ADVANCED CUSTOMIZATION

Graphics for communication

We have mostly been focused on **exploratory data analysis**

- i.e., used plots as tools for exploration

After you understand your data, you need to **communicate** your understanding to others.

Artwork by @allison_horst

`{ggplot2}` provides defaults ...

- but every aspect of the plot can be changed
- colors are controlled through **scales**
- **themes** control presentation of non-data elements

Outline

1. labels & annotations
2. `{ggplot2}` scales
3. scales & color choices
4. themes

Adding labels

You add labels with the `labs()` function.

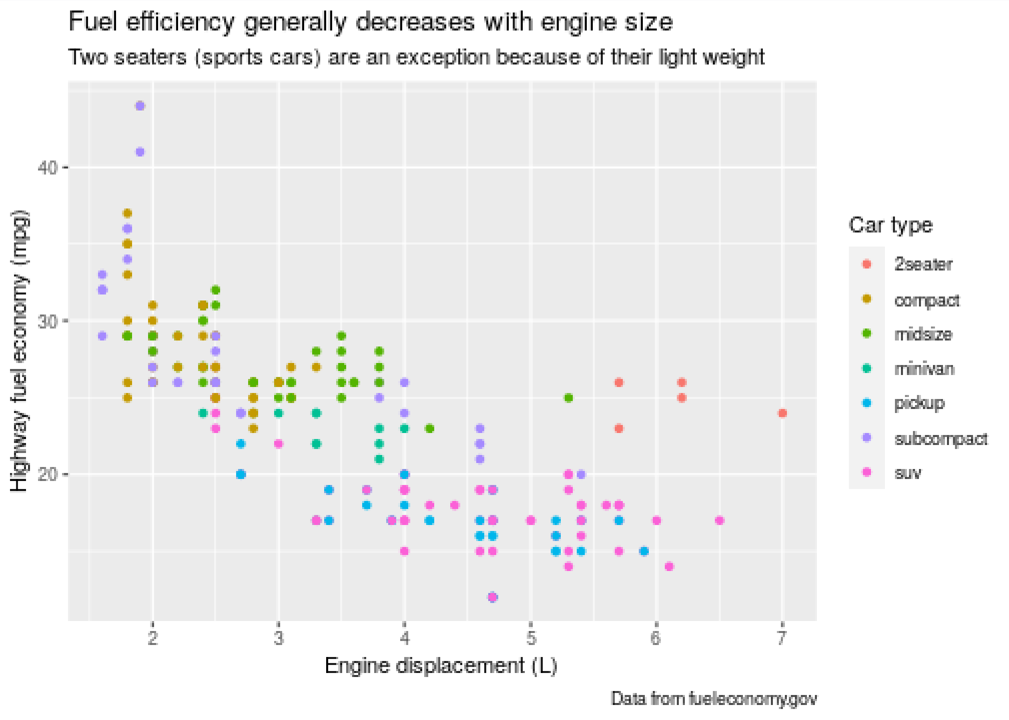
- Labels that can be modified include:
    - `x`
    - `y`
    - `title`
    - `subtitle`
    - `caption`
    - `color`

Other methods of modifying labels:

- `ggtitle(main, subtitle)`: plot title & subtitle
- `xlab()`, `ylab()`: axes titles

Adding labels

```
ggplot(mpg, aes(displ, hwy)) + geom_point(aes(color = class)) +
  labs(title = "Fuel efficiency generally decreases with engine size",
    subtitle = "Two seaters (sports cars) are an exception because of their ligh
    caption = "Data from fueleconomy.gov",
    x = "Engine displacement (L)", y = "Highway fuel economy (mpg)",
    colour = "Car type")
```



Adding text

Create a subset of the data using {dplyr} containing the most efficient car in each class

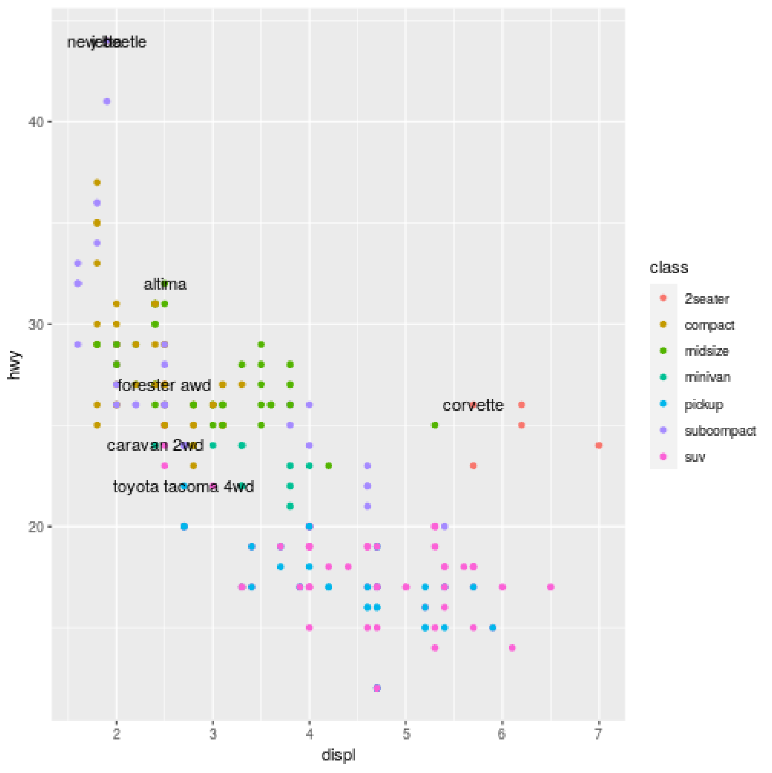
```
best_in_class <- mpg %>%
  group_by(class) %>%
  filter(row_number(desc(hwy)) == 1)

best_in_class
```

```
## # A tibble: 7 × 11
## # Groups:   class [7]
##   manufacturer model        displ  y
##   <chr>        <chr>        <dbl> <i
## 1 chevrolet    corvette       5.7  1
## 2 dodge        caravan 2wd    2.4  1
## 3 nissan       altima         2.5  2
## 4 subaru       forester a…    2.5  2
## 5 toyota       toyota tac…    2.7  2
## 6 volkswagen   jetta          1.9  1
## 7 volkswagen   new beetle     1.9  1
```

Adding text

Use `geom_text()` or `geom_label()` to label interesting observations.

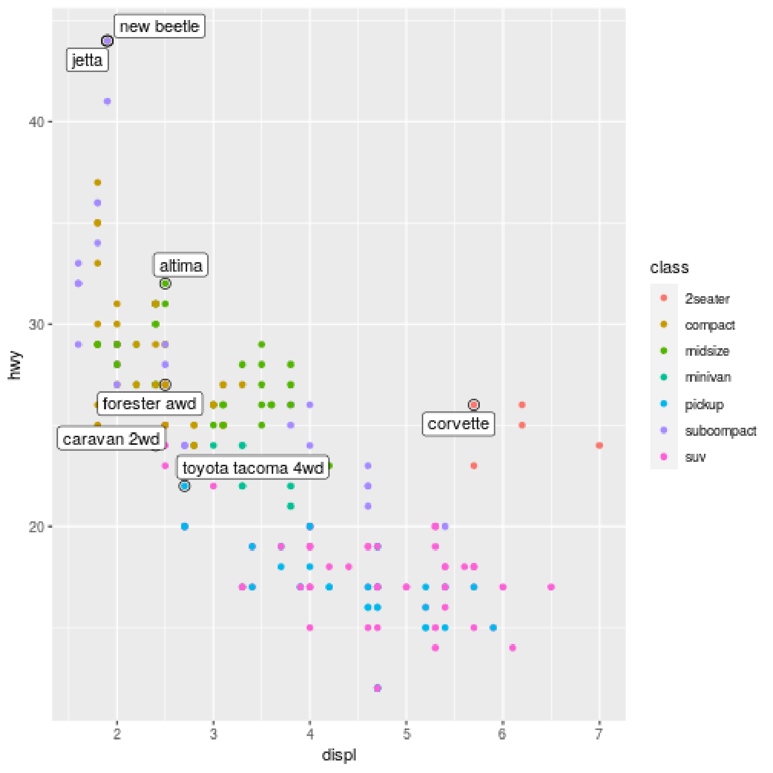
```r
best_in_class <- mpg %>%
  group_by(class) %>%
  filter(row_number(desc(hwy)) == 1)

ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  geom_text(data = best_in_class,
            aes(label = model))
```



Adding text

Use `geom_label()` (or even better, use `ggrepel::geom_label_repel()`) for increased readability

