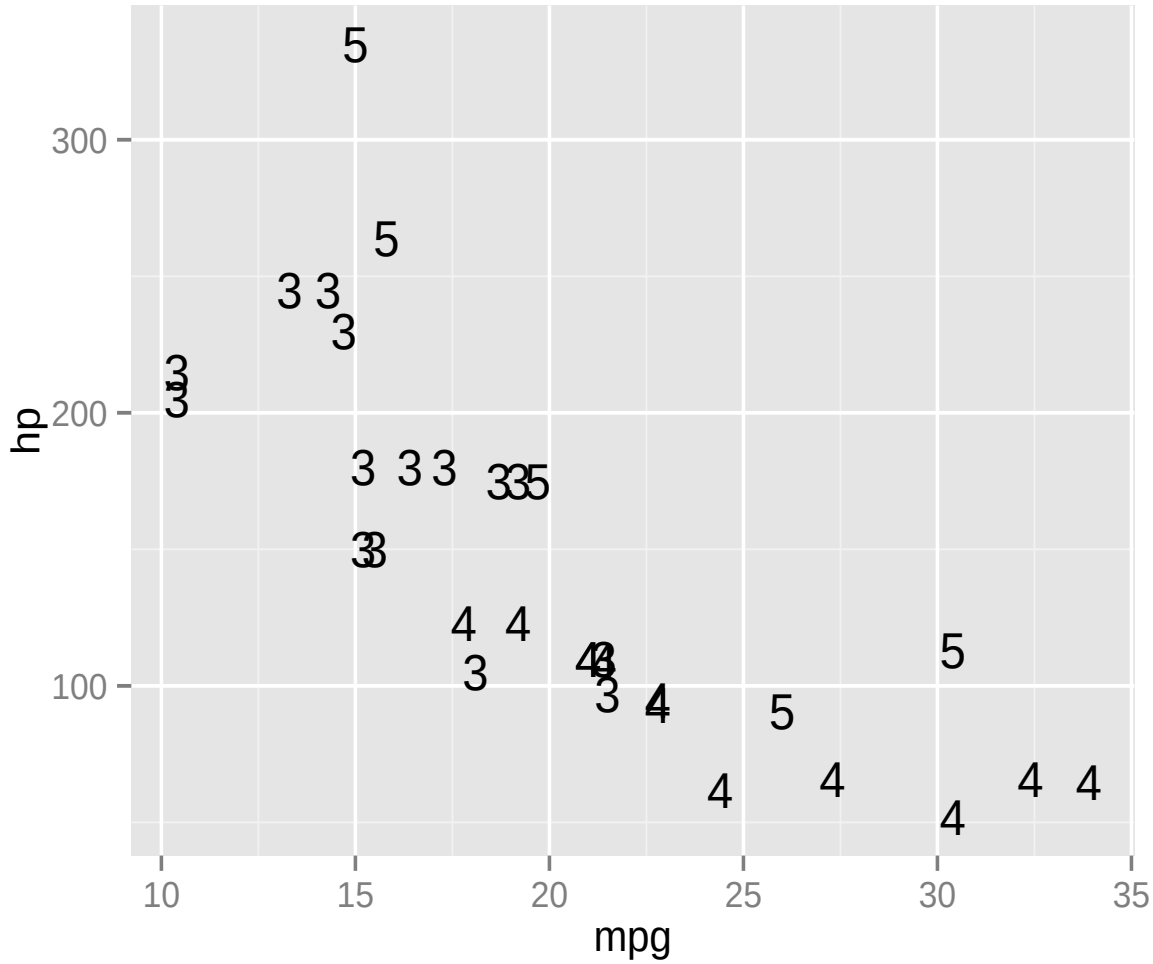
Aesthetic attributes can be either **mapped** —via `aes()`— or **set**

```
# mapping aesthetic color
ggplot(mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = cyl))

# setting aesthetic color
ggplot(mtcars, aes(x = mpg, y = hp)) +
  geom_point(color = "blue")
```

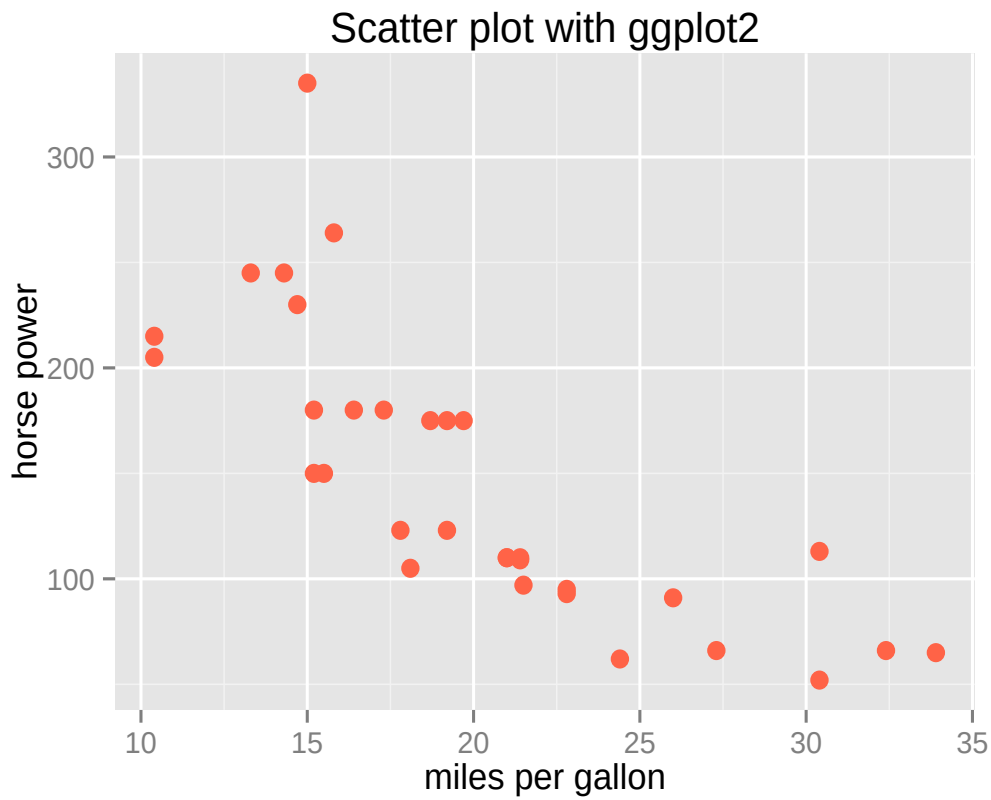
Geom text, and mapping labels

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_text(aes(label = gear))
```



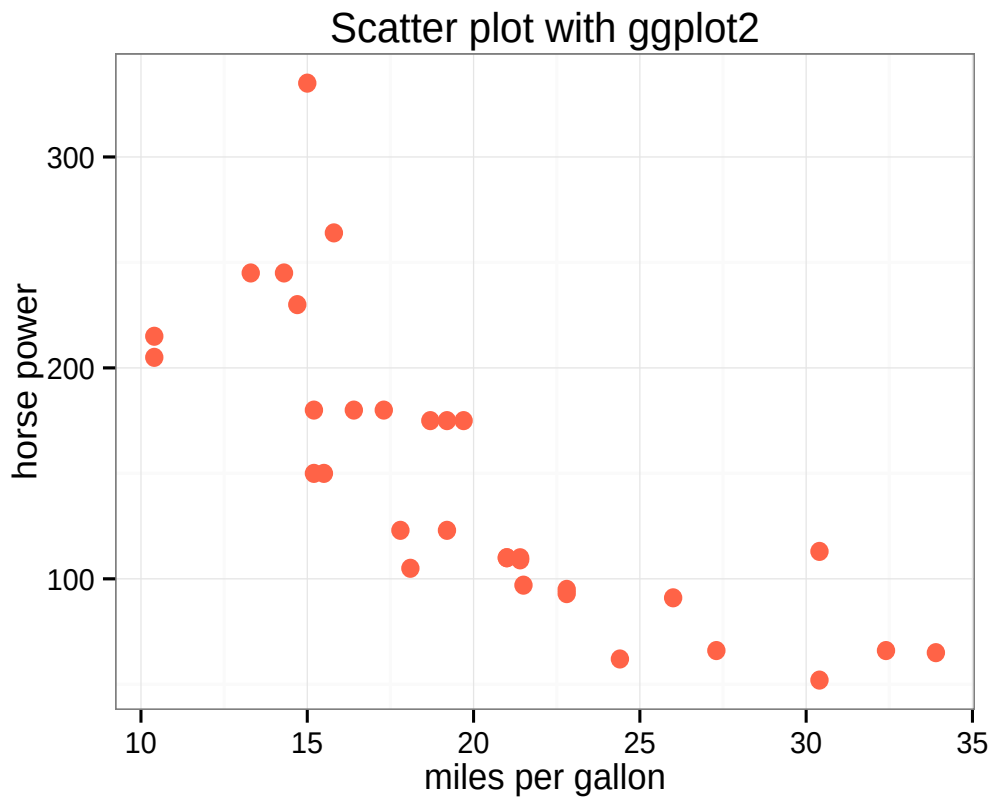
Changing axis labels and title

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "tomato") +
  xlab("miles per gallon") +
  ylab("horse power") +
  ggtitle("Scatter plot with ggplot2")
```

