# R package ggplot2

STAT 133

Gaston Sanchez

Department of Statistics, UC–Berkeley

gastonsanchez.com
github.com/gastonstat/stat133
Course web: gastonsanchez.com/teaching/stat133

## ggplot2

## Scatterplot with "ggplot2"

Terminology

- aesthetic mappings
- geometric objects
- statistical transformations
- scales
- non-data elements (themes & elements)
- facets

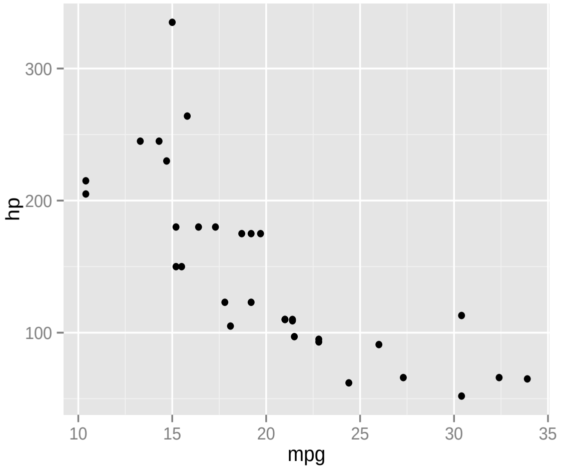
## Considerations

Specifying graphical elements from 3 sources:

- The data values (represented by the geometric objects)
- The scales and coordinate system (axes, legends)
- Plot annotations (background, title, grid lines)

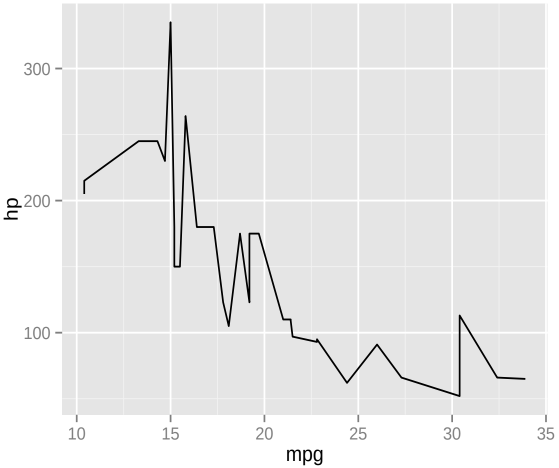
## Scatterplot with geom_point

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



## Another geom

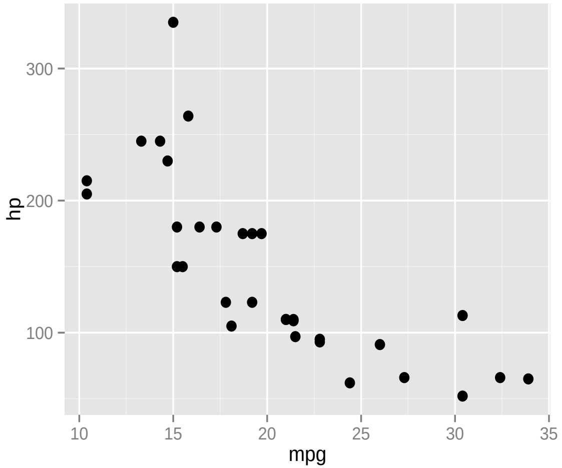
```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_line()
```



## Mapping Attributes -vs- Setting Attributes

# Increase size of points

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



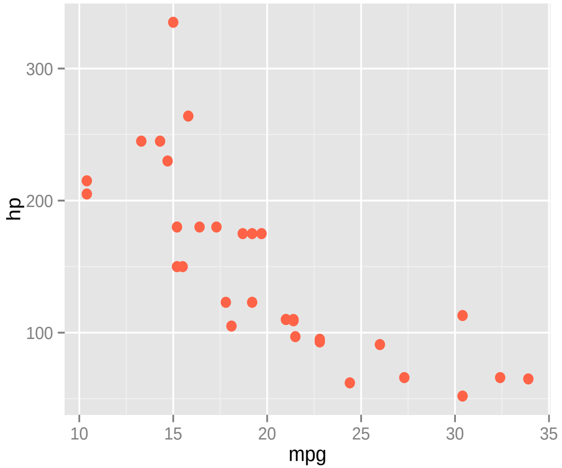
## How does it work?

