Introduction to ggplot2

R Pruim

CVC 2016

Goals

What I will try to do

- give a tour of `ggplot2`
- explain how to think about plots the `ggplot2` way
- prepare/encourage you to learn more later

What I can't do in one session

- show every bell and whistle
- make you an expert at using `ggplot2`

Set up

```r
require(mosaic)
require(lubridate) # package for working with dates
data(Births78)     # restore fresh version of Births78
head(Births78, 3)
```

```
##         date births dayofyear wday
## 1 1978-01-01   7701         1  Sun
## 2 1978-01-02   7527         2  Mon
## 3 1978-01-03   8825         3 Tues
```

The grammar of graphics

geom: the geometric "shape" used to display data (glyph)

- bar, point, line, ribbon, text, etc.

aesthetic: an attribute controlling how geom is displayed

- x position, y position, color, fill, shape, size, etc.

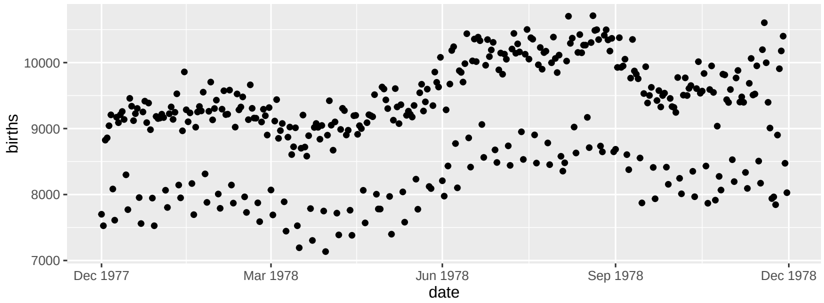
scale: conversion of raw data to visual display

- particular assignment of colors, shapes, sizes, etc.

guide: helps user convert visual data back into raw data (legends, axes)
stat: a transformation applied to data before geom gets it

- example: histograms work on binned data

How do we make this plot?



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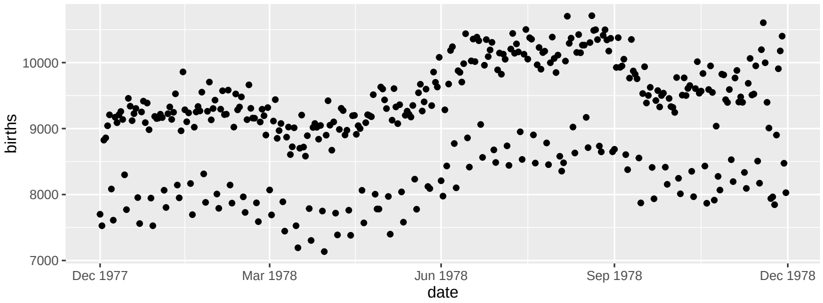
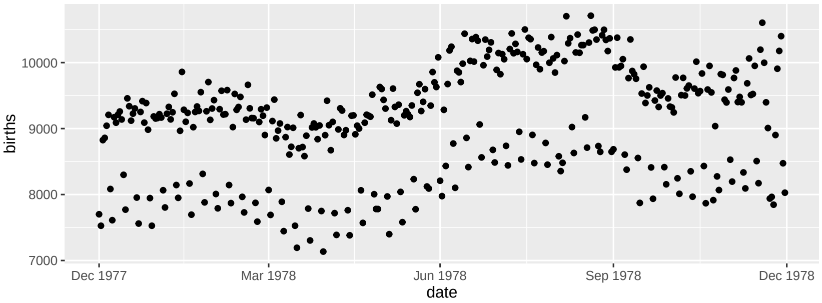


Two Questions:

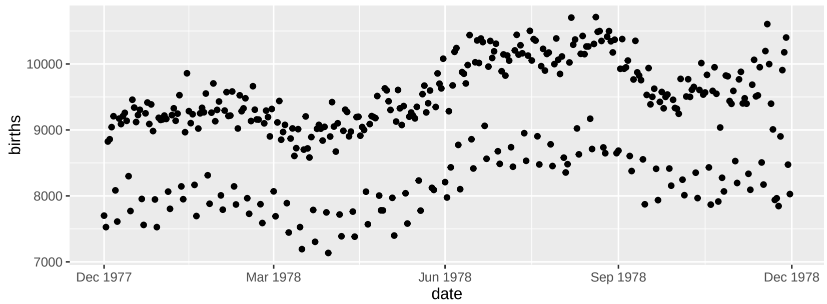
How do we make this plot?