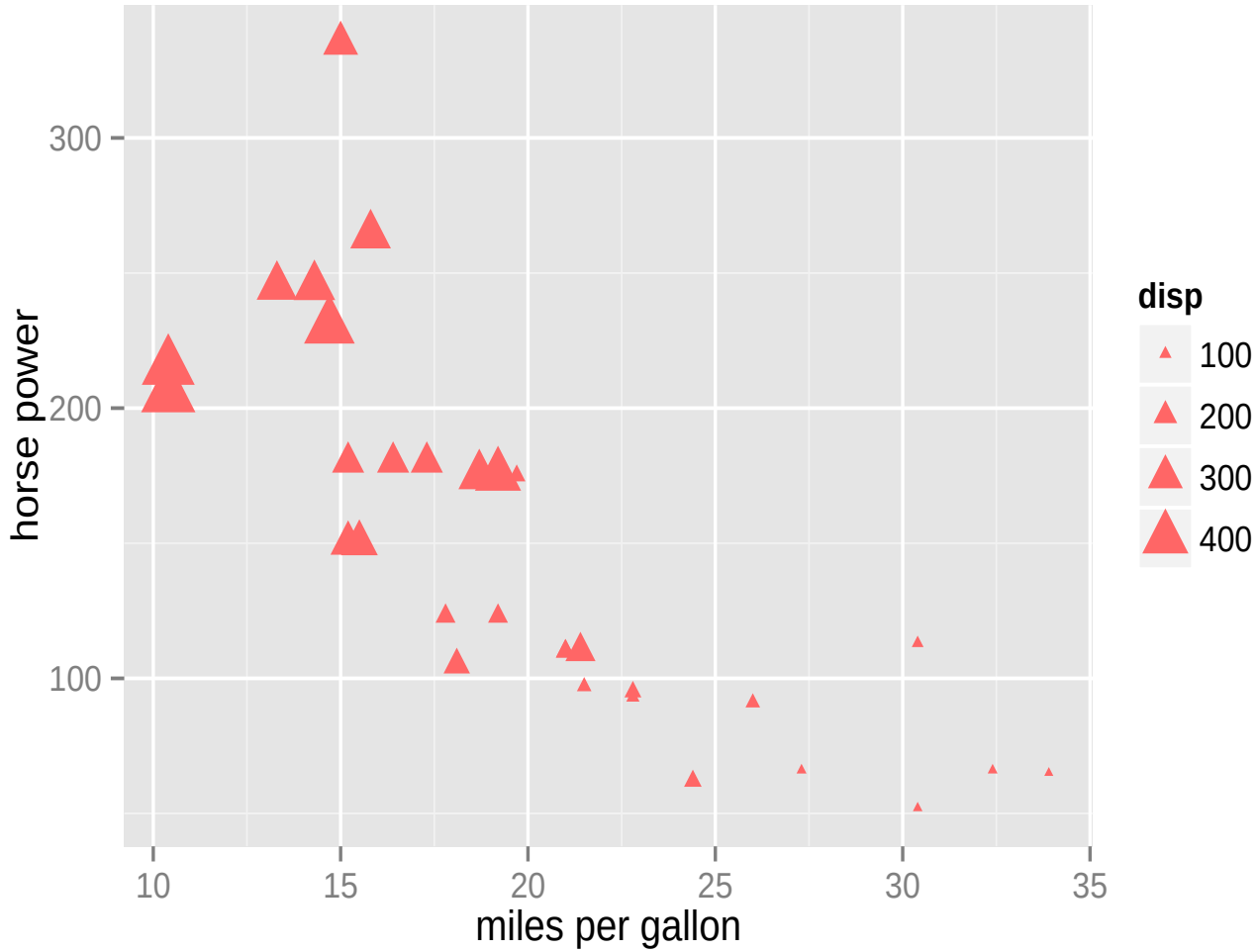


Changing background theme

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "tomato") +
  xlab("miles per gallon") +
  ylab("horse power") +
  ggtitle("Scatter plot with ggplot2") +
  theme_bw()
```



Your turn: Replicate this figure



Your turn: Replicate this figure

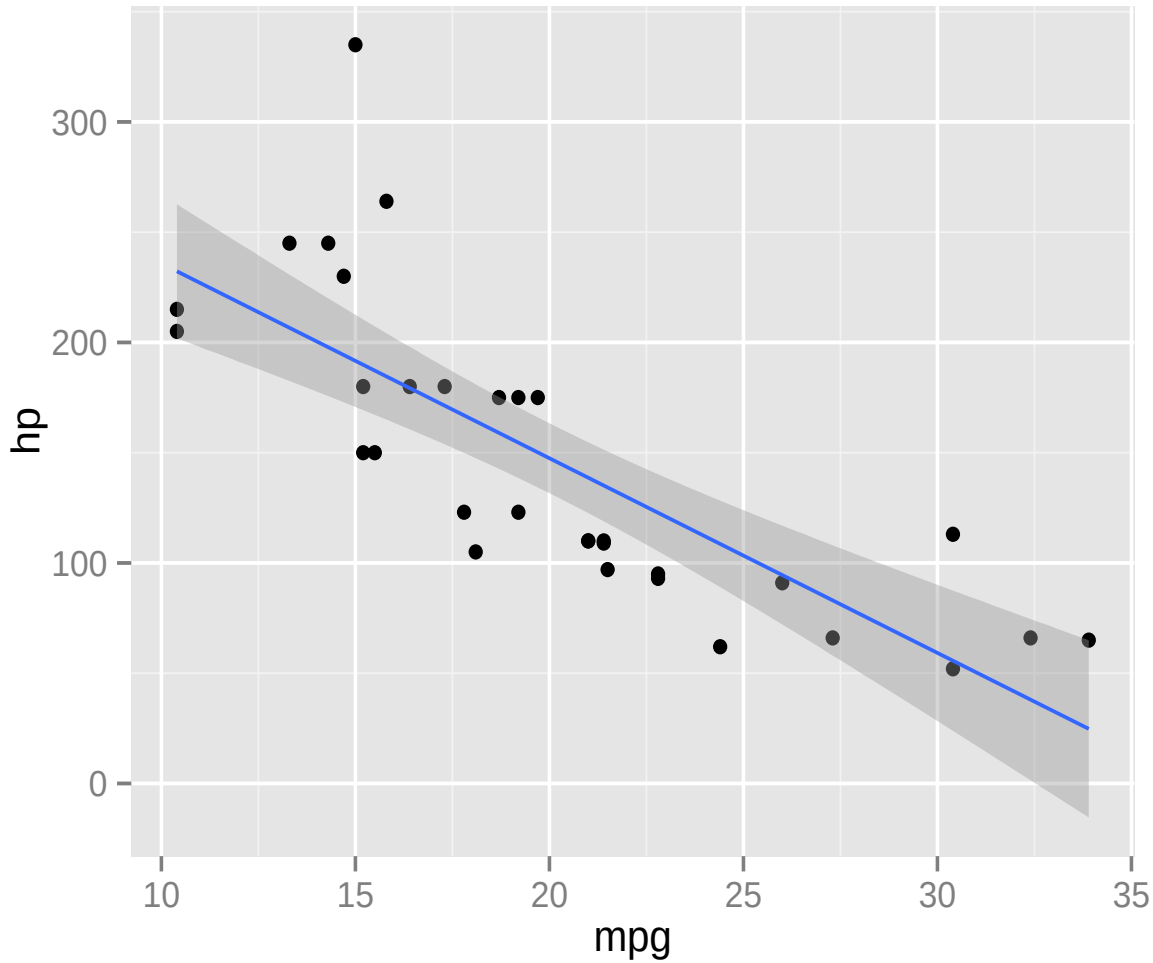
- Specify a color in hex notation
- Change the shape of the point symbol
- Map `disp` to attribute size of points
- Add axis labels

Your turn

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(size = disp),
             color = "#ff6666", shape = 17) +
  xlab("miles per gallon") +
  ylab("horse power")
```

More geoms

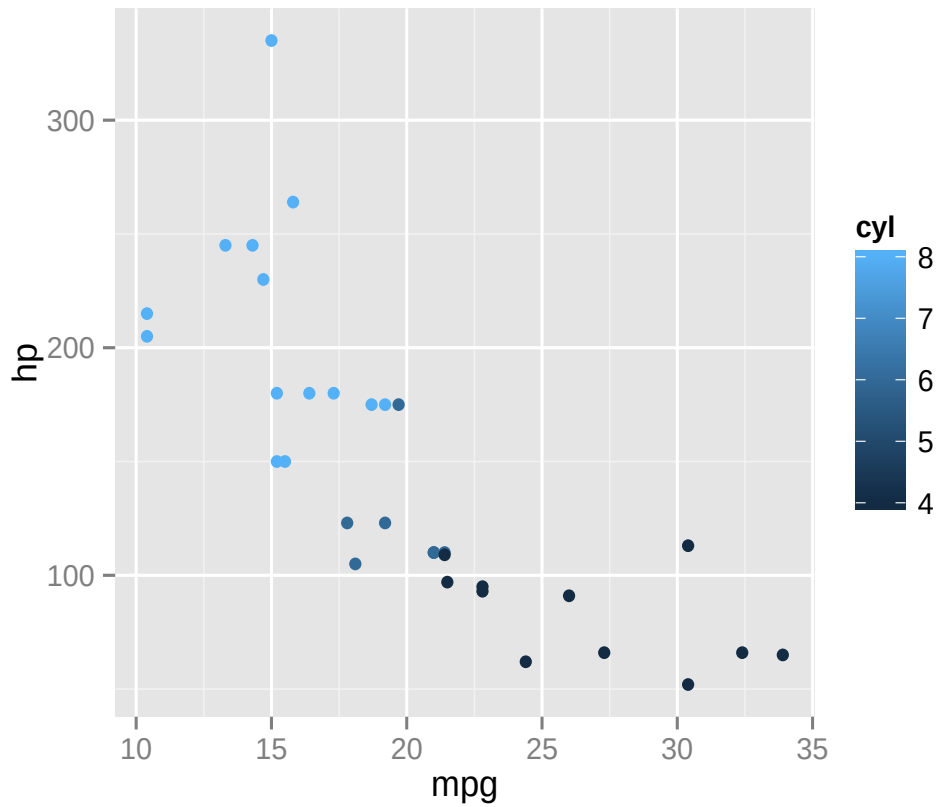
```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point() +
  geom_smooth(method = "lm")
```



More geoms

We can map variable to a color aesthetic. Here we map `color` to `cyl` (cylinders)

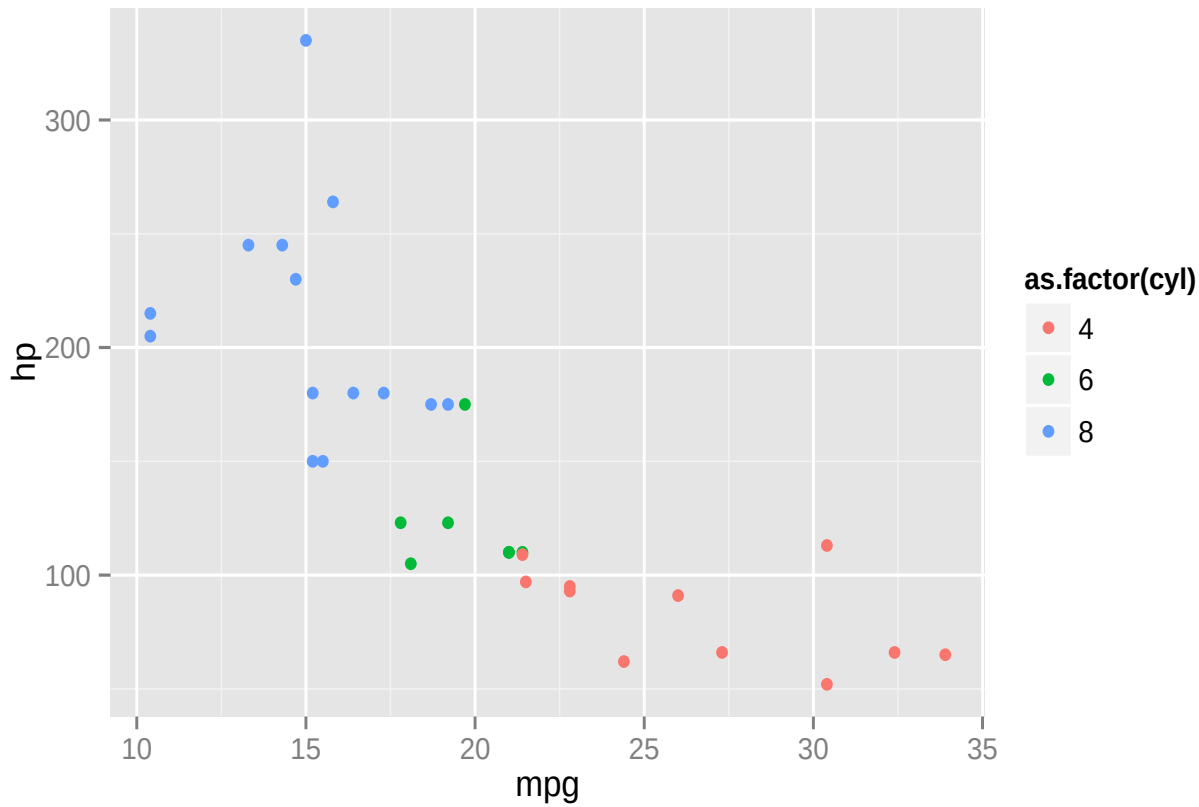
```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = cyl))
```