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)
```

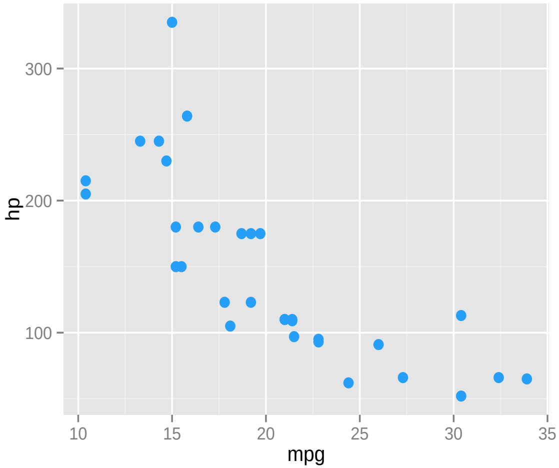
# Adding color

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



# Adding color

```r
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(size = 3, color = "#259ff8")
```



## Test your knowledge

Identify the valid hex-color

A) `"345677"`

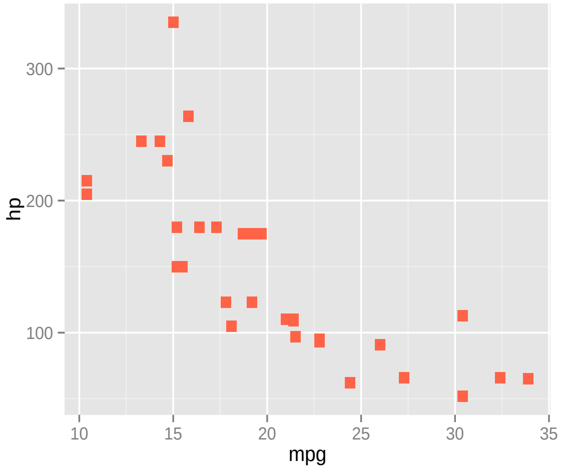
B) `"#1234567"`

C) `"#AAAAAA"`

D) `"#GG0033"`

## Changing points shape

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



## Setting and Mapping

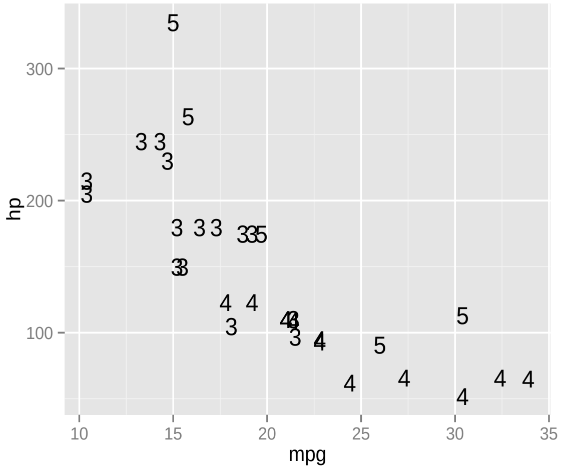
Aesthetic attributes can be either **mapped** —via aes()— or **set**

```r
# 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")
```

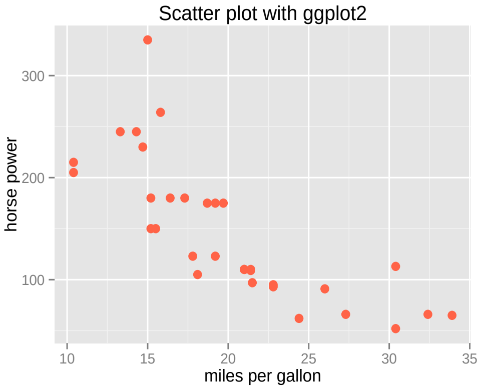
# Geom text, and mapping labels

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



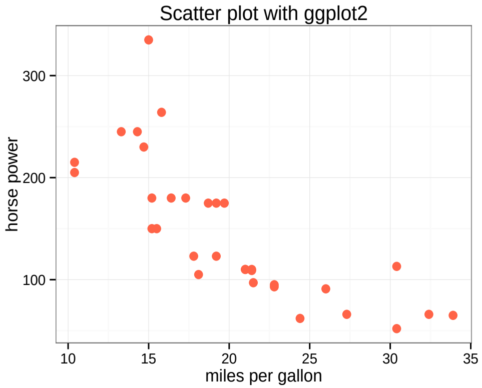
## Changing axis labels and title

