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Lecture 6: Data Visualization II

Data Science for Business Analytics

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Graphics for communications

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Two weeks ago, you learned how to use plots as tools for *exploration*:

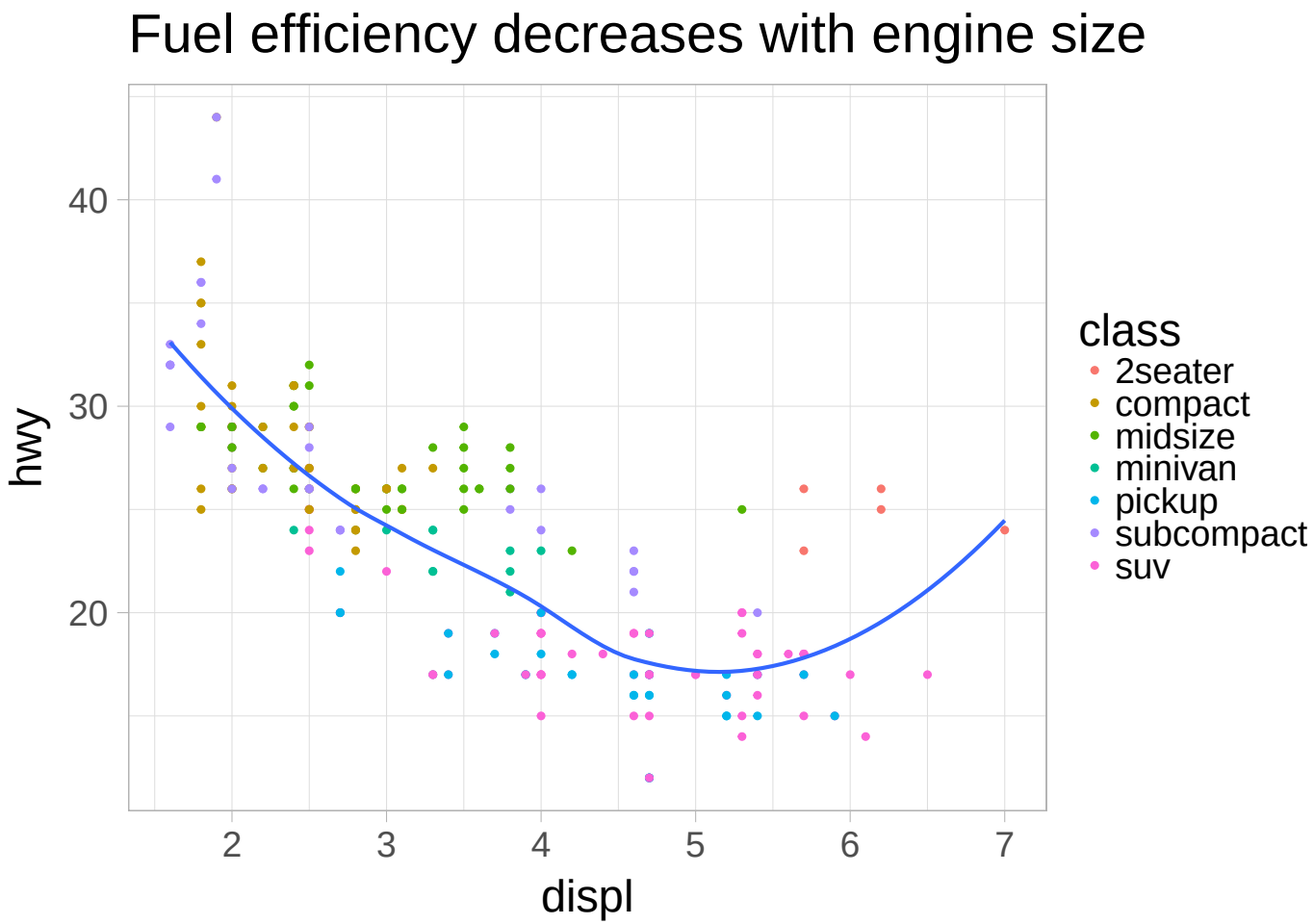
- With exploratory plots, you know—even before looking—which variables the plot will display.
- Each plot is made for a purpose, then is quickly looked at, and finally discarded the next plot.

Once you understand your data, you need to

- **communicate** your understanding to others,
- and to help do that quickly, make your plots self-explanatory.

Label

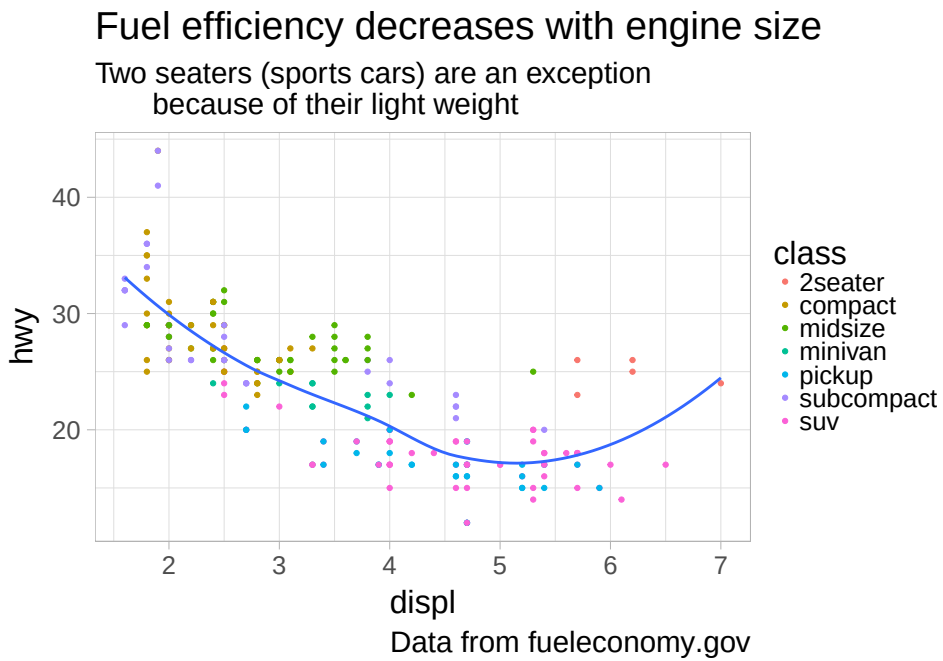

```
ggplot(mpg, aes(displ, hwy)) + geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  labs(title = "Fuel efficiency decreases with engine size")
```



More text

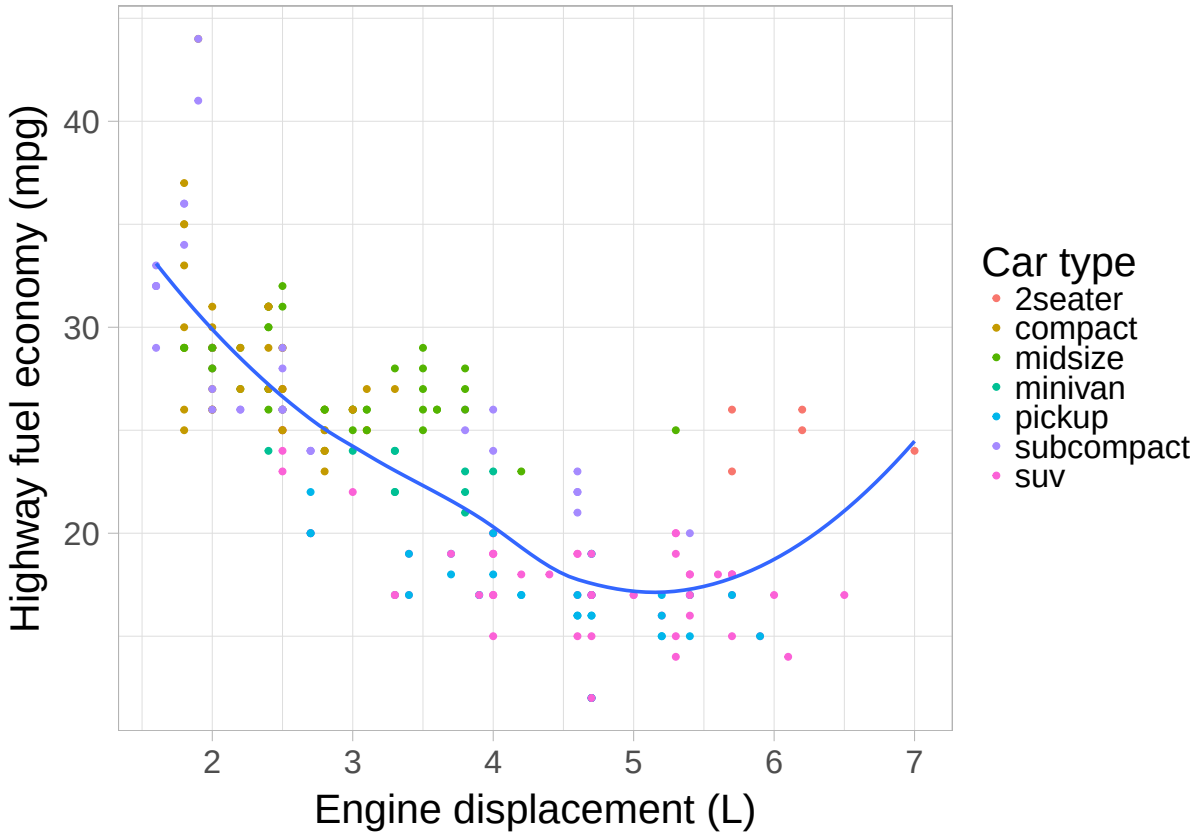
- `subtitle` adds additional detail beneath the title.
- `caption` adds text at the bottom right of the plot.

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(color = class)) + geom_smooth(se = FALSE) +
  labs(title = "Fuel efficiency decreases with engine size",
       subtitle = "Two seaters (sports cars) are an exception
       because of their light weight",
       caption = "Data from fueleconomy.gov")
```



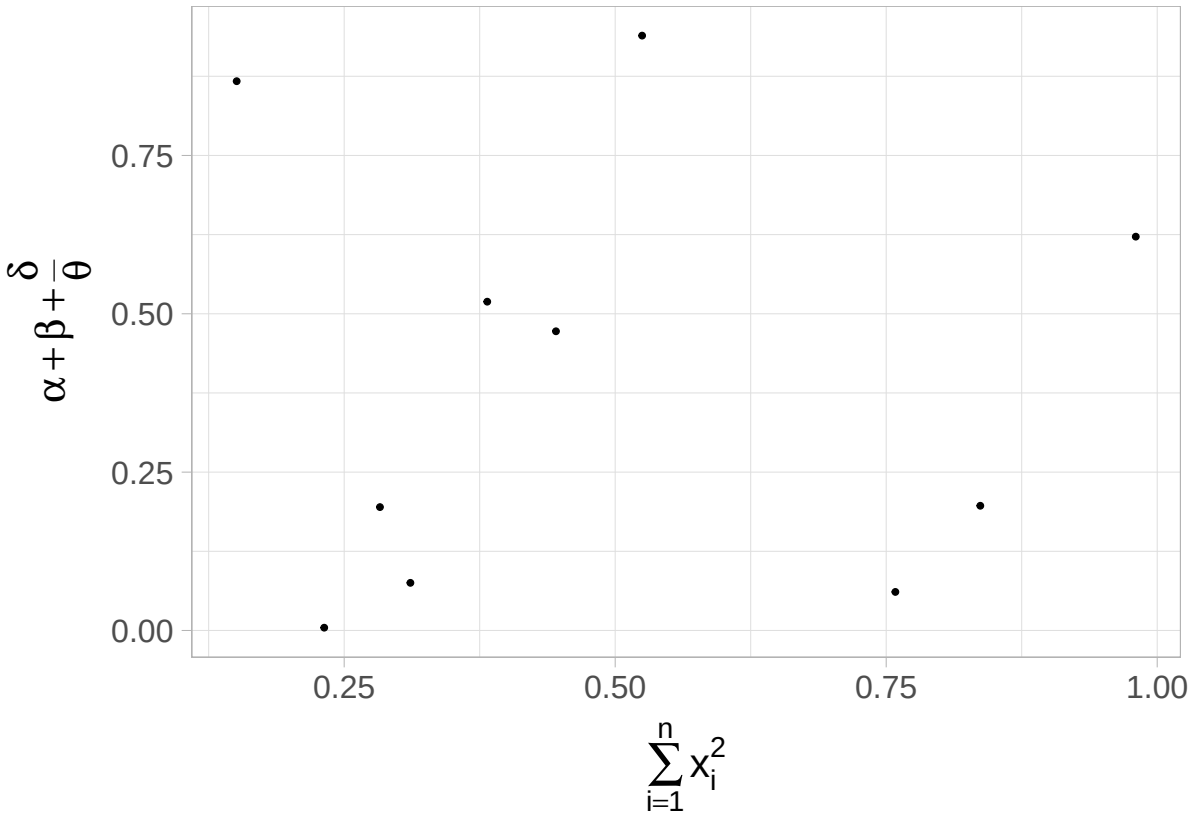
Axis


