Introduction to R Programming

Data Visualitazion with ggplot2

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ggplot2:
Build a data
MASTERPIECE
e_minimal
classic
me_bw
THEMES
gEOMS
pch
aes
fill
color
gganimate
plotly
HORST '18

Introduction

- In lecture you will learn how to visualise data with the ggplot2 package.
- ggplot2 is one of the most elegant and versatile systems for making graphs.
- ggplot2 implements the grammar of graphics (Wickham 2010), a coherent system for describing and building graphs.

Preliminars

```r
library(ggplot2)
```

- To access the datasets, help pages, and functions that we will use, load the ggplot2 package.

The mpg dataset

The mpg dataset contains information about 38 models of cars. Among the variables in mpg are:

- displ: engine size, in litres
- cyl: number of cylinders
- cty: city miles per gallon
- hwy: fuel efficiency on the highway, in miles per gallon (mpg).
- class: type of car

```
View(mpg)
```

For additional information see ?mpg.

My first `ggplot()`

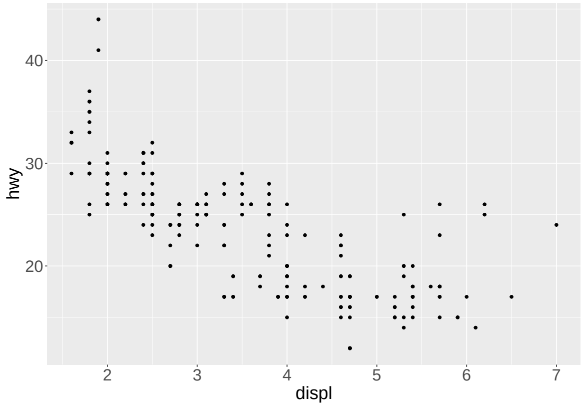
Let's build a graph to answer the following questions:

- Do cars with big engines use more fuel than cars with small engines?
- What does the relationship between engine size and fuel efficiency look like? Is it positive? Negative? Linear? Nonlinear?

We start by plotting engine size (`displ`) versus fuel efficiency (`hwy`).

My first ggplot()

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



My first `ggplot()`

- The plot shows a negative relationship between engine size and fuel efficiency.
- In other words: on average, cars with big engines use more fuel.

A simple ggplot() template

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

- The first argument of `ggplot()` is a dataset
- You complete your graph by adding layers to `ggplot()`
- `geom_point()` adds a layer of points, creating scatterplot.
- ggplot2 has many geom functions that each add a different type of layer to a plot.

A simple `ggplot()` template

- Each geom function takes a `mapping` argument.
- The `mapping` argument is always paired with `aes()`.
- The `x` and `y` arguments of `aes()` specify which variables to map to the `x` and `y` axes.

Geometrical objects

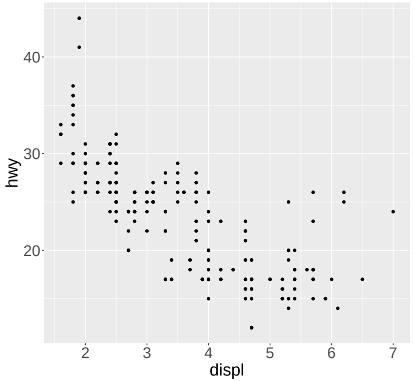
- A **geom** is the geometrical object that a plot uses to represent data (e.g. points, bars, lines. . .).
- People often describe plots by the type of **geom** that it uses:
  - Bar charts use **bar** geoms
  - Line charts use **line** geoms
  - Boxplots use **boxplot** geom
  - . . .
- Scatterplots break the trend: they use the **point** geom.
- In ggplot2, you add geoms to a plot with **geom functions**.
- Different geom functions add different geoms to the plot.

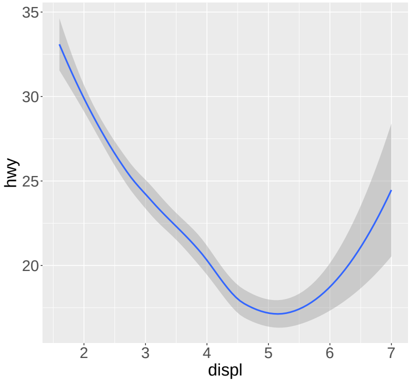
Geometrical objects

Compare the next two plots. How are they similar?

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

right <- ggplot(data = mpg) +
geom_smooth(mapping = aes(x = displ, y = hwy))

ggarrange(left, right, nrow = 1)
```

Geometrical objects





Geometrical objects

Both plots:

- use the same data
- have the same `x` variable
- have the same `y` variable

But they are not identical:

- Each plot uses a different **geom**.
- The plot on the left uses the **point** geom.
- The plot on the right uses the **smooth** geom, a smooth line fitted to the data.

The ggplot2 cheatsheet

- ggplot2 provides over 40 geoms
- The best way to get a comprehensive overview is the ggplot2 cheatsheet.

Aesthetics

- **Aesthetics** are visual properties of the **geoms**.
- **Aesthetics** include things like the size, shape, and color of the points in a scatterplot.
- `aes()` builds **aesthetic mappings** that define how variables in the dataset are mapped to aesthetics of the geoms.
- To map an aesthetic to a variable, associate the name of the aesthetic to the name of the variable inside `aes()`.
- Every geom function needs an aesthetic mapping, but not every aesthetic works with every geom, for example:
  - You can set the shape of a point, but not of a line.
  - You can set the linetype of a line, but not of a point.

My first `ggplot()` revisited

One group of points (highlighted in red) seems to fall outside the linear trend. How can we explain these cars?

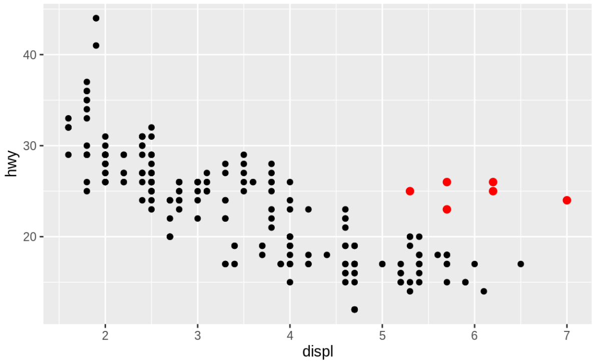


Figure 1: Some cars have a higher mileage than we might expect

My first `ggplot()` revisited

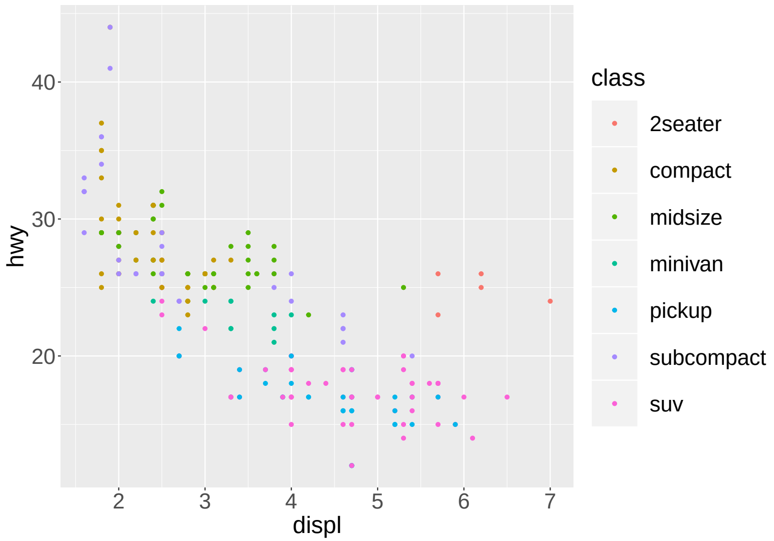
- The highlited cars may have some common caractheristic with respect to some other variable (e.g. they might all be hybrids).
- Lets try `class`, a variable that classifies cars into groups such as compact, midsize, and SUV.
- We can add a third variable to a two dimensional scatterplot by mapping it to an aesthetic.

The color aesthetic

For example, we can map the color of the points to the `class` variable, so that the graph reveals the class of each car:

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

The color aesthetic



The color aesthetic

Now we know that all but one of the highlited cars are two-seater cars! Let's find their model and manufacturer:

```r
subset(mpg, class == "2seater",
       select = c("manufacturer", "model", "year"))
```

```
## # A tibble: 5 x 3
##   manufacturer model     year
##   <chr>        <chr>    <int>
## 1 chevrolet    corvette  1999
## 2 chevrolet    corvette  1999
## 3 chevrolet    corvette  2008
## 4 chevrolet    corvette  2008
## 5 chevrolet    corvette  2008
```

The color aesthetic

- These cars are, in fact, sports cars!
- Sports cars have large engines like SUVs and pickup trucks, but small bodies like midsize and compact cars, which improves their gas mileage.

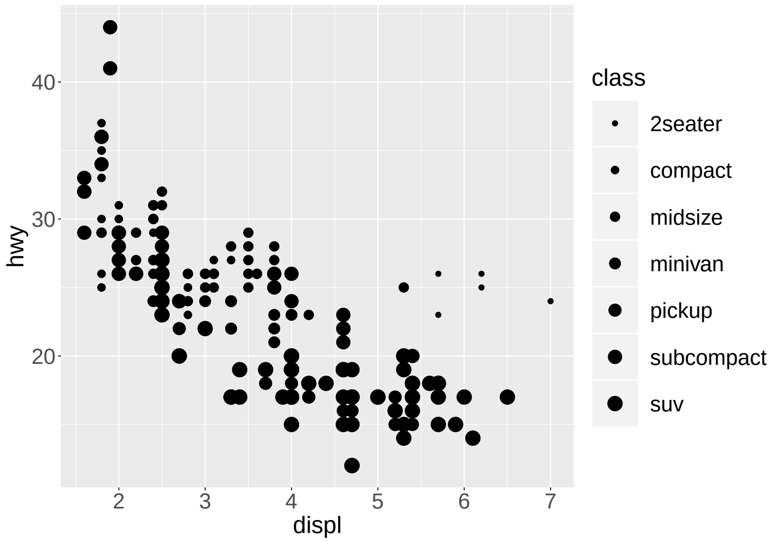
Figure 2: 2008 Chevrolet Corvette

The size aesthetic

Now let´s map `class` to the size aesthetic:

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

The size aesthetic



The size aesthetic

- Each level of the `class` variable is assigned to a different size.
- This plot, however, came with a warning message:

```
#> Using size for a discrete variable is not advised.
```

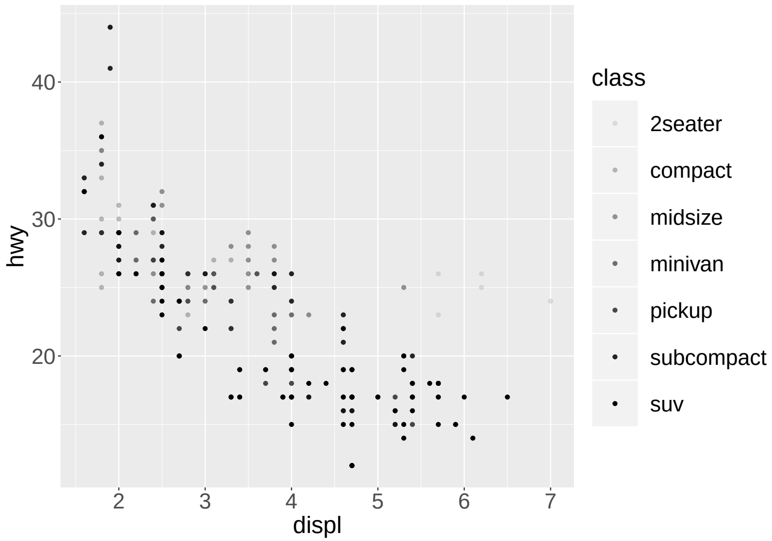
- This is because mapping an unordered variable (`class`) to ordered aesthetic (`size`) is not a good idea.
- Ordered aesthetics, like `size` and `alpha`, are more appropriate for continuous variables.

The alpha aesthetic

The `alpha` aesthetic changes the transparency of the points:

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

The alpha aesthetic

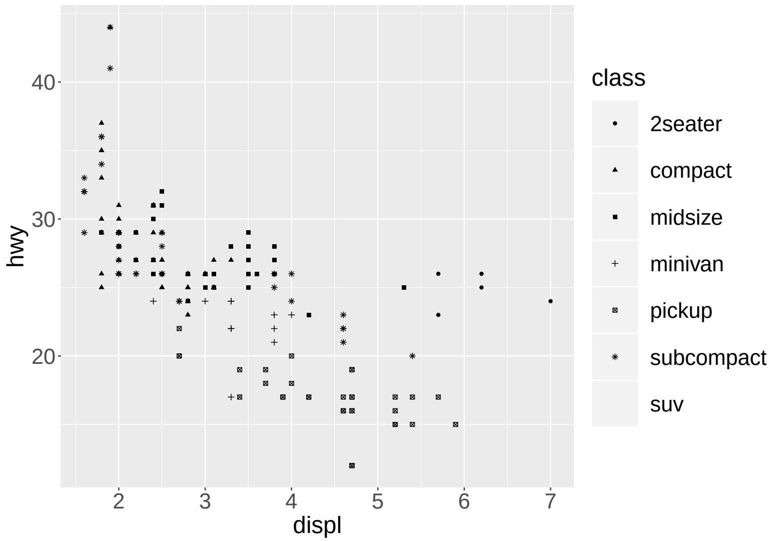


The shape aesthetic

The `shape` aesthetic changes the shape of the points:

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

The shape aesthetic



The shape aesthetic

- What happened to the SUVs?
- By default ggplot2 uses only up to six shapes at a time.
- This is because points become difficult to discriminate if we use too many shapes.
- We can, however, use more than six shapes if we set them "manually" with `scale_shape_manual()`.

The shape aesthetic

We can choose the following shapes of points by their number:

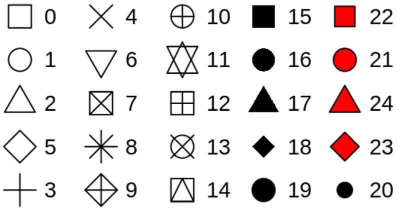


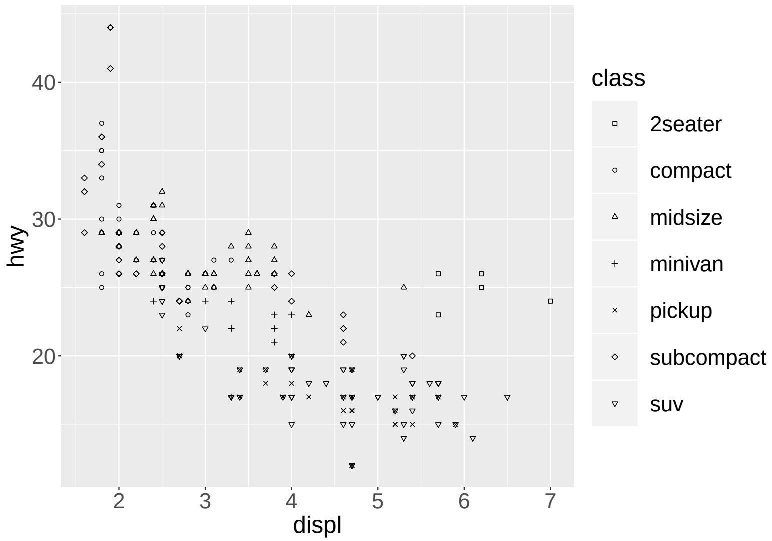
Figure 3: R Built in shapes

The shape aesthetic

Let's choose the first 7 shapes:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy, shape = class)) +
  scale_shape_manual(values = 0:6)
```