Two Questions:

1. What do we want R to do? (What is the goal?)
2. What does R need to know?

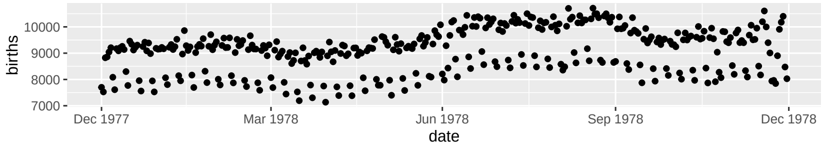
How do we make this plot?



Two Questions:

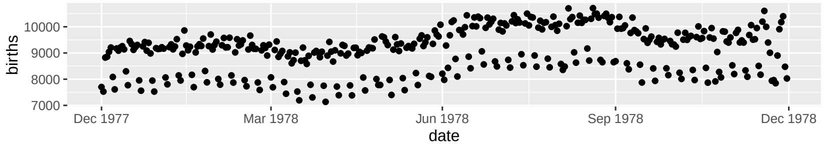
1. Goal: scatterplot = a plot with points
2. What does R need to know?
    - data source: `Births78`
    - aesthetics:
        - `date -> x`
        - `births -> y`
        - default color (same for all points)

How do we make this plot?



1. Goal: scatterplot = a plot with points
   - `ggplot() + geom_point()`
2. What does R need to know?
   - data source: `data = Births78`
   - aesthetics: `aes(x = date, y = births)`

How do we make this plot?



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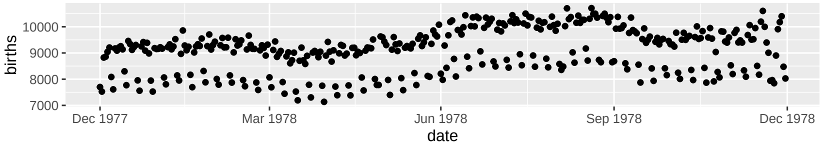
   - aesthetics: `aes(x = date, y = births)`

```r
ggplot(data = Births78, aes(x = date, y = births)) +
  geom_point()
```

How do we make this plot?



1. Goal: scatterplot = a plot with points
   - `ggplot() + geom_point()`
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```r
ggplot(data = Births78, aes(x = date, y = births)) +
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```
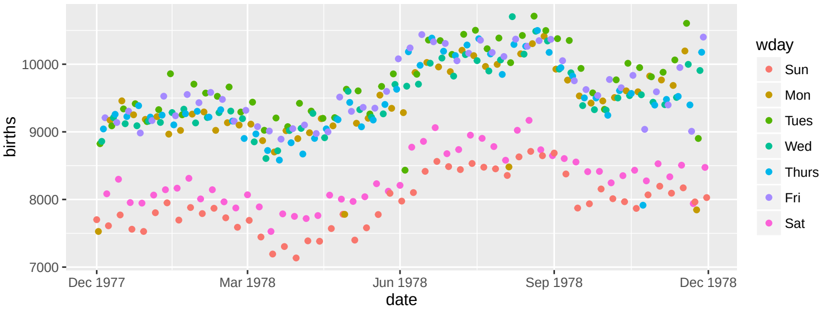
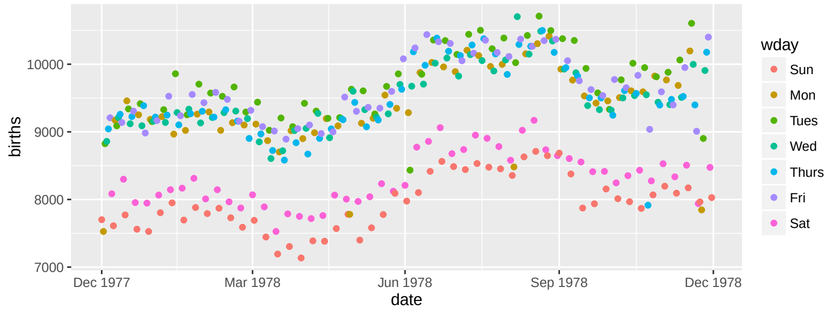

```r
ggplot() +
  geom_point(data = Births78, aes(x = date, y = births))
```

How do we make this plot?



What has changed?

How do we make this plot?



What has changed?

- new aesthetic: mapping color to day of week

Adding day of week to the data set

The `wday()` function in the `lubridate` package computes the day of the week from a date.