```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  geom_smooth(se = FALSE) +
  labs(x = "Engine displacement (L)",
       y = "Highway fuel economy (mpg)",
       colour = "Car type")
```



Mathematical expressions

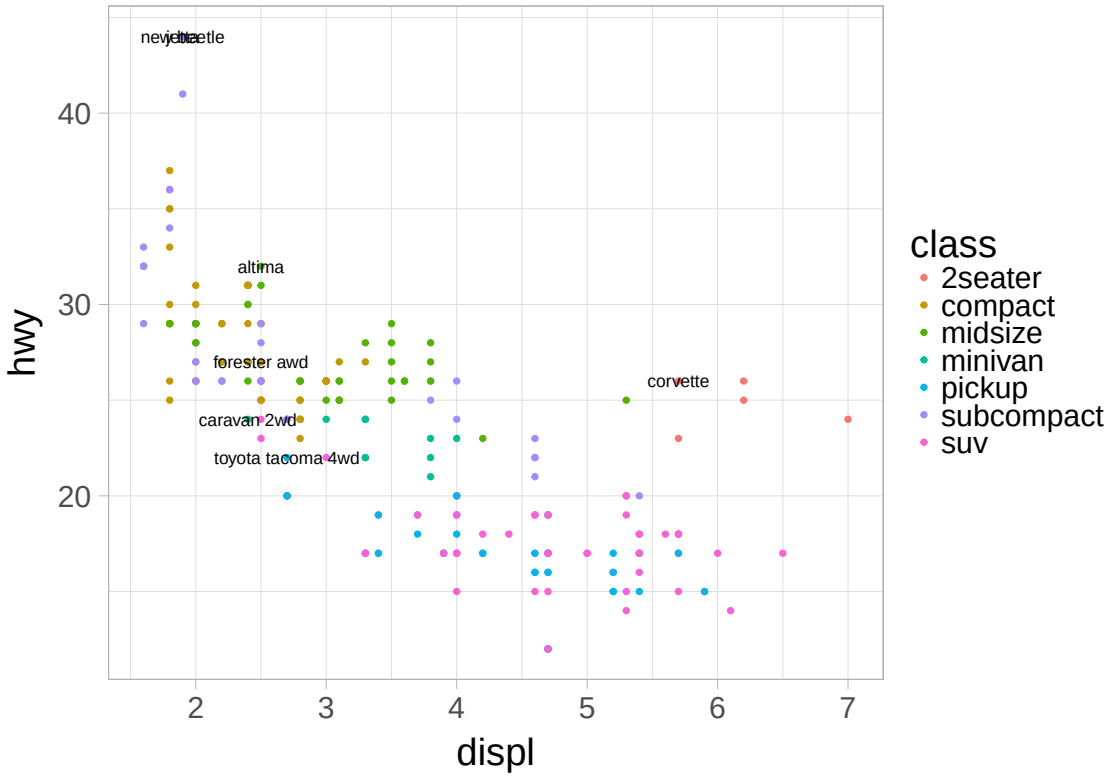

```
df <- tibble(x = runif(10),
             y = runif(10))
ggplot(df, aes(x, y)) + geom_point() +
  labs(x = quote(sum(x[i] ^ 2, i == 1, n)),
       y = quote(alpha + beta + frac(delta, theta)))
```



Annotations

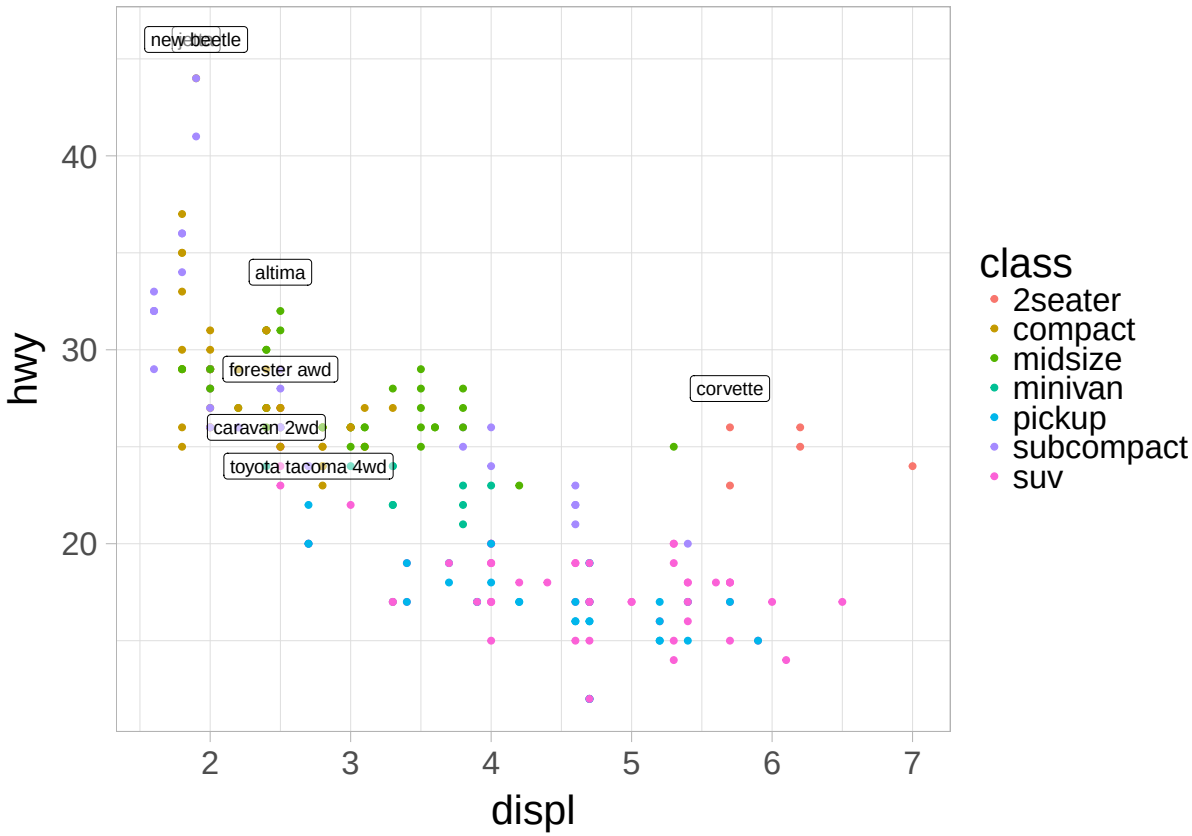

```
best_in_class <- mpg %>%
  group_by(class) %>%
  filter(row_number(desc(hwy)) == 1)