The shape aesthetic

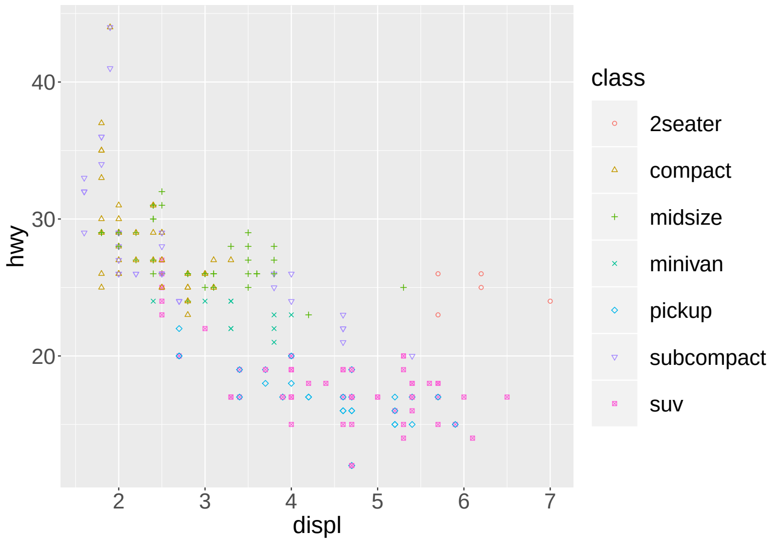


Mapping one variable to two aesthetics

- Mapping a single variable to multiple aesthetics is redundant, and should be avoided in most cases.
- In this case, however, since we have many categories, it can improving visual discrimanation.
- Let´s map `class` to `color` and `shape`:

```
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy,
                 shape = class, color = class)) +
  scale_shape_manual(values = 1:7)
```

Mapping one variable to two aesthetics



Mapping continuous variables to aesthetics

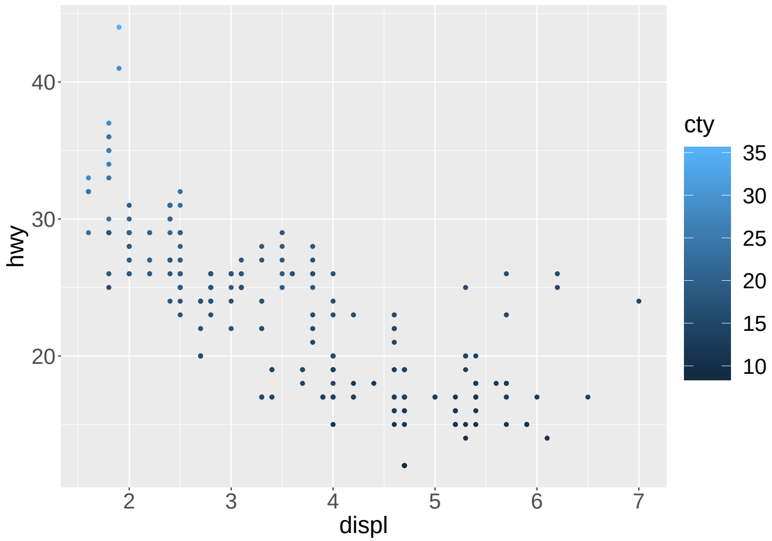
- So far we mapped `class`, a categorical variable, to the `color`, `size`, `shape` and `alpha` aesthetics of `geom_point()`.
- Now let´s map continuous variables to these aesthetics and see how they behaves differently for categorial versus continuous variables.

Mapping continuous variables to aesthetics

The variable `cty` (city miles per gallon) is a continuous variable. Let's map it to the `color` aesthetic:

```r
ggplot(mpg) +
  geom_point(aes(x = displ,y = hwy, colour = cty))
```

Mapping continuous variables to aesthetics

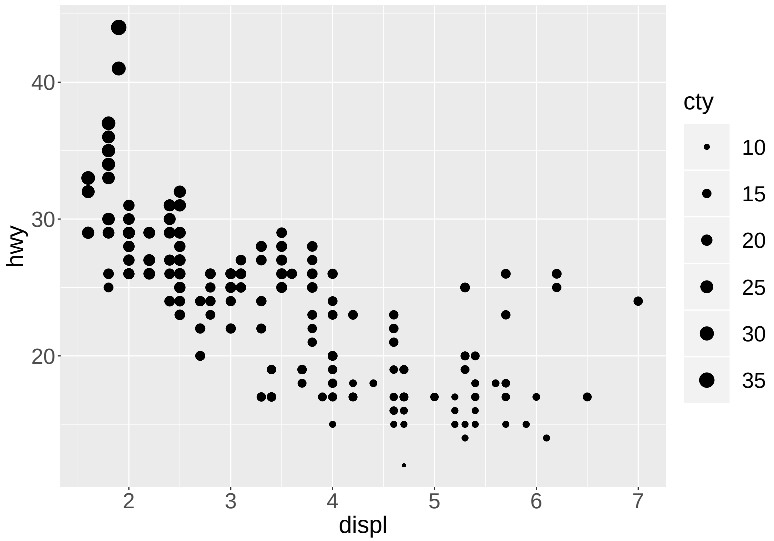


Mapping continuous variables to aesthetics

Now let's map `cty` to the `size` aesthetic:

```r
ggplot(mpg) +
  geom_point(aes(x = displ, y = hwy, size = cty))
```

Mapping continuous variables to aesthetics

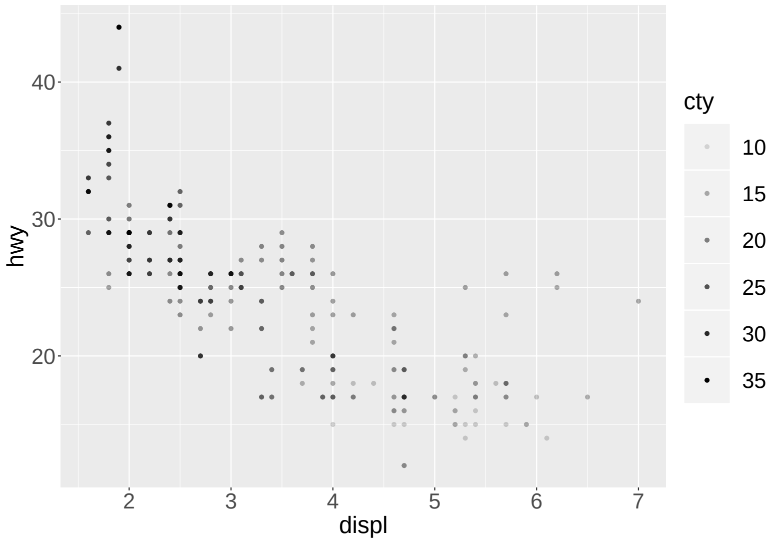


Mapping continuous variables to aesthetics

Now let's map `cty` to the `alpha` aesthetic:

```r
ggplot(mpg) +
  geom_point(aes(x = displ, y = hwy, alpha = cty))
```

Mapping continuous variables to aesthetics



Mapping continuous variables to aesthetics

And finally let's map `cty` to the `size` aesthetic:

```
ggplot(mpg) +
  geom_point(aes(x = displ, y = hwy, shape = cty))

#> Error: A continuous variable can not be mapped to
#> shape
```

Aesthetic mappings: categorical vs continuous variables

Color and **alpha** aesthetics:

- Each level of a categorival variable is assgined to a different (discrete) color.
- The values of continuous variables are mapped to a continuous color scale, varying from light to dark.

Size aestietic:

- Each level of a categorival variable is assigned to a different (discrete) size.
- The size of the points vary continuously as a function of the values of a continuous variables.

Aesthetic mappings: categorical vs continuous variables

Shape aestietic:

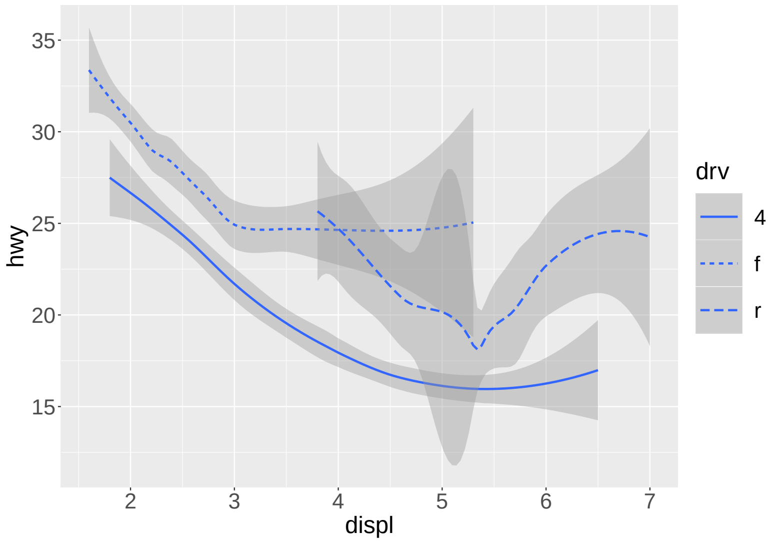
- A different shape is assigned to each level of a categorical value.
- The shape aesthetic can not be mapped to continuous variables
  .

The `linetype` aesthetic

`geom_smooth()` draws a different type of line for each level of the variable that is mapped to the `linetype` aesthetic:

```r
ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, linetype = drv))
```

The `linetype` aesthetic



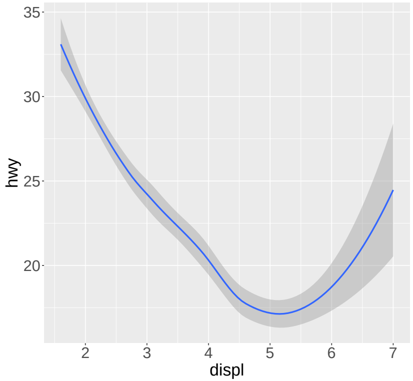
The `group` aesthetic

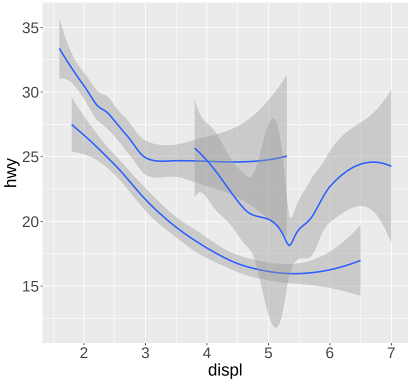
- Many geoms, `like geom_smooth()`, use a single geometric object to display multiple rows of data.
- For these geoms, you can map the `group` aesthetic to a categorical variable to draw multiple objects. ggplot2 will draw a separate object for each level of the grouping variable.

The group aesthetic

```r
p1 <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy))

p2 <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, group = drv))

ggarrange(p1, p2, nrow = 1)
```

The `group` aesthetic



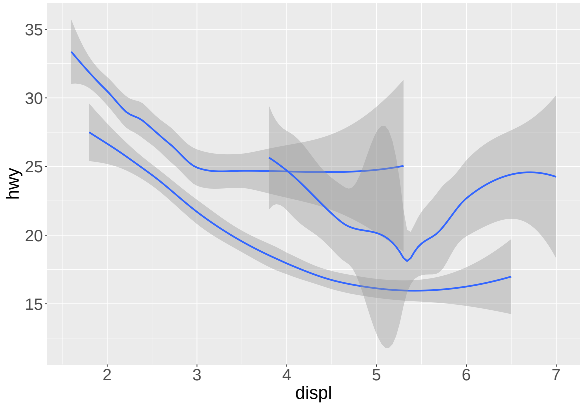


The `group` aesthetic

- In practice, ggplot2 will automatically group the data for these geoms whenever you map an aesthetic to a discrete variable.
- It is convenient to rely on this feature because the `group` aesthetic by itself does not add a legend or distinguishing features to the geoms.
- Compare the three examples below:

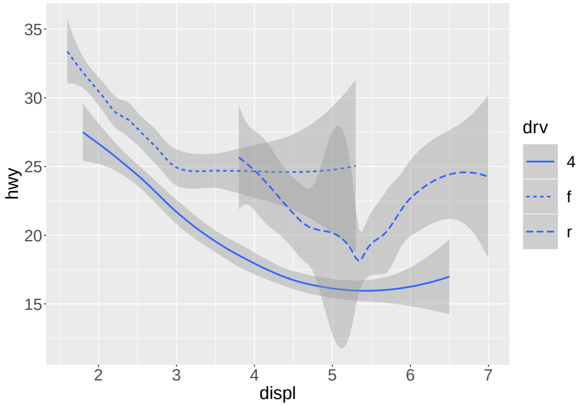
geom_smooth() with the group aesthetic

```
ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, group = drv))
```



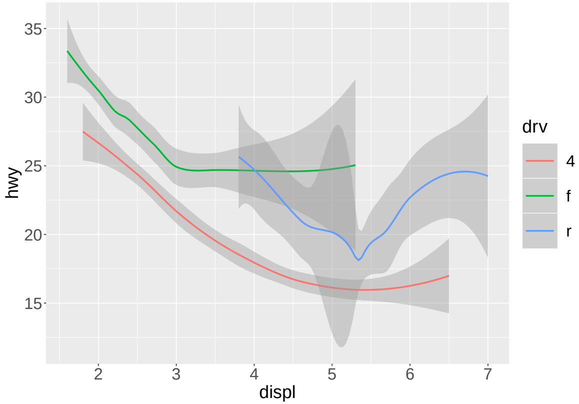
geom_smooth() with the linetype aesthetic

```r
ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, linetype = drv))
```



geom_smooth() with the color aesthetic

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



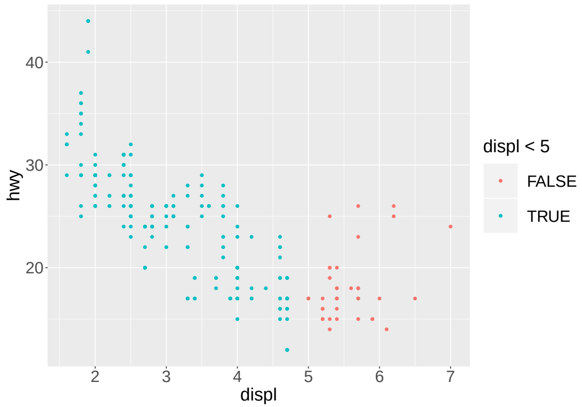
Aesthetics and logical conditions

Aesthetics can be mapped to logical expressions. For example, if you map an aesthetic to `displ < 5`:

- `ggplot()` creates a temporary variable with values equal to the result `displ < 5`.
- The result of `displ < 5` is a logical variable.
- `ggplot()` then maps aesthetics to the temporary variable.