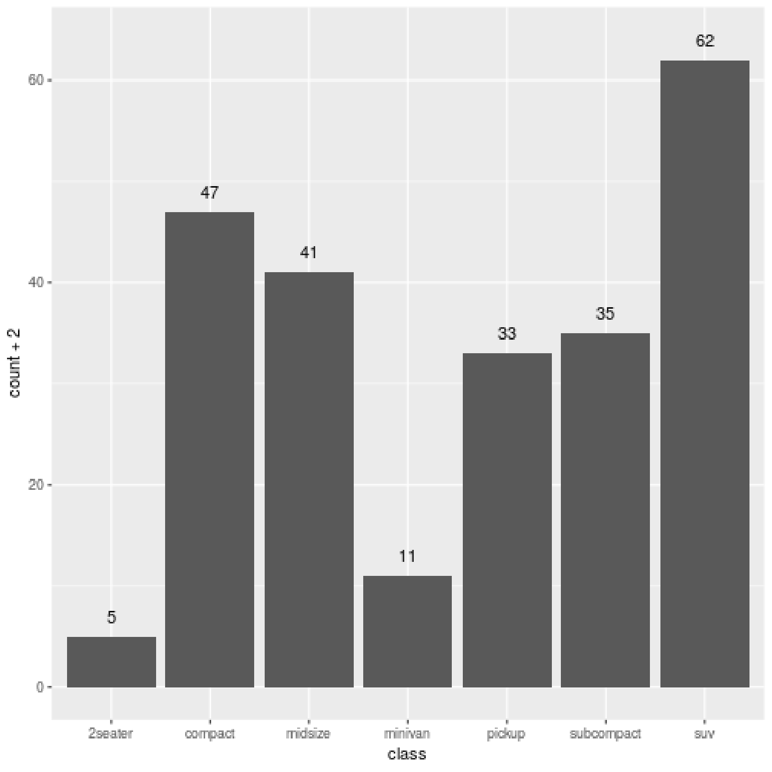
```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  geom_point(data = best_in_class,
             size = 3, shape = 1) +
  ggrepel::geom_label_repel(
    data = best_in_class,
    aes(label = model))
```



Adding text

Make use of `stats` and `after_stat()` for placement

```r
ggplot(mpg, aes(class)) +
  geom_bar() +
  geom_text(
    aes(
      y = after_stat(count + 2),
      label = after_stat(count)
    ),
    stat = "count"
  )
```



Annotations

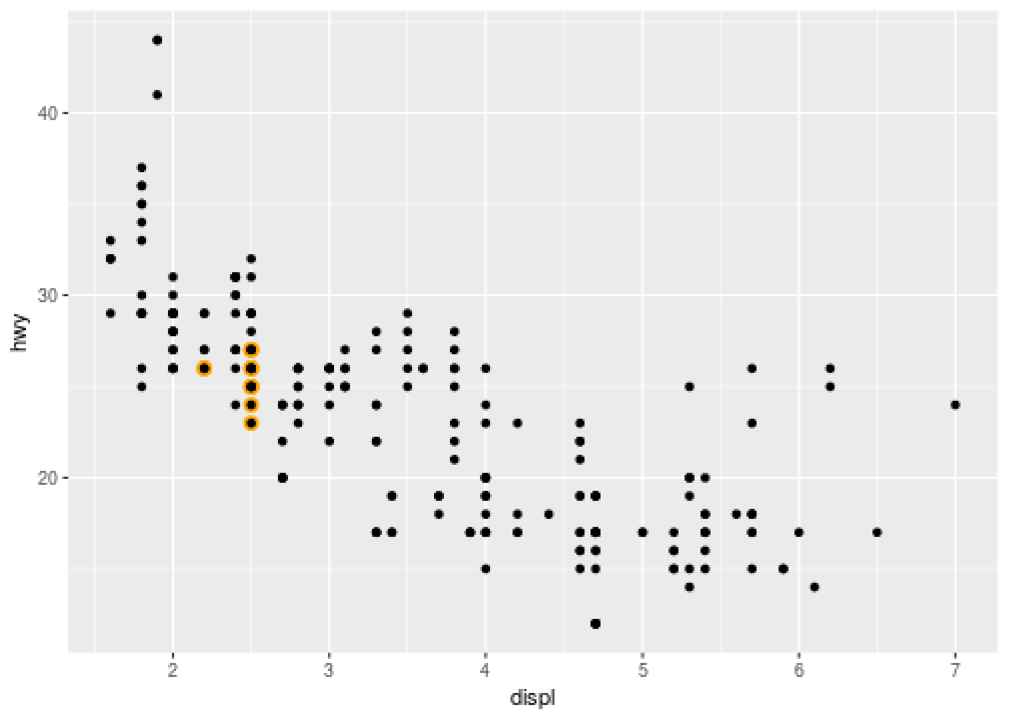
An **annotation** is a separate layer that doesn't connect to other elements in the plot and is used to add fixed elements to a data visualization

The `annotate()` function creates an annotation layer

- arguments include `geom`, and positions (`x`, `y`, `xmin`, `ymin`, etc.)

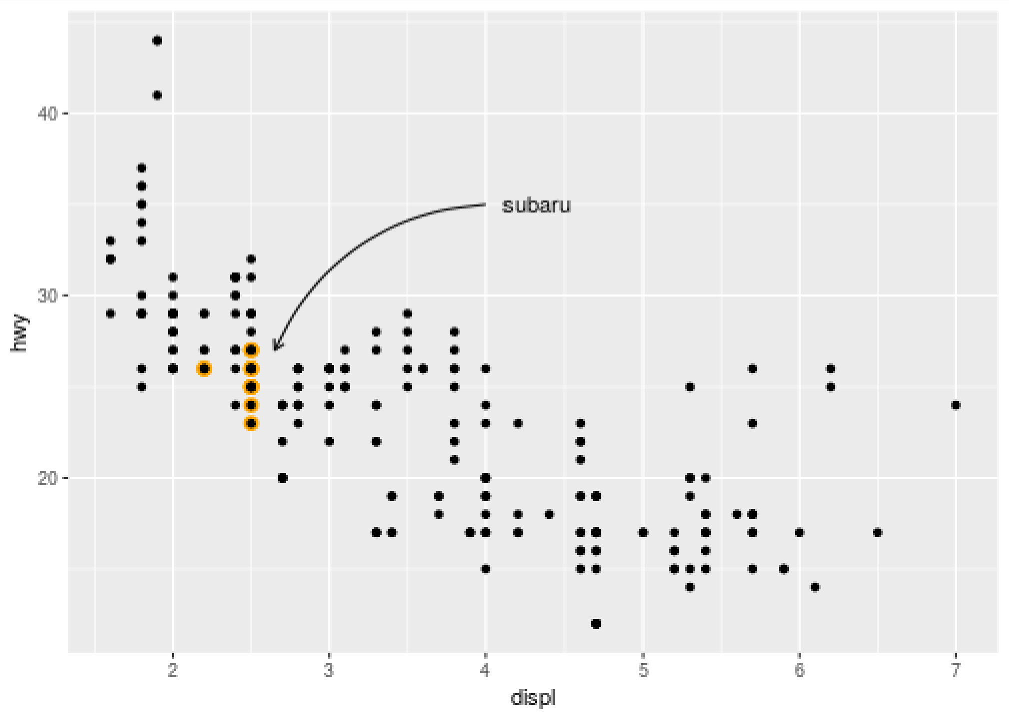
Example

```
p <- ggplot(mpg, aes(displ, hwy)) +
  geom_point(data = dplyr::filter(mpg, manufacturer == "subaru"),
             colour = "orange", size = 3) +
  geom_point()
p
```



Adding annotations

```
p +
  annotate(geom = "curve", x = 4, y = 35, xend = 2.65, yend = 27,
           curvature = .3, arrow = arrow(length = unit(2, "mm"))) +
  annotate(geom = "text", x = 4.1, y = 35, label = "subaru", hjust = "left")
```



Your Turn

Annotate this plot by adding a reference line with `geom_abline()`

- Modify the color or size of the line.

```r
library(NCME23data)
ggplot(pisa_usa, aes(x = math, y = reading)) +
  geom_point(color = "#3C5488", alpha = .7)
```

Scales

Scales

Recall: Scales control the details of how data values are translated to visual properties.