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



Nudge annotations

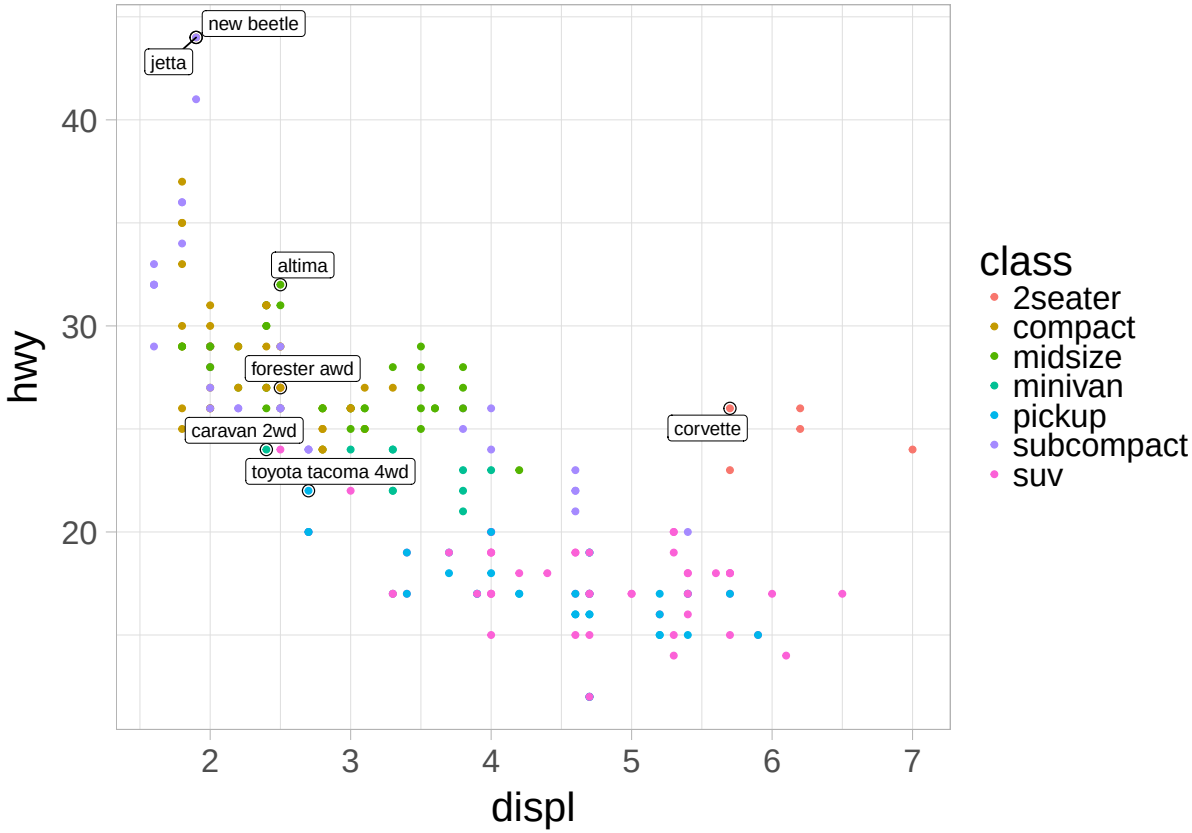

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  geom_label(aes(label = model), data = best_in_class,
             nudge_y = 2, alpha = 0.5)
```



Or better

The **ggrepel** package by Kamil Slowikowski:

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



Replace legend by labels on the plot

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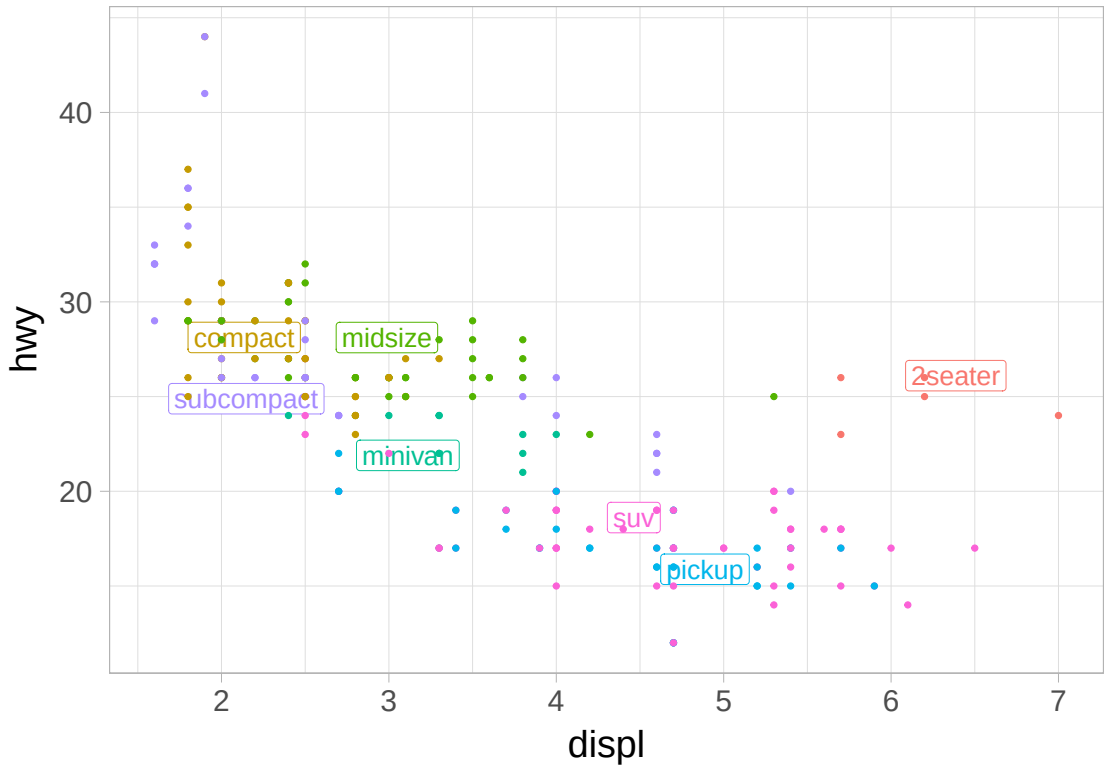
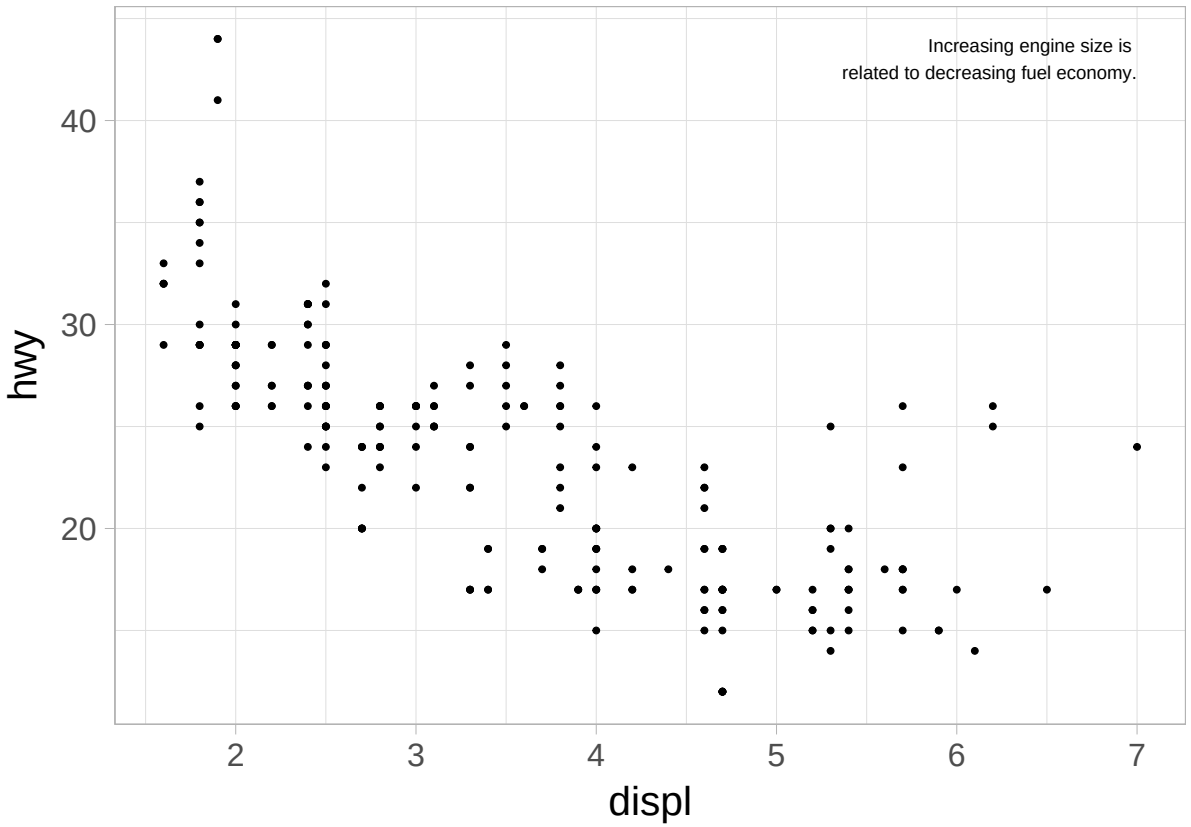
```
class_avg <- mpg %>% group_by(class) %>%
  summarise(displ = median(displ), hwy = median(hwy))

ggplot(mpg, aes(displ, hwy, colour = class)) +
  ggrepel::geom_label_repel(aes(label = class), data = class_avg, size = 6,
                            label.size = 0, segment.color = NA) +
  geom_point() + theme(legend.position = "none")
```



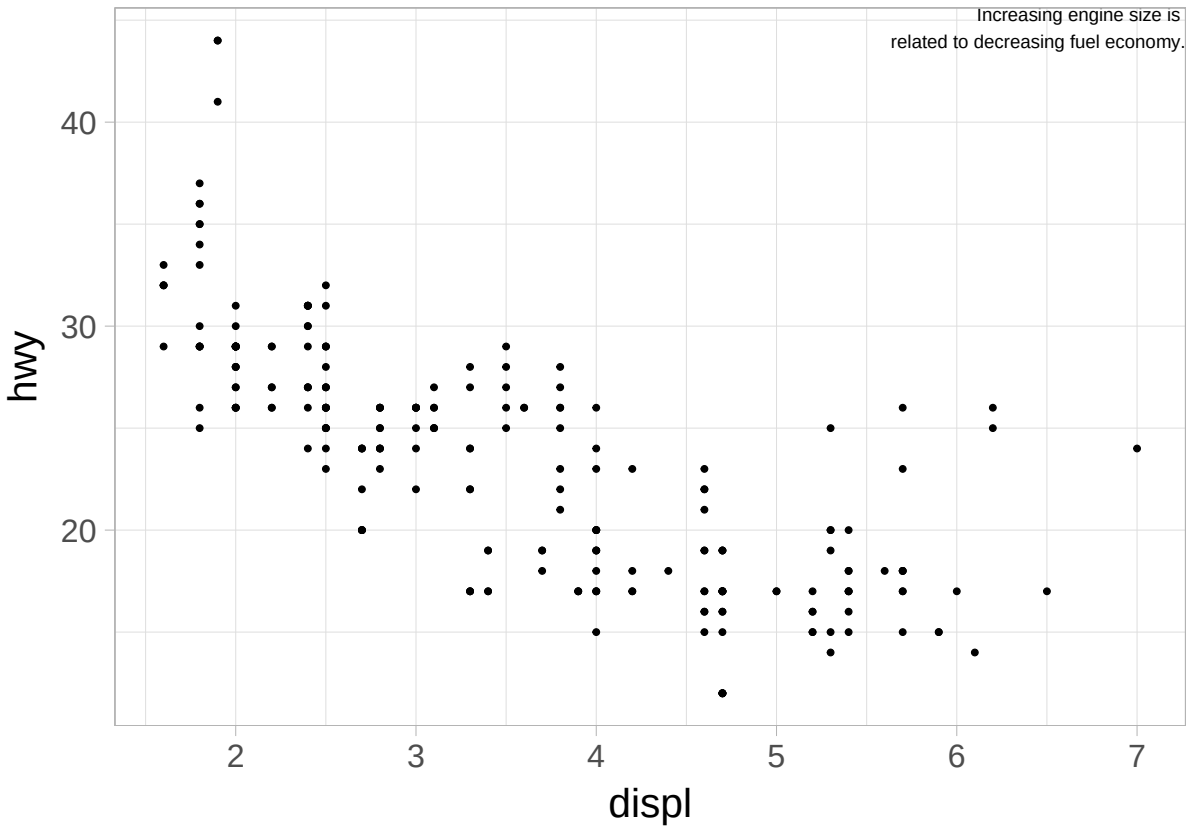
To add a single label to the plot


```
label <- mpg %>%
  summarise(displ = max(displ), hwy = max(hwy),
label = "Increasing engine size is \nrelated to decreasing fuel economy.")

ggplot(mpg, aes(displ, hwy)) + geom_point() +
  geom_text(aes(label = label), data = label, vjust = "top", hjust = "right")
```



An alternative


```
label <- tibble(displ = Inf, hwy = Inf,
label = "Increasing engine size is \nrelated to decreasing fuel economy.")

ggplot(mpg, aes(displ, hwy)) + geom_point() +
  geom_text(aes(label = label), data = label,
            vjust = "top", hjust = "right")
```



To automatically add line breaks


```
"Increasing engine size is related to decreasing fuel economy." %>%
  stringr::str_wrap(width = 40) %>%
  writeLines()
```

```
## Increasing engine size is related to
## decreasing fuel economy.
```

To control the alignment of the label

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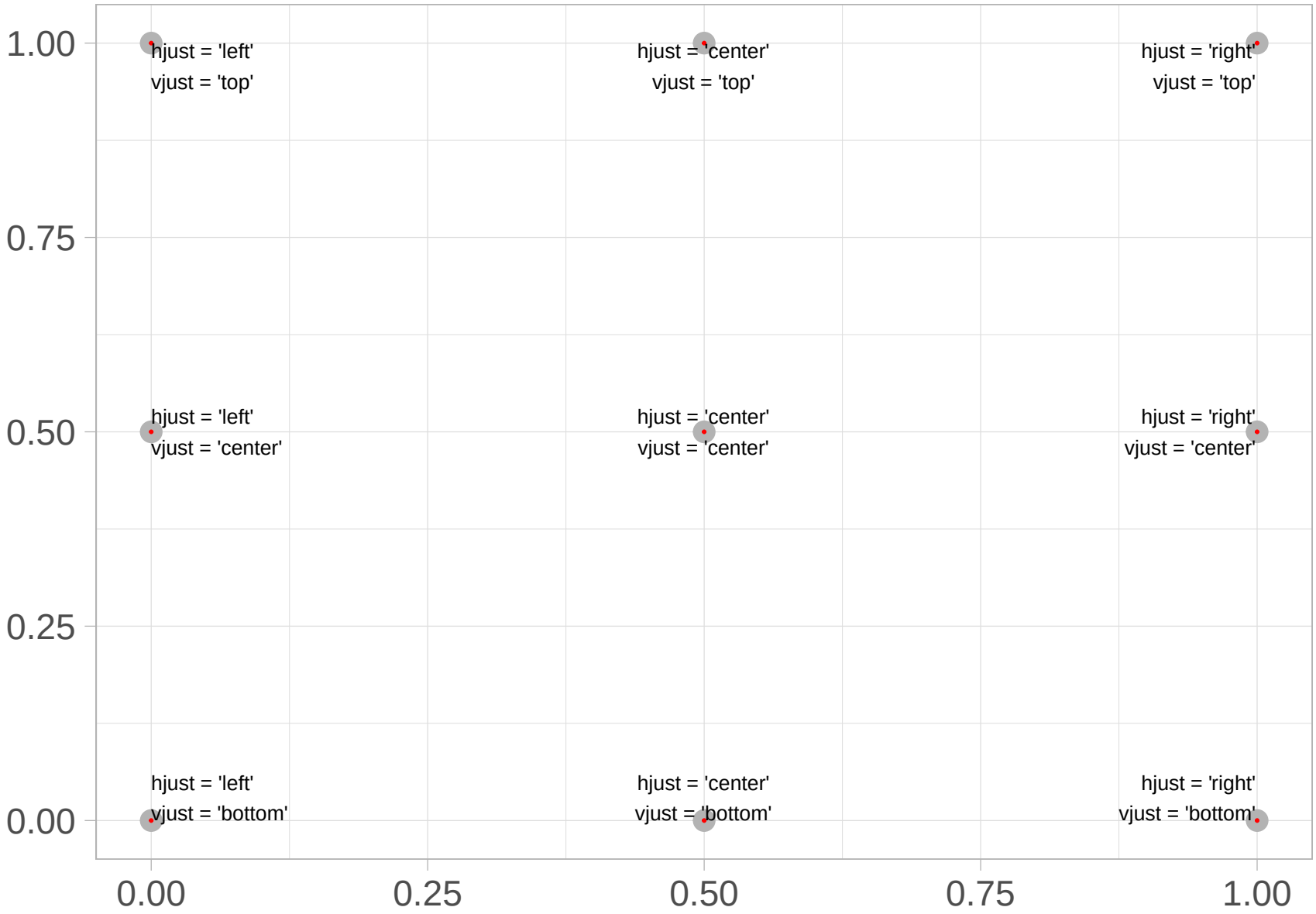


Geoms to help annotate your plot

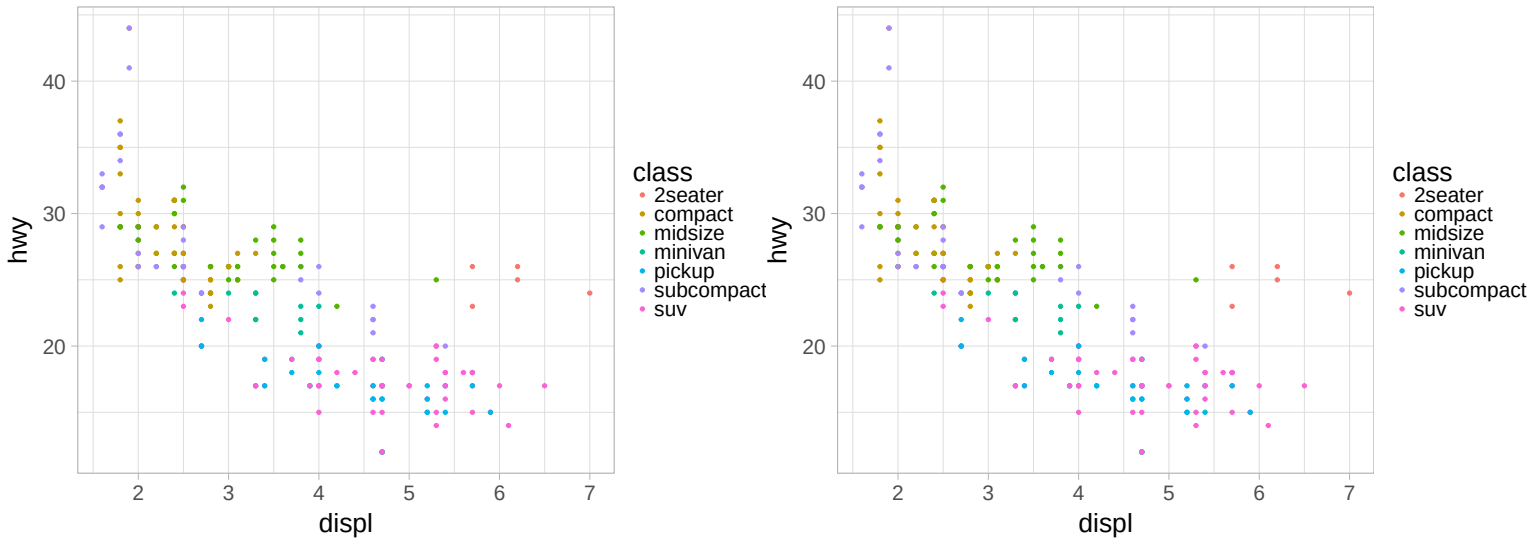
- `geom_hline()` and `geom_vline()` to add reference lines (using e.g. `size = 2` is often a good idea)
- `geom_rect()` to draw a rectangle around points of interest (boundaries by `xmin`, `xmax`, `ymin`, `ymax`).
- `geom_segment()` with the `arrow` argument to draw attention to a point with an arrow (`x` and `y` define the starting location, and `xend` and `yend` define the end location).

The only limit is your imagination (and your patience)!

Scales