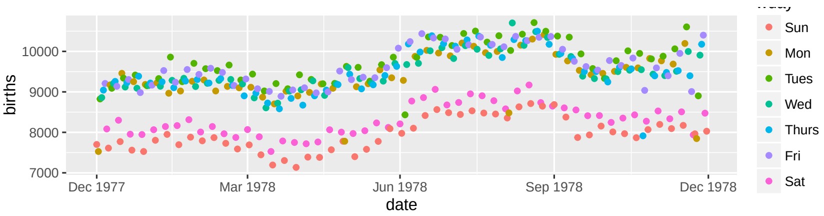
```r
Births78 <-
  Births78 %>%
  mutate(wday = wday(date, label = TRUE))
```

Adding day of week to the data set

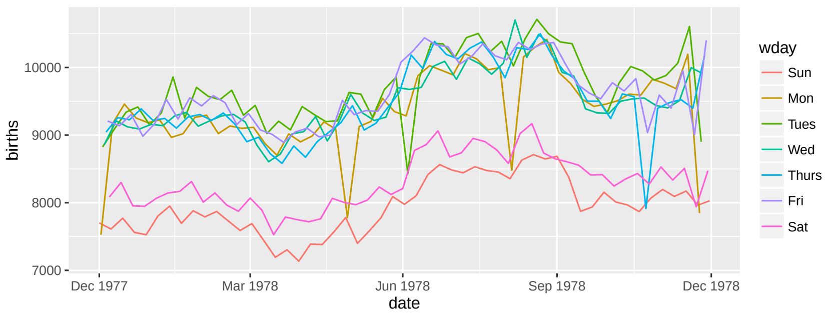
The `wday()` function in the `lubridate` package computes the day of the week from a date.

```
Births78 <-
  Births78 %>%
  mutate(wday = wday(date, label = TRUE))
```

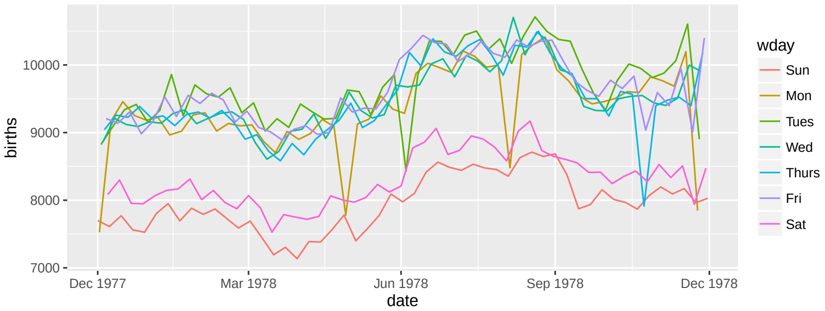
```
ggplot(data = Births78) +
  geom_point(aes(x = date, y = births, color = wday))
```



How do we make this plot?



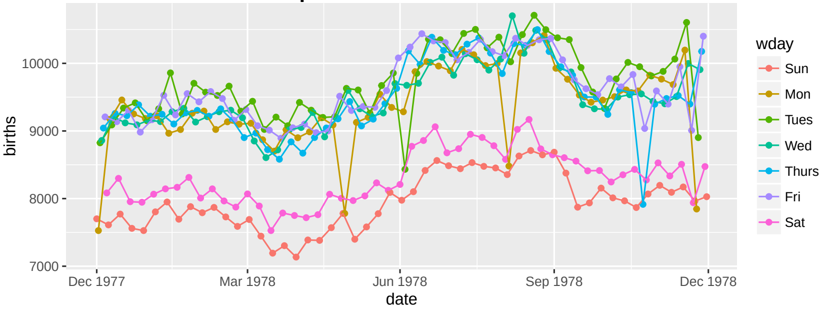
How do we make this plot?



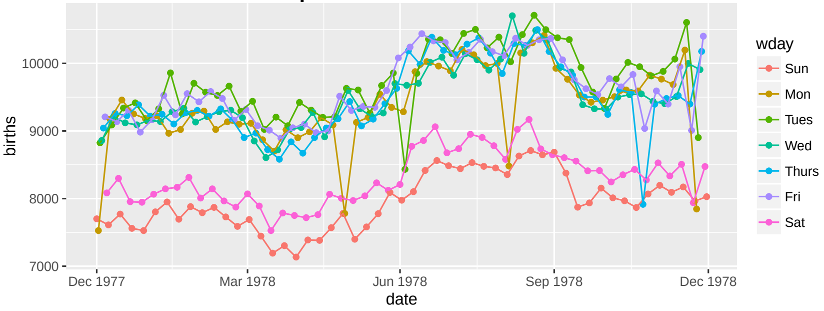
This time we use lines instead of dots

```
ggplot(data = Births78) +
  geom_line(aes(x = date, y = births, color = wday))
```

How do we make this plot?