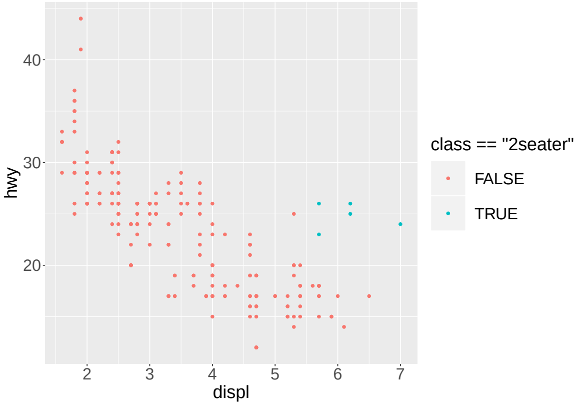
Aesthetics and logical conditions

```r
ggplot(mpg) +
  geom_point(aes(x = displ, y = hwy,
                 colour = displ < 5))
```



Aesthetics and logical conditions

```r
ggplot(mpg) +
  geom_point(aes(x = displ, y = hwy,
                 colour = class == "2seater"))
```



Changing default aesthetic properties of geoms

- We can change the default aesthetic properties of the geom functions.
- To change a default aesthetic property, set the aesthetic by name as an argument of the geom function.
- Names of colors should be indicated as character strings.
- Size of points should be indicated in mm.

Changing default aesthetic properties of geoms

Shapes are identified by the numbers in figure 3.

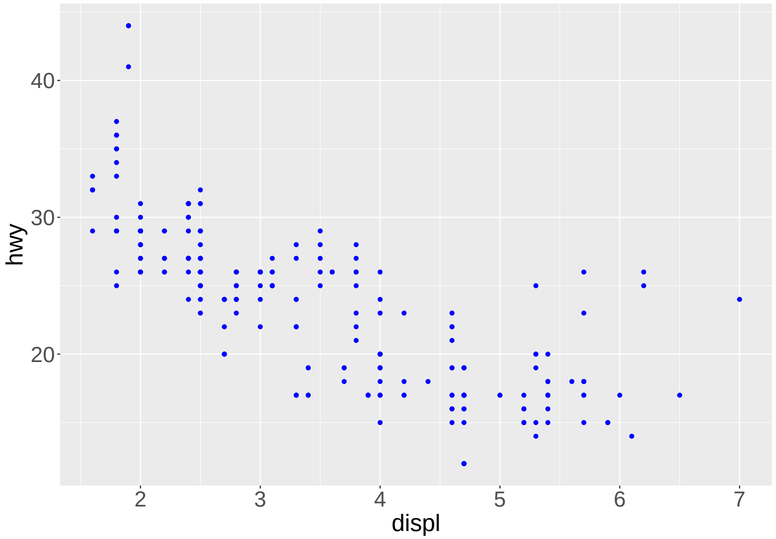
- There are some seeming duplicates (e.g. 0, 15, and 22 are all squares).
- The difference comes from the interaction of the `colour` and `fill` aesthetics:
    - The hollow shapes (0–14) have a border determined by the `colour` aesthetic
    - The solid shapes (15–18) are filled with the colour `aesthetic`;
    - The filled shapes (21–24) have a border set by the `colour` aesthetic and are filled with the `fill` aesthetic.

Changing default aesthetic properties of geoms

For example, we can make all of the points blue:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "blue")
```

Changing default aesthetic properties of geoms

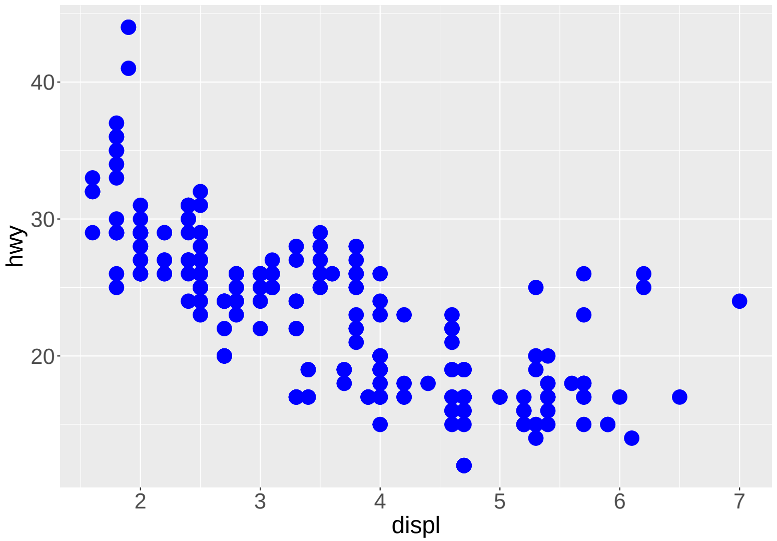


Changing default aesthetic properties of geoms

Now let's change the size of the points:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "blue",
    size = 6)
```

Changing default aesthetic properties of geoms

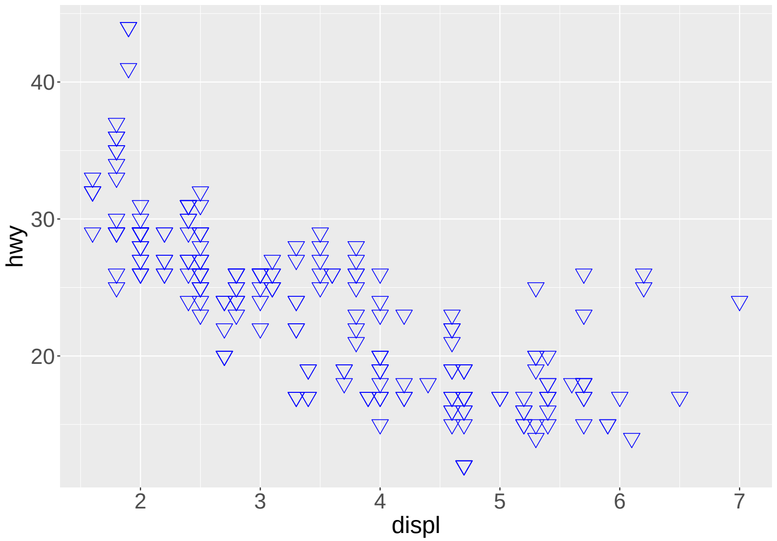


Changing default aesthetic properties of geoms

We can also change the default shape of the points:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "blue",
    size = 5,
    shape = 6)
```

Changing default aesthetic properties of geoms

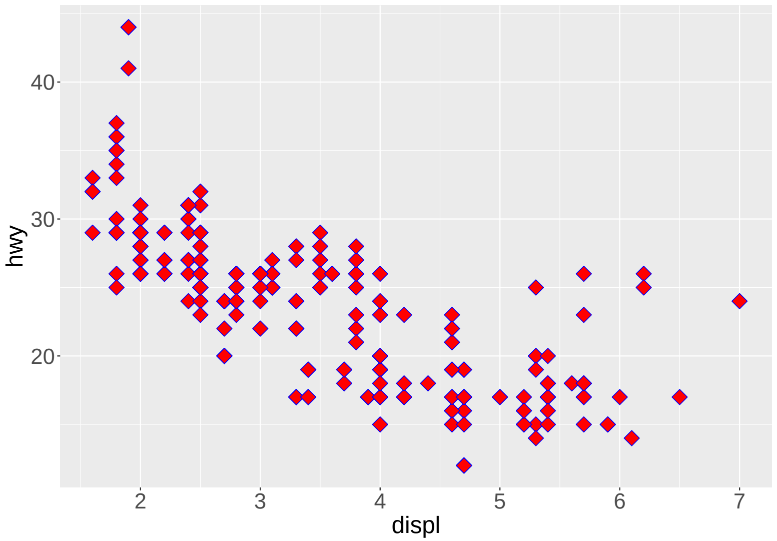


Changing default aesthetic properties of geoms

- Shape 6 is a hollow shape, it interacts only with the `color` aesthetic.
- If we want triangles filled with color, we must use shape 23, which interacts both with the color and `fill` aesthetics:

```r
ggplot(data = mpg) +
  geom_point(
    mapping = aes(x = displ, y = hwy),
    color = "blue",
    size = 5,
    shape = 23,
    fill = "red"
  )
```

Changing default aesthetic properties of geoms

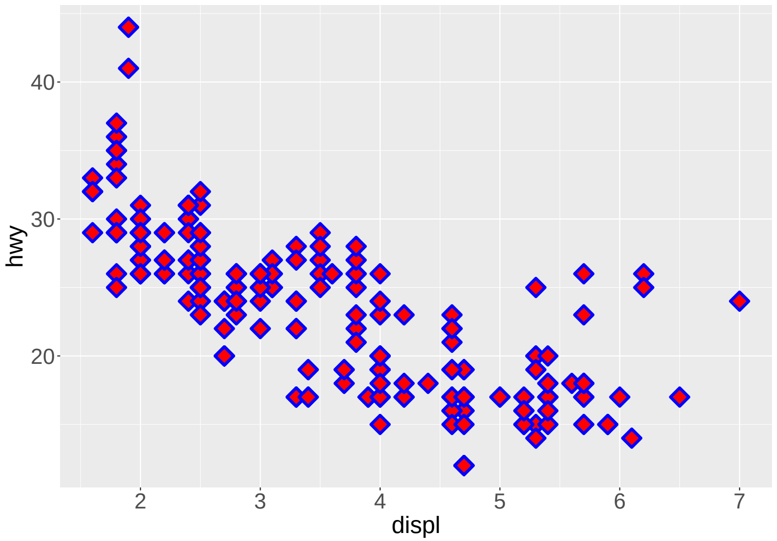


Changing default aesthetic properties of geoms

The `stroke` aesthetic changes the thickness of the border of the shapes:

```
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "blue",
    size = 5,
    shape = 23,
    fill = "red",
    stroke = 2
  )
```

Changing default aesthetic properties of geoms

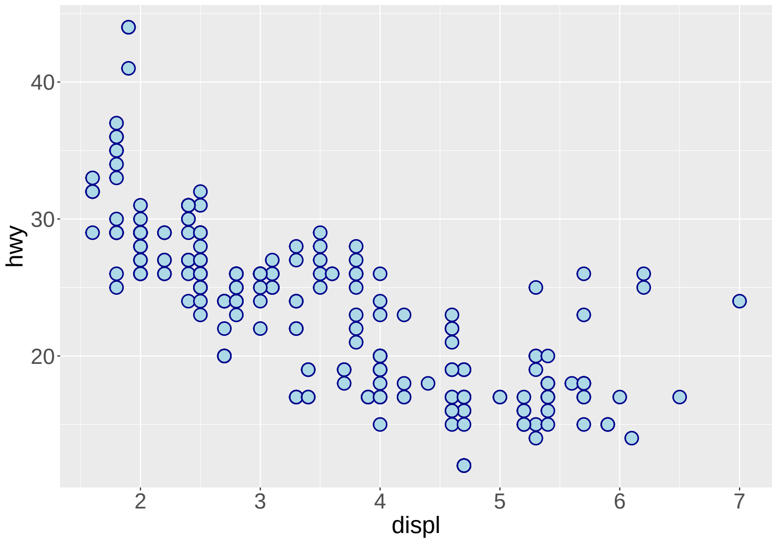


Changing default aesthetic properties of geoms

You can also use colors like dark blue and light blue:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "darkblue",
    fill = "lightblue",
    shape = 21,
    size = 5,
    stroke = 1
  )
```

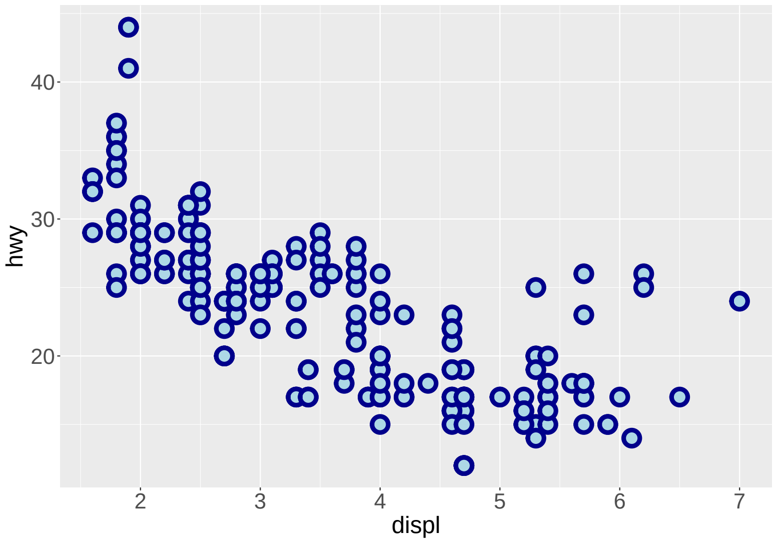
Changing default aesthetic properties of geoms