```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class))

ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  scale_x_continuous() +
  scale_y_continuous() +
  scale_colour_discrete()
```

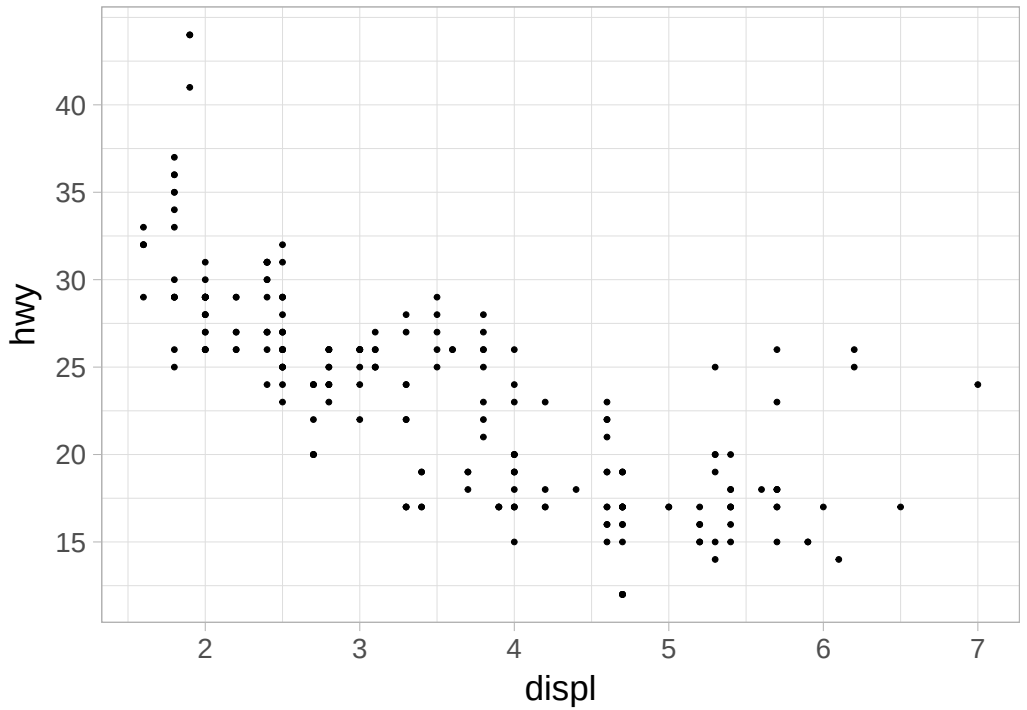


Axis ticks and legend keys

To control the ticks on the axes and the keys on the legend:

- `breaks` controls the position of the ticks, or the values associated with the keys.
- `labels` controls the text label associated with each tick/key.

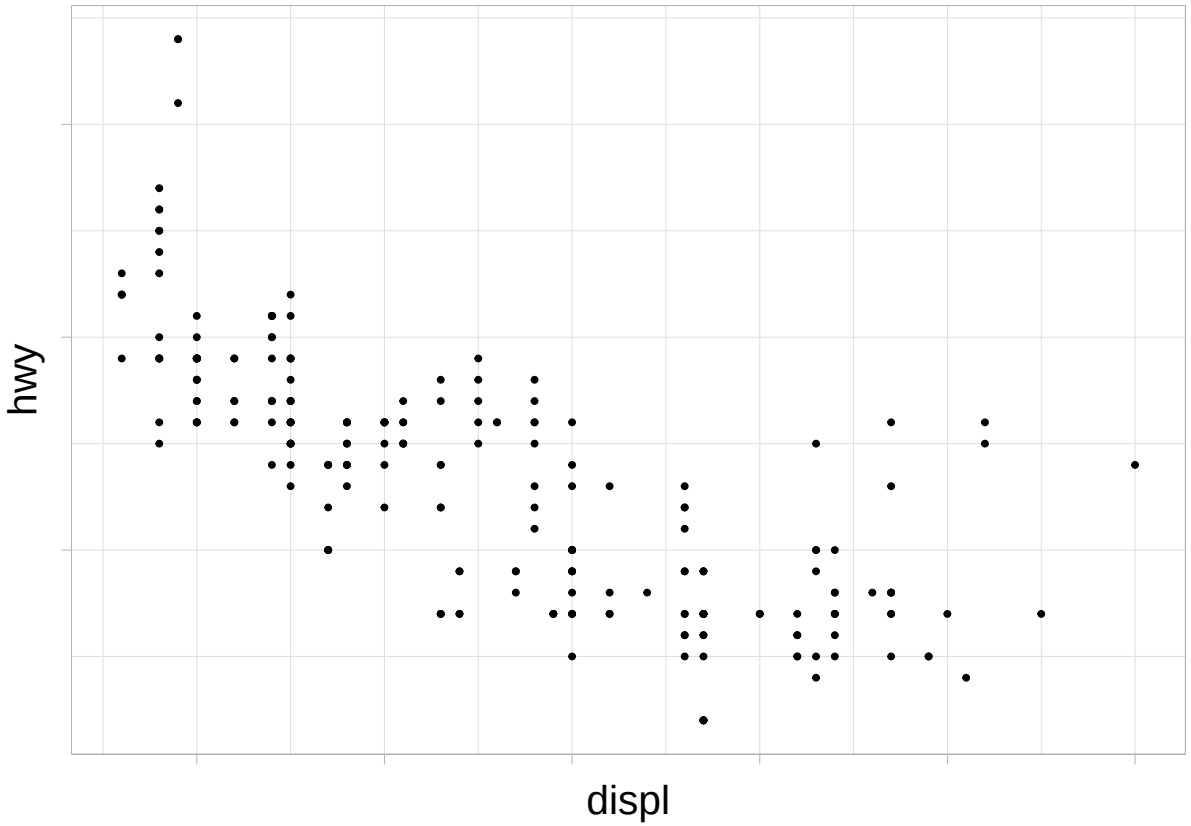
```
ggplot(mpg, aes(displ, hwy)) + geom_point() +
  scale_y_continuous(breaks = seq(15, 40, by = 5))
```



Axis ticks and legend keys II

A useful trick for maps, or for publishing plots where you can't share the absolute numbers:

```
ggplot(mpg, aes(displ, hwy)) + geom_point() +
  scale_x_continuous(labels = NULL) +
  scale_y_continuous(labels = NULL)
```



Two remarks

1. Collectively axes and legends are called **guides**:

   - Axes are used for x and y aesthetics;
   - legends are used for everything else.

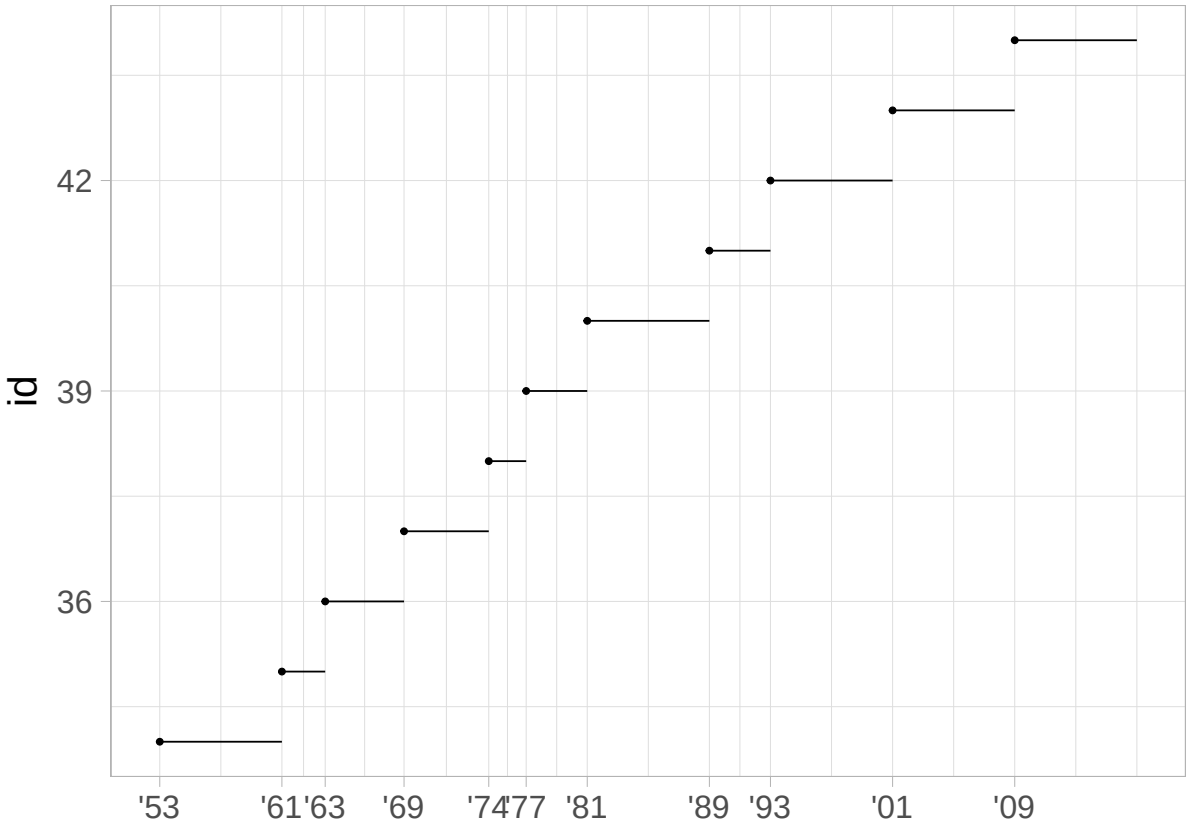
Hence, you can also use `breaks` and `labels` to control the appearance of legends.

2. Breaks and labels for date and datetime scales is a little different:

   - `date_labels` takes a format specification, in the same form as `parse_datetime()`.
   - `date_breaks` (not shown here), takes a string like "2 days" or "1 month".

`breaks` highlighting exactly where the observations occur

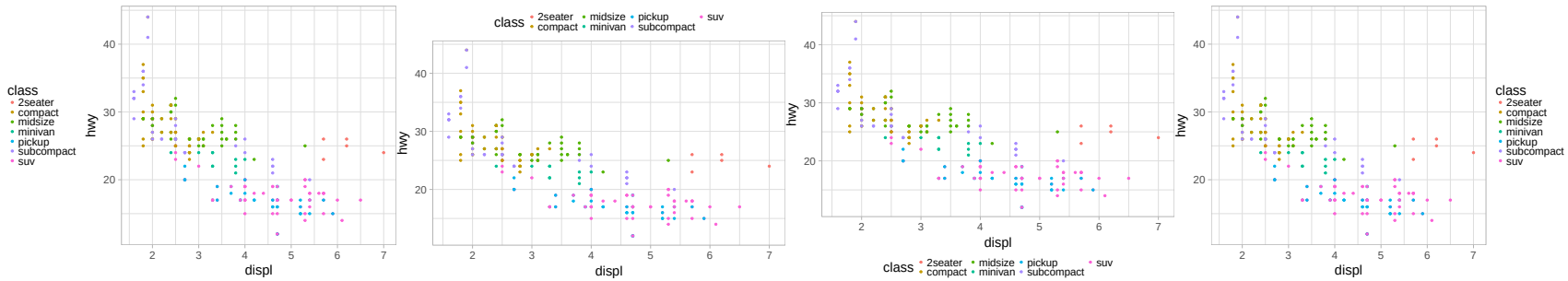