```
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")
```

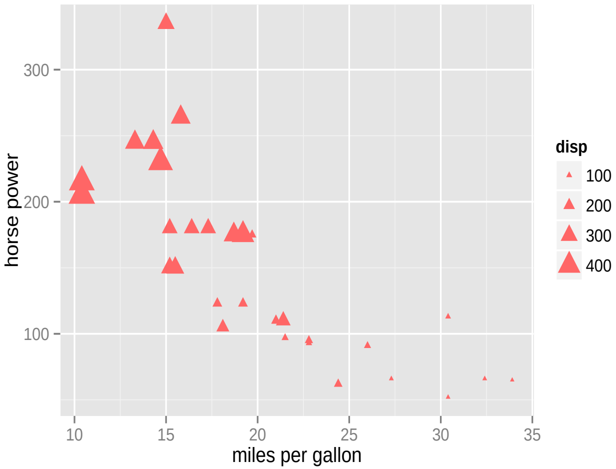


## Changing background theme

```r
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

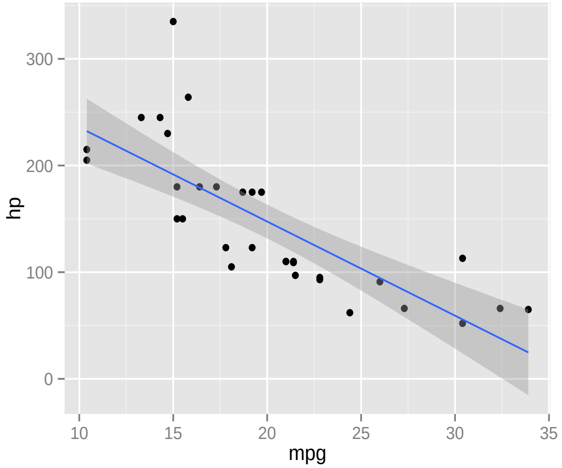
- Specify a color in hex notation
- Change the shape of the point symbol
- Map `disp` to attribute size of points
- Add axis labels