- Every aes value has a corresponding family of scales functions
  - `scale_{aes}_*()`, e.g. `scale_x_continuous()`
  - Values of the `*` depend on the aes
- These scale functions have many arguments including:
  - `name`: label of the axis/legend
  - `breaks`: numeric positions of breaks on axes/legends
  - `labels`: labels of the breaks on axes/legends
  - `limits`: continuous axis limits
  - `expand`: padding around data
  - `na.value`: what to do with missings
  - `trans`: continuous transformations of data
  - `guide`: function to create guide/legend
  - `date_breaks`: breaks for date variables

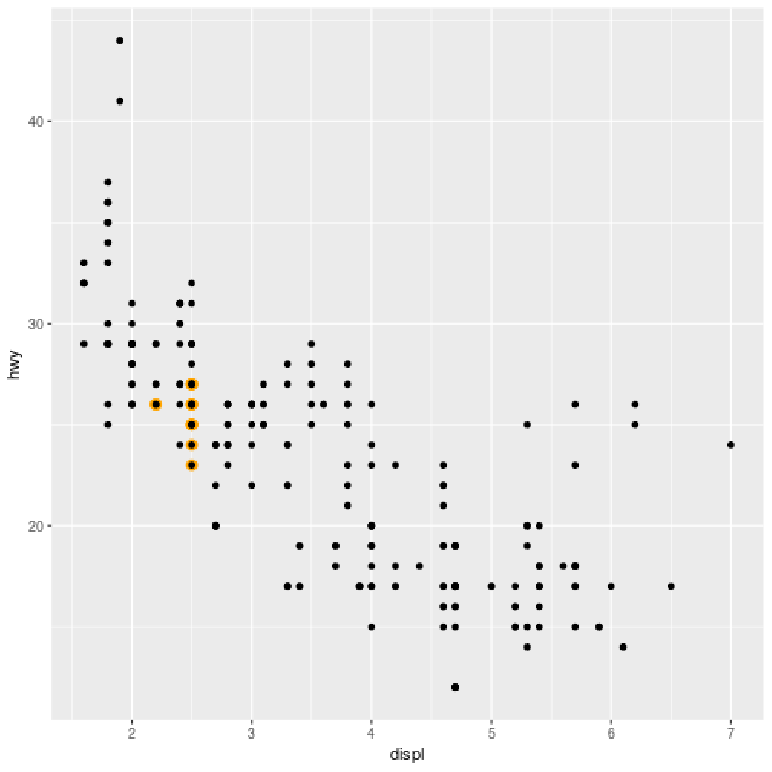
Scales for axes

`scale_x_*()`, `scale_y_*()`

- continuous
- discrete
- binned
- log10
- sqrt
- date
- datetime
- reverse

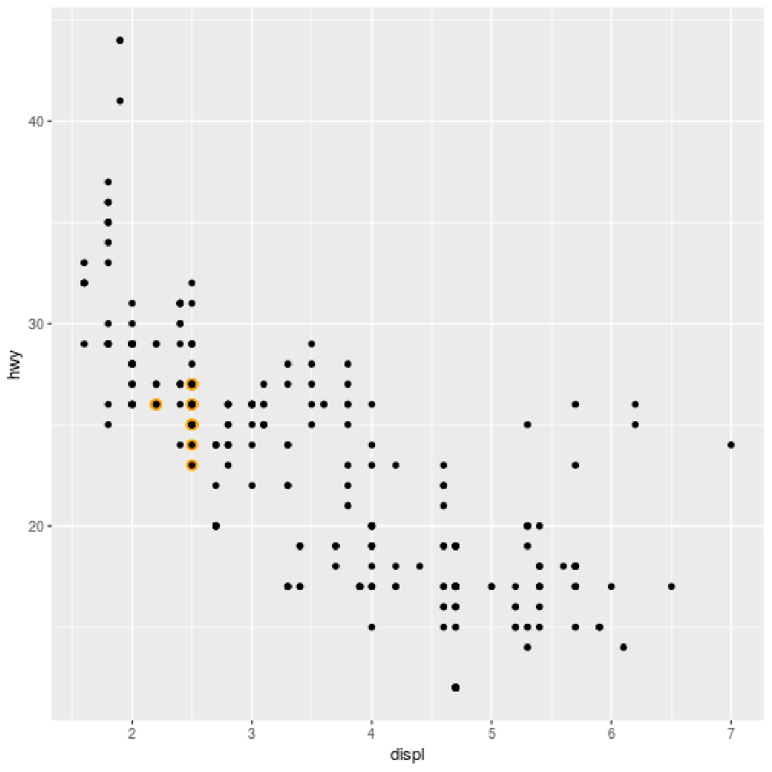
Scales for axes

```
p
```



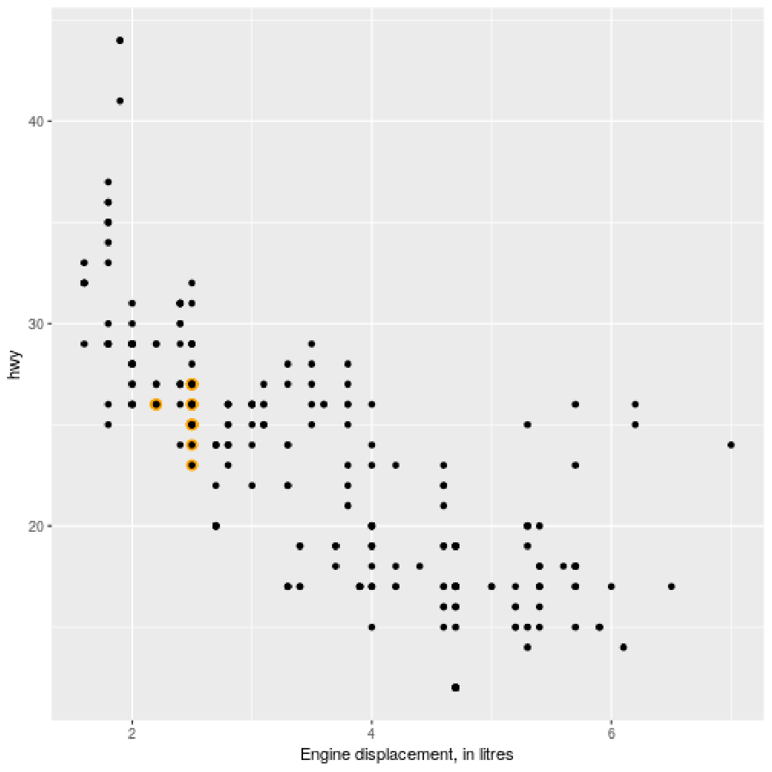
Scales for axes

```
p +
  scale_x_continuous()
```



Scales for axes

```
p +
  scale_x_continuous(
    "Engine displacement, in litres",
    breaks = c(2,4,6)
  )
```



Scales for color

- Colors are controlled through scales
    - `scale_colour_discrete` (`scale_colour_hue`) and `scale_colour_continuous` (`scale_colour_gradient`) are the default choices for factor variables and numeric variables
- we can change parameters of the default scale, or we can change the scale function

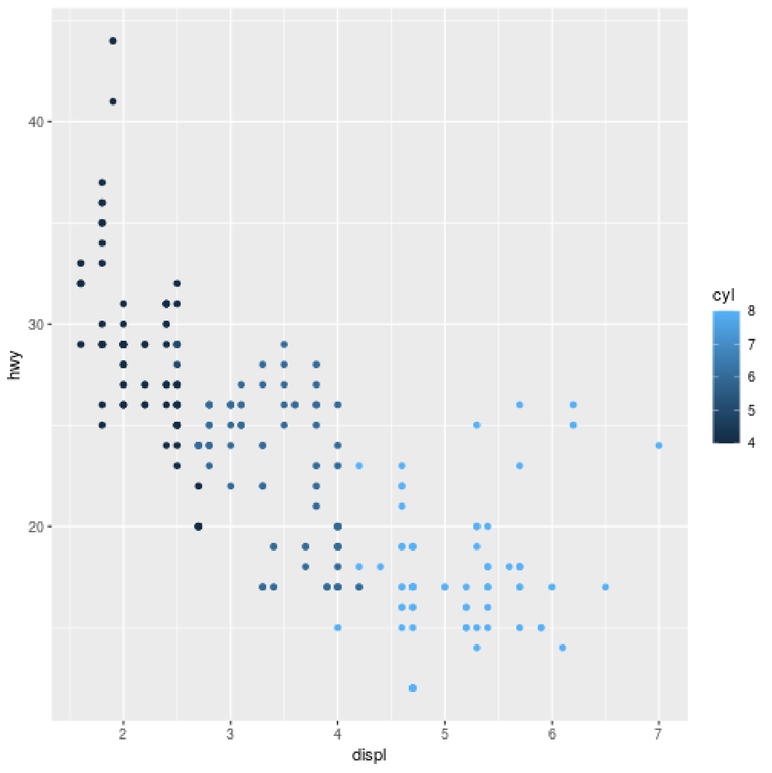
`scale_color_*()`, `scale_fill_*()`

- manual
- continuous
- brewer/distiller/fermenter
- gradient/gradient2/gradientn
- steps
- viridis