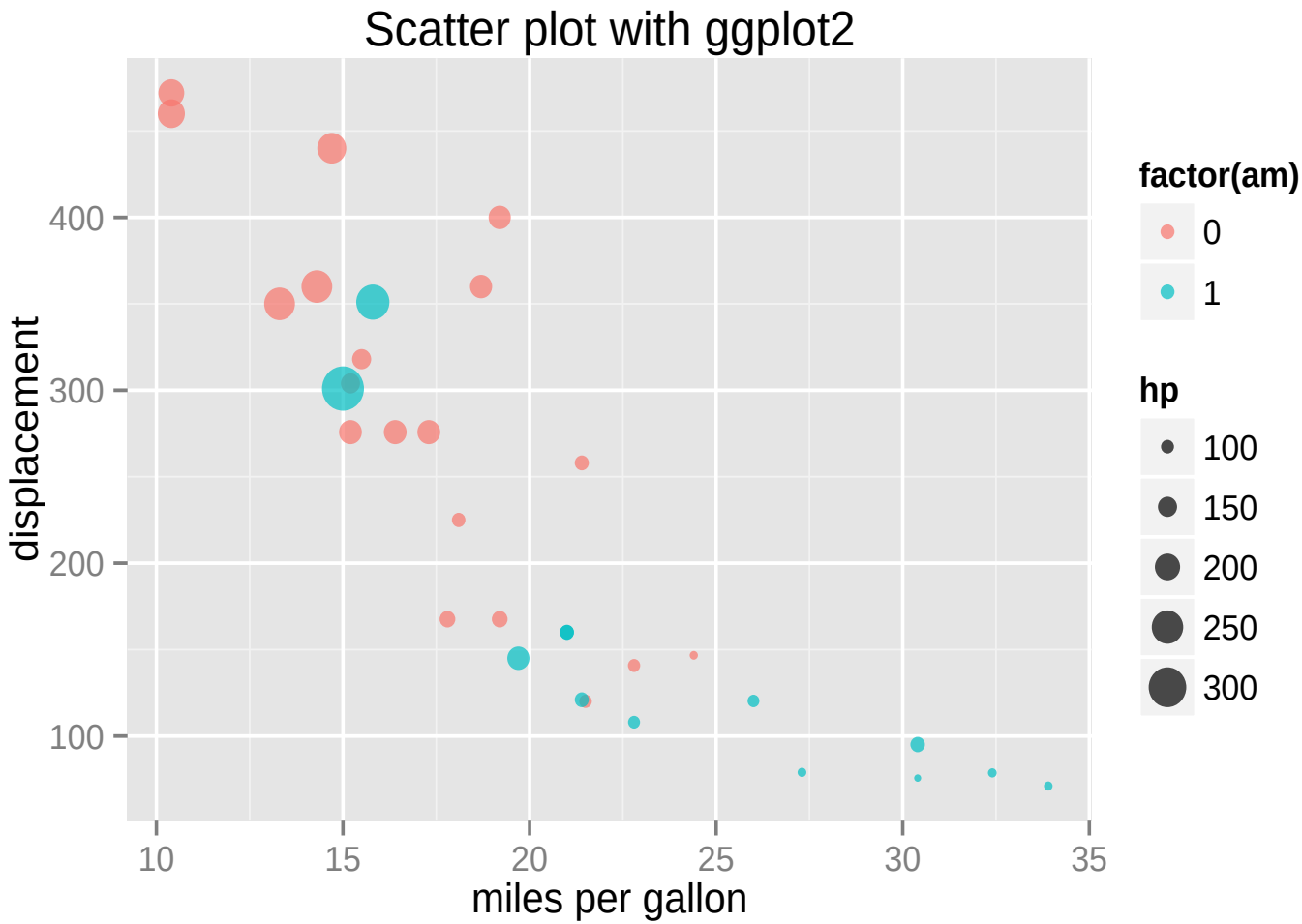
More geoms

If the variable that maps to color is a factor, then the color scale will change

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = as.factor(cyl)))
```



Your turn: Replicate this figure



Your turn: example 2

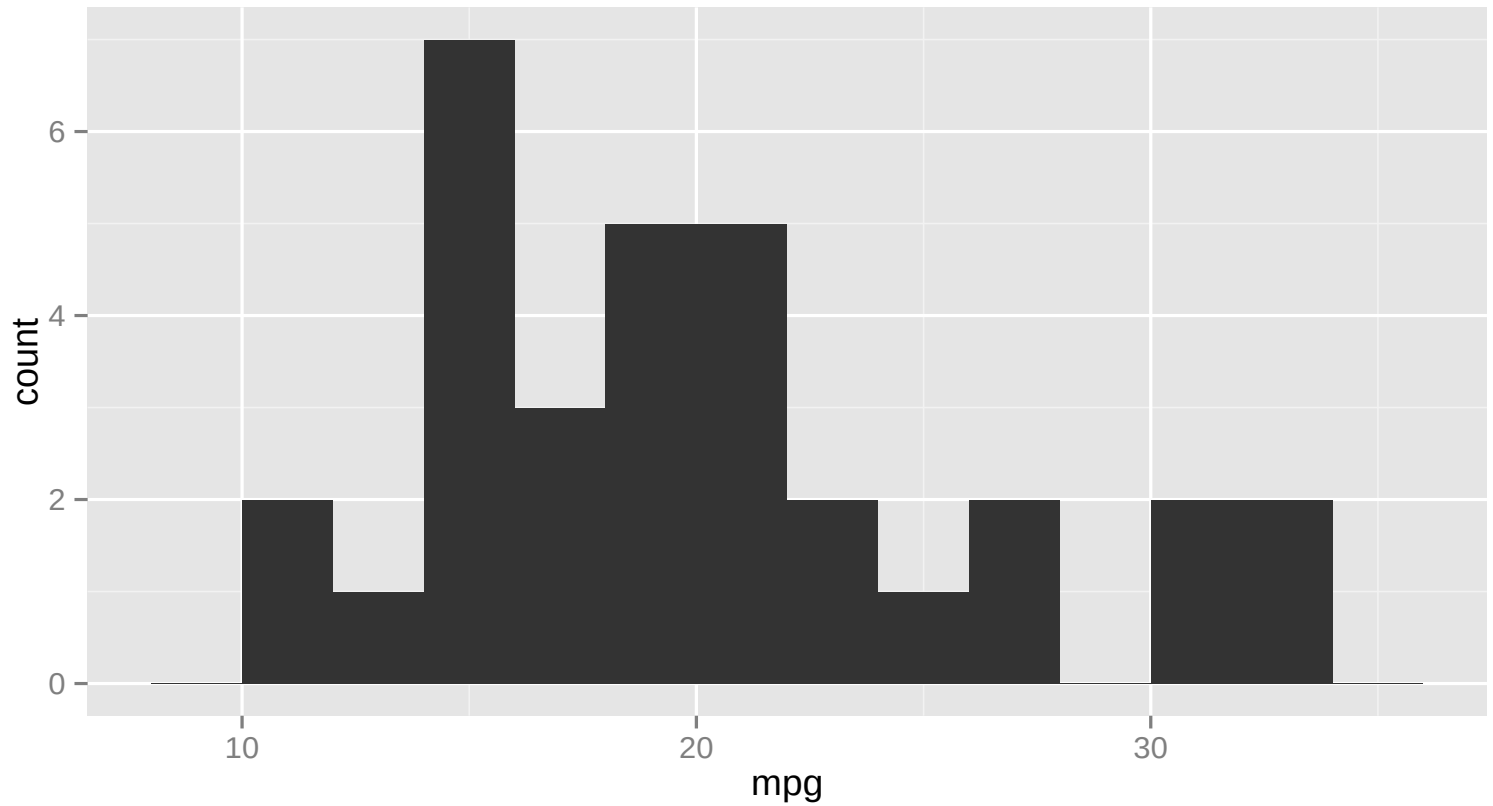
- Map `hp` to attribute size of points
- Map `am` (as factor) to attribute color points
- Add an alpha transparency of 0.7
- Change the shape of the point symbol
- Add axis labels
- Add a title

Your turn: example 2

```
ggplot(data = mtcars, aes(x = mpg, y = disp)) +
  geom_point(aes(size = hp, color = factor(am)),
             alpha = 0.7) +
  xlab("miles per gallon") +
  ylab("displacement") +
  ggtitle("Scatter plot with ggplot2")
```

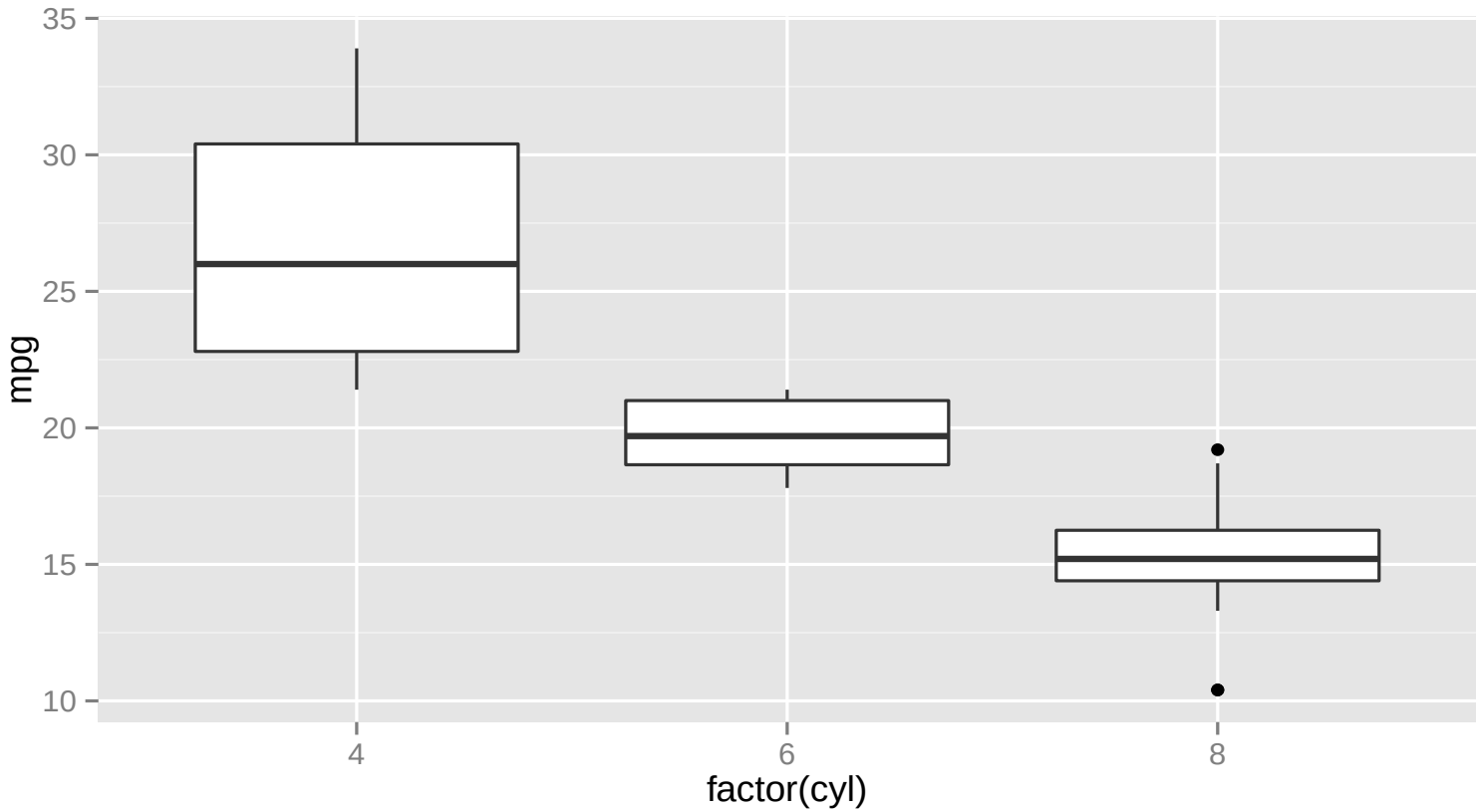
Histogram

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_histogram(binwidth = 2)
```