# Your turn

```r
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

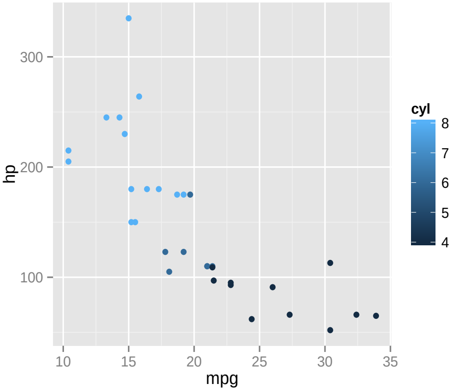
```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point() +
  geom_smooth(method = "lm")
```



## More geoms

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

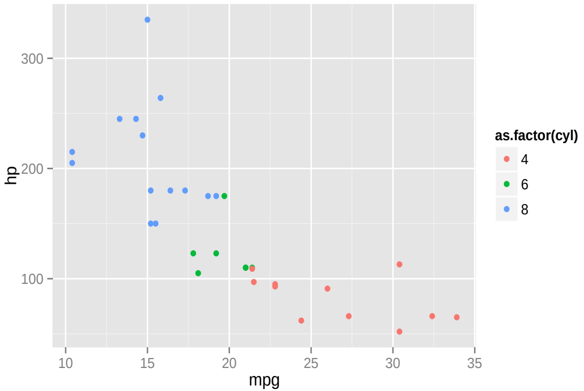
```
ggplot(data = mtcars, aes(x = mpg, y = hp)) +
  geom_point(aes(color = cyl))
```



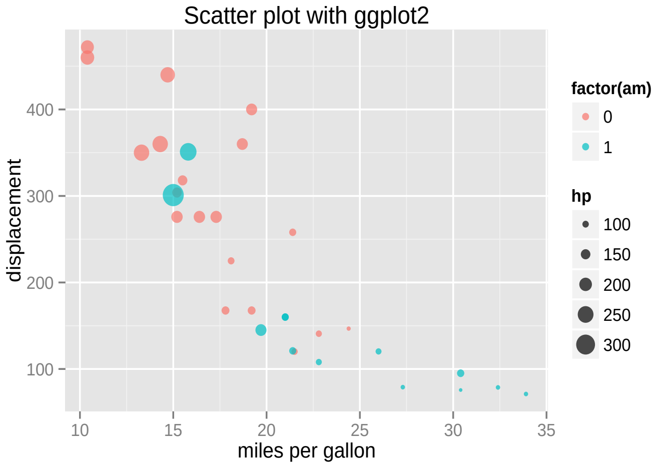
# More geoms

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

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



## Your turn: Replicate this figure



## Your turn: example 2

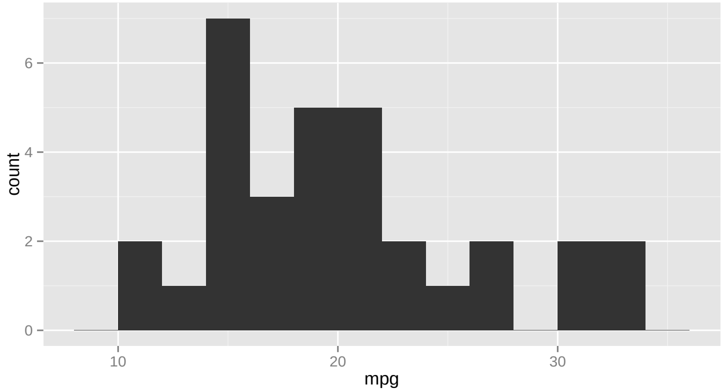
- Map `hp` to attribute size of points
- Map `am` (as factor) to attribute color points
- Add an alpha transparency of 0.7
- Change the shape of the point symbol
- Add axis labels
- Add a title

## Your turn: example 2