Continuous color scales

Default continuous colour scheme

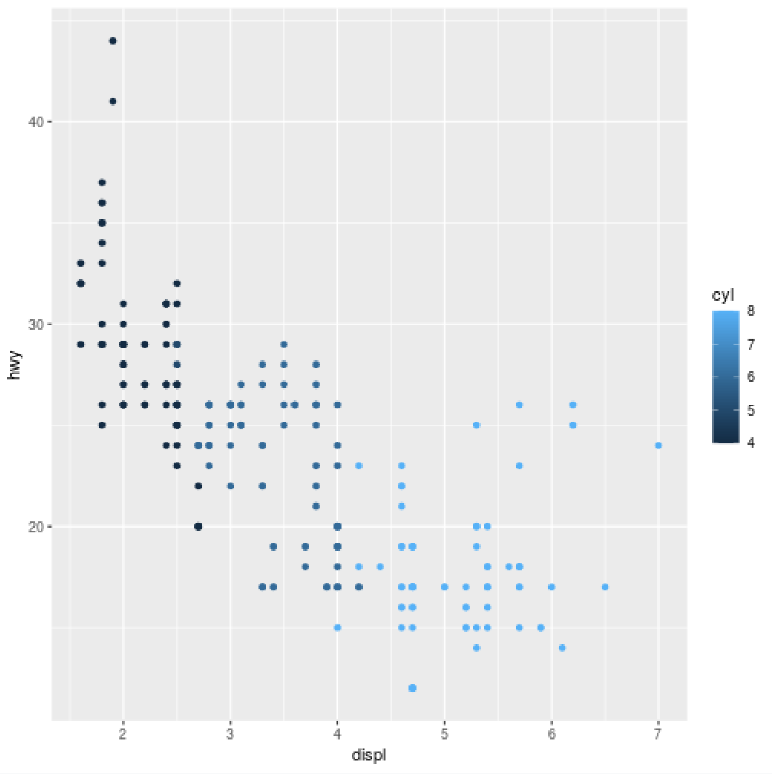
```
ggplot(mpg,
       aes(x = displ, y = hwy)) +
  geom_point(aes(color = cyl))
```



Continuous color scales

Default continuous colour scheme

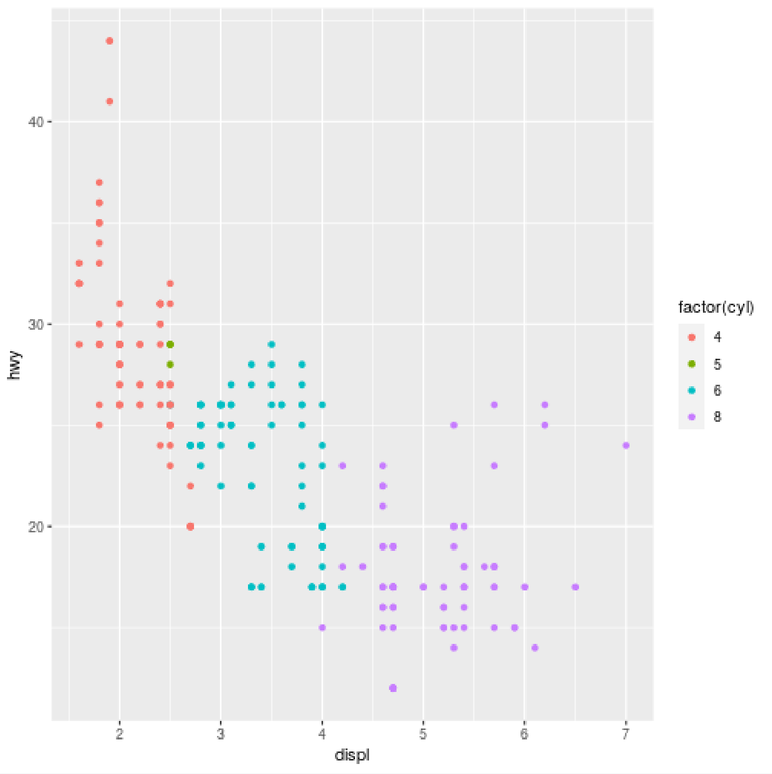
```
ggplot(mpg,
       aes(x = displ, y = hwy)) +
  geom_point(aes(color = cyl)) +
  scale_colour_continuous()
```



Discrete color scales

Default discrete colour scheme

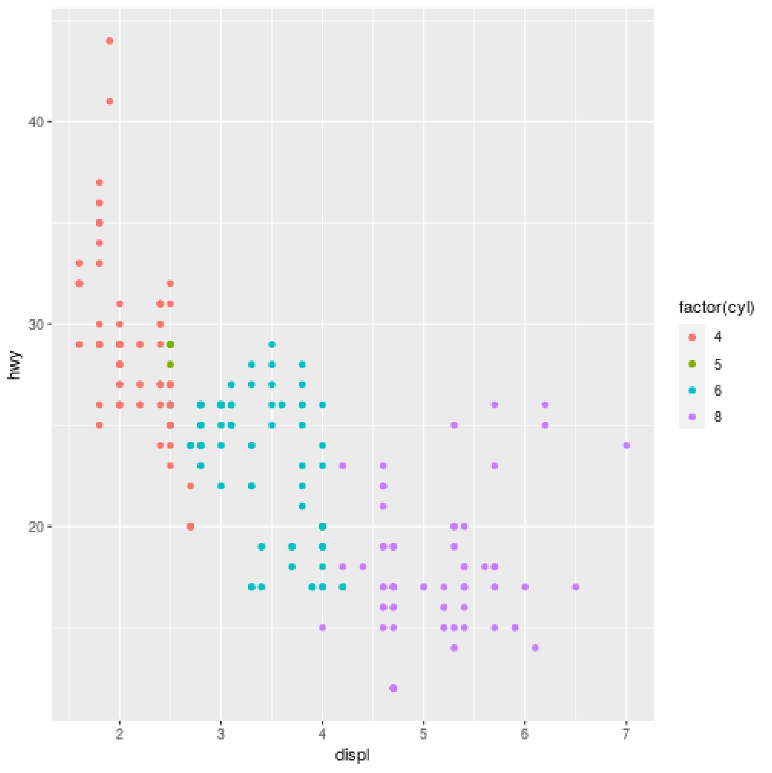
```
ggplot(mpg,
       aes(x = displ, y = hwy)) +
  geom_point(
    aes(color = factor(cyl))
  )
```



Discrete color scales

Default discrete colour scheme

```
ggplot(mpg,
       aes(x = displ, y = hwy)) +
  geom_point(
    aes(color = factor(cyl))
  ) +
  scale_colour_discrete()
```



Color & Fill

Area geoms (barcharts, histograms, polygons) use `fill` to map values to the fill color

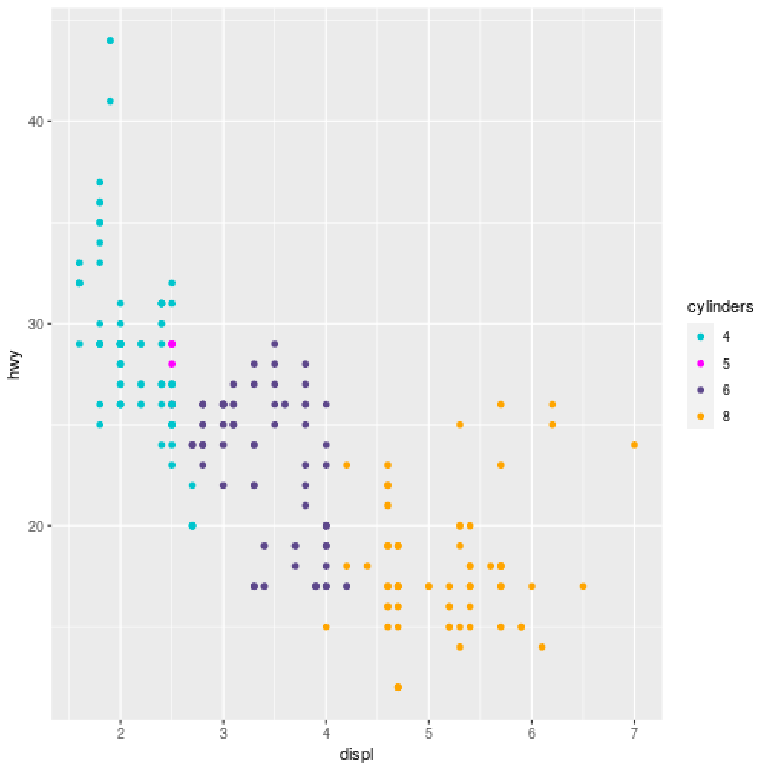
- only discrete color scales can be used e.g. `scale_fill_brewer`
- most general: `scale_fill_manual(..., values)`
  - `values` is a vector of color values.
  - at least as many colors as levels in the variable have to be listed

Color Values:

- can be defined as a hex value or a name of a color
- R colors pdf

Manual color scales

```
ggplot(mpg,
       aes(x = displ,
           y = hwy,
           color = factor(cyl)
       )) +
  geom_point() +
  scale_color_manual(
    "cylinders",
    values = c(
      "turquoise3", "magenta",
      "mediumpurple4", "orange"
    )
  )
```