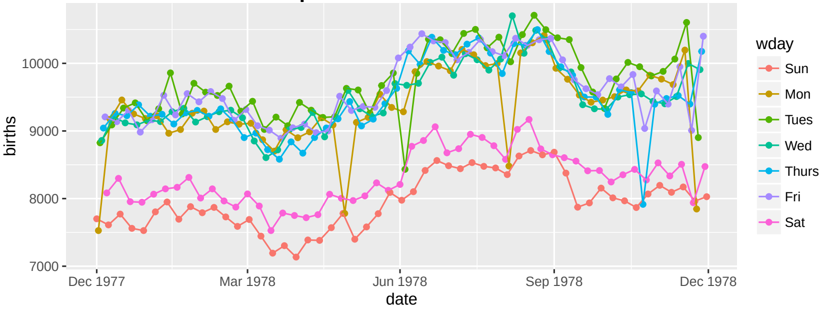
How do we make this plot?



This time we have two **layers**, one with points and one with lines

```
ggplot(data = Births78,
       aes(x = date, y = births, color = wday)) +
  geom_point() +  geom_line()
```

How do we make this plot?



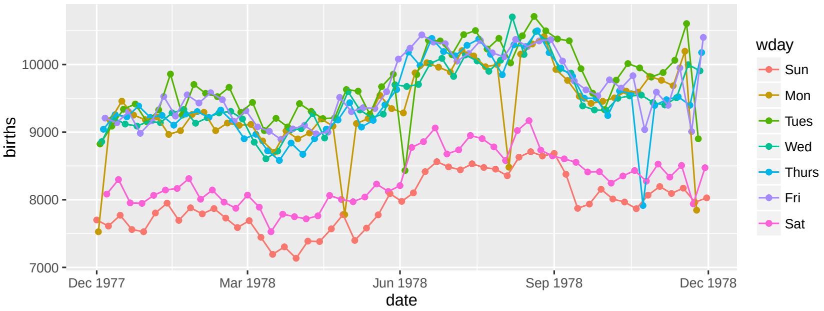
This time we have two **layers**, one with points and one with lines

```
ggplot(data = Births78,
       aes(x = date, y = births, color = wday)) +
  geom_point() +  geom_line()
```

- The layers are placed one on top of the other: the points are *below* and the lines are *above*.
- `data` and `aes` specified in `ggplot()` affect all geoms

Alternative Syntax

```
Births78 %>%
  ggplot(aes(x = date, y = births, color = wday)) +
  geom_point() +
  geom_line()
```

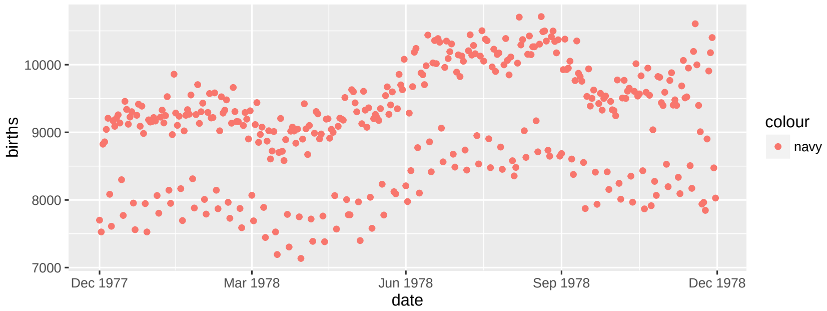


What does this do?

```r
Births78 %>%
  ggplot(aes(x = date, y = births, color = "navy")) +
  geom_point()
```

What does this do?

```r
Births78 %>%
  ggplot(aes(x = date, y = births, color = "navy")) +
  geom_point()
```

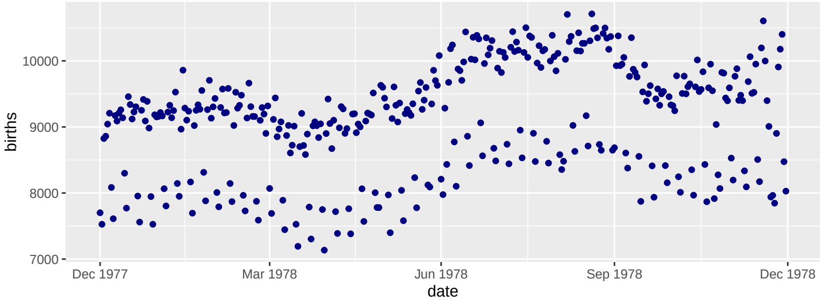


This is *mapping* the color aesthetic to a new variable with only one value ("navy").
So all the dots get set to the same color, but it's not navy.