```r
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")
```

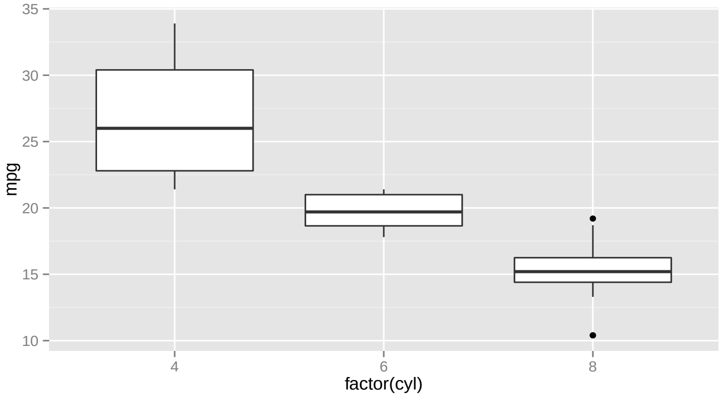
## Histogram

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



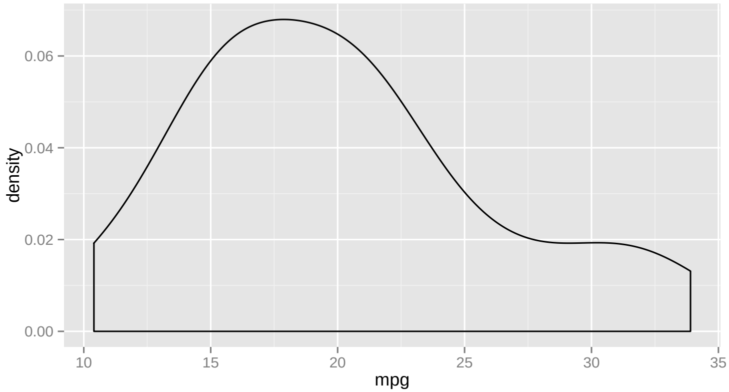
## Boxplots

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



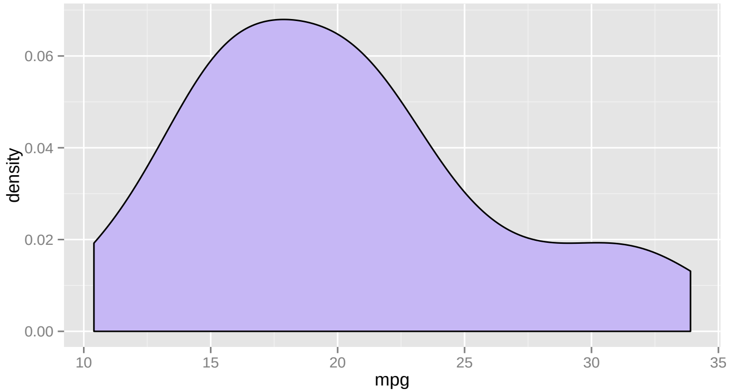
# Density Curves

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



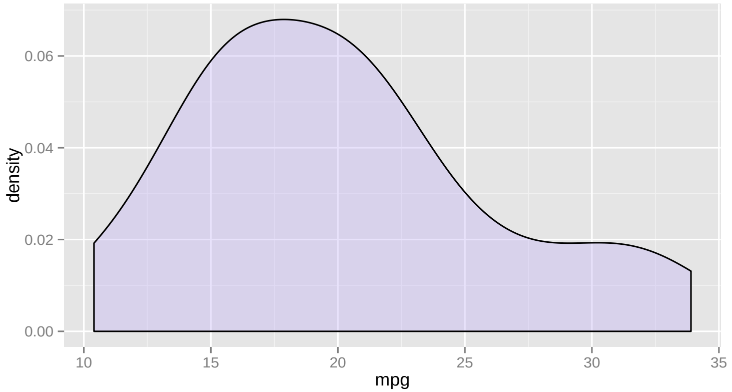
# Density Curves

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



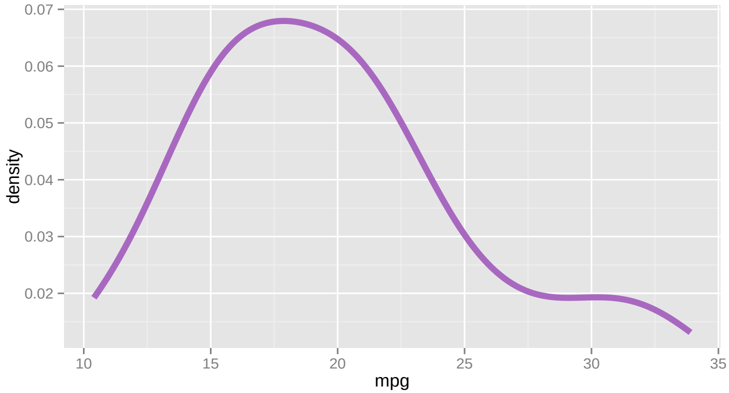
## Density Curves

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



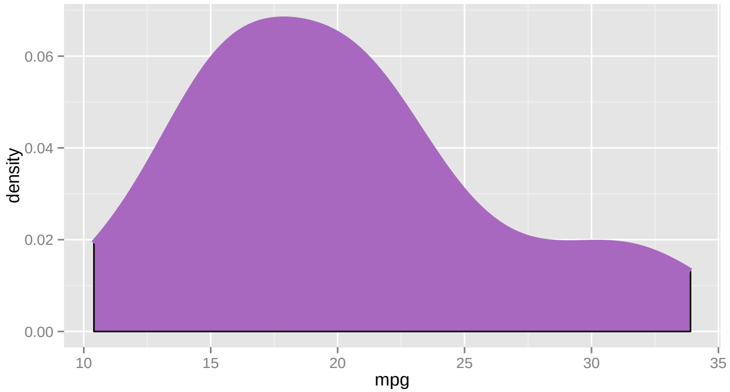
## Density Curves

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



# Density Curves

```r
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):

```r
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()`