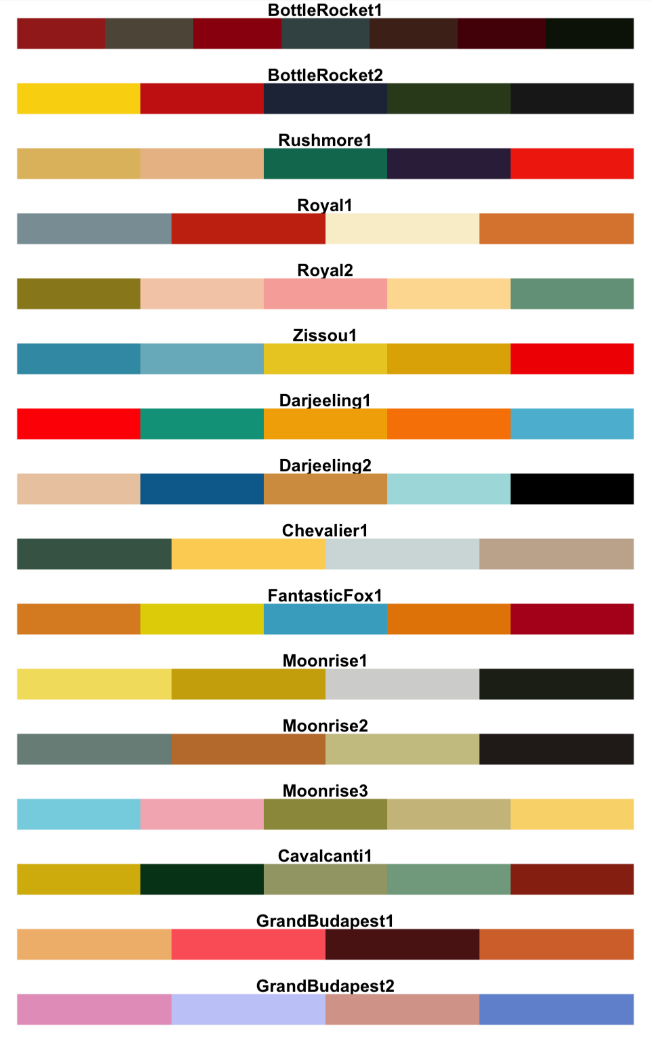


Predefined color palettes

The most commonly used color scales, include:

- Okabe-Ito palette [ggokabeito package]
- Viridis color scales [viridis package]
- Colorbrewer palettes [RColorBrewer package]
- Scientific journal color palettes [ggsci package]
- Wes Anderson color palettes [wesanderson package]

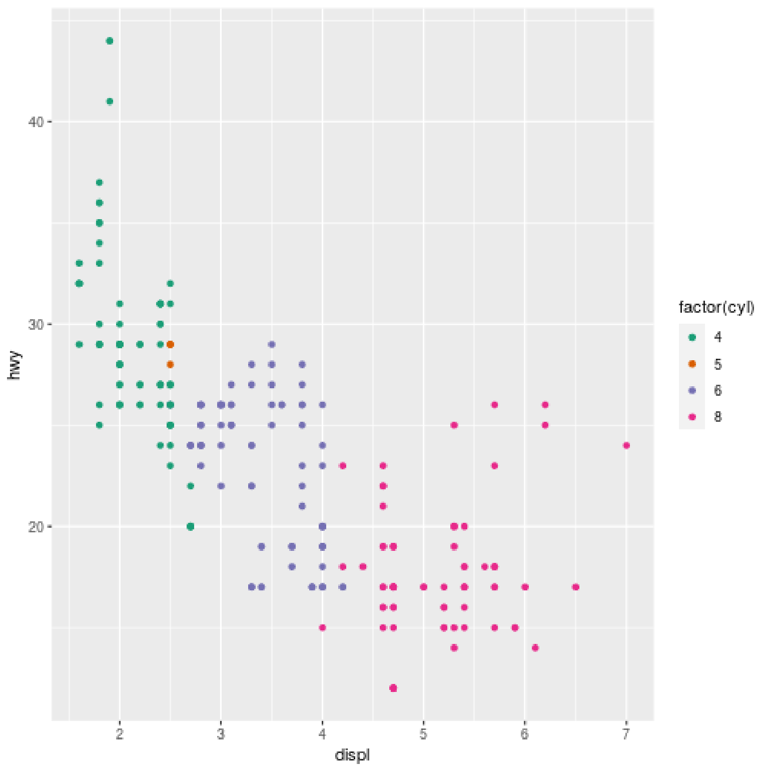
For the most extensive list I've found, look here



Other color scales

While function name is predictable, arguments are not

```
ggplot(mpg,
       aes(x = displ,
           y = hwy,
           color = factor(cyl)
       )) +
  geom_point() +
  scale_colour_brewer(
    palette = 'Dark2'
  )
```



Legends

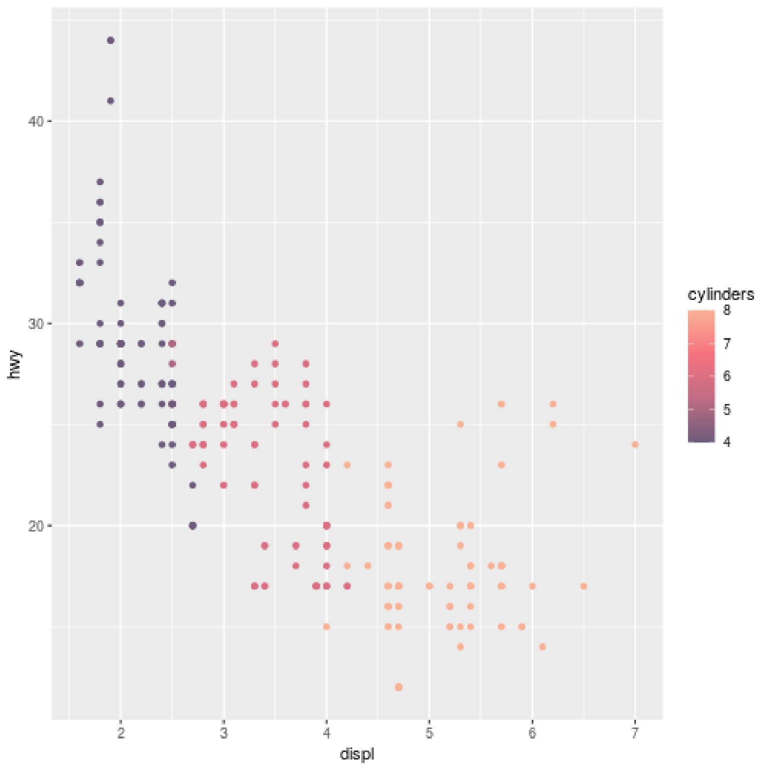
The **guide** or **legend** connects non-axis aesthetics in the data visualization like color and size to the data

The `guides()` function controls all legends by connecting to the aes.

- `guide_colorbar()`: continuous colors
- `guide_legend()`: discrete values (shapes, colors)
- `guide_axis()`: control axis text/spacing, add a secondary axis
- `guide_bins()`: creates "bins" of values in the legend
- `guide_colorsteps()`: makes colorbar discrete

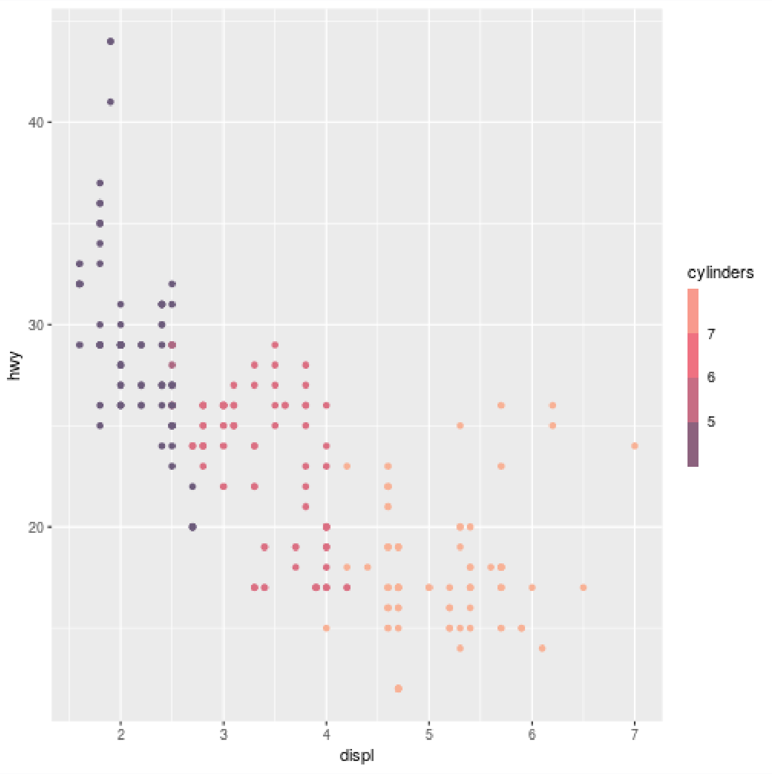
Guides

```
ggplot(mpg,
       aes(x = displ,
           y = hwy,
           color = cyl
       )) +
  geom_point() +
  scale_color_gradientn(
    "cylinders",
    colours = c(
      "#6C5B7B", "#C06C84",
      "#F67280", "#F8B195"
    )
  )
```