Setting vs. Mapping

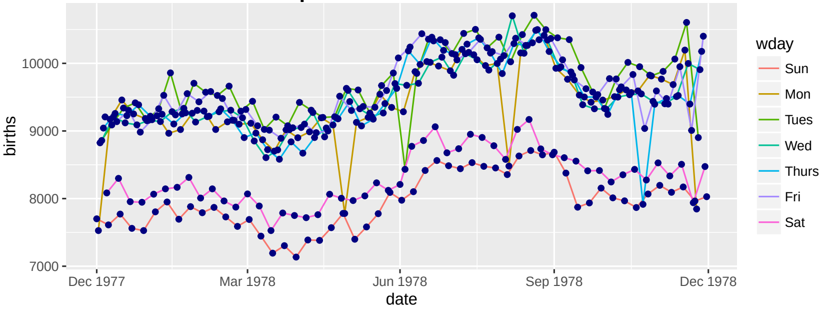
If we want to *set* the color to be navy for all of the dots, we do it this way:

```r
Births78 %>%
  ggplot(aes(x = date, y = births)) +   # map these
  geom_point(color = "navy")          # set this
```



- Note that `color = "navy"` is now outside of the aesthetics list. That's how `ggplot2` distinguishes between mapping and setting.

How do we make this plot?



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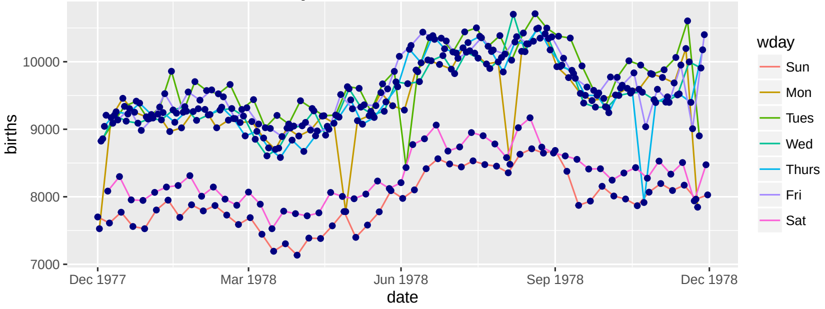


```
Births78 %>%
  ggplot(aes(x = date, y = births)) +
  geom_line(aes(color = wday)) +        # map color here
  geom_point(color = "navy")            # set color here
```

- `ggplot()` establishes the default data and aesthetics for the geoms, but each geom may change these defaults.
- good practice: put into `ggplot()` the things that affect all (or most) of the layers; rest in `geom_blah()`

Other geoms

```r
apropos("^geom_") %>% head(21)
```

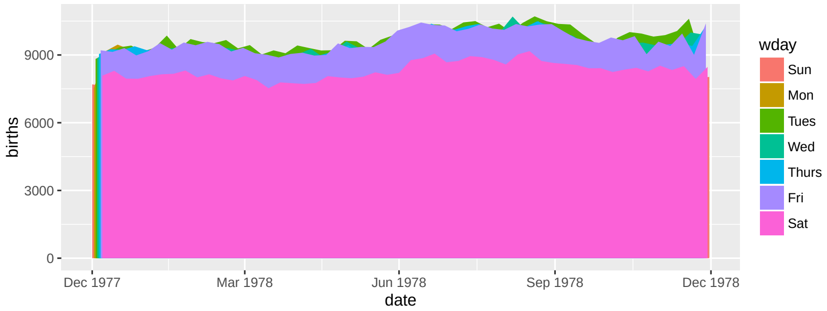
```
 [1] "geom_abline"     "geom_area"       "geom_bar"
 [4] "geom_bin2d"      "geom_blank"      "geom_boxplot"
 [7] "geom_contour"    "geom_count"      "geom_crossbar"
[10] "geom_curve"      "geom_density"    "geom_density_2d"
[13] "geom_density2d"  "geom_dotplot"    "geom_errorbar"
[16] "geom_errorbarh"  "geom_freqpoly"   "geom_hex"
[19] "geom_histogram"  "geom_hline"      "geom_jitter"
```

help pages will tell you their aesthetics, default stats, etc.

```r
?geom_area                 # for example
```

Let's try geom_area

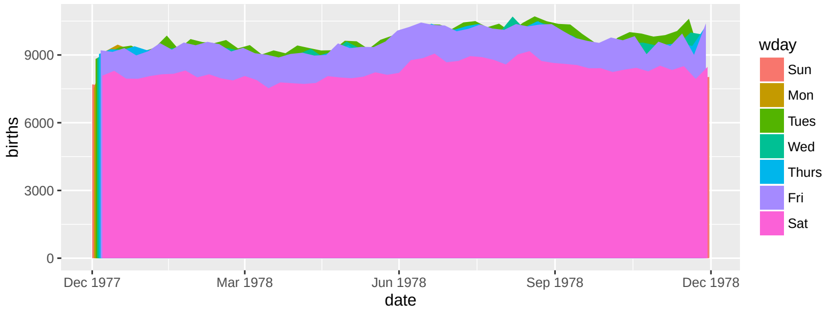
```
Births78 %>%
  ggplot(aes(x = date, y = births, fill = wday)) +
  geom_area()
```



This is not a good plot

Let's try geom_area

```r
Births78 %>%
  ggplot(aes(x = date, y = births, fill = wday)) +
  geom_area()
```



This is not a good plot

- overplotting is hiding much of the data
- extending y-axis to 0 may or may not be desirable.