```r
print(mpg_hp)
```

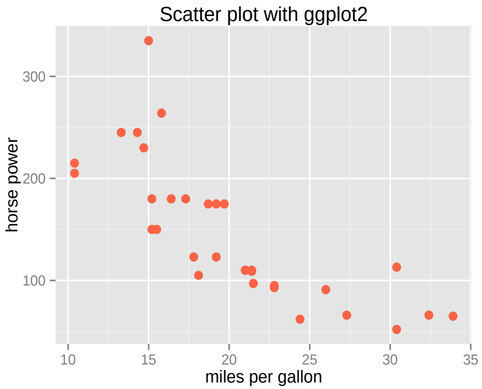
## "ggplot2" objects

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:

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



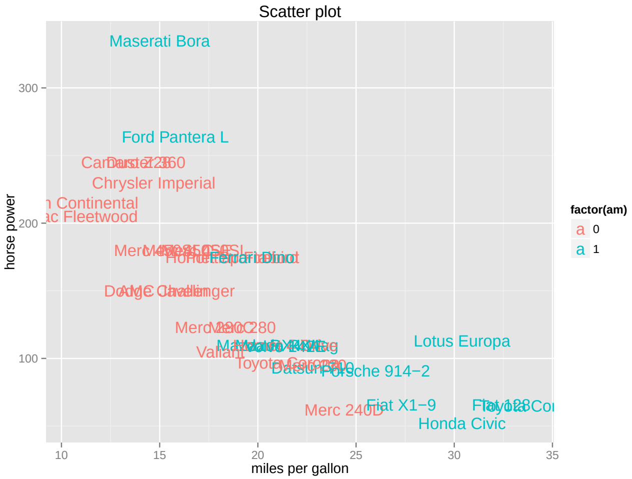
## Your turn: example 3

Create the following ggplot object:

```r
# 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

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

## Scales

## Scales

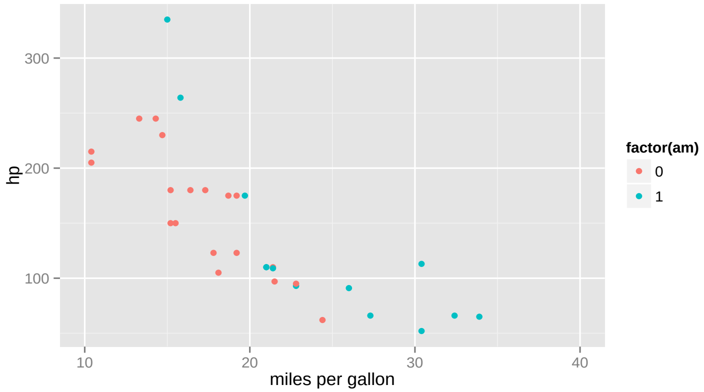
- The **scales** component encompases the ideas of both axes and legends on plots, e.g.:
- Axes can be continuous or discrete
- Legends involve colors, symbol shapes, size, etc
  - `scale_x_continuous`
  - `scale_y_continuous`
  - `scale_color_manual`
- **scales** will often automatically generate appropriate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

## Continuous axis scales

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

```r
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

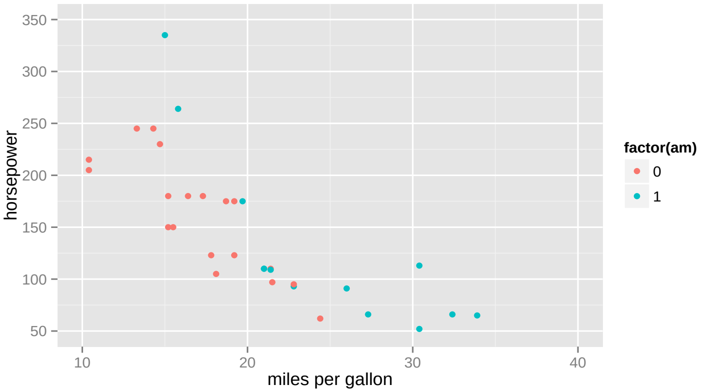


## Continuous axis scales

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