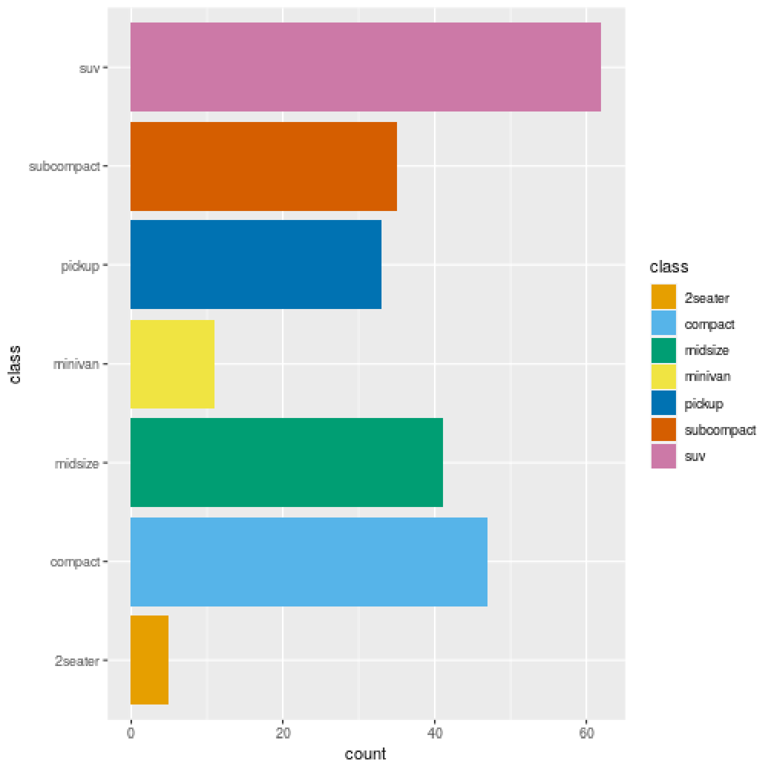
Guides

```
ggplot(mpg,
       aes(x = displ,
           y = hwy,
           color = cyl
       )) +
  geom_point() +
  scale_color_gradientn(
    "cylinders",
    colours = c(
      "#6C5B7B", "#C06C84",
      "#F67280", "#F8B195"
    ),
    guide = guide_colorsteps(
      barwidth = 0.5,
      barheight = 8
    )
  )
```



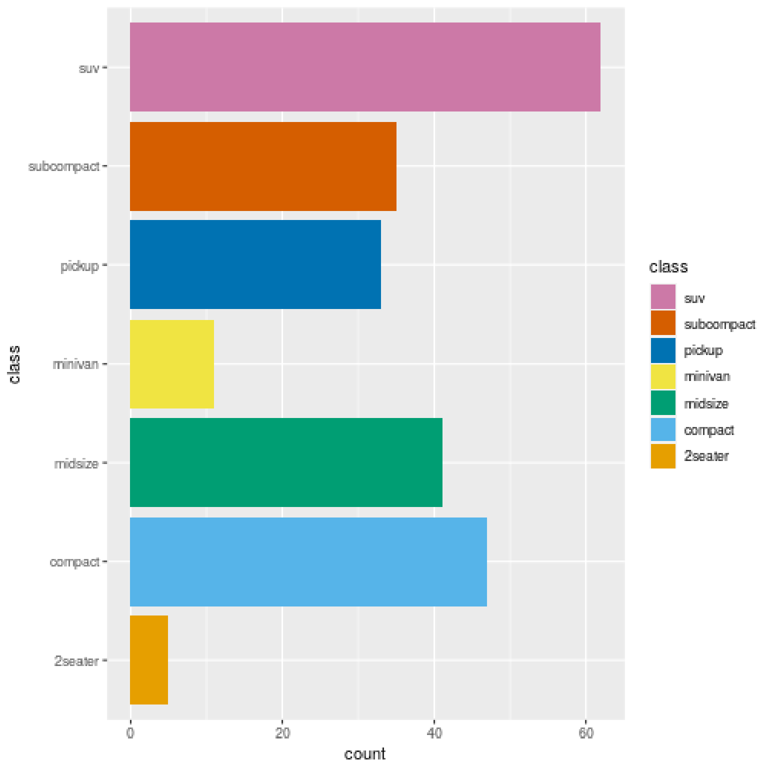
Guides

```
ggplot(mpg,
       aes(y = class,
           fill = class
       )) +
  geom_bar() +
  ggokabeito::scale_fill_okabe_ito()
```



Guides

```
ggplot(mpg,
       aes(y = class,
           fill = class
       )) +
  geom_bar() +
  ggokabeito::scale_fill_okabe_ito(
    guide = guide_legend(
      reverse = TRUE
    )
  )
```



Themes

Themes

The **theme** describes the appearance of the plot, such as the background color, font size, positions of labels, etc.

Specific themes:

- `theme_grey()`: default
- `theme_bw()`: white background, gray gridlines
- `theme_classic()`: looks more like base R plots
- `theme_void()`: removes all background elements, all axes elements, keeps legends

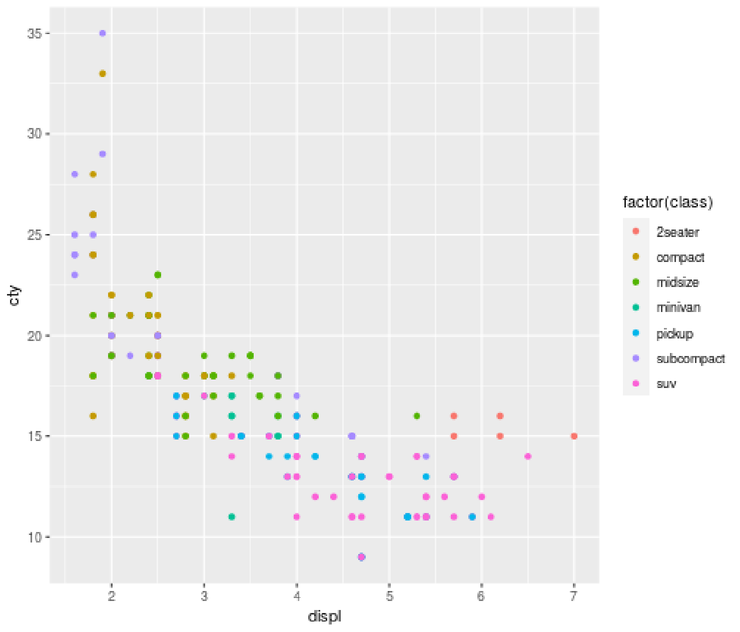
In addition to `{ggplot2}`'s built-in themes, other packages like `{ggthemes}` allow you to choose from even more styles.

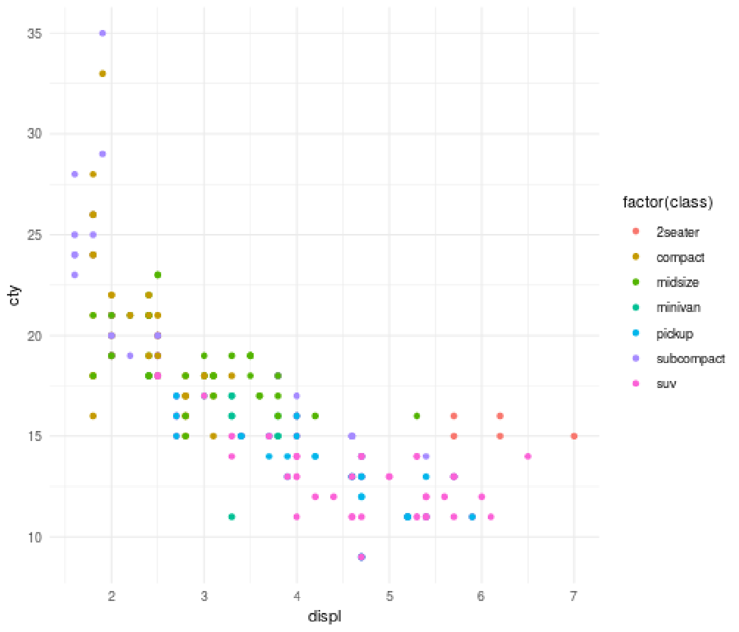
Theme examples

```
p <- ggplot(mpg, aes(x = displ, y =  cty, colour= factor(class))) + geom_point()
```

```
p + theme_grey()
```

```
p + theme_minimal()
```