Side note: what makes a plot good?

Most (all?) graphics are intended to help us make comparisons

- How does something change over time?
- Do my treatments matter? How much?
- Do men and women respond the same way?

Key plot metric: Does my plot make the comparisions I am interested in

- easily, and
- accurately?

Time for some different data

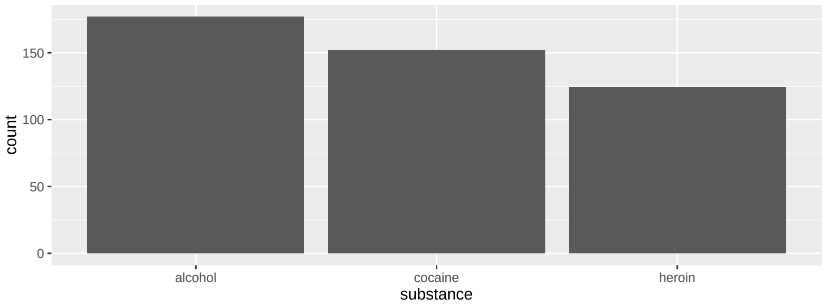
HELPrct: Health Evaluation and Linkage to Primary care randomized clinical trial

```
?HELPrct
```

Subjects admitted for treatment for addiction to one of three substances.

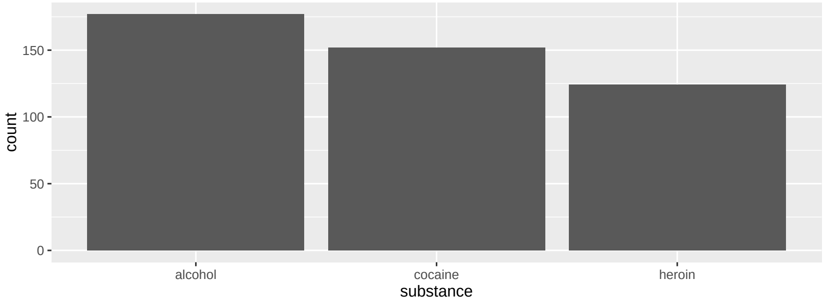
Why are these people in the study?

```
HELPrct %>%
  ggplot(aes(x = substance)) +
  geom_bar()
```



Why are these people in the study?

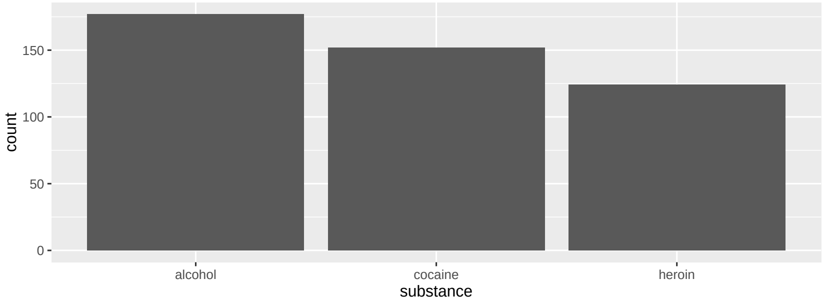
```
HELPrct %>%
  ggplot(aes(x = substance)) +
  geom_bar()
```



- Hmm. What's up with `y`?

Why are these people in the study?

```r
HELPrct %>%
  ggplot(aes(x = substance)) +
  geom_bar()
```



- Hmm. What's up with `y`?
  - `stat_bin()` is being applied to the data before the `geom_bar()` gets to do its thing. Binning creates the `y` values.

Data Flow

$$\text{org data} \xrightarrow{\text{stat}} \text{statified} \xrightarrow{\text{aesthetics}} \text{aesthetic data} \xrightarrow{\text{scales}} \text{scaled data}$$

Simplifications:

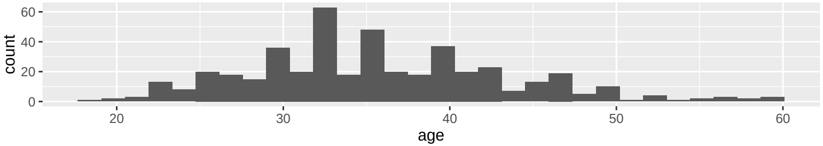
- Aesthetics get computed twice, once before the stat and again after. Examples: bar charts, histograms
- We need to look at the aesthetics to figure out which variable to bin
  - then the stat does the binning
  - bin counts become part of the aesthetics for geom: `y = ..count..`
- This process happens *in each layer*
- `stat_identity()` is the “do nothing” stat.