Changing default aesthetic properties of geoms

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
    color = "darkblue",
    fill = "lightblue",
    shape = 21,
    size = 5,
    stroke = 3
  )
```

Changing default aesthetic properties of geoms



Changing default aesthetic properties of geoms

- For a list of available colors and their names see: http://sape.inf.usi.ch/quick-reference/ggplot2/colour

Changing default aesthetic properties of geoms

- Alternatively, you can use RBG codes.
- The RGB model reproduces a broad array of colors by mixing together red, green, and blue in different combinations.
- You can specify colors like in HTML/CSS, using the hexadecimal values (00 to FF) for red, green, and blue, concatenated into a string, prefixed with a "#".
- A pure red colour this is represented with "#FF0000".

See:

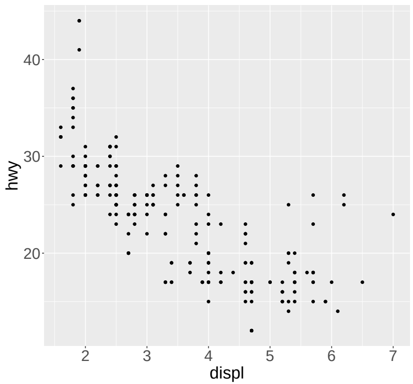
- https://www.rapidtables.com/web/color/RGB_Color.html
- https://htmlcolorcodes.com

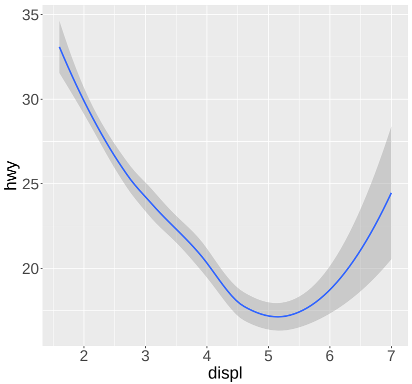
Changing default aesthetic properties of geoms

We already saw that `geom_smooth()` adds a smoothed line:

```
left <- ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy))

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy))

ggarrange(left, right, nrow = 1)
```

Changing default aesthetic properties of geoms





Changing default aesthetic properties of geoms

We can change the default line type of geom functions like `geom_smooth()`. These are the available line types:

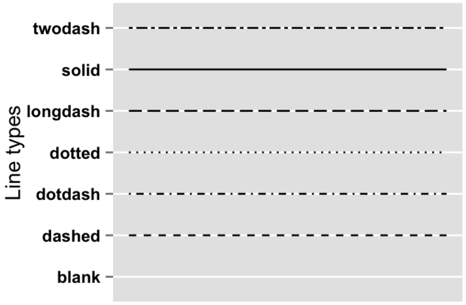


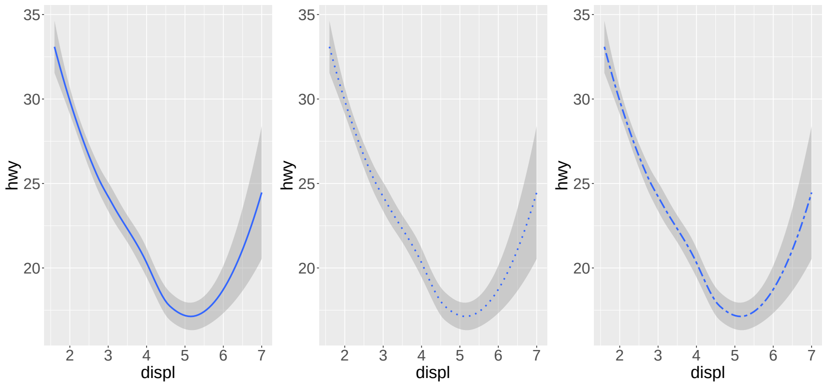
Figure 4: Built in line types

Changing default aesthetic properties of geoms

To change the default linetype, set it as an argument of the geom function:

```
lefl <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy))

center <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
    linetype = "dotted")

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
    linetype = "twodash")

ggarrange(left, center, right, nrow = 1)
```

Changing default aesthetic properties of geoms

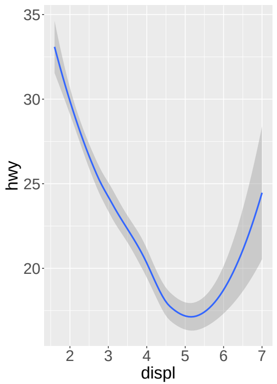


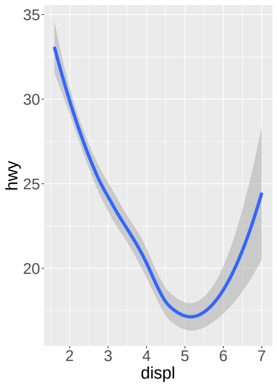
Changing default aesthetic properties of geoms

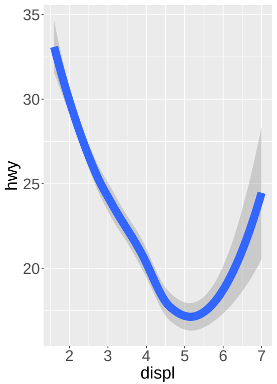
We can also change the thickness of the lines:

```r
left <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy))

center <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy), size = 2)

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy), size = 5)

ggarrange(left, center, right, nrow = 1)
```

Changing default aesthetic properties of geoms



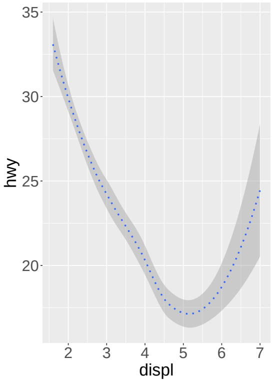


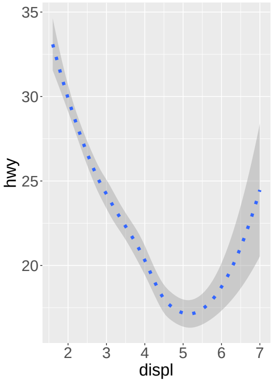


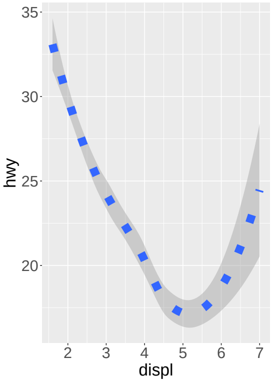
Changing default aesthetic properties of geoms

```r
left <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
              linetype = "dotted")

center <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
              linetype = "dotted", size = 2)

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
              linetype = "dotted", size = 5)

ggarrange(left, center, right, nrow = 1)
```

Changing default aesthetic properties of geoms





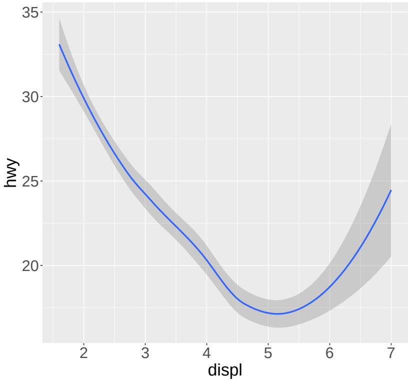


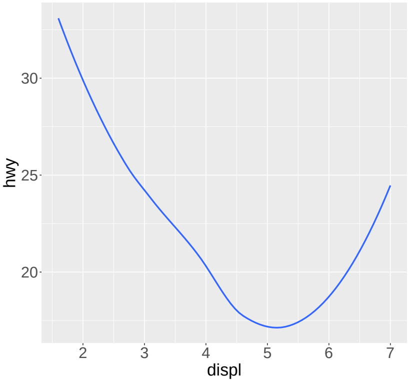
Changing default aesthetic properties of geoms

- By default, `geom_smooth()` displays confidence intervals around the smoothed line.
- Confidence intervals may be disabled by setting the `se` (standard error) aesthetic to `FALSE`:

```r
left <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy))

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy),
    se = FALSE)

ggarrange(left, right, nrow = 1)
```

Changing default aesthetic properties of geoms

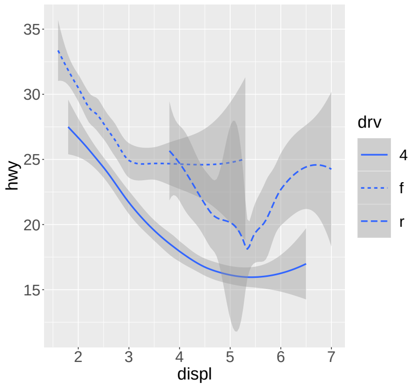


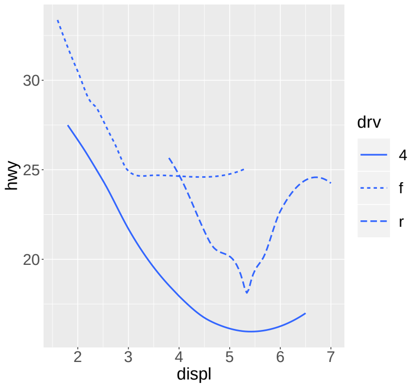


Changing default aesthetic properties of geoms

```r
left <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, linetype = drv))

right <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, linetype = drv),
    se = FALSE)

ggarrange(left, right, nrow = 1)
```

Changing default aesthetic properties of geoms

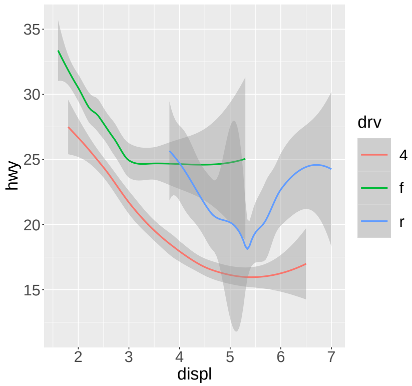


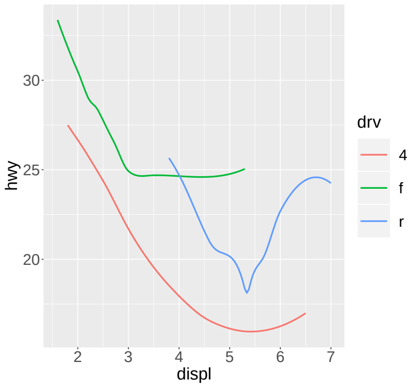


Changing default aesthetic properties of geoms

```r
l <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, color = drv))

r <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, color = drv),
    se = FALSE)

ggarrange(l, r, nrow = 1)
```

Changing default aesthetic properties of geoms



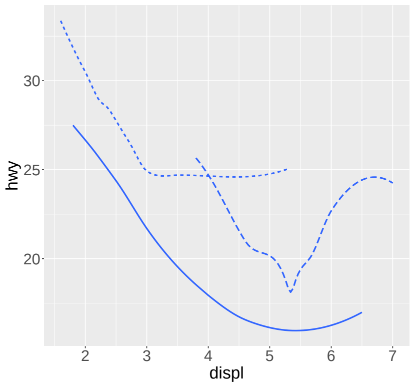


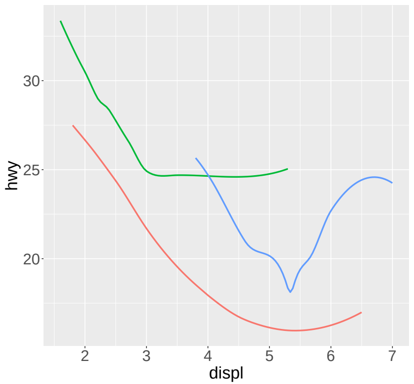
Changing default aesthetic properties of geoms

Legends can also be disabled:

```r
l <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, linetype = drv),
    se = FALSE)

r <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, color = drv),
    se = FALSE)

ggarrange(l, r, nrow = 1)
```

Changing default aesthetic properties of geoms





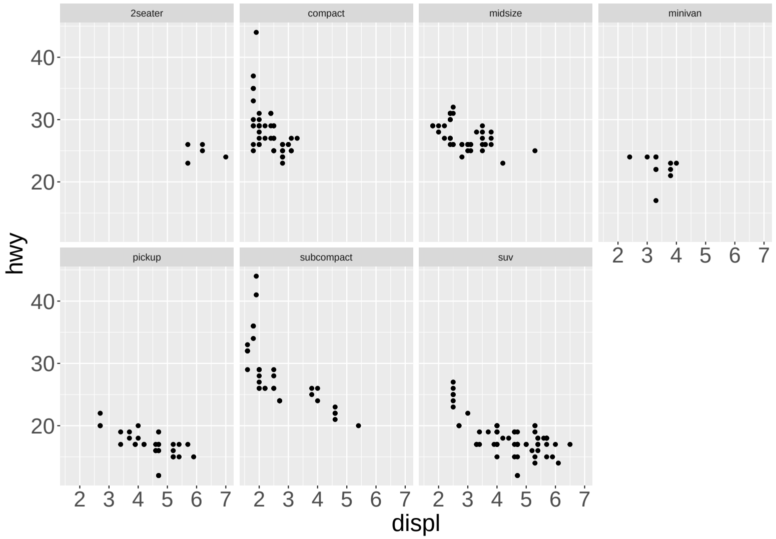
Facets

- One way to add additional variables to a plot is with **aesthetics**.
- Another way, particularly useful for categorical variables, is to split your plot into **facets**, subplots that each display one subset of the data.
- To facet your plot by a single variable, use **`facet_wrap()`**.
- The first argument of `facet_wrap()` should be `"~"` followed the name of a variable.

Facets

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

Facets

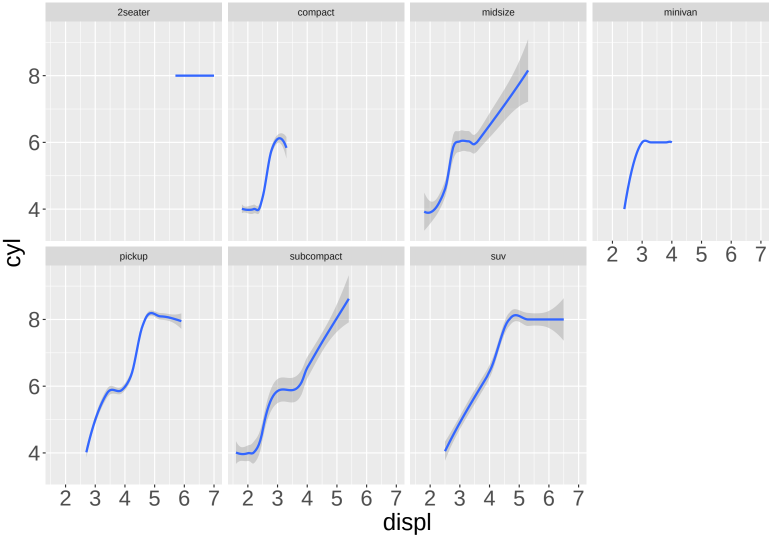


2seater
compact
midsize
minivan
pickup
subcompact
suv
hwy
displ
20
30
40
2
3
4
5
6
7

Facets