```
presidential %>%
  mutate(id = 33 + row_number()) %>%
  ggplot(aes(start, id)) + geom_point() +
    geom_segment(aes(xend = end, yend = id)) +
    scale_x_date(NULL, breaks = presidential$start, date_labels = "'%y")
```



Legend layout


```
base <- ggplot(mpg, aes(displ, hwy)) + geom_point(aes(colour = class))

base + theme(legend.position = "left")
base + theme(legend.position = "top")
base + theme(legend.position = "bottom")
base + theme(legend.position = "right") # the default
```

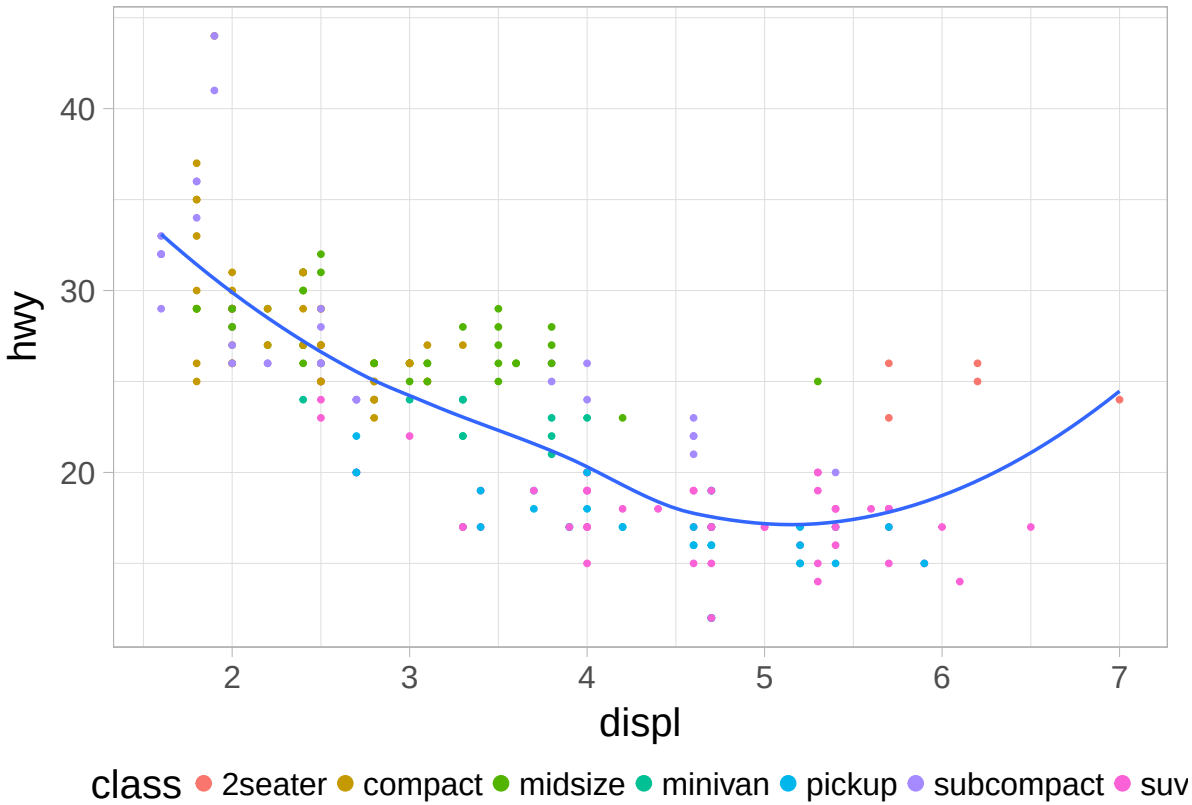


`legend.position = "none"` suppresses the display of the legend!

To control individual legends

Use guides(), guide_legend() or guide_colourbar():

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(colour = class)) +
  geom_smooth(se = FALSE) +
  theme(legend.position = "bottom") +
  guides(colour = guide_legend(nrow = 1, override.aes = list(size = 4)))
```



How could we improve the scale?

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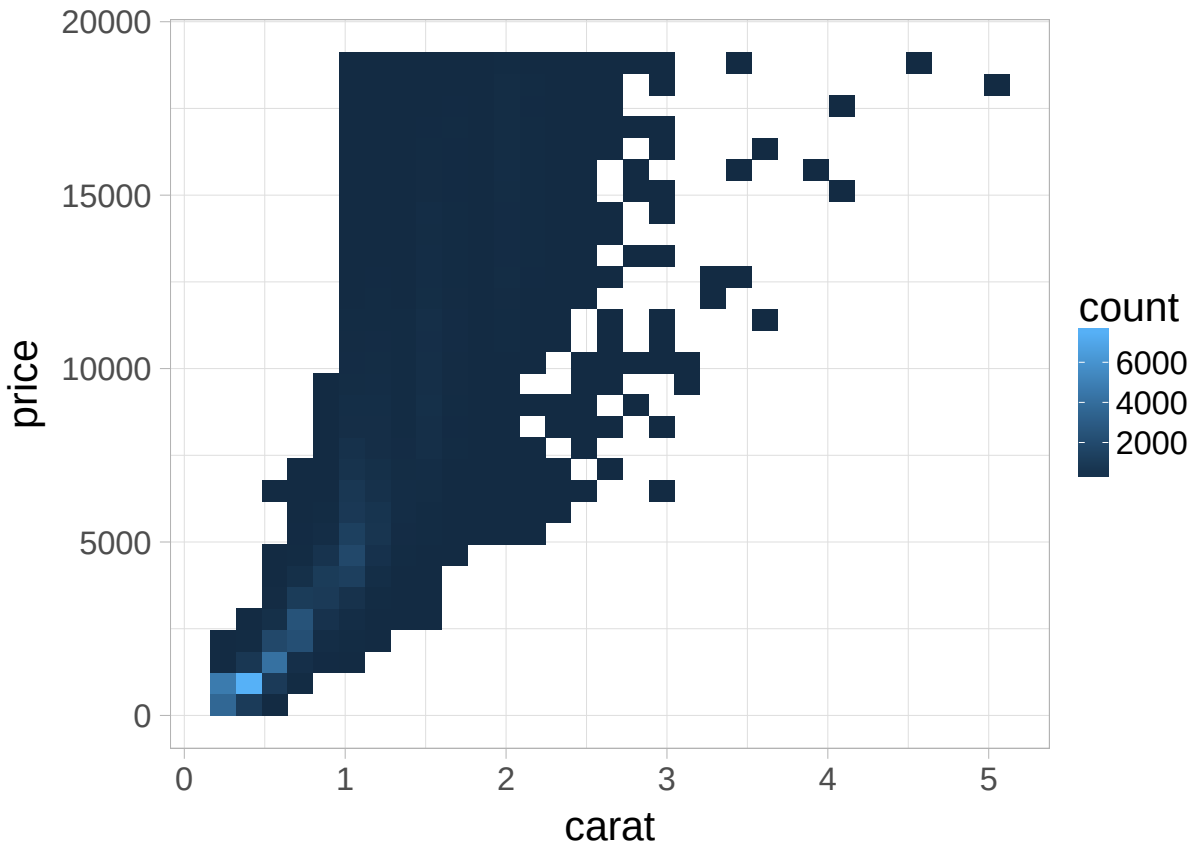
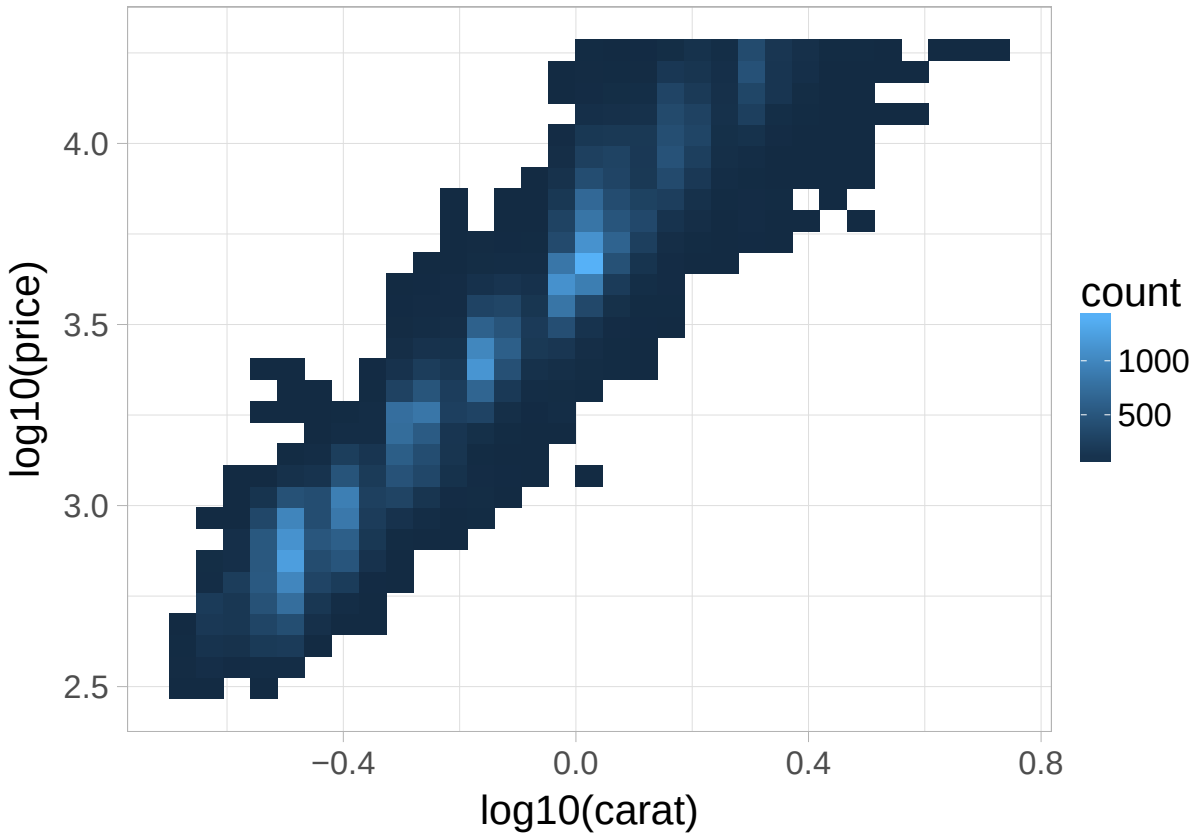
```
ggplot(diamonds, aes(carat, price)) +
  geom_bin2d()
```