How old are people in the HELP study?

How old are people in the HELP study?

```r
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_histogram()
```

```
## `stat_bin()` using `bins = 30`. Pick better value with
## `binwidth`.
```

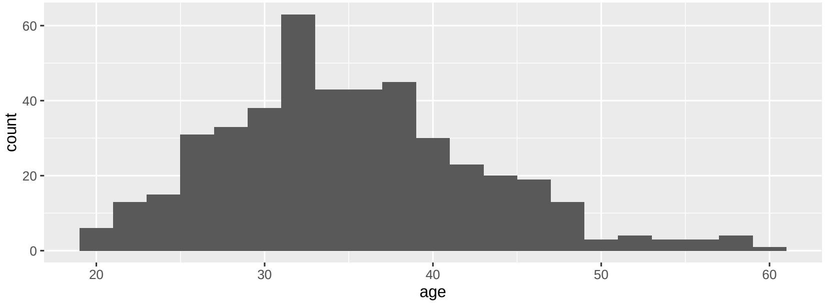


Notice the messages

- `stat_bin`: Histograms are not mapping the raw data but binned data.
  `stat_bin()` performs the data transformation.
- `binwidth`: a default binwidth has been selected, but we should really choose our own.

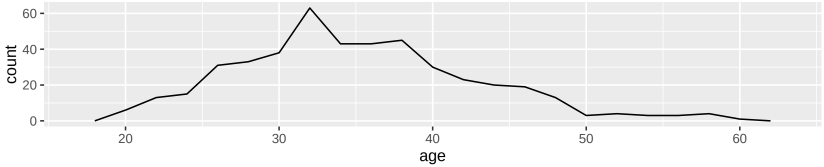
Setting the binwidth manually

```
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_histogram(binwidth = 2)
```

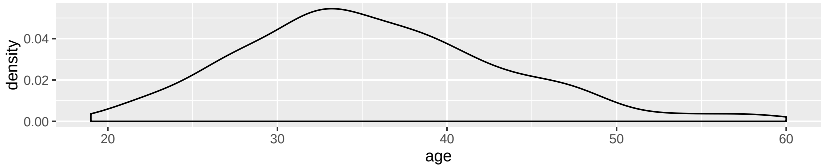


How old are people in the HELP study? – Other geoms

```
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_freqpoly(binwidth = 2)
```



```
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_density()
```

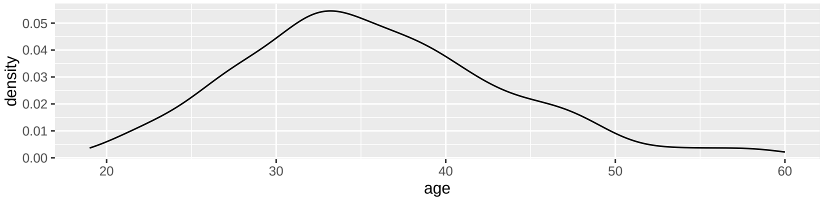


Selecting stat and geom manually

Every geom comes with a default stat

- for simple cases, the stat is `stat_identity()` which does nothing
- we can mix and match geoms and stats however we like

```r
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_line(stat = "density")
```

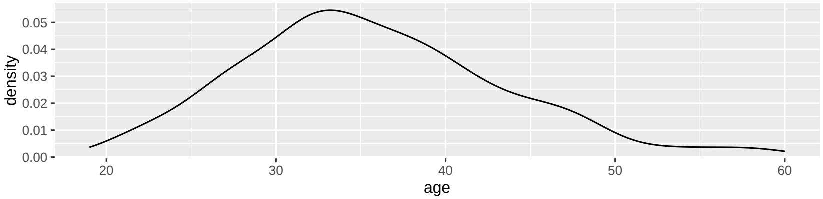


Selecting stat and geom manually

Every stat comes with a default geom, every geom with a default stat

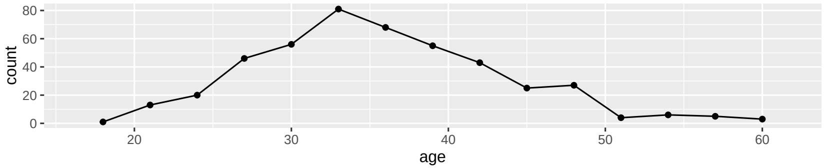
- we can specify stat instead of geom, if we prefer
- we can mix and match geoms and stats however we like

```
HELPrct %>%
  ggplot(aes(x = age)) +
  stat_density( geom = "line")
```