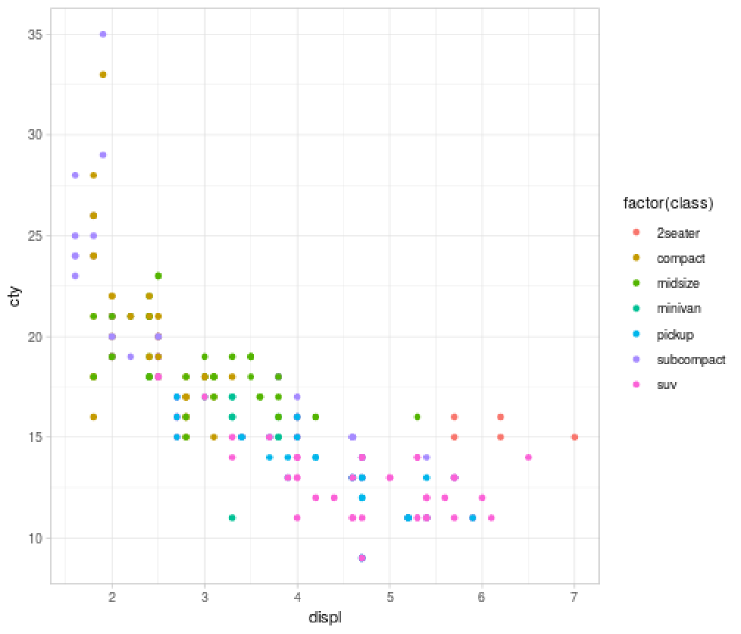


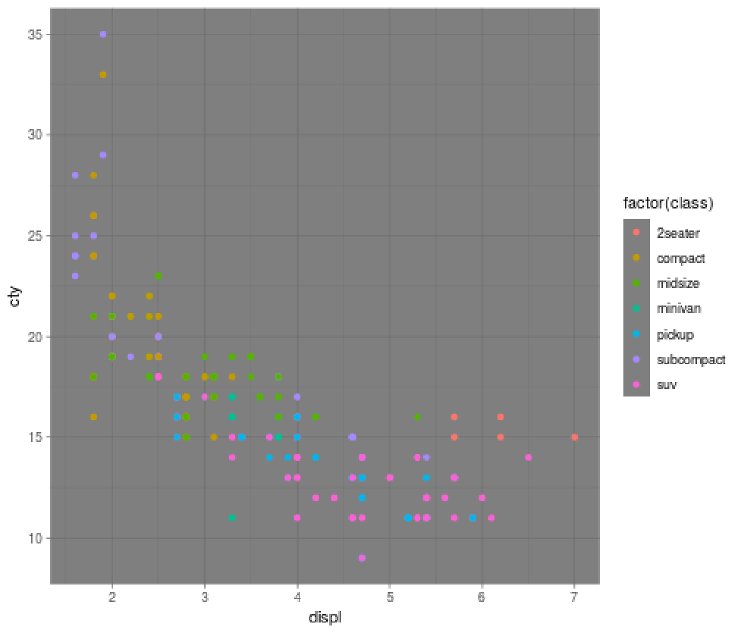
Theme examples

```
p <- ggplot(mpg, aes(x = displ, y =  cty, colour= factor(class))) + geom_point()
```

```
p + theme_light()
```

```
p + theme_dark()
```

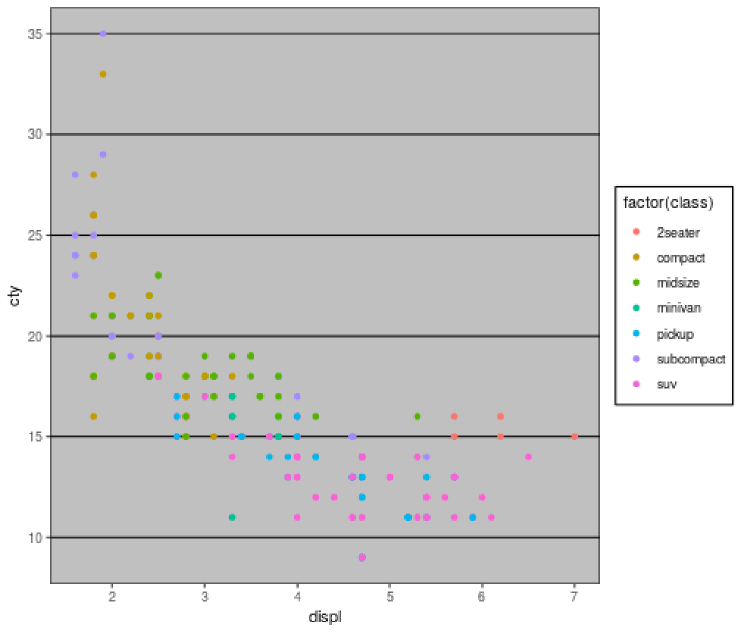




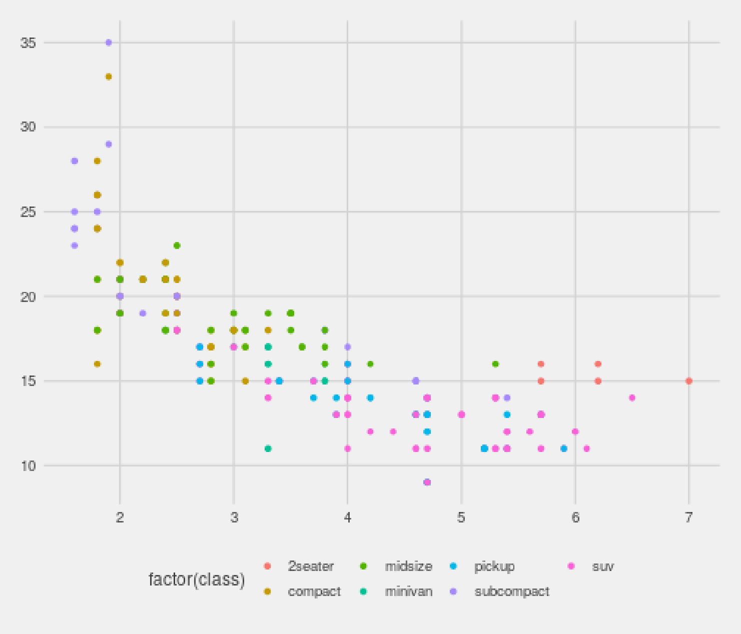
More themes

```
library(ggthemes)
```

```
p + theme_excel()
```



```
p + theme_fivethirtyeight()
```



Theme customization

The `theme()` function can modify any non-data element of the plot.

- adjust the appearance of every "non-data element" of the viz
- fonts, background, text positioning, legend appearance, facet appearance, etc.

Rule of thumb: when changing an element that shows data, use `aes()` and scales. Otherwise, use themes.

Elements of themes

- **Line elements**: axis lines, minor and major grid lines, plot panel border, axis ticks background color, etc.
- **Text elements**: plot title, axis titles, legend title and text, axis tick mark labels, etc.
- **Rectangle elements**: plot background, panel background, legend background, etc.

There is a specific function to modify each of these three elements :

- `element_line()` to modify the line elements of the theme
- `element_text()` to modify the text elements
- `element_rect()` to change the appearance of the rectangle elements
- `element_blank()` to draw nothing and assign no space

Elements of themes

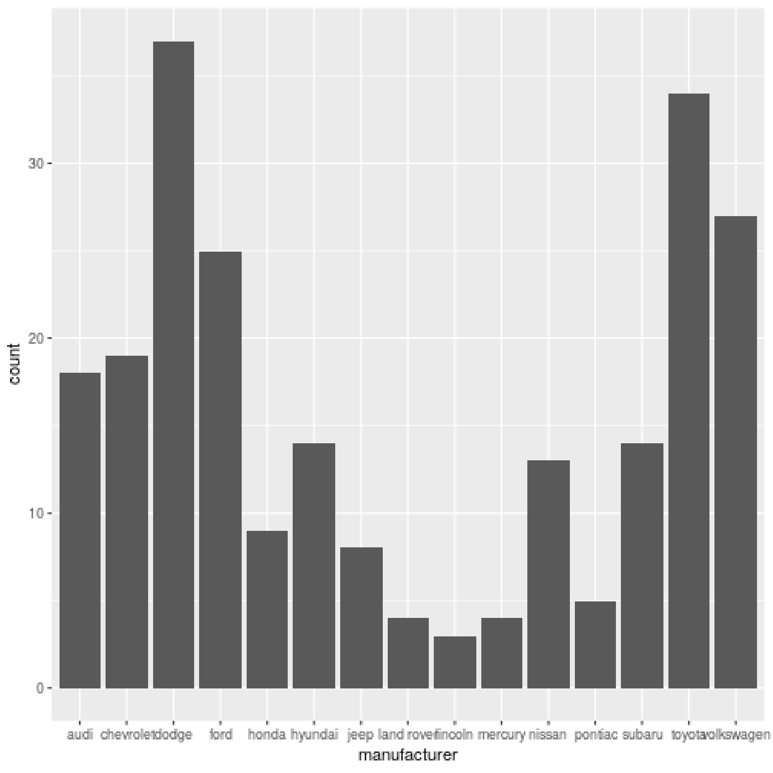
- Axis: `axis.line`, `axis.text.x`, `axis.text.y`, `axis.ticks`, `axis.title.x`, `axis.title.y`
- Legend: `legend.background`, `legend.key`, `legend.text`, `legend.title`
- Panel: `panel.background`, `panel.border`, `panel.grid.major`, `panel.grid.minor`
- Strip (facetting): `strip.background`, `strip.text.x`, `strip.text.y`