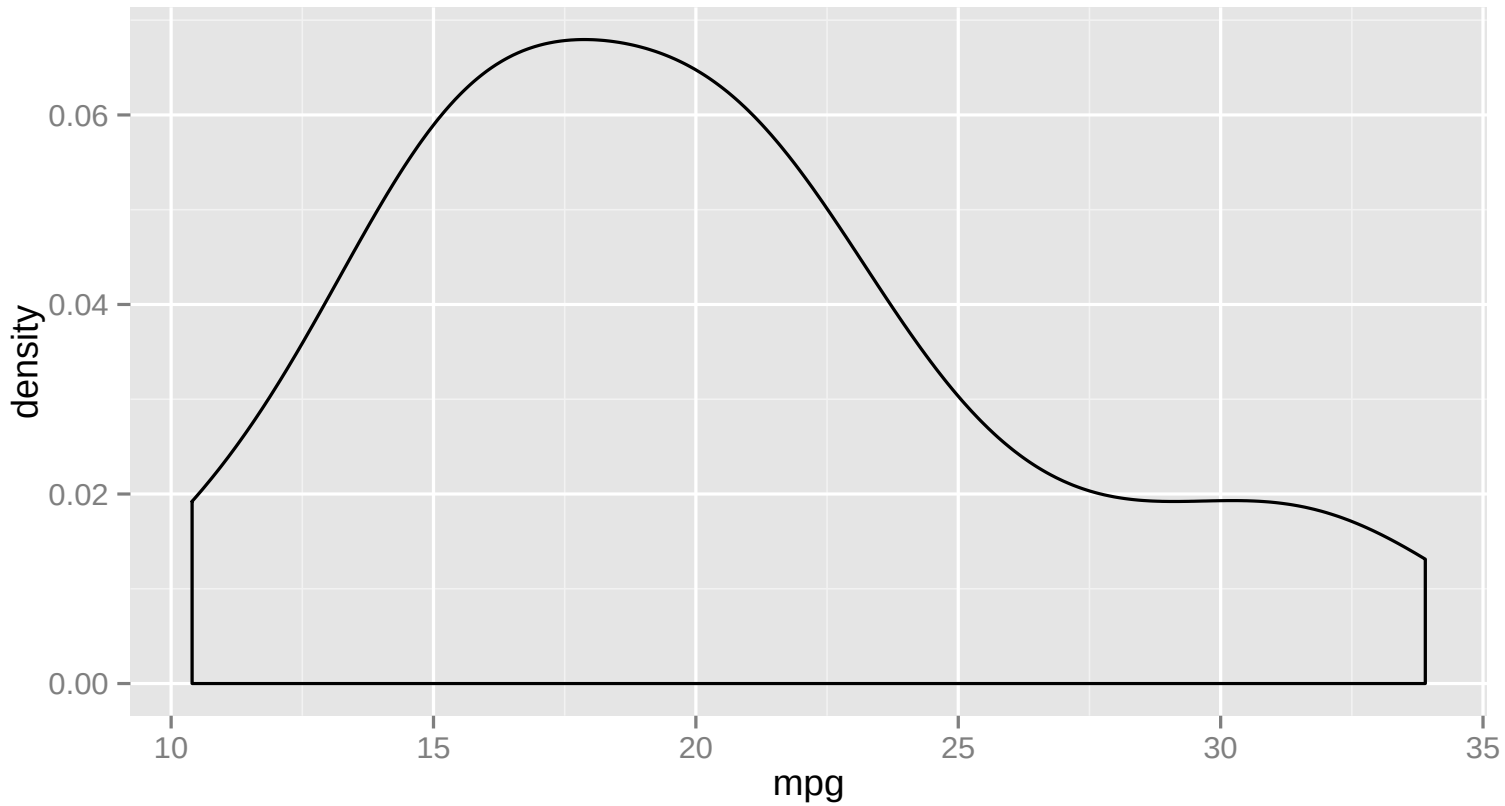
Boxplots

```
ggplot(data = mtcars, aes(x = factor(cyl), y = mpg)) +
  geom_boxplot()
```



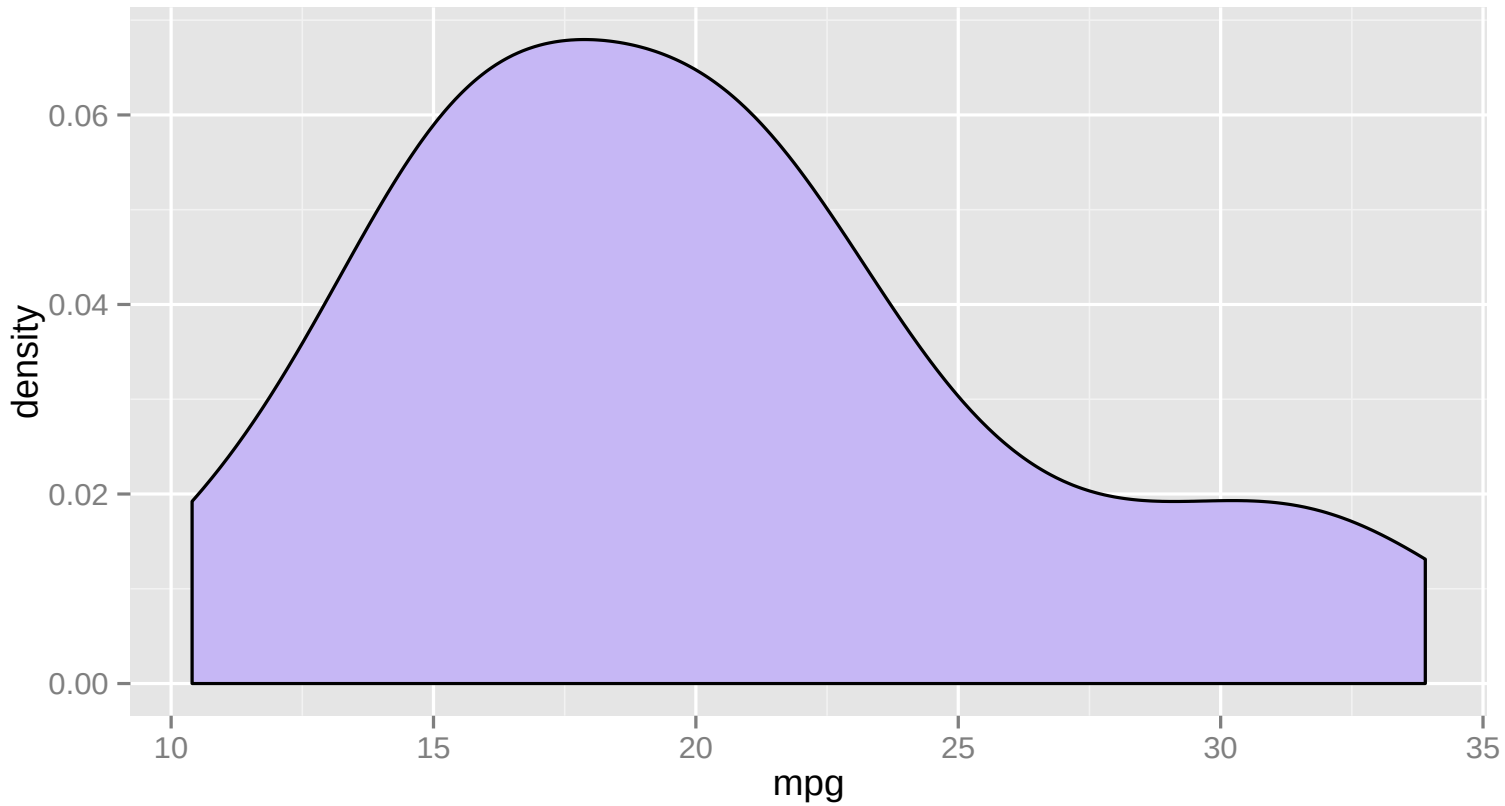
Density Curves

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_density()
```



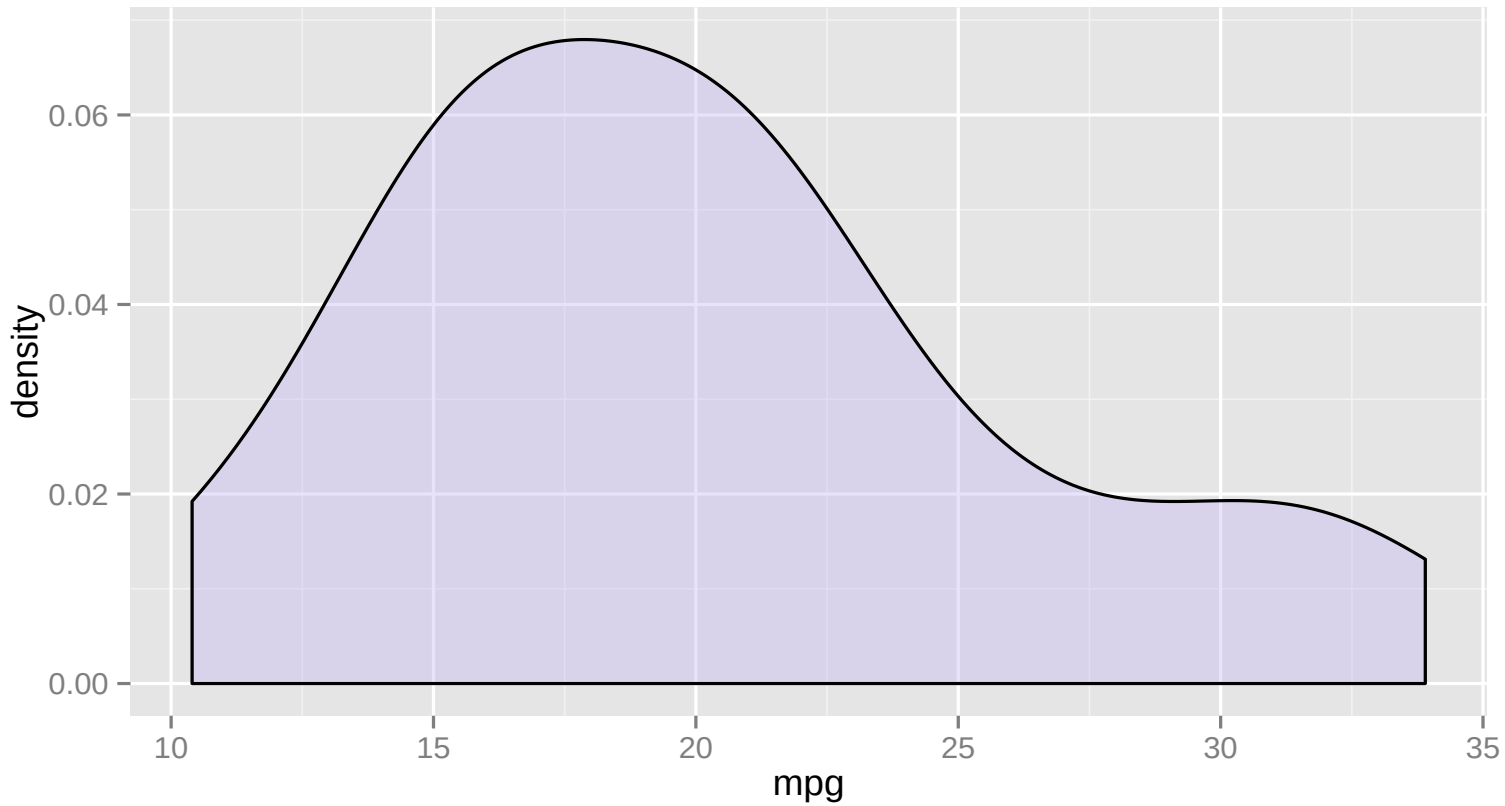
Density Curves

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_density(fill = "#c6b7f5")
```