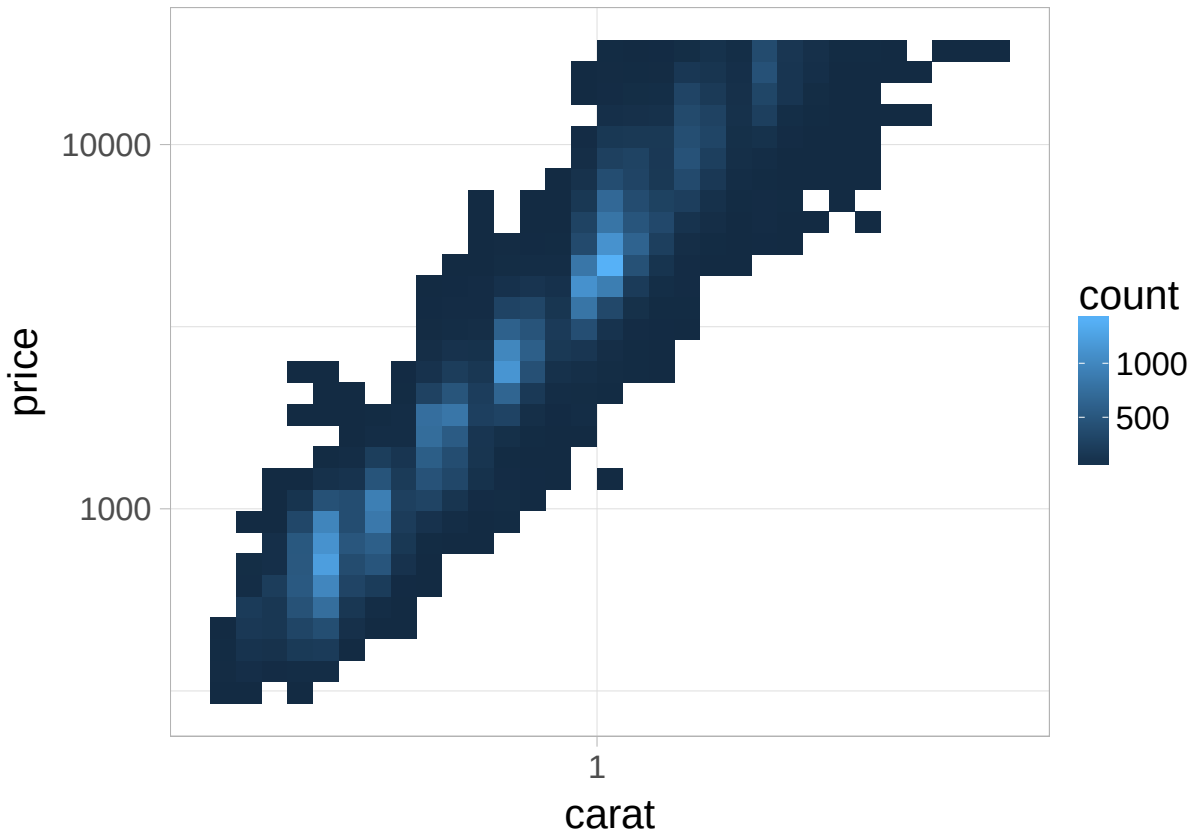
Log-transform the variables


```
ggplot(diamonds, aes(log10(carat), log10(price))) +
  geom_bin2d()
```



. . . or simply replace the scale

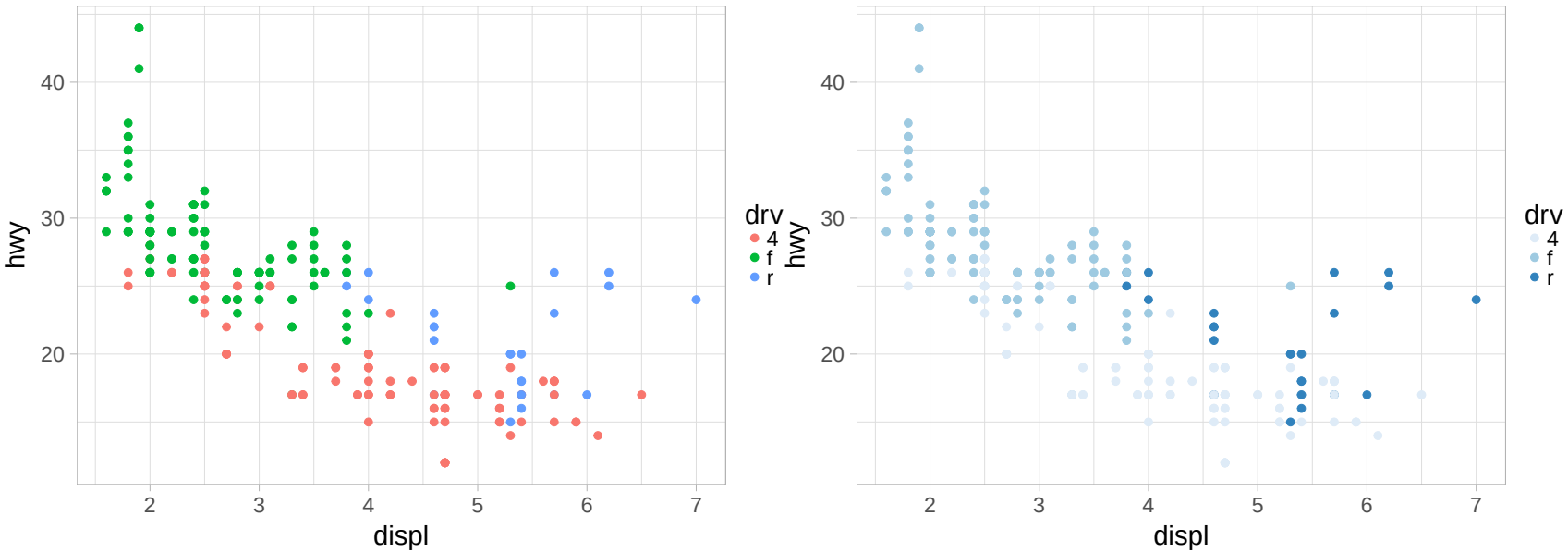

```
ggplot(diamonds, aes(carat, price)) + geom_bin2d() +
  scale_x_log10() + scale_y_log10()
```



Replacing color scales

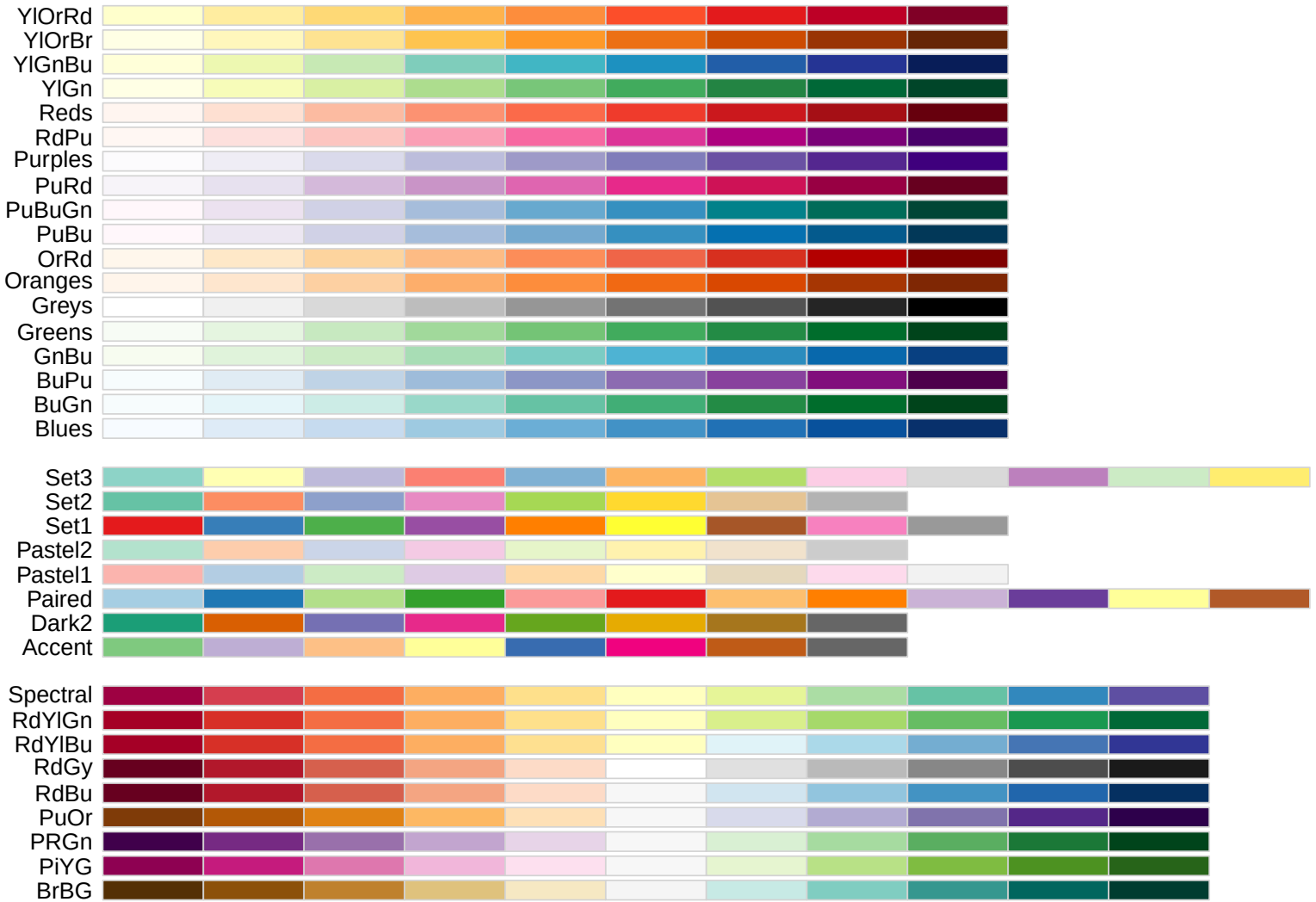

```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(color = drv), size = 3)

ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(color = drv), size = 3) +
  scale_color_brewer(palette = "Blues")
```



The ColorBrewer scales

- Documented online at http://colorbrewer2.org/
- Available via the **RColorBrewer** package (Erich Neuwirth).



Using mannually defined mappings

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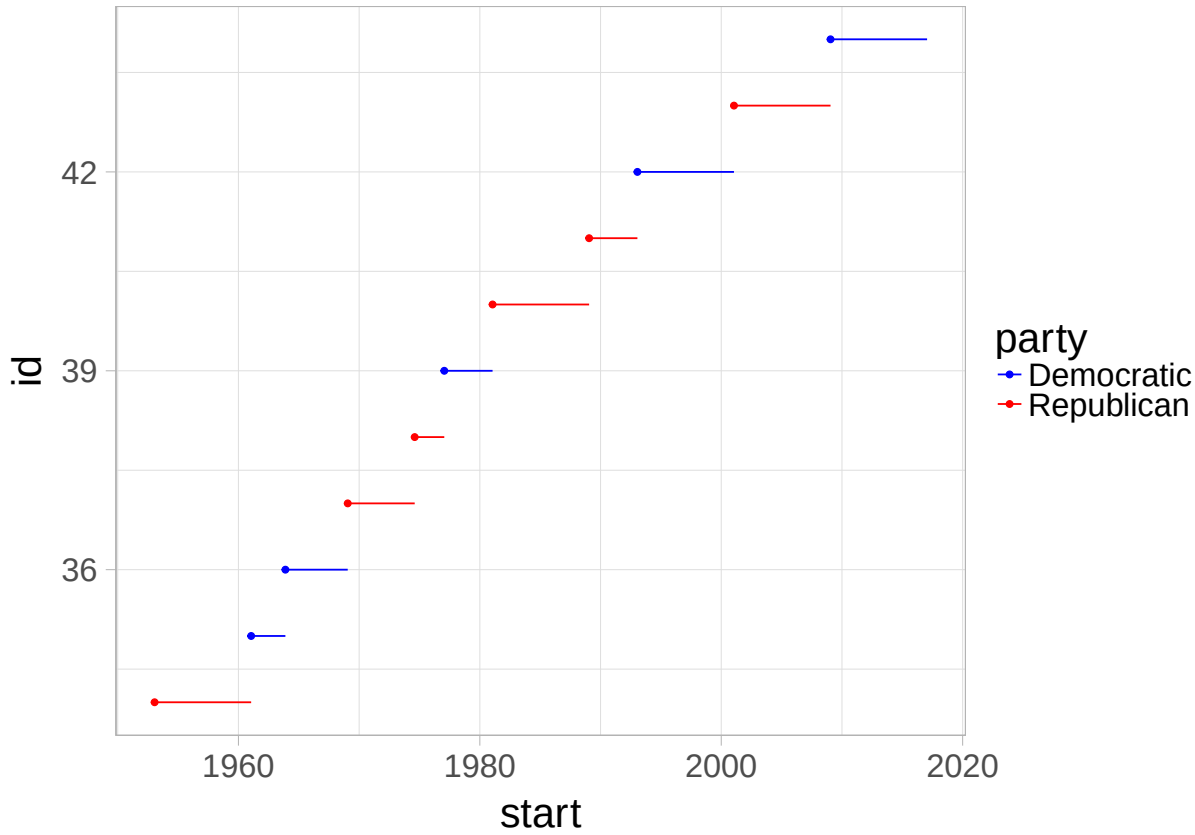
```
presidential %>%
  mutate(id = 33 + row_number()) %>%
  ggplot(aes(start, id, colour = party)) + geom_point() +
    geom_segment(aes(xend = end, yend = id)) +
    scale_colour_manual(values = c(Republican = "red", Democratic = "blue"))
```