```r
ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = cyl)) +
  facet_wrap(~class, nrow = 2)
```

Facets



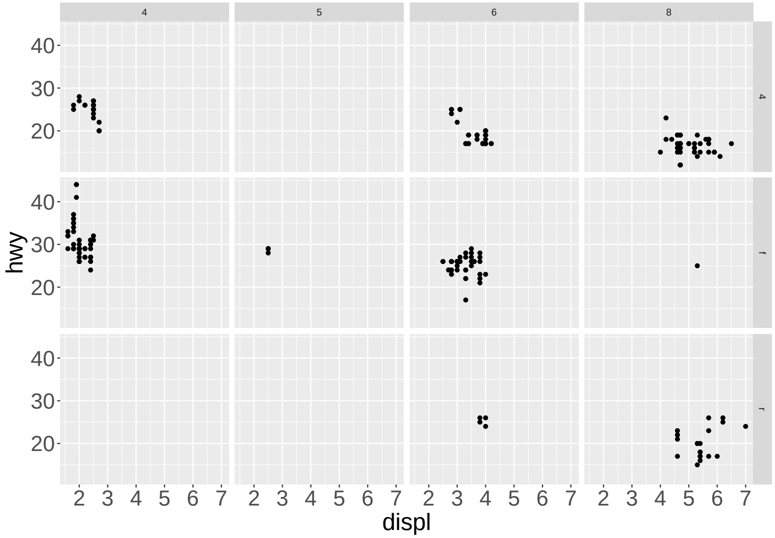
2seater
compact
midsize
minivan
pickup
subcompact
suv
cyl
displ
4
6
8
2
3
4
5
6
7

Facets

- To facet your plot on the combination of two variables, use **`facet_grid()`**.
- The first argument of `facet_grid()` should contain the two variable names separated by `"~"`.

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

Facets

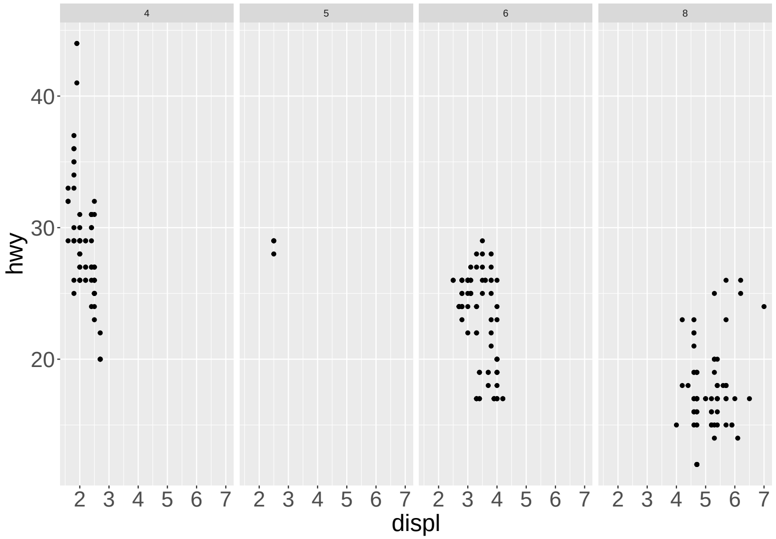


Facets

If you prefer to not facet in the rows (or columns), use a "." instead of a variable name for example:

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy)) +
  facet_grid(. ~ cyl)
```

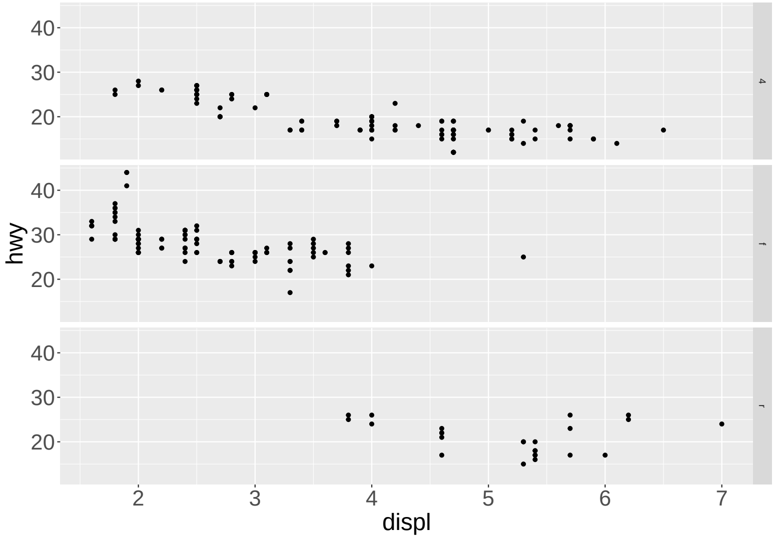
Facets



Facets

```r
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy)) +
  facet_grid(drv ~ .)
```

Facets

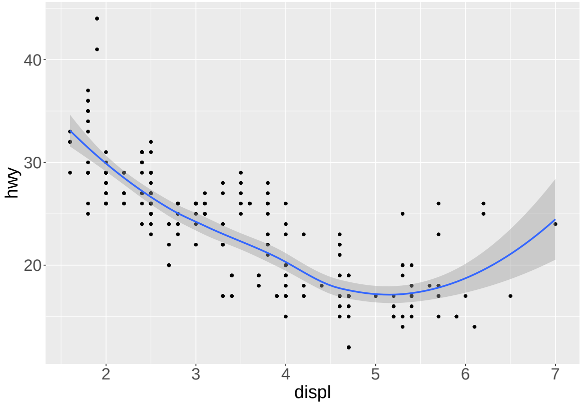


Multiple geoms

- We can have multiple geoms in the same graph.
- For example, we can overlap points and lines.
- This is archieved by adding multiple geom functions to `ggplot()`.

Multiple geoms

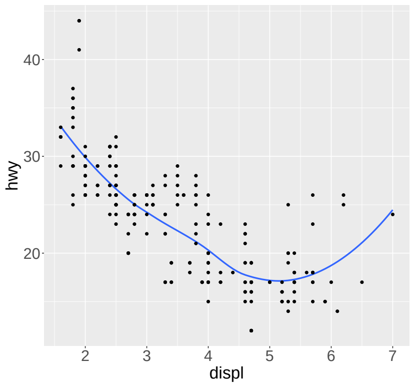
```
ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy)) +
  geom_smooth(aes(x = displ, y = hwy))
```

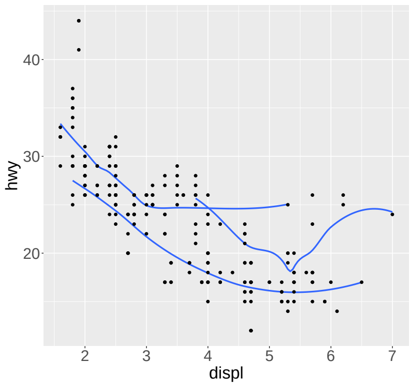


Multiple geoms

```r
p1 <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy), se = FALSE) +
  geom_point(aes(x = displ, y = hwy))

p2 <- ggplot(data = mpg) +
  geom_smooth(aes(x = displ, y = hwy, group = drv),
              se = FALSE) +
  geom_point(aes(x = displ, y = hwy))

ggarrange(p1, p2, nrow = 1)
```

Multiple geoms





Multiple geoms

- This, however, induces duplication in our code.
- We built the same aesthetic mapping twice in each graph.
- We can avoid this type of repetition by passing a set of mappings to `ggplot()`.
- ggplot2 will treat these mappings as global mappings that apply to each geom in the graph.

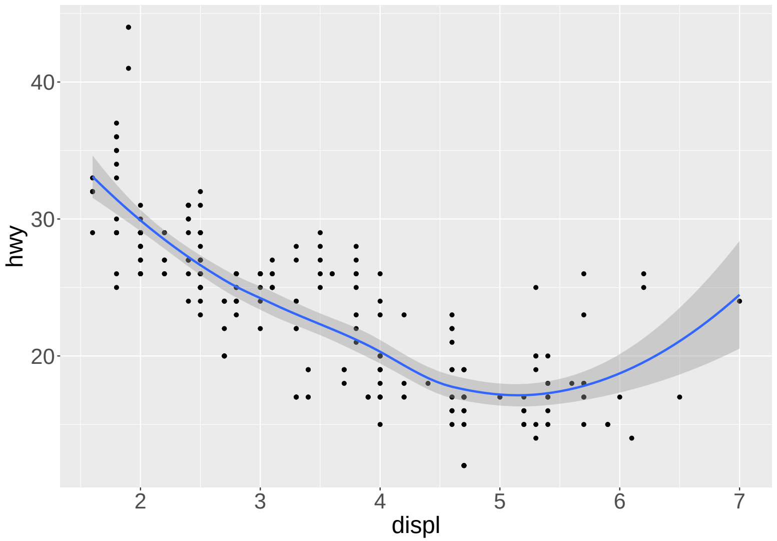
Multiple geoms

These two chunks of code result in the same plot:

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

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

Multiple geoms



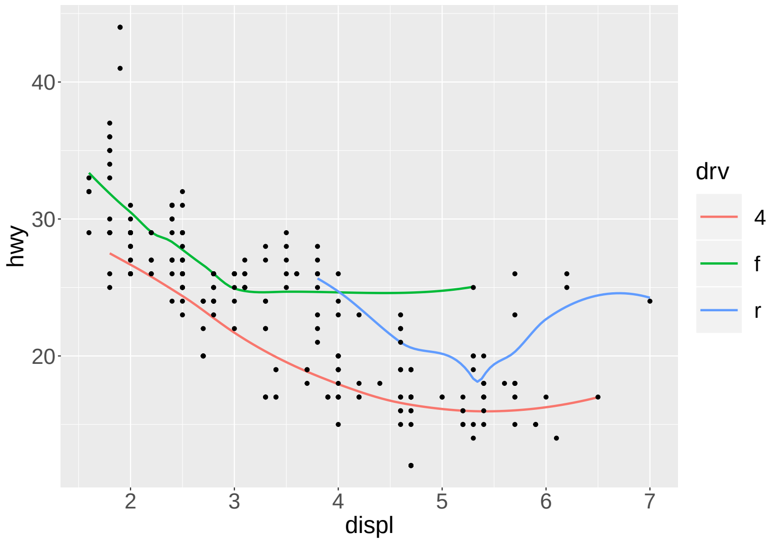
Multiple geoms

- If you place mappings in a geom function, ggplot2 will treat them as local mappings for that layer.
- It will use these mappings to extend or overwrite the global mappings for that layer only.
- This makes it possible to display different aesthetics in different layers.

Multiple geoms

```
ggplot(data = mpg, aes(x = displ, y = hwy)) +
  geom_smooth(aes(color = drv), se = FALSE) +
  geom_point()
```

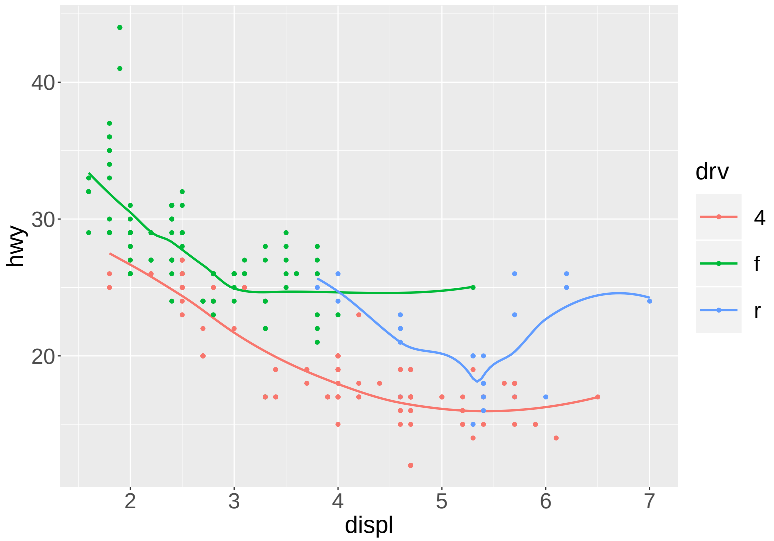
Multiple geoms



Multiple geoms

```r
ggplot(data = mpg,
       aes(x = displ, y = hwy, color = drv)) +
  geom_smooth(se = FALSE) +
  geom_point()
```

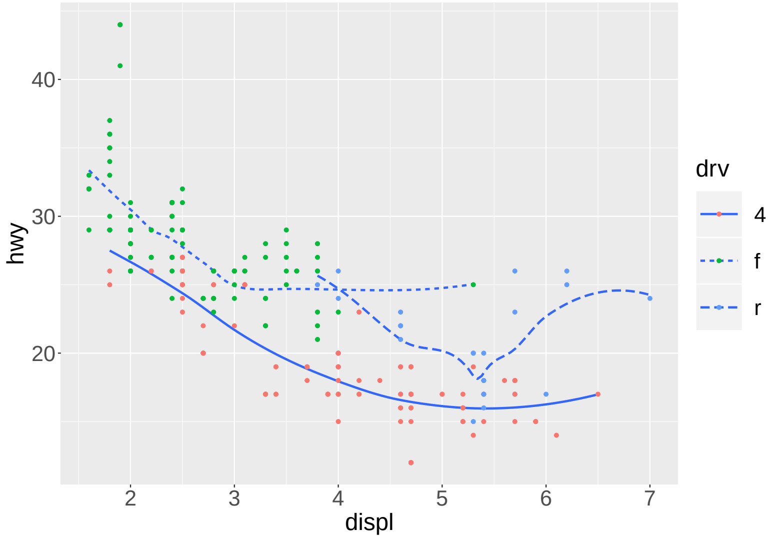
Multiple geoms



Multiple geoms

```r
ggplot(data = mpg, aes(x = displ, y = hwy)) +
   geom_smooth(aes(linetype = drv), se = FALSE) +
   geom_point(aes(color = drv))
```