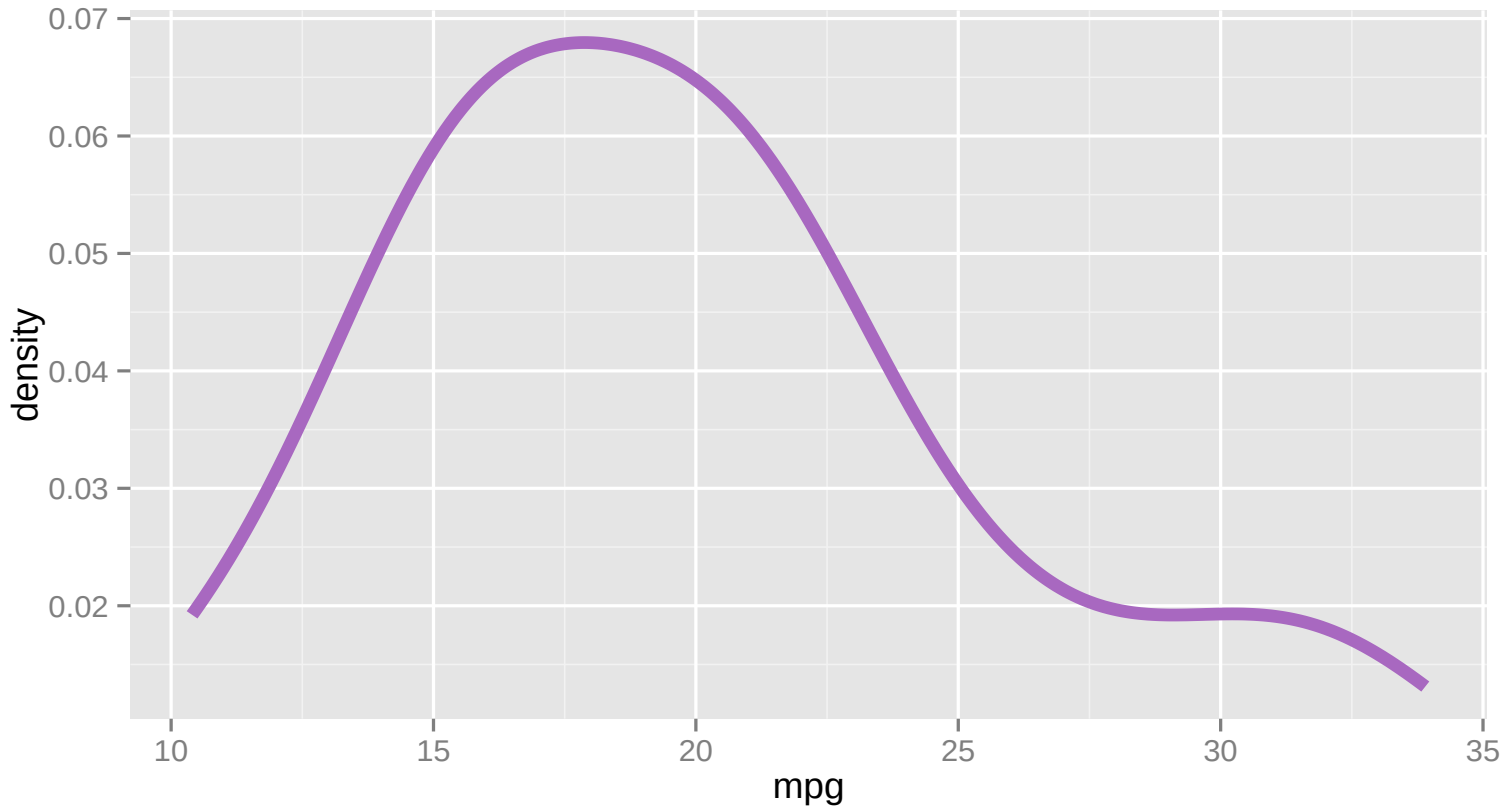
Density Curves

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_density(fill = "#c6b7f5", alpha = 0.4)
```



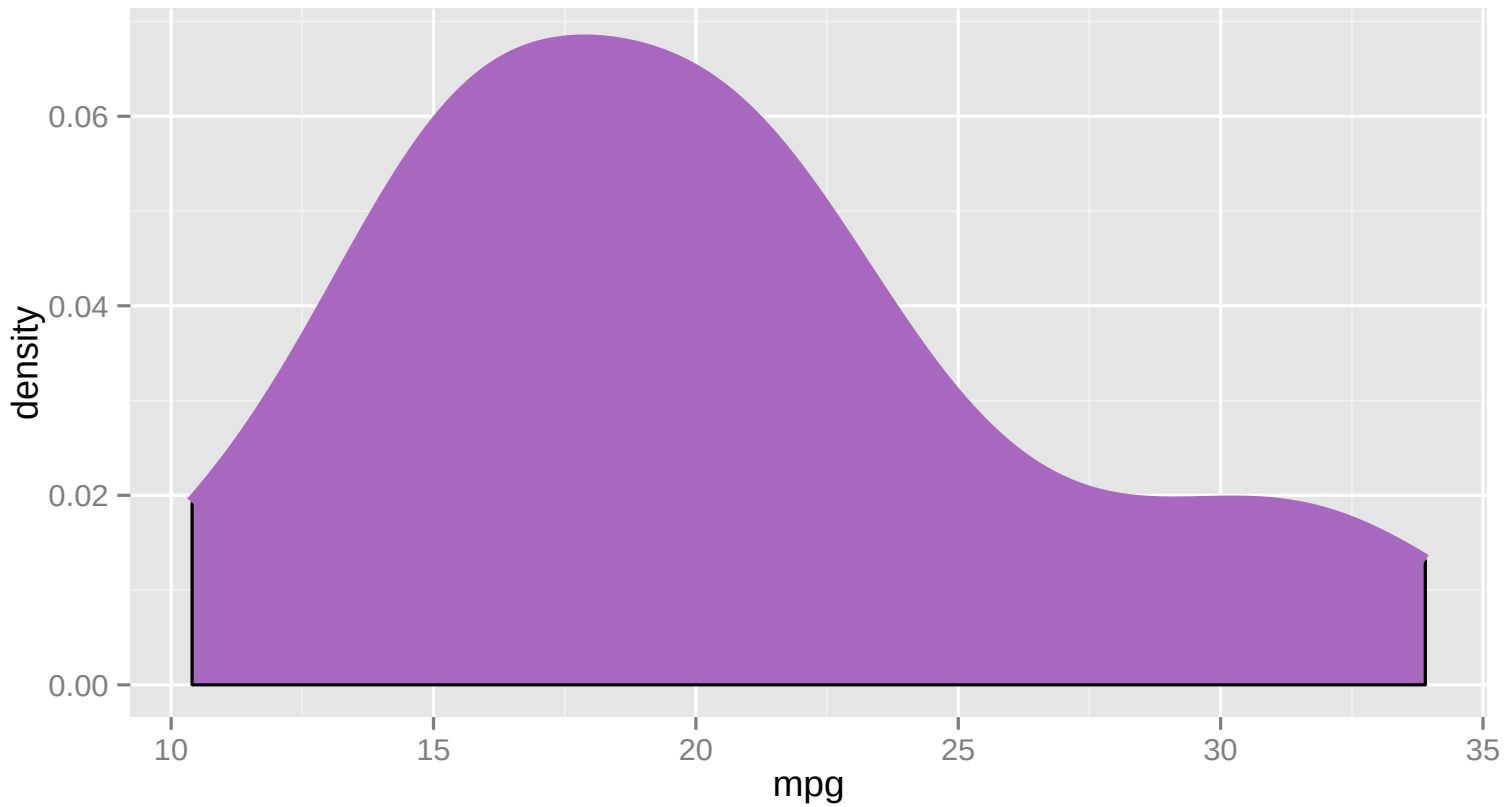
Density Curves

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_line(stat = 'density', col = "#a868c0", size = 2)
```



Density Curves

```
ggplot(data = mtcars, aes(x = mpg)) +
  geom_density(fill = '#a868c0') +
  geom_line(stat = 'density', col = "#a868c0", size = 2)
```



ggplot objects

Plot objects

You can assign a plot to a new object (this won't plot anything):

```
mpg_hp <- ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "tomato")
```

To show the actual plot associated to the object `mpg_hp` use the function `print()`

```
print(mpg_hp)
```

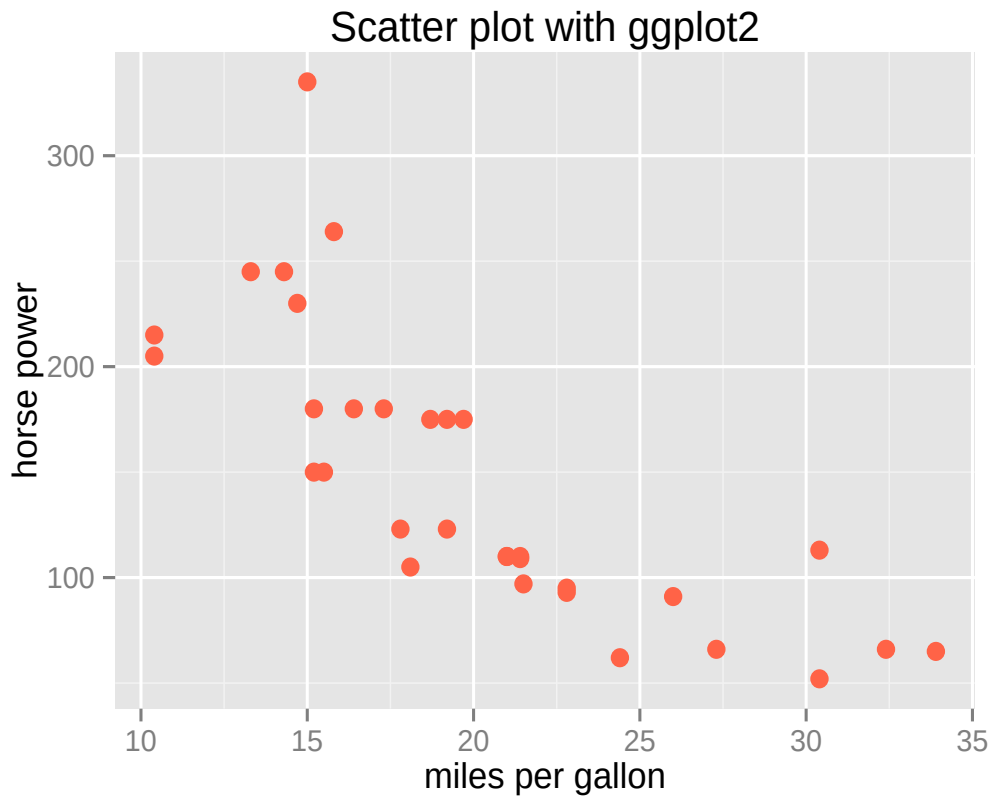
"ggplot2" objects

working with ggplot objects, we can ...