```r
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

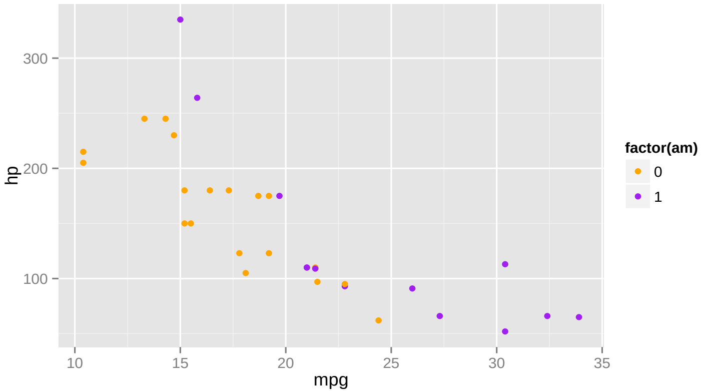


## Example: color scale

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

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

## Example: color scale

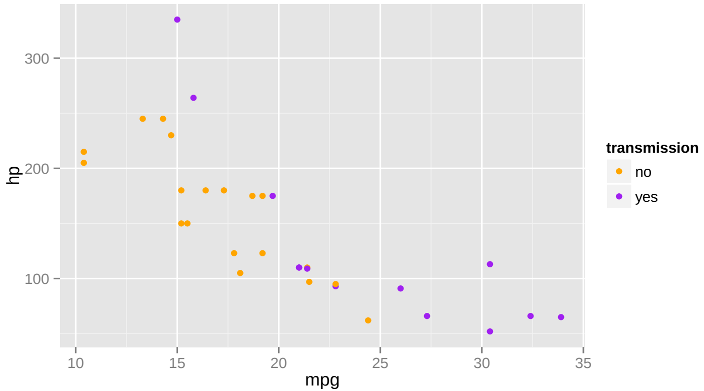


## Example: modifying legend

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'))
```

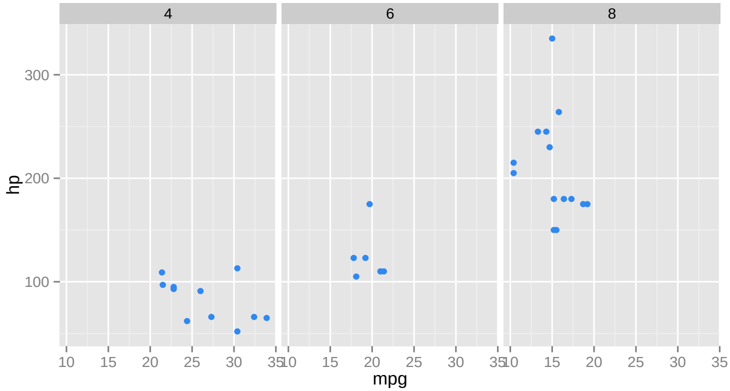
## Example: modifying legend



## Faceting

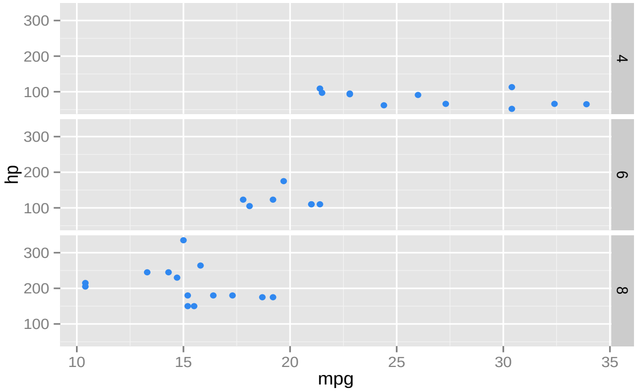
# Faceting with facet_wrap()

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



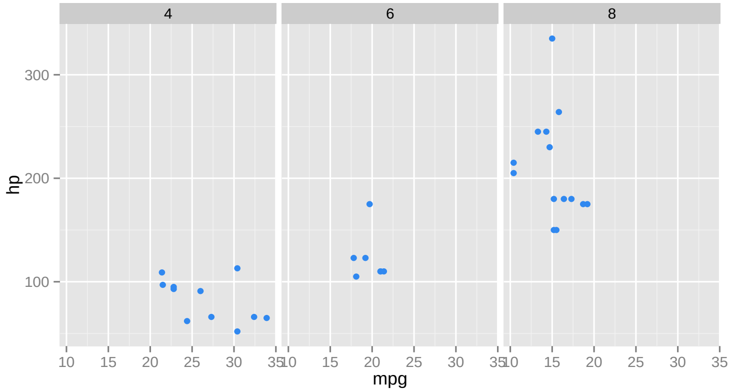
# Faceting with facet_grid()

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



# Faceting with facet_grid()

```r
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