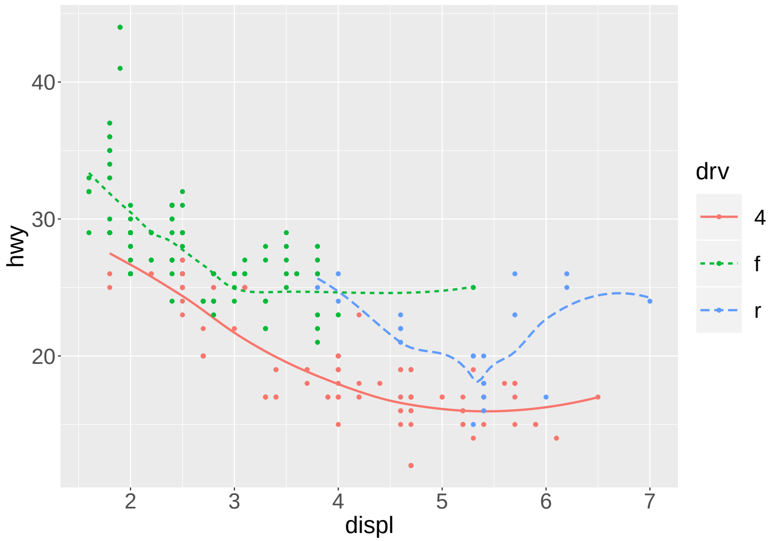
Multiple geoms



Multiple geoms

```r
ggplot(data = mpg, aes(x = displ, y = hwy,
                       color = drv)) +
  geom_smooth(aes(linetype = drv), se = FALSE) +
  geom_point()
```

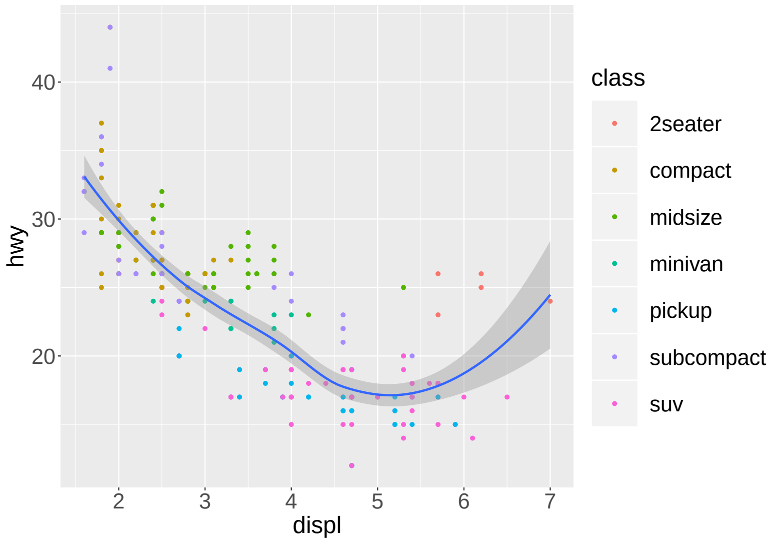
Multiple geoms



Multiple geoms

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

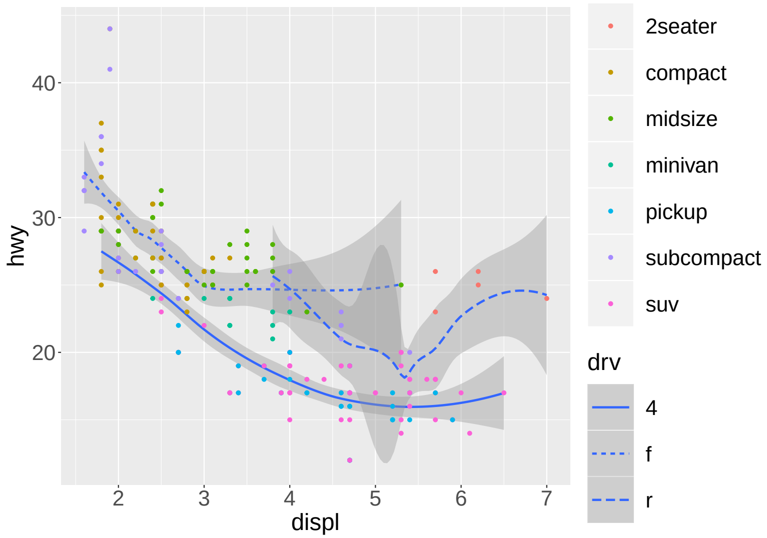
Multiple geoms



Multiple geoms

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

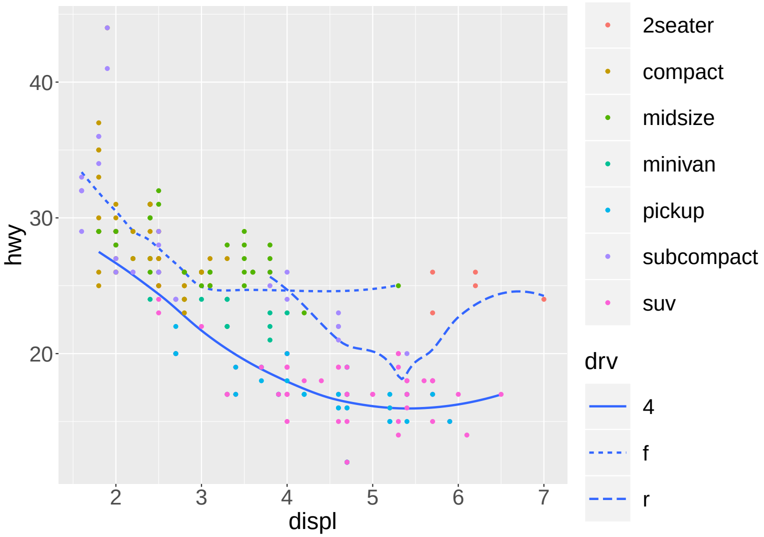
Multiple geoms



Multiple geoms

```r
ggplot(data = mpg, aes(x = displ, y = hwy)) +
  geom_smooth(aes(linetype = drv), se = FALSE) +
  geom_point(aes(color = class))
```

Multiple geoms



Multiple geoms

- You can use the same logic to specify different data for each layer.

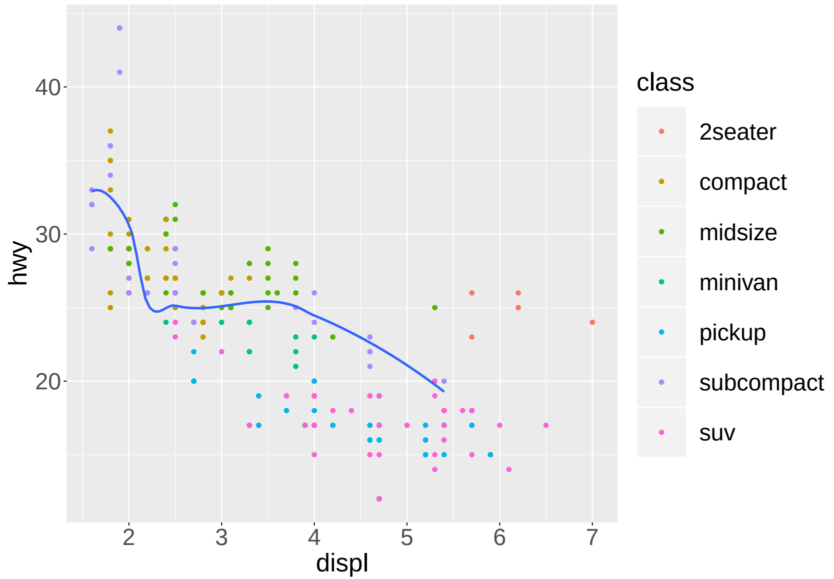
Multiple geoms

In this example:

- The smooth line displays just a subset of the mpg dataset, the subcompact cars.
- The local data argument in geom_smooth() overrides the global data argument in ggplot() for that layer only.

```r
ggplot(data = mpg, aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(
    data = subset(mpg, class == "subcompact"),
    se = FALSE
  )
```

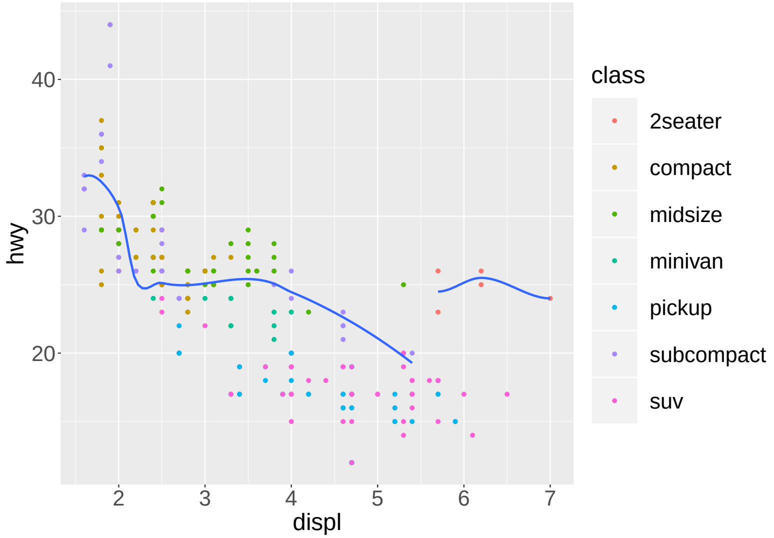
Multiple geoms



Multiple geoms

```r
ggplot(data = mpg, aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(
    data = subset(mpg, class == "subcompact"),
    se = FALSE
  ) +
  geom_smooth(
    data = subset(mpg, class == "2seater"),
    se = FALSE
  )
```

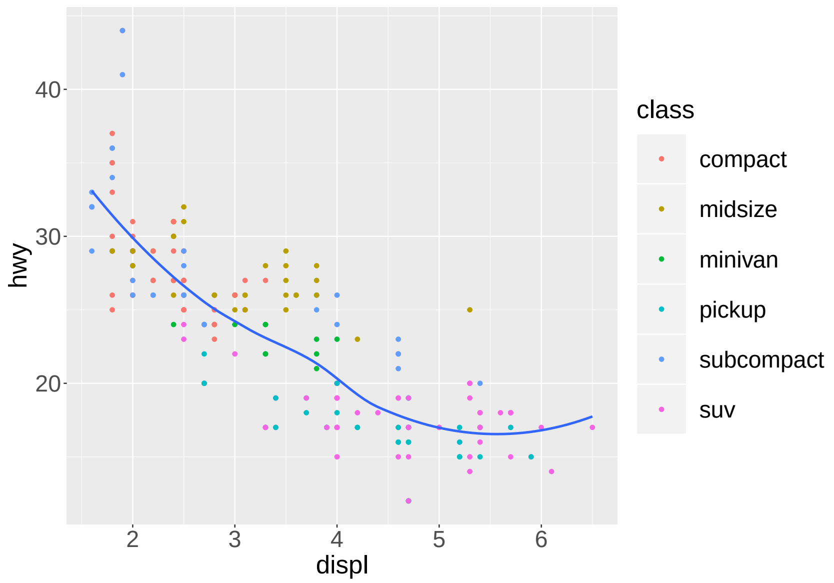
Multiple geoms



Multiple geoms

```r
ggplot(data = subset(mpg, class != "2seater"),
       aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(se = FALSE)
```

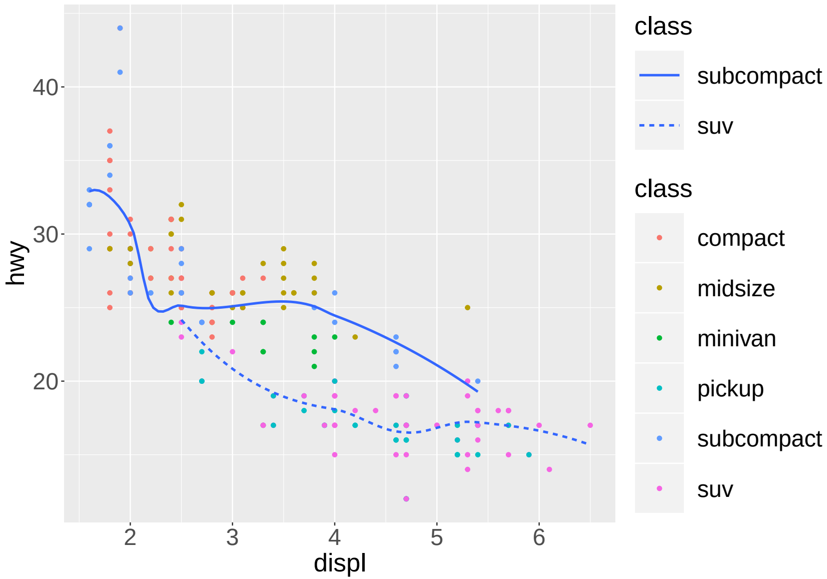
Multiple geoms



Multiple geoms

```r
ggplot(data = subset(mpg, class != "2seater"),
       aes(x = displ, y = hwy)) +
  geom_point(aes(color = class)) +
  geom_smooth(
    data = subset(mpg,
                  class %in% c("suv", "subcompact")),
    aes(linetype = class), se = FALSE)
```

Multiple geoms



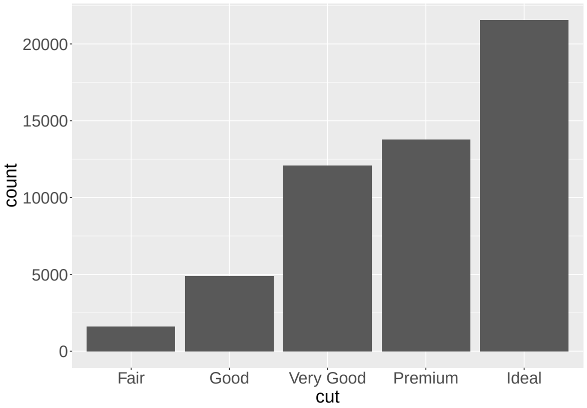
The `diamonds` dataset

- Diamonds is a dataset included in the ggplot2 package.
- Contains attributes of almost 54000 diamonds.
- The variables include price, carat, quality of the cut, color and clarity

Bar charts

Let's use a bar chart to display the number of diamonds for each quality of cut:

```r
ggplot(data = diamonds) +
  geom_bar(aes(x = cut))
```



Statistical transformations

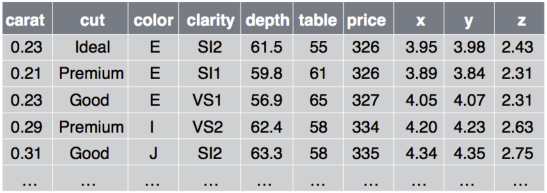
- On the y-axis, bar charts displays counts.
- But counts are not a variable in diamonds dataset!
- Many graphs, like scatterplots, plot the raw values the dataset.
- Other graphs, like bar charts, calculate new values to plot.
- The algorithm used to calculate new values for a graph is called a **stat**, short for statistical transformation.