- define a basic plot, to which we can add or change layers without typing everything again
- render it on screen with `print()`
- describe its structure with `summary()`
- render it to disk with `ggsave()`
- save a cached copy to disk with `save()`

Adding a title and axis labels to a ggplot2 object:

```
mpg_hp + ggtitle("Scatter plot with ggplot2") +
  xlab("miles per gallon") + ylab("horse power")
```



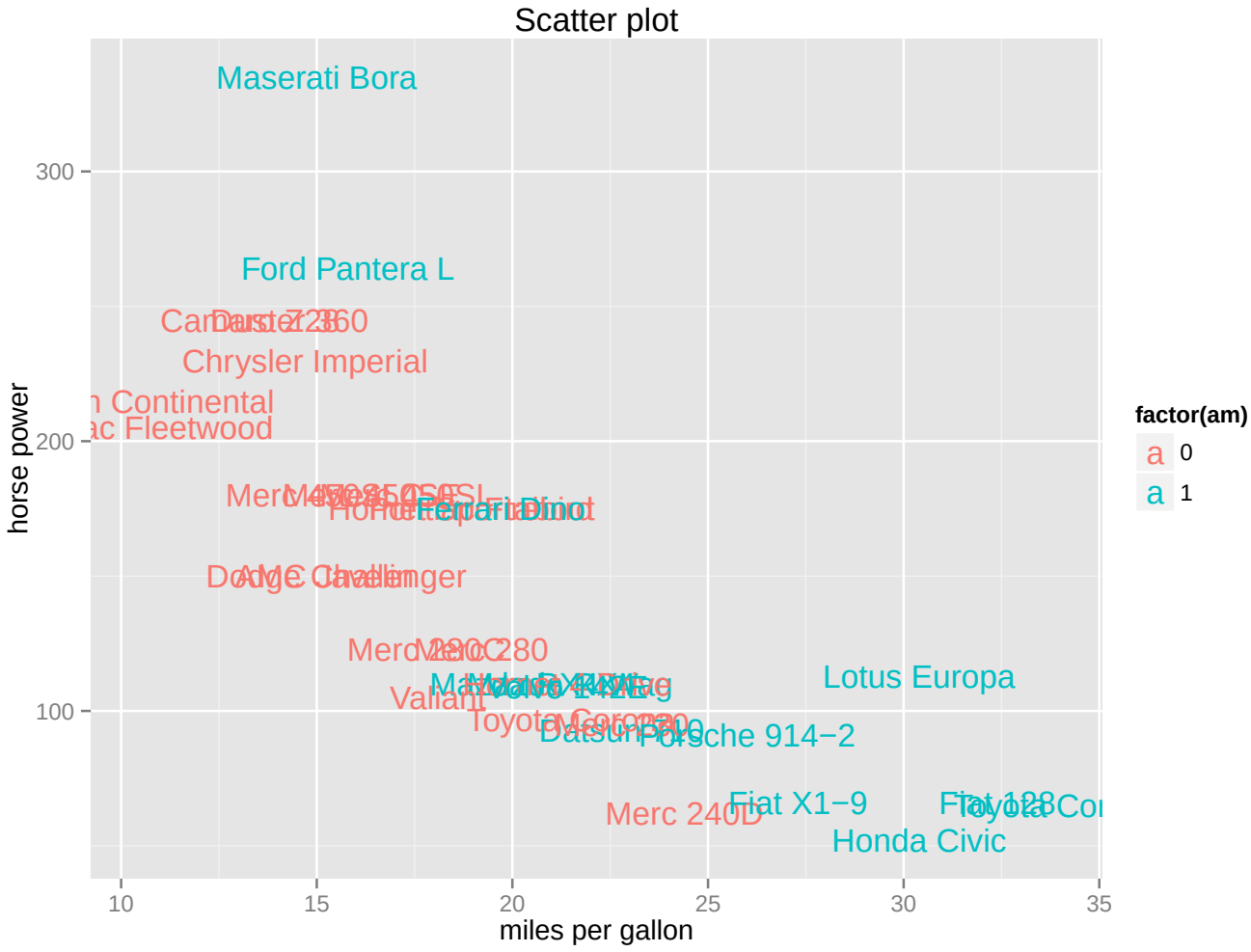
Your turn: example 3

Create the following ggplot object:

```
# ggplot object
obj <- ggplot(data = mtcars,
          aes(x = mpg, y = hp, label = rownames(mtcars)))
```

Add more layers to the object ""obj" in order to replicate the figure in the following slide:

Your turn: example 3



Your turn: example 3

```
obj +
  geom_text(aes(color = factor(am))) +
  ggtitle("Scatter plot") +
  xlab("miles per gallon") +
  ylab("horse power")
```

Scales

Scales

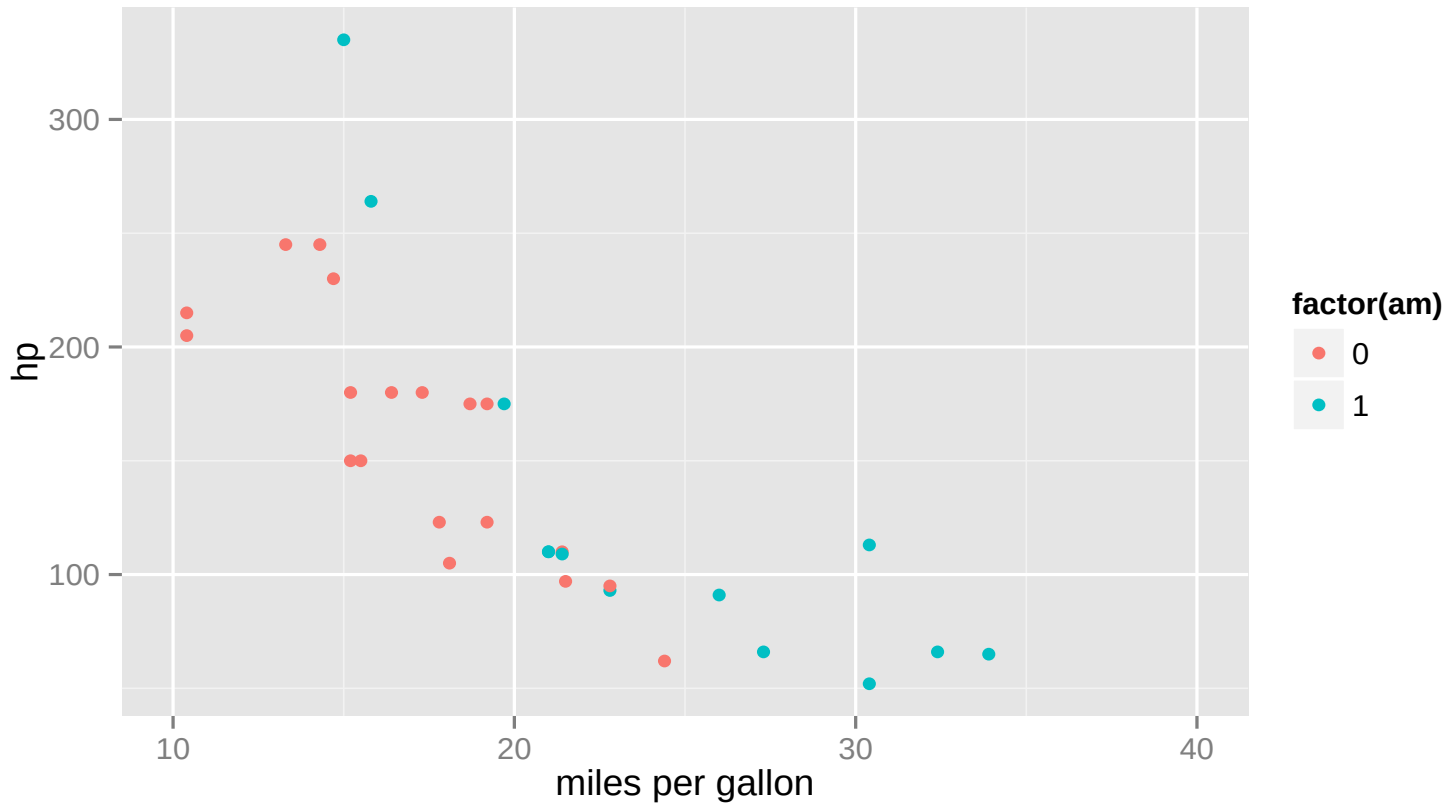
- The **scales** component encompasses the ideas of both axes and legends on plots, e.g.:
- Axes can be continuous or discrete
- Legends involve colors, symbol shapes, size, etc
  - `scale_x_continuous`
  - `scale_y_continuous`
  - `scale_color_manual`
- **scales** will often automatically generate appropriate scales for plots
- Explicitly adding a scale component overrrides the default scale