For a complete overview see `?theme`

Changing elements manually

To change an element, add the theme function and specify inside:

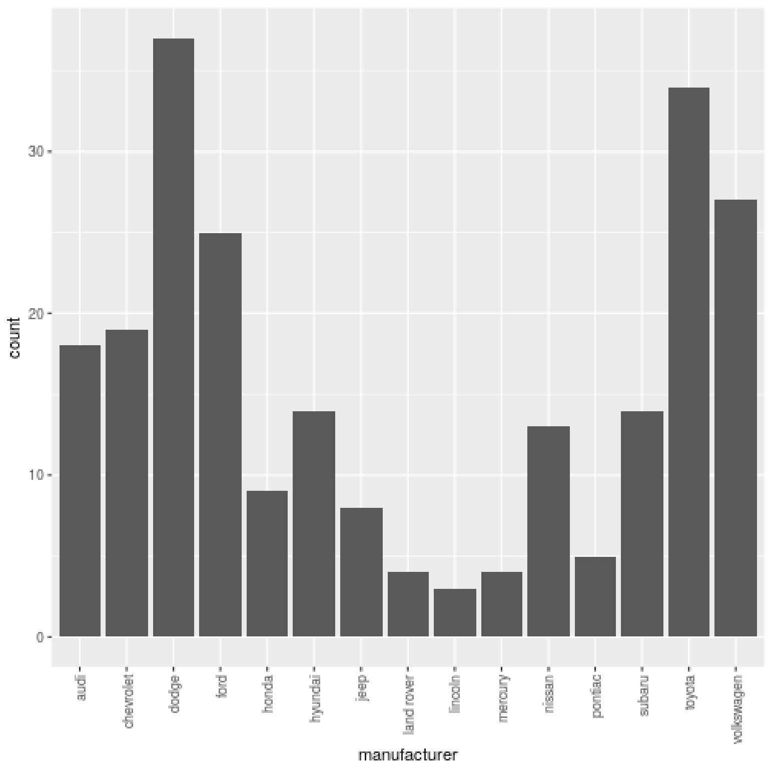
```
ggplot(mpg, aes(x = manufacturer)) +
  geom_bar()
```



Changing elements manually

To change an element, add the theme function and specify inside:

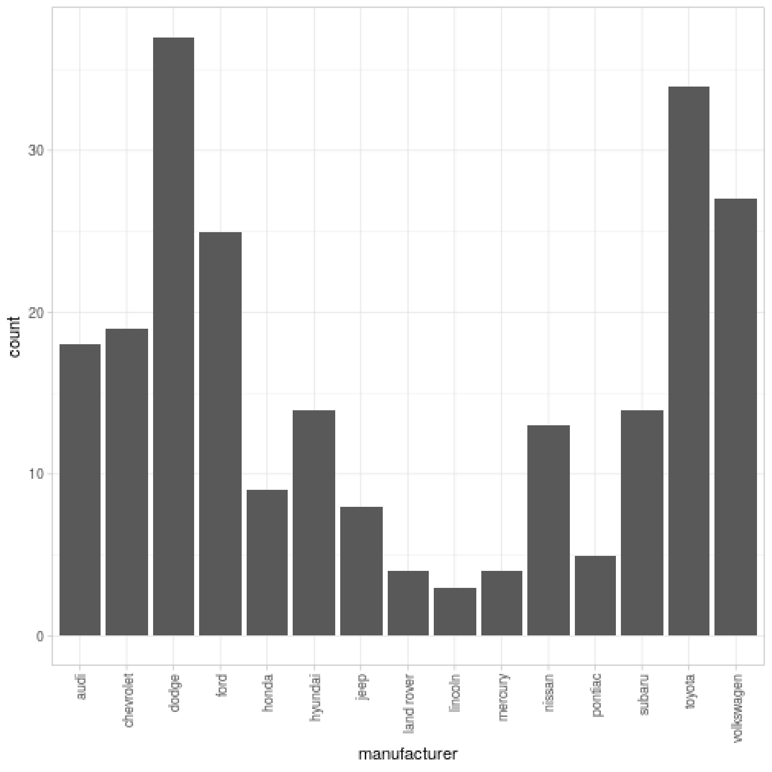
```
ggplot(mpg, aes(x = manufacturer)) +
  geom_bar() +
  theme(
    axis.text.x = element_text(
      angle=90,
      vjust=0.5,
      hjust=1)
    )
```



Changing elements manually

To modify a predefined theme, add modifications *afterwards*

```
ggplot(mpg, aes(x = manufacturer)) +
  geom_bar() +
  theme_light() +
  theme(
    axis.text.x = element_text(
      angle=90,
      vjust=0.5,
      hjust=1)
    )
```



Your Turn

Statrting with the previous example, add color to various elements of the theme and modify their sizes:

- Make the x-axis text green
- Make the x-axis text big and green and the y-axis text small and purple
- Change something else!

```r
ggplot(mpg, aes(x = manufacturer)) +
  geom_bar() +
  theme_light() +
  theme(axis.text.x = element_text(angle=90, vjust=0.5, hjust=1))
```

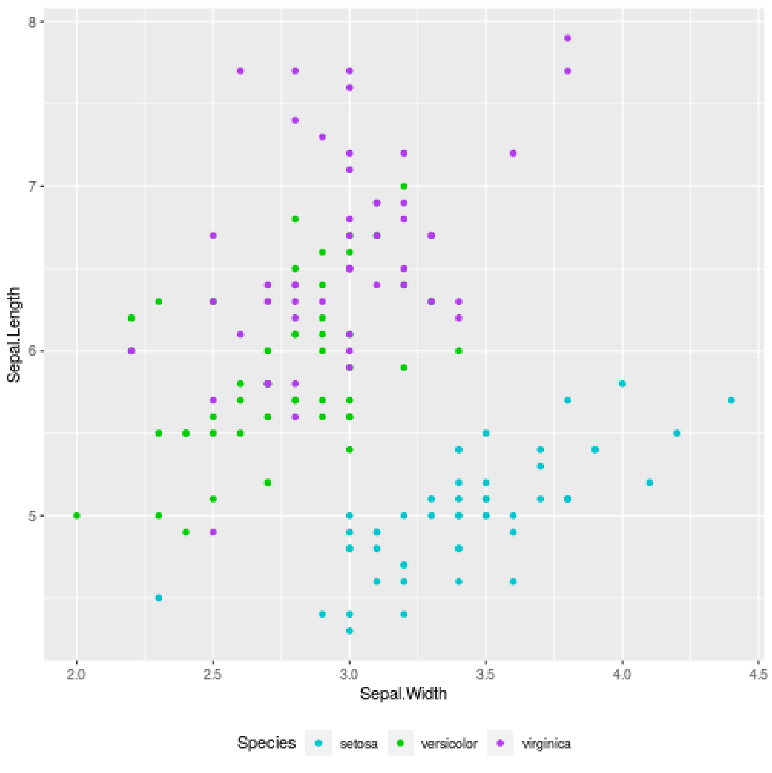
Saving your Work

Saving your Work

We can save the plot to a file (as an image) using the `ggsave()` function:

```
iris_plot <-
  ggplot(
    data = iris,
    aes(x = Sepal.Width,
        y = Sepal.Length,
        color = Species)
    ) +
  geom_point() +
  scale_color_manual(
    values = c("turquoise3", "green3",
    ) +
  theme(
    legend.position = "bottom",
    legend.background = element_blank()
iris_plot
```

```
ggsave("iris-scatter.png",
       plot = iris_plot)
```



Resources

- Documentation: http://ggplot2.tidyverse.org/reference/
- RStudio cheat sheet for ggplot2
- Sam Tyner's ggplot2 workshop
- Thomas Lin Pedersen's ggplot2 webinar: part 1 and part 2
- Cedric Scherer's "A ggplot2 tutorial for beautiful plotting in R"