Statistical transformations

- Bar charts, histograms, and frequency polygons bin your data and then plot bin counts.
- Smoothers fit a model to your data and then plot predictions from the model.
- Boxplots compute summary statistics and then display them on specially formatted box.

Statistical transformations

1. **`geom_bar()`** begins with the **`diamonds`** data set

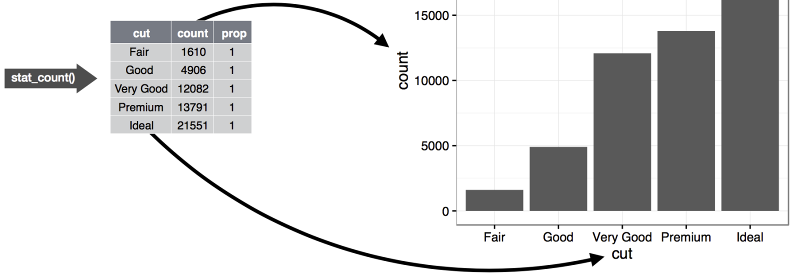


carat	cut	color	clarity	depth	table	price	x	y	z
0.23	Ideal	E	SI2	61.5	55	326	3.95	3.98	2.43
0.21	Premium	E	SI1	59.8	61	326	3.89	3.84	2.31
0.23	Good	E	VS1	56.9	65	327	4.05	4.07	2.31
0.29	Premium	I	VS2	62.4	58	334	4.20	4.23	2.63
0.31	Good	J	SI2	63.3	58	335	4.34	4.35	2.75
...	...	...	...	...	...	...	...	...	...

Statistical transformations

2. **`geom_bar()`** transforms the data with the "count" stat, which returns a data set of cut values and counts.

3. **`geom_bar()`** uses the transformed data to build the plot. cut is mapped to the x axis, count is mapped to the y axis.



cut	count	prop
Fair	1610	1
Good	4906	1
Very Good	12082	1
Premium	13791	1
Ideal	21551	1

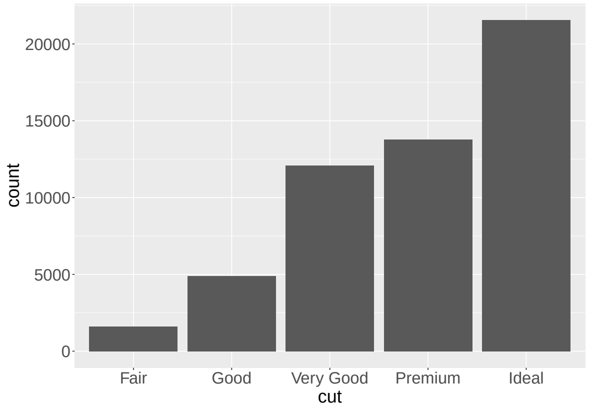
Statistical transformations

- You can learn which stat a geom function uses by inspecting the default value of the `stat` argument.
- For example, with `?geom_bar` we learn that the default `stat` of `geom_bar()` is `count`.
- This means that `geom_bar()` uses `stat_count()` as the default statistical transformation.
- You can generally use geoms and stats interchangeably.

Statistical transformations

For example, you can recreate the previous plot using `stat_count()` instead of `geom_bar()`:

```
ggplot(data = diamonds) +
  stat_count(aes(x = cut))
```



Statistical transformations

This works because:

- Every geom has a default stat, and every stat has a default geom.
- The default `stat` of `geom_bar()` is `count`.
- The default `geom` of `stat_count()` is `bar`.

Overwrithing the default stat

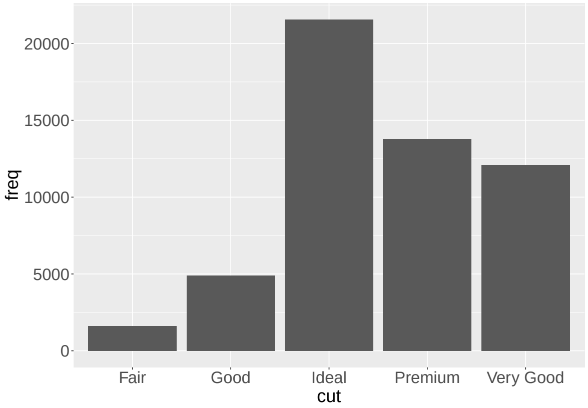
What if we want a bar chart that plot data as is?

- We may have a table with column heights.
- In that case, we need to change the default statistical transformation

```r
tib <- tribble(
  ~cut,         ~freq,
  "Fair",       1610,
  "Good",       4906,
  "Very Good",  12082,
  "Premium",    13791,
  "Ideal",      21551
)
```

Overriding the default stat

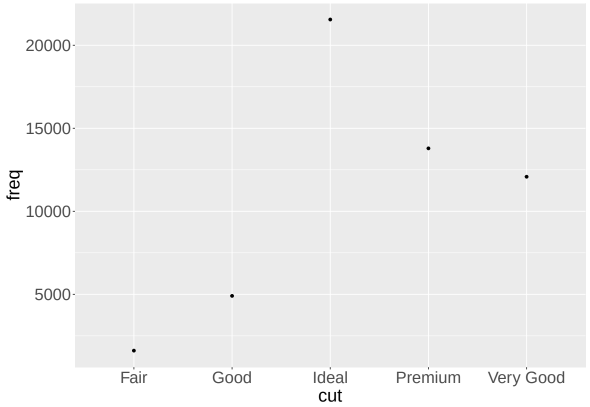
```r
ggplot(data = tib) +
  geom_bar(aes(x = cut, y = freq),
    stat = "identity")
```



Overriding the default stat

The default stat of `stat_identity()` is `point`, not `bar`:

```
ggplot(data = tib) +
  stat_identity(aes(x = cut, y = freq))
```

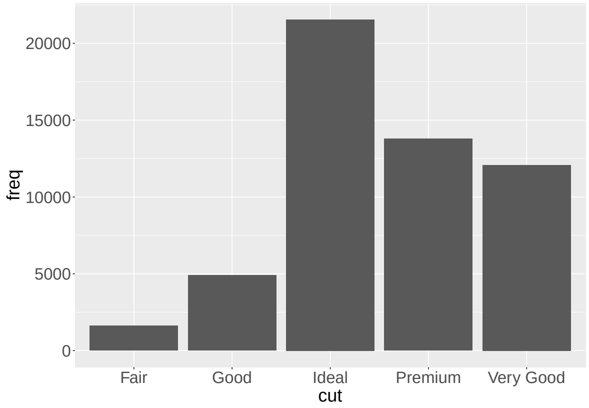


`geom_col()`

- To plot data as is, we can use `geom_col()`.
- The default stat of `geom_col()` is `stat_identity()`.
- `geom_col()` expects a column of y values with bar heights.

geom_col()

```
ggplot(data = tib) +
  geom_col(aes(x = cut, y = freq))
```



Statistical transformations

- Stat functions calculate more variables than the ones that end up being displayed.
- To find the variables computed by a stat, look for the help section titled “computed variables”.
- From `?stat_count` we learn that the computed variables are counts and proportions.
- `ggplot_build()` let’s us see every value that is calculated in the process of building a graph.

Statistical transformations

```r
plt_1 <- ggplot(data = diamonds) +
  geom_bar(aes(x = cut))

plt_1 <- ggplot_build(plt_1)
plt_1$data[[1]][, 1:8]
```

```
##       y count prop x PANEL group ymin  ymax
## 1  1610  1610    1 1     1     1    0  1610
## 2  4906  4906    1 2     1     2    0  4906
## 3 12082 12082    1 3     1     3    0 12082
## 4 13791 13791    1 4     1     4    0 13791
## 5 21551 21551    1 5     1     5    0 21551
```

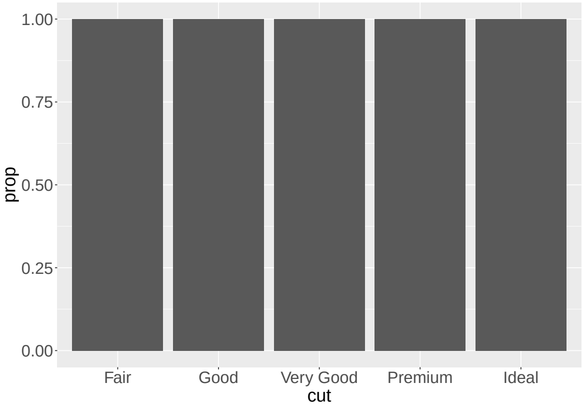
Mapping from transformed variables to aesthetics

- We can override the default mapping from transformed variables to aesthetics.
- For example, we might want to display a bar chart of proportions rather than counts.

Mapping from transformed variables to aesthetics

Let´s map proportions, instead of counts, to the y axis:

```
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, y = stat(prop)))
```



What went wrong?

Mapping from transformed variables to aesthetics

Lets see the computed values:

```
plt_2 <- ggplot(data = diamonds) +
  geom_bar(aes(x = cut, y = stat(prop)))

plt_2 <- ggplot_build(plt_2)
plt_2$data[[1]][, 1:8]
```

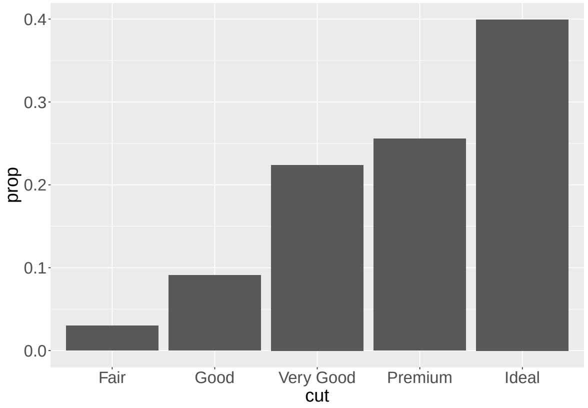
```
##   y count prop x PANEL group ymin ymax
## 1 1  1610    1 1     1     1    0    1
## 2 1  4906    1 2     1     2    0    1
## 3 1 12082    1 3     1     3    0    1
## 4 1 13791    1 4     1     4    0    1
## 5 1 21551    1 5     1     5    0    1
```

Mapping from transformed variables to aesthetics

- The `prop` column is created as `count` divided by the sum of all of the counts that belong to the same group.
- By default, ggplot2 created one group for each level of x, so:
  - Each proportion is calculated by dividing the count of each group by itself.
  - All the proportions are set to 1.
- To display proportions instead of counts we have to tell ggplot2 that there is only one group so that it divides the counts by the total number of observations.

Mapping from transformed variables to aesthetics

```
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, y = stat(prop), group = 1))
```



Mapping from transformed variables to aesthetics

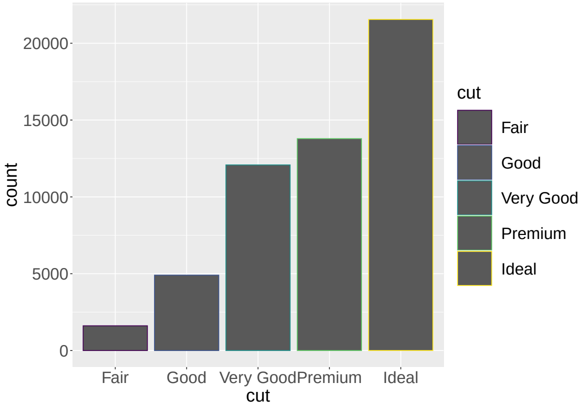
```
plt_3 <- ggplot(data = diamonds) +
  geom_bar(aes(x = cut, y = stat(prop), group = 1))
plt_3 <- ggplot_build(plt_3)

plt_3$data[[1]][, 1:5]
```

```
##            y count       prop x group
## 1 0.02984798  1610 0.02984798 1     1
## 2 0.09095291  4906 0.09095291 2     1
## 3 0.22398962 12082 0.22398962 3     1
## 4 0.25567297 13791 0.25567297 4     1
## 5 0.39953652 21551 0.39953652 5     1
```

Aesthetic of bar charts

You can map the color aesthetic to the grouping variable:

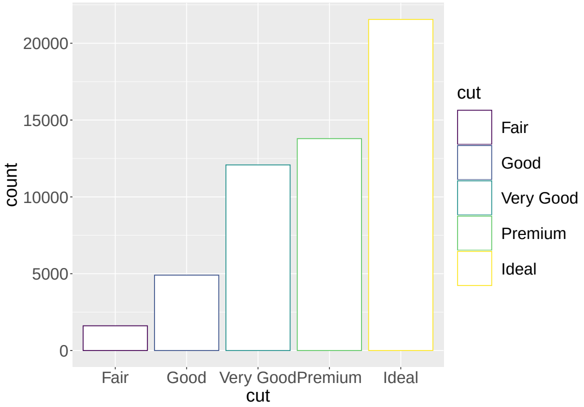
```
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, color = cut))
```



Aesthetic of bar charts

We can also change the default `fill` color of `geom_bar()`:

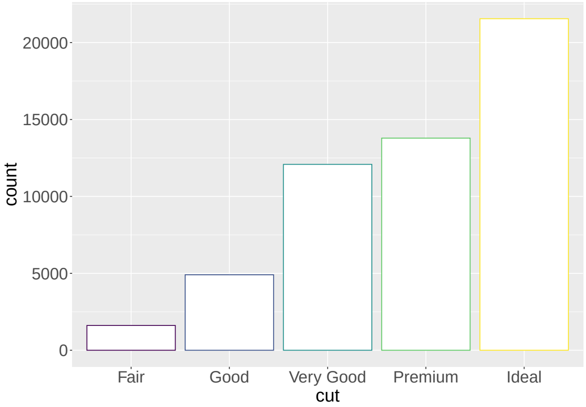
```r
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, color = cut), fill = "white")
```



Aesthetic of bar charts

And disable the legend:

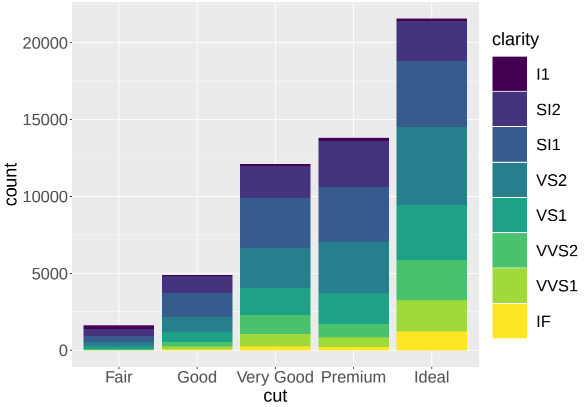
```r
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, color = cut),
           fill = "white", show.legend = FALSE)
```



Stacked bar charts

The fill aesthetic can be mapped to variables other than x to add a dimension to the plot:

```r
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, fill = clarity))
```



Position adjustments

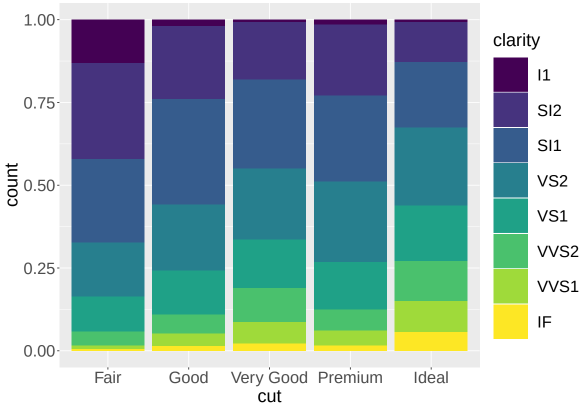
- Each colored rectangle represents a combination of cut and clarity.
- The stacking is performed automatically by the position adjustment specified in the `position` argumen of the geom function.
- The default value is `stack`.