Continuous axis scales

Use `scale_x_continuous()` to modify the default values in the x axis

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = factor(am))) +
  scale_x_continuous(name = "miles per gallon",
                     limits = c(10, 40),
                     breaks = c(10, 20, 30, 40))
```

Continuous axis scales

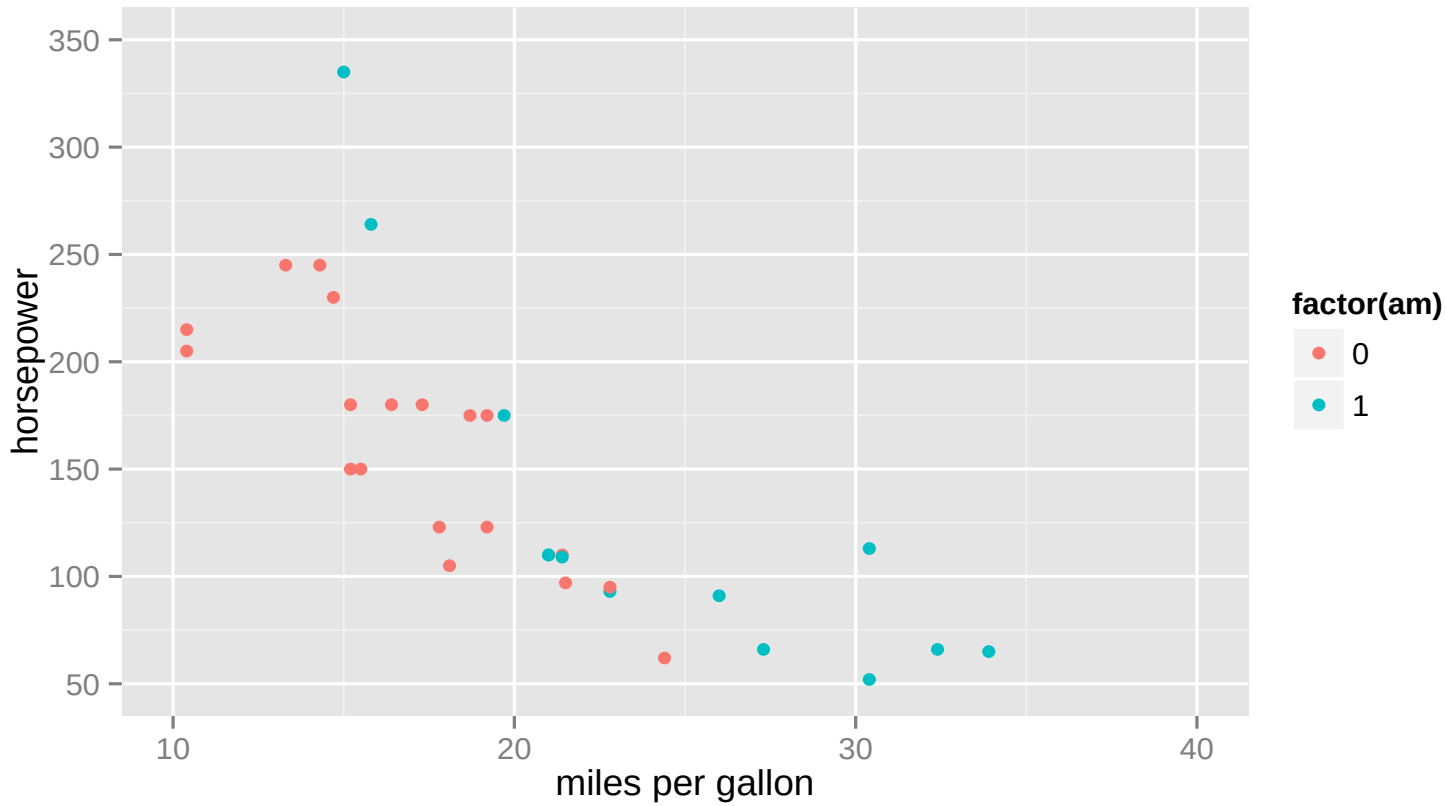


Continuous axis scales

Use `scale_y_continuous()` to modify the default values in the y axis

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = factor(am))) +
  scale_x_continuous(name = "miles per gallon",
                     limits = c(10, 40),
                     breaks = c(10, 20, 30, 40)) +
  scale_y_continuous(name = "horsepower",
                     limits = c(50, 350),
                     breaks = seq(50, 350, by = 50))
```

Continuous axis scales

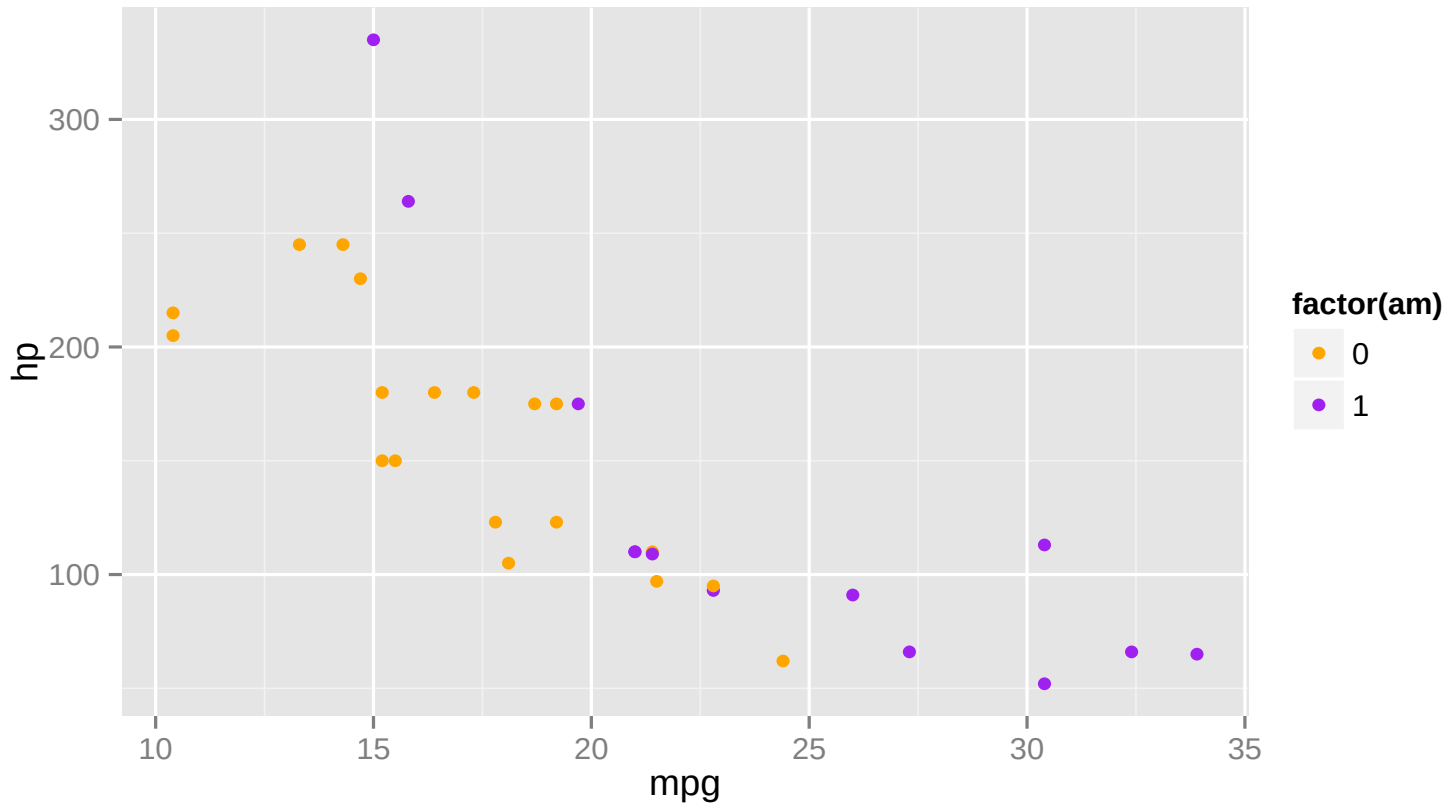


Example: color scale

Use `scale_color_manual()` to modify the colors associated to a factor

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = factor(am))) +
  scale_color_manual(values = c("orange", "purple"))
```

Example: color scale



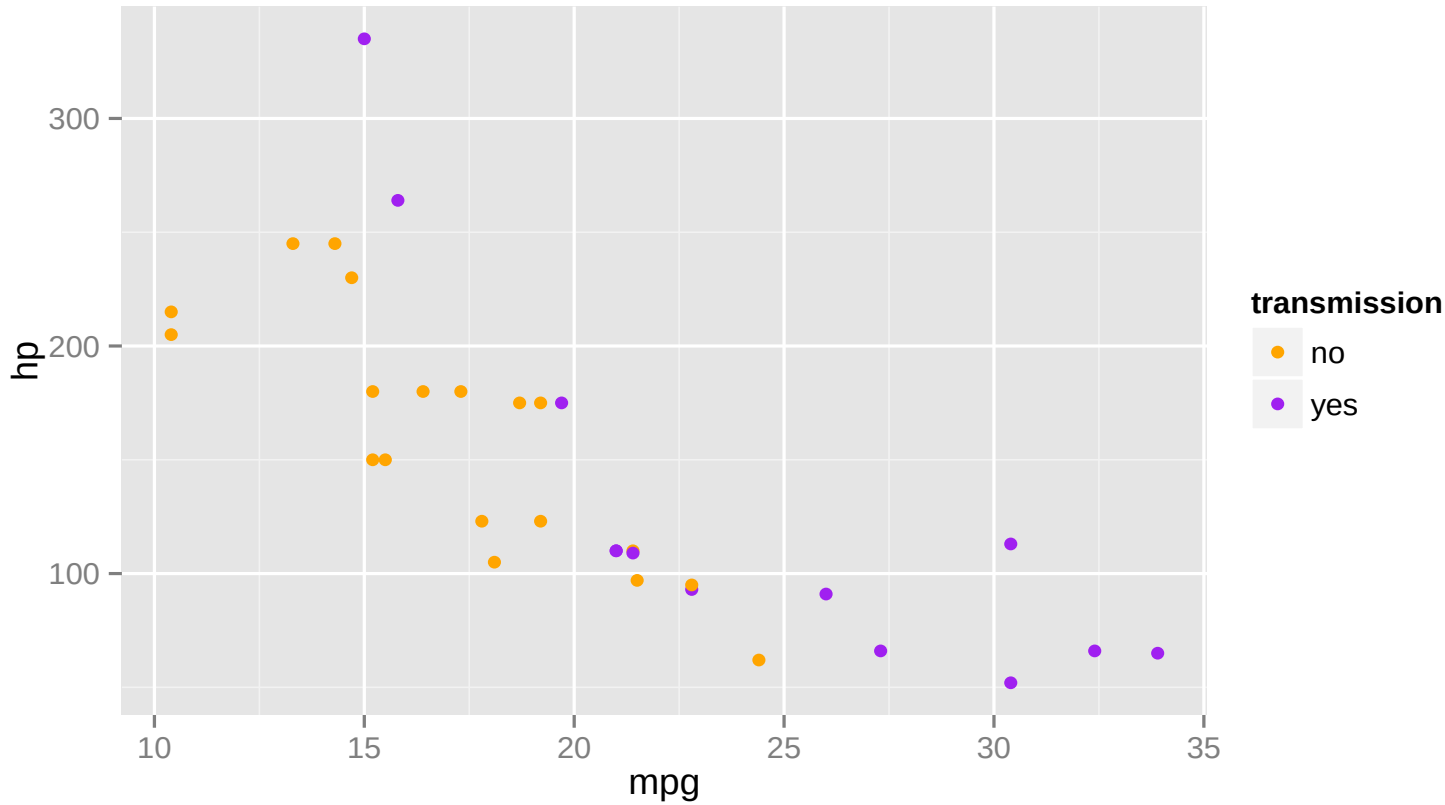
Example: legend

Modifying legends depends on the type of scales (e.g. color, shapes, size, etc)

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = factor(am))) +
  scale_color_manual(values = c("orange", "purple"),
                     name = "transmission",
                     labels = c('no', 'yes'))
```