Contiunous vs diverging color scales

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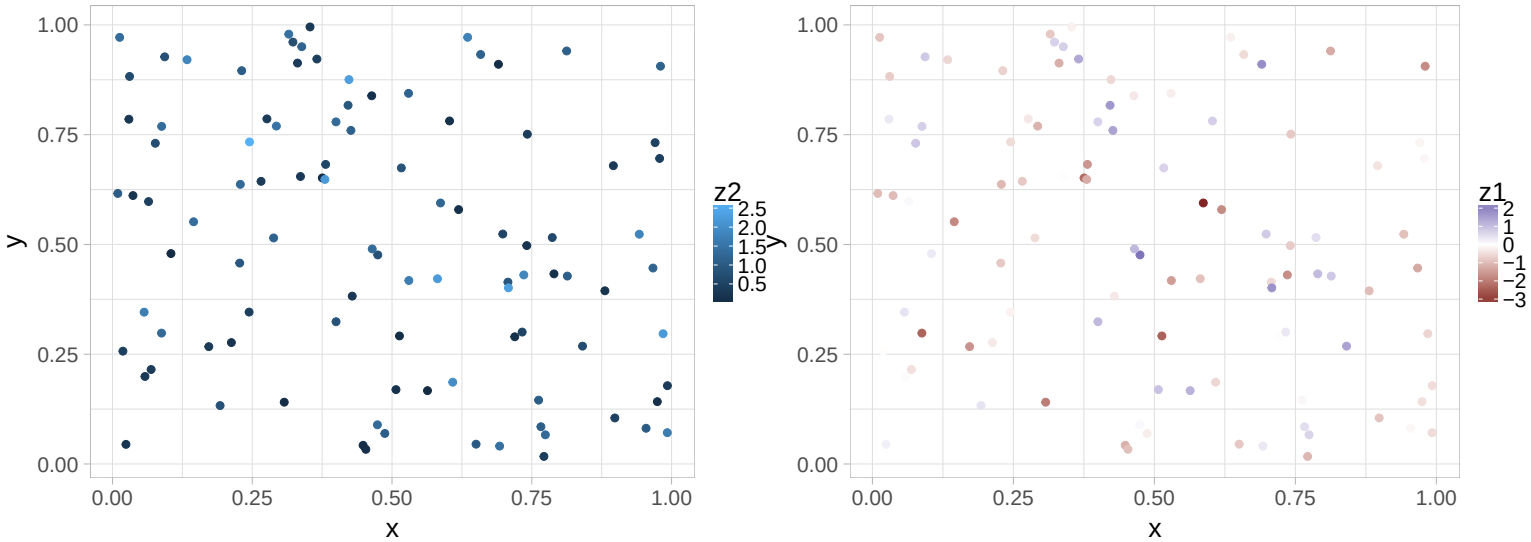
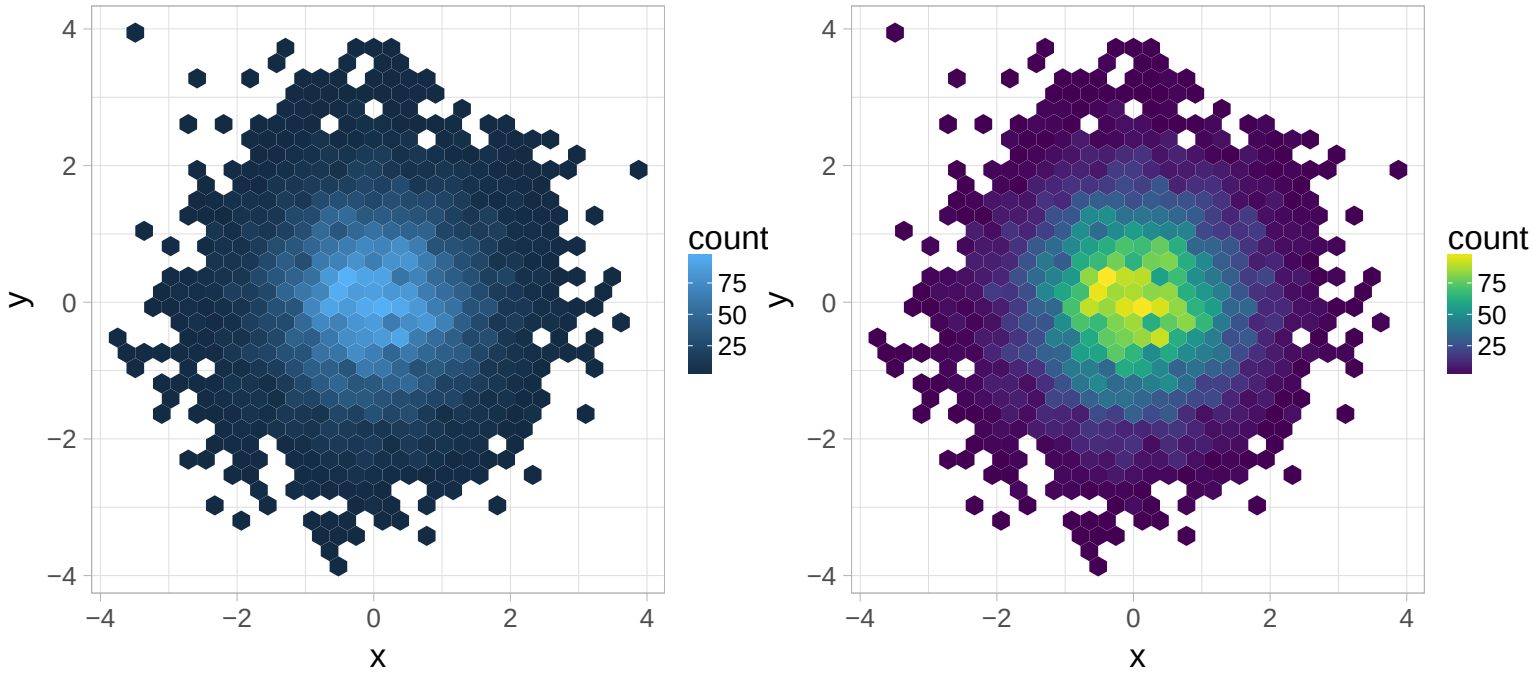
```
df <- data.frame(x = runif(100), y = runif(100),
                 z1 = rnorm(100), z2 = abs(rnorm(100)))

ggplot(df, aes(x, y)) + geom_point(aes(colour = z2), size = 3)

ggplot(df, aes(x, y)) + geom_point(aes(colour = z1), size = 3) +
  scale_colour_gradient2()
```



A continuous analog of the categorical ColorBrewer


```
df <- tibble(x = rnorm(10000), y = rnorm(10000))
p <- ggplot(df, aes(x, y)) + geom_hex() + coord_fixed()
p
p + viridis::scale_fill_viridis()
```



Remark

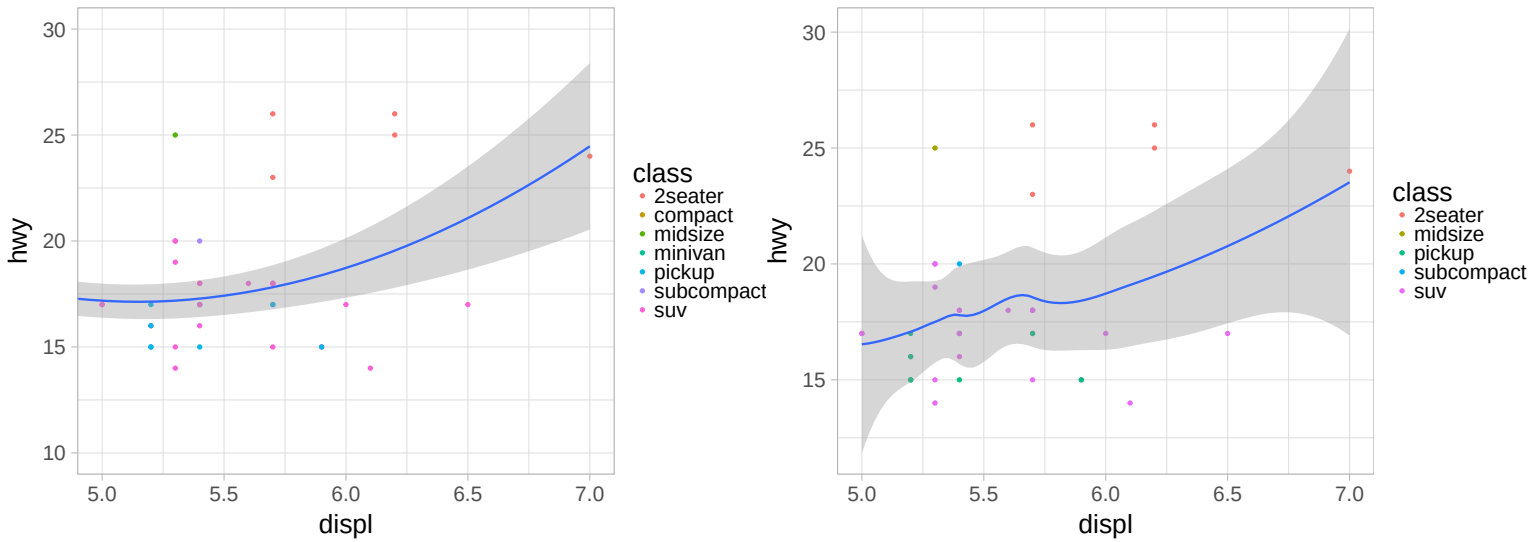
All color scales come in two variety:

- `scale_color_x()` for the `color` aesthetics (available in UK/US spellings)
- `scale_fill_x()` for the `fill` aesthetics.

Zooming

1. Adjusting what data are plotted
2. Setting the limits in each scale
3. Setting `xlim` and `ylim` in `coord_cartesian()`

```
ggplot(mpg, mapping = aes(displ, hwy)) +
  geom_point(aes(color = class)) + geom_smooth() +
  coord_cartesian(xlim = c(5, 7), ylim = c(10, 30))

mpg %>% filter(displ >= 5, displ <= 7, hwy >= 10, hwy <= 30) %>%
  ggplot(aes(displ, hwy)) +
  geom_point(aes(color = class)) + geom_smooth()
```



Set the `limits` on individual scales.

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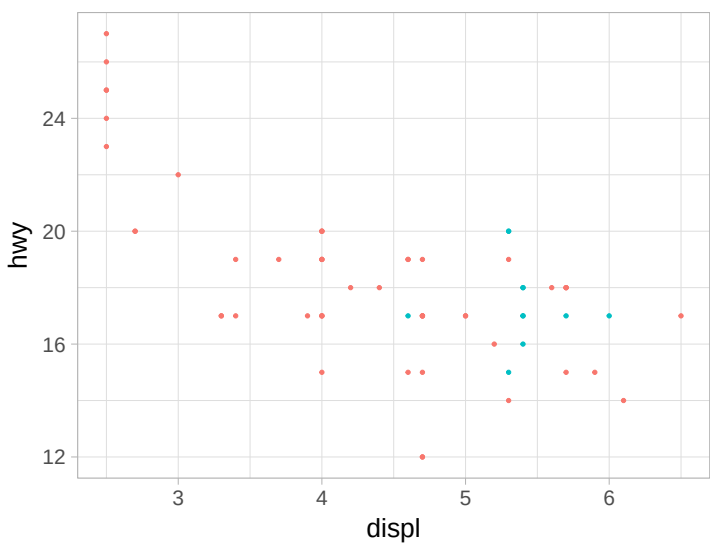
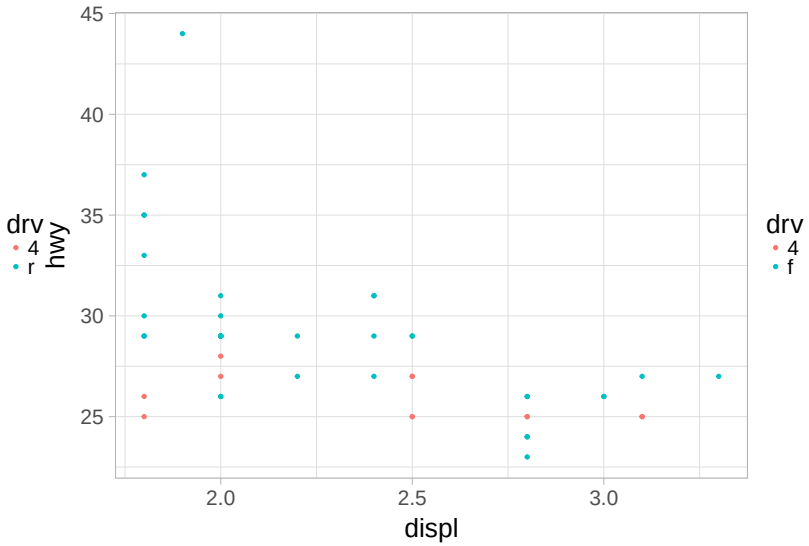
```
suv <- mpg %>% filter(class == "suv")
compact <- mpg %>% filter(class == "compact")

ggplot(suv, aes(displ, hwy, colour = drv)) + geom_point()
ggplot(compact, aes(displ, hwy, colour = drv)) + geom_point()
```