Position adjustments

- `position = "fill"` works like stacking but makes each set of stacked bars the same height.
- This makes it easier to compare proportions across groups.

Position adjustments

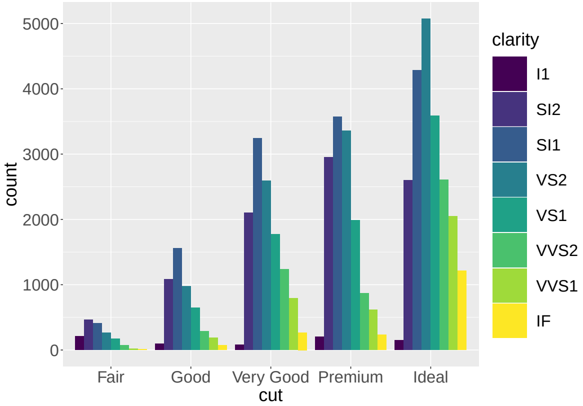
```
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, fill = clarity),
           position = "fill")
```



Position adjustments

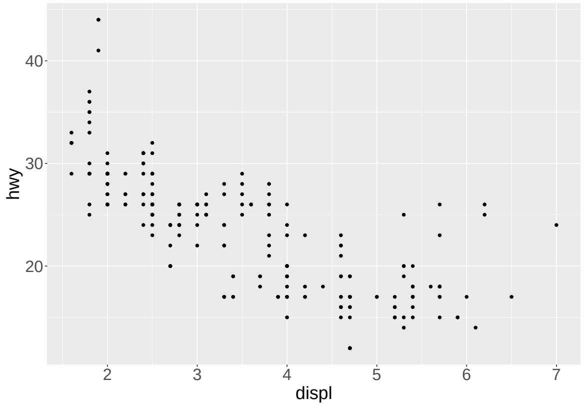
Setting `position = "dodge"` places overlapping objects directly beside one another:

```r
ggplot(data = diamonds) +
  geom_bar(aes(x = cut, fill = clarity),
           position = "dodge")
```



Position adjustments

Recall our first scatterplot:



Did you notice that the plot displays only 126 points, even though there are 234 observations in the dataset?

Position adjustments

- The values of `hwy` and `displ` are rounded, and many points overlap each other.
- This problem is known as overplotting.
- This makes it hard to see where the mass of the data is.
- Are the data points spread equally throughout the graph, or is there one special combination of hwy and displ that contains 109 values?

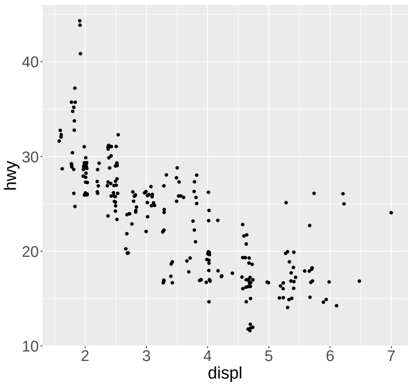
Position adjustments

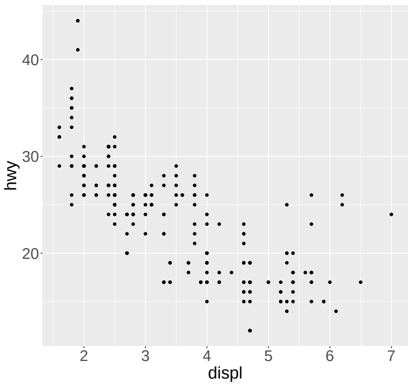
- Setting position = “jitter” adds a small amount of random noise to each point, spreading the points.
- While it makes your graph less accurate at small scales, it makes your graph more revealing at large scales.
- ggplot2 comes with a shorthand for `geom_point(position = "jitter")`:
    - `geom_jitter()`.

Position adjustments

```r
p1 <- ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy),
             position = "jitter")

p2 <- ggplot(data = mpg) +
  geom_point(aes(x = displ, y = hwy))

ggarrange(p1, p2, nrow = 1)
```

Position adjustments



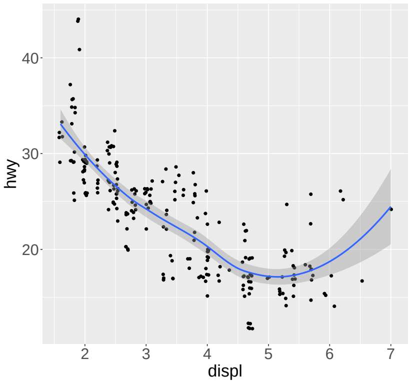


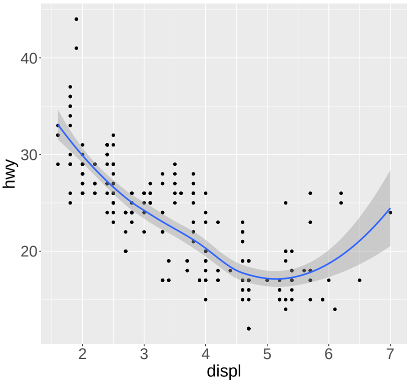
Position adjustments

```r
p1 <- ggplot(data = mpg, aes(x = displ, y = hwy)) +
  geom_point(position = "jitter") +
  geom_smooth()

p2 <- ggplot(data = mpg,  aes(x = displ, y = hwy)) +
  geom_point() +
  geom_smooth()

ggarrange(p1, p2, nrow = 1)
```

Position adjustments

The confidence interval of the smoothed lines can also help:





Position adjustments

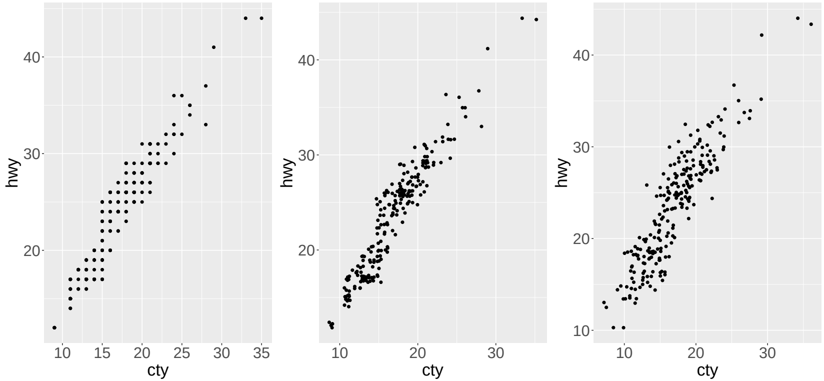
There are two optional arguments to jitter:

- Width controls the amount of vertical displacement.
- Height controls the amount of horizontal displacement.

Position adjustments

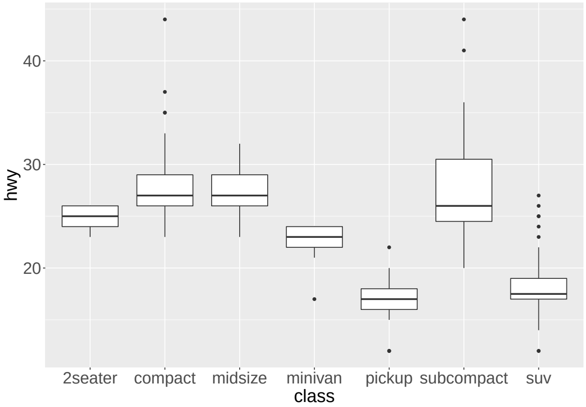
```
p1 <- ggplot(data = mpg, aes(x = cty, y = hwy)) +
        geom_point()

p2 <- ggplot(data = mpg, aes(x = cty, y = hwy)) +
        geom_jitter()

p3 <- ggplot(data = mpg, aes(x = cty, y = hwy)) +
  geom_jitter(height = 2, width = 2)

ggarrange(p1, p2, p3, nrow = 1)
```

Position adjustments



Boxplots

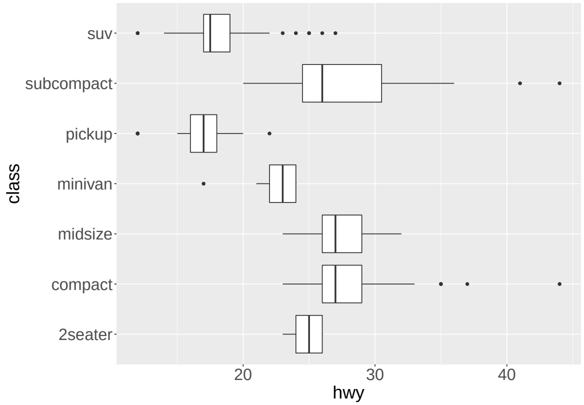
```r
ggplot(data = mpg, aes(x = class, y = hwy)) +
  geom_boxplot()
```



Coordinate systems

`coord_flip()` flpis the coordinate system:

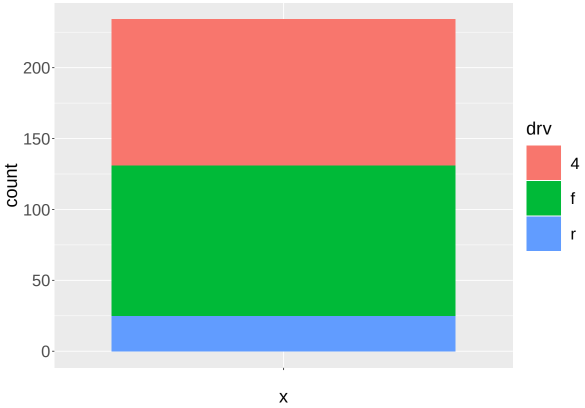
```
ggplot(data = mpg, aes(x = class, y = hwy)) +
  geom_boxplot() +
  coord_flip()
```



Coordinate systems

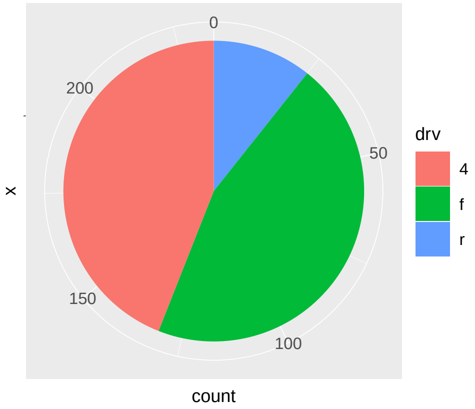
A pie chart is a stacked bar chart with polar coordinates:

```r
ggplot(mpg, aes(x = "", fill = drv)) +
  geom_bar()
```



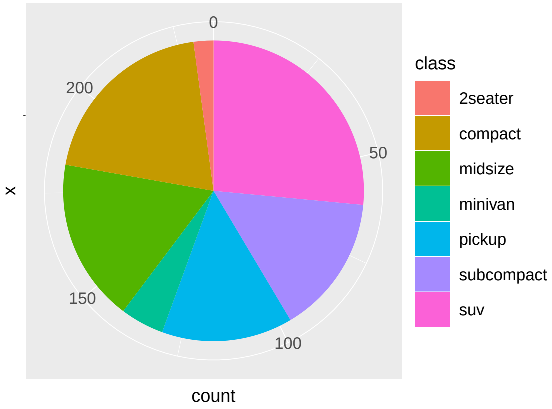
Coordinate systems

```r
ggplot(mpg, aes(x = "", fill = drv)) +
  geom_bar() +
  coord_polar("y")
```



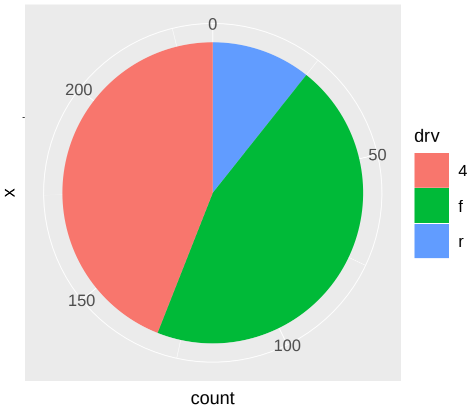
Coordinate systems

```
ggplot(mpg, aes(x = "", fill = class)) +
  geom_bar() +
  coord_polar("y")
```



Coordinate systems

```
ggplot(mpg, aes(x = "", fill = drv)) +
  geom_bar() +
  coord_polar("y")
```



The ggplot template

```r
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(
     mapping = aes(<MAPPINGS>),
     stat = <STAT>,
     position = <POSITION>
  ) +
  <COORDINATE_FUNCTION> +
  <FACET_FUNCTION>
```

Bibliography

Wichkam, Hadley, and Garrett Grolemund. 2016. “R for Data Science.” *O’Reilly*.

Wickham, Hadley. 2010. “A Layered Grammar of Graphics.” *Journal of Computational and Graphical Statistics* 19 (1). Taylor & Francis: 3–28.