Example: legend

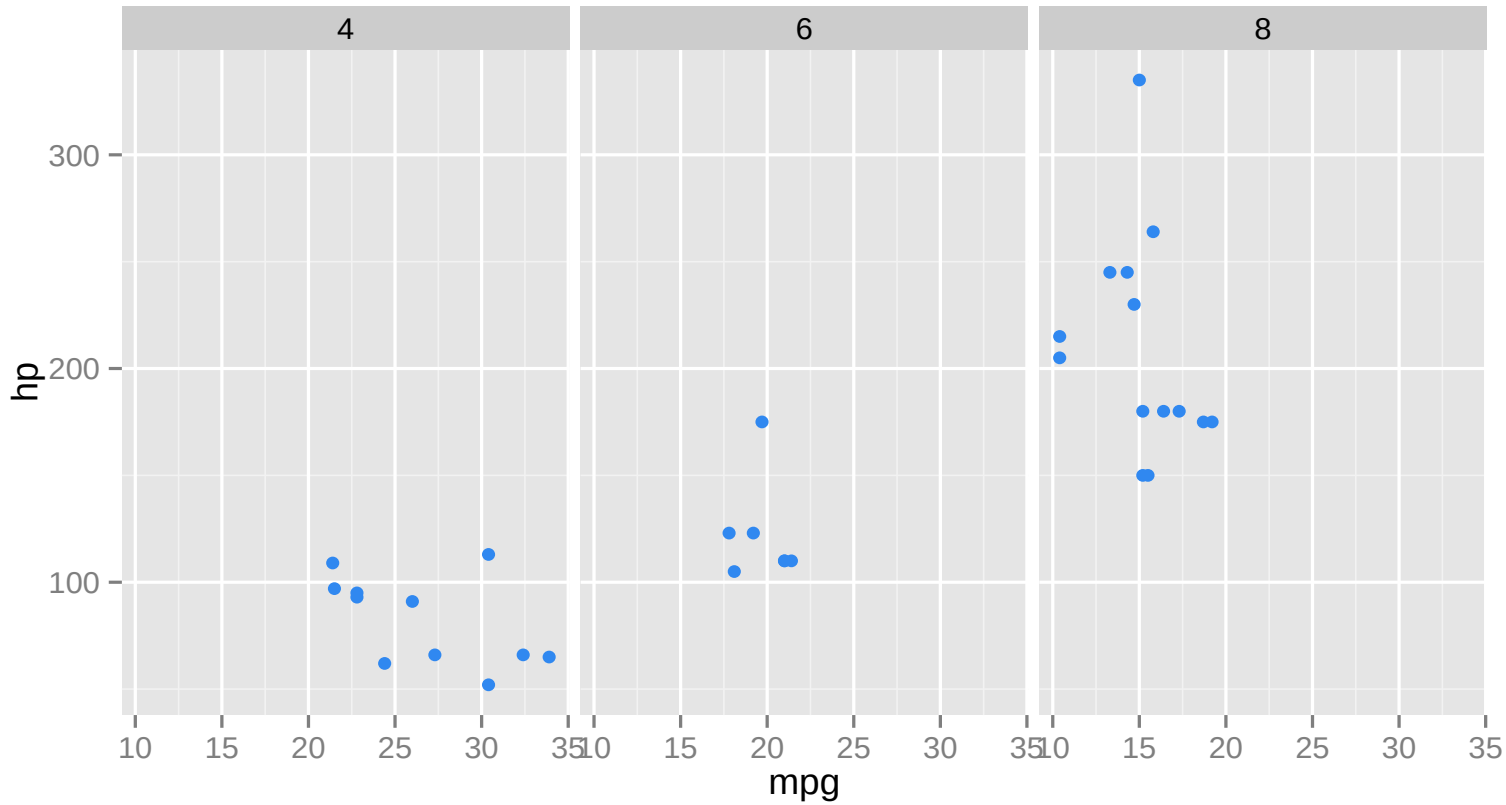
Modifying legends depends on the type of scales (e.g. color, shapes, size, etc)



Faceting

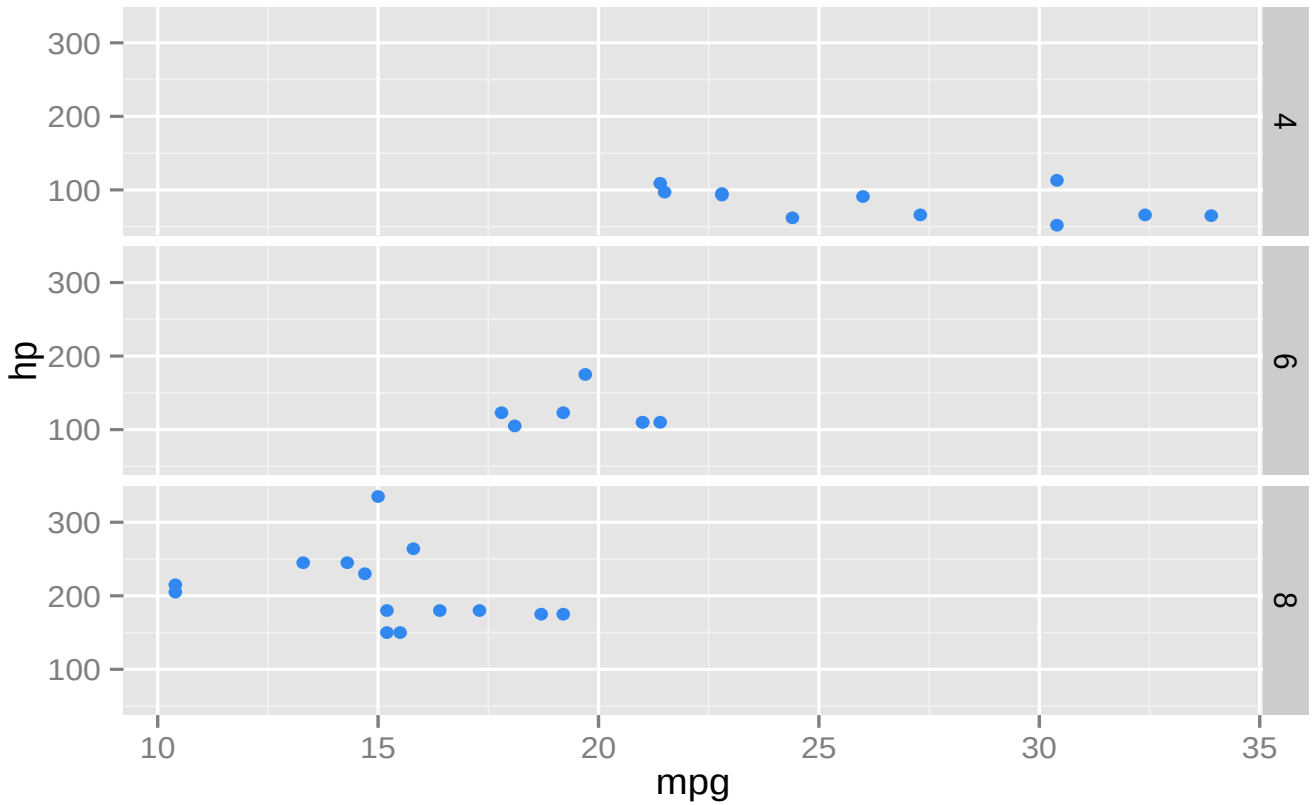
Faceting with `facet_wrap()`

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(color = "#3088f0") +
  facet_wrap(~ cyl)
```



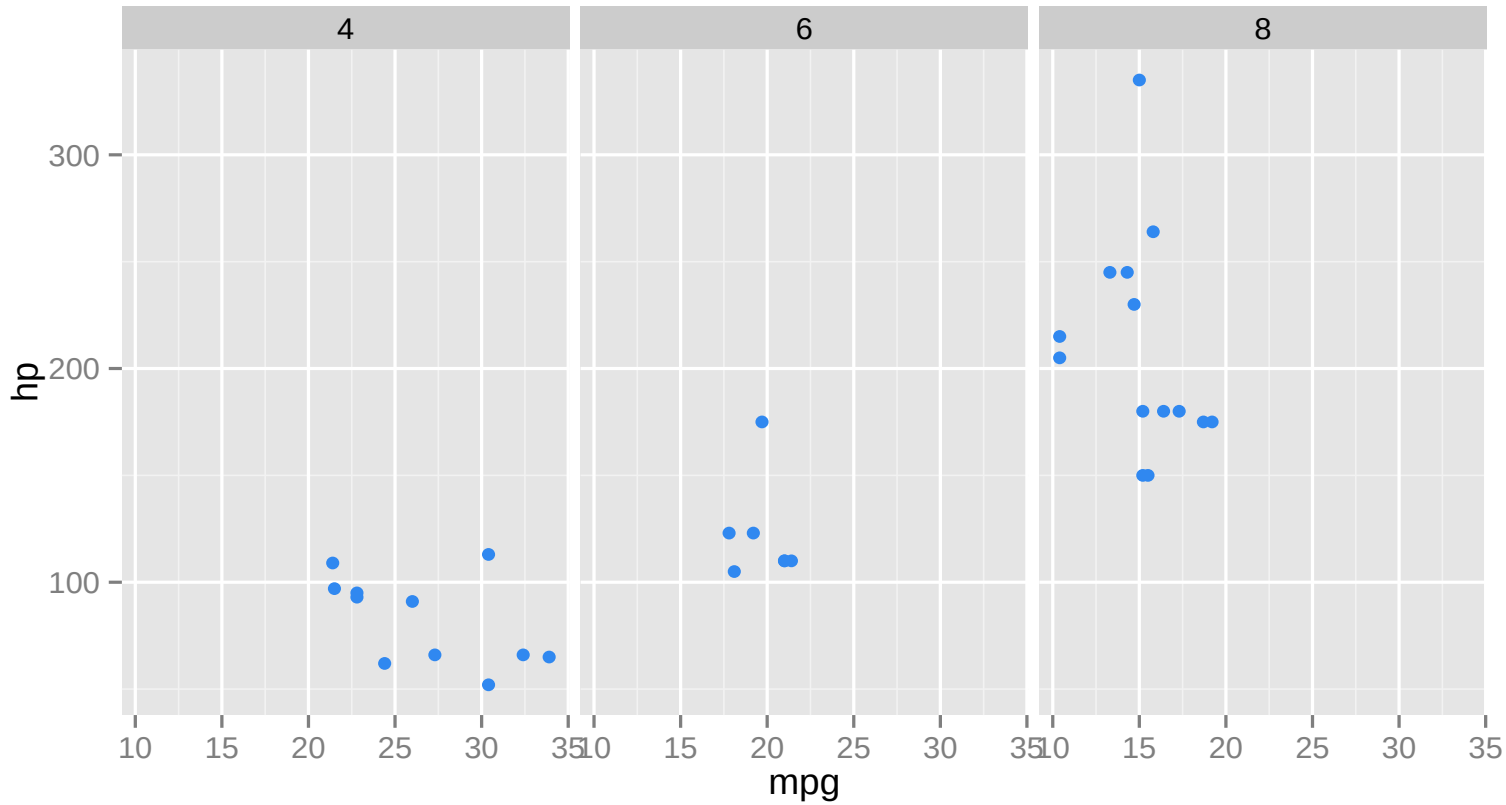
Faceting with `facet_grid()`

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(color = "#3088f0") +
  facet_grid(cyl ~ .)
```



Faceting with `facet_grid()`

```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(color = "#3088f0") +
  facet_grid(. ~ cyl)
```



Layered Grammar

About `"ggplot2"`

- Key concept: **layer** (layered grammar of graphics)
- Designed to work in a layered fashion
- Starting with a layer showing the data
- Then adding layers of annotations and statistical transformations
- Core idea: independents components combined togehter

Some Concepts

- the **data** to be visualized
- a set of **aesthetic mappings** describing how varibales are mapped to aesthetic attributes
- geometric objects, **geoms**, representing what you see on the plot (points, lines, etc)
- statistical transformations, **stats**, summarizing data in various ways
- **scales** that map values in the data space to values in an aesthetic space
- a coordinate system, **coord**, describing how data coordinates are mapped to the plane of the graphic
- a **faceting** specification describing how to break up the data into subsets and to displays those subsets