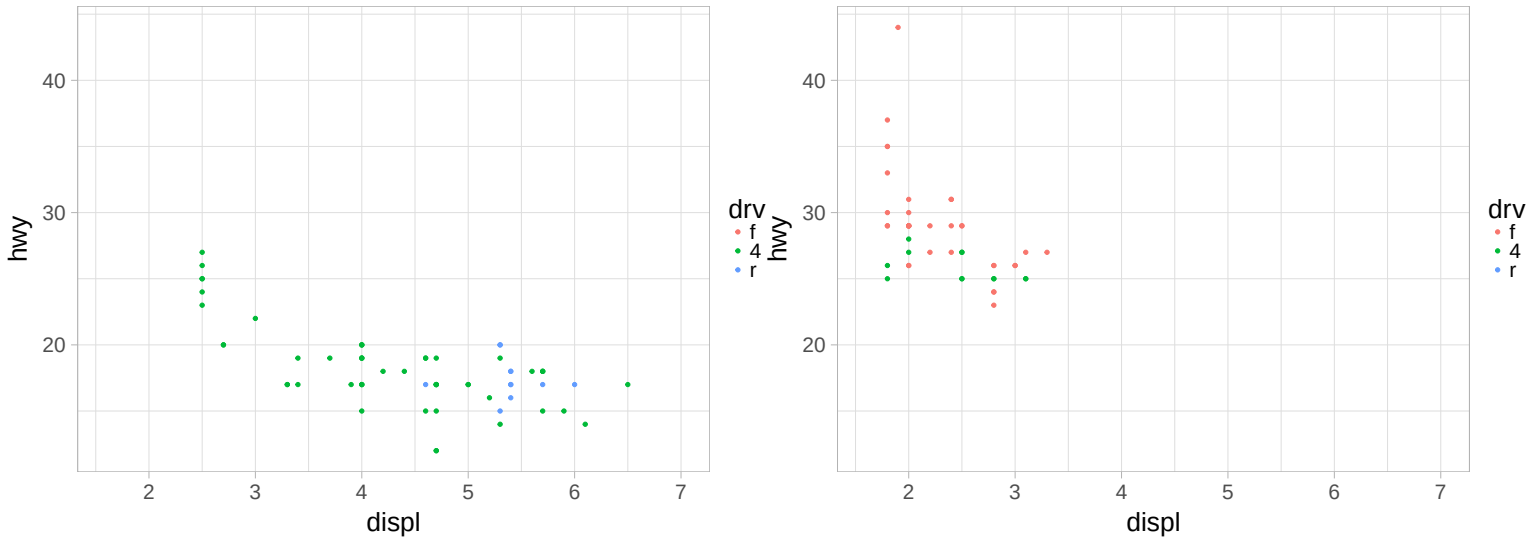




Share scales across multiple plots

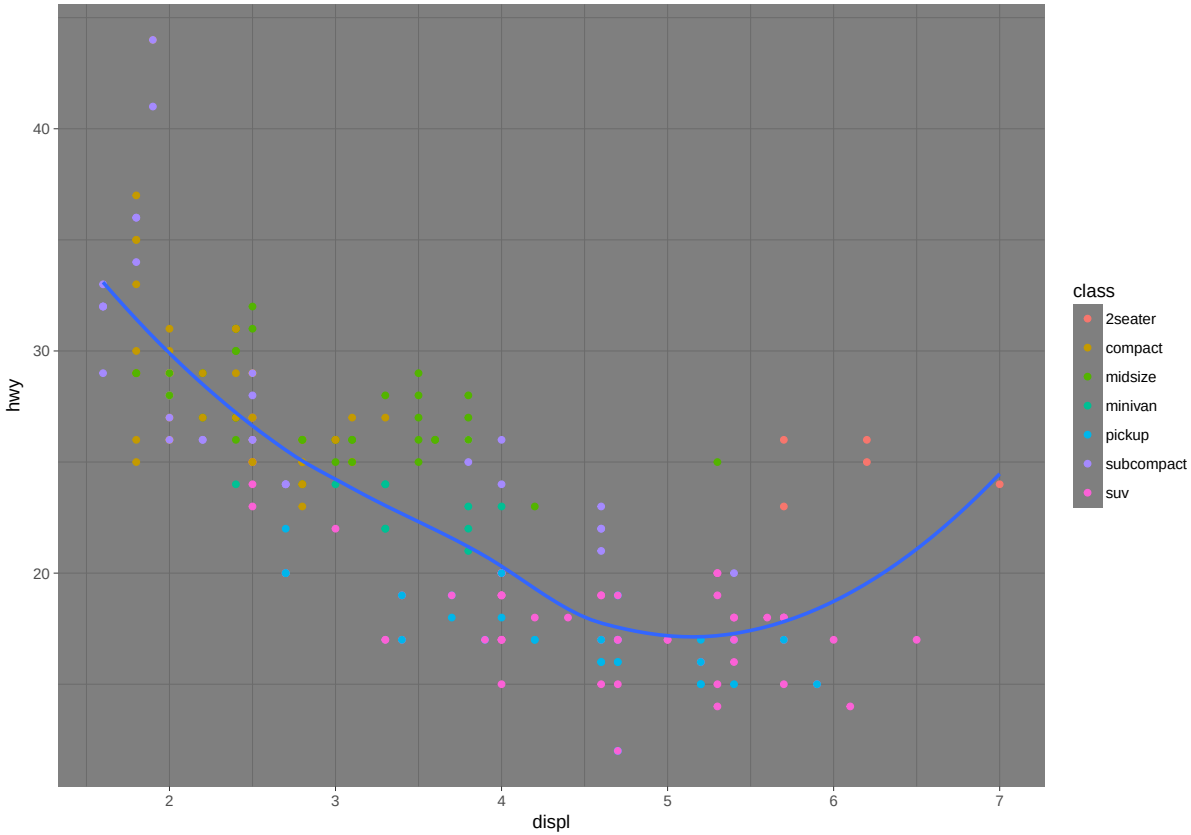
Training the scales with the `limits` of the full data:

```
x_scale <- scale_x_continuous(limits = range(mpg$displ))
y_scale <- scale_y_continuous(limits = range(mpg$hwy))
col_scale <- scale_colour_discrete(limits = unique(mpg$drv))

ggplot(suv, aes(displ, hwy, colour = drv)) + geom_point() +
  x_scale + y_scale + col_scale

ggplot(compact, aes(displ, hwy, colour = drv)) + geom_point() +
  x_scale + y_scale + col_scale
```

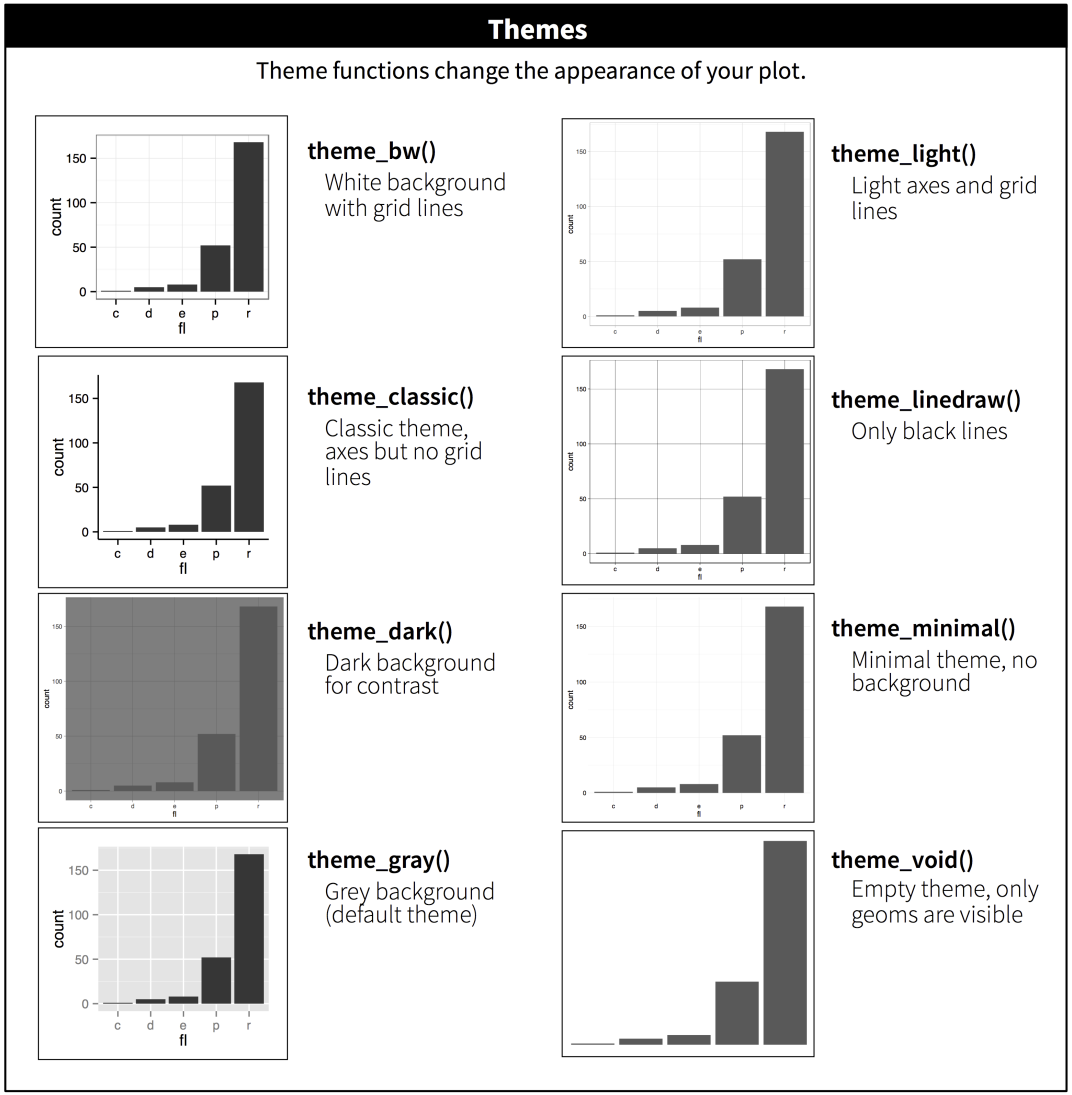


Themes


```
ggplot(mpg, aes(displ, hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE) +
  theme_dark()
```



ggplot2 default themes



More in add-on packages like ggthemes

Saving your plots

Two main ways to get your plots out of R and into your final write-up:

- ggsave()
- knitr

```
ggplot(mpg, aes(displ, hwy)) + geom_point()
ggsave("my-plot.pdf")
```

Two remarks:

- Without specifying `width` and `height`, they are taken from the dimensions of the current plotting device. For reproducible code, you should **ALWAYS** specify them.
- You should be assembling your final reports using R Markdown, so rather focus on the important code chunk options.

Figure sizing

- Biggest challenge of graphics in R Markdown: getting your figures the right size and shape.
- Five main options: `fig.width`, `fig.height`, `fig.asp`, `out.width` and `out.height`.

Hadley's advice is to use three of the five options:

- Set `fig.width = 6` and `fig.asp = 0.618` as defaults. Then in individual chunks, adjust `fig.asp` if needed.
- Set `out.width` to a percentage of the line width (e.g., default to `out.width = "70%"` and `fig.align = "center"`)
- For multiple plots in a single row, set `out.width` to 50% for two plots, 33% for 3 plots, or 25% to 4 plots, and set `fig.align = "default"`.

More advices

On figure sizing:

- If you have to squint to read the text, tweak `fig.width`.
  - If `fig.width` is larger than the size the figure is rendered in the final doc, the text will be too small.
  - If `fig.width` is smaller, the text will be too big.
  - Experiment to figure out the right ratio between the `fig.width` and the eventual width in your document.

In general:

- Set `fig.show = "hold"`.
- Add captions to your plots, using `fig.cap = "something interesting"`.
- Use RStudio's data visualization cheatsheet.
- Inspire yourself from the R graph gallery.