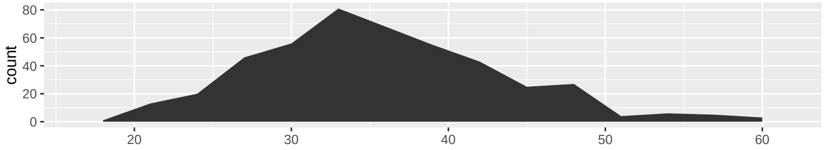


More combinations

```
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_point(stat = "bin", binwidth = 3) +
  geom_line(stat = "bin", binwidth = 3)
```



```
HELPrct %>%
  ggplot(aes(x = age)) +
  geom_area(stat = "bin", binwidth = 3)
```

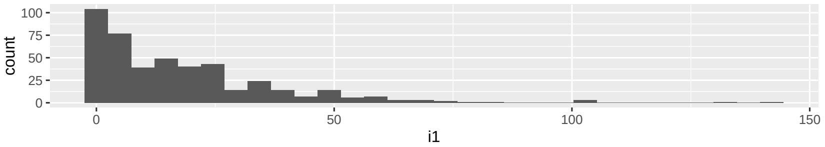


Your turn: How much do they drink? (i1)

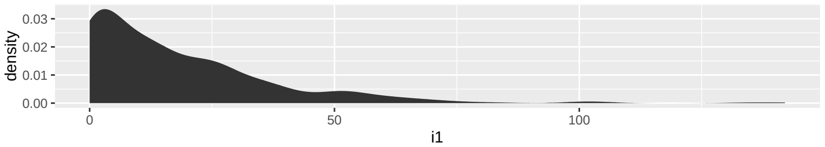
Create a plot that shows the distribution of the average daily alcohol consumption in the past 30 days (`i1`).

How much do they drink? (i1)

```r
HELPrct %>%
  ggplot(aes(x = i1)) + geom_histogram()
```



```r
HELPrct %>%
  ggplot(aes(x = i1)) + geom_area(stat = "density")
```



Covariates: Adding in more variables

Q. How does alcohol consumption (or age, your choice) differ by sex and substance (alcohol, cocaine, heroin)?
Decisions:

- How will we display the variables: `i1` (or `age`), `sex`, `substance`
- What comparisons are we most interested in?

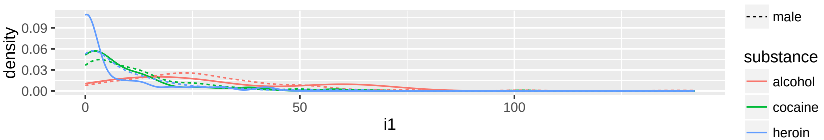
Give it a try.

- Note: I'm cheating a bit. You may want to do some things I haven't shown you yet. (Feel free to ask.)

Covariates: Adding in more variables

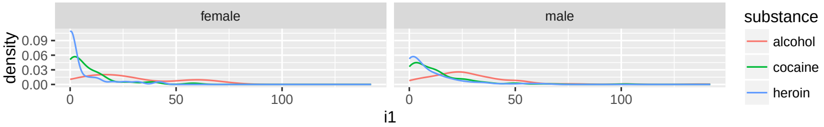
Using color and linetype:

```
HELPrct %>%
  ggplot(aes(x = i1, color = substance, linetype = sex)) +
  geom_line(stat = "density")
```



Using color and facets

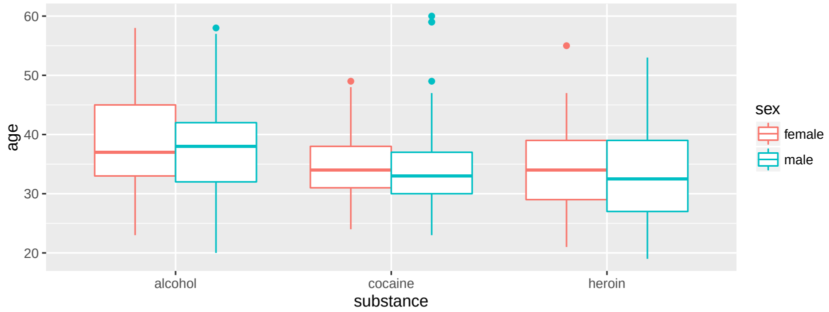
```
HELPrct %>%
  ggplot(aes(x = i1, color = substance)) +
  geom_line(stat = "density") + facet_grid( . ~ sex )
```



Boxplots

Boxplots use `stat_quantile()` which computes a five-number summary (roughly the five quartiles of the data) and uses them to define a “box” and “whiskers”. The quantitative variable must be `y`, and there must be an additional `x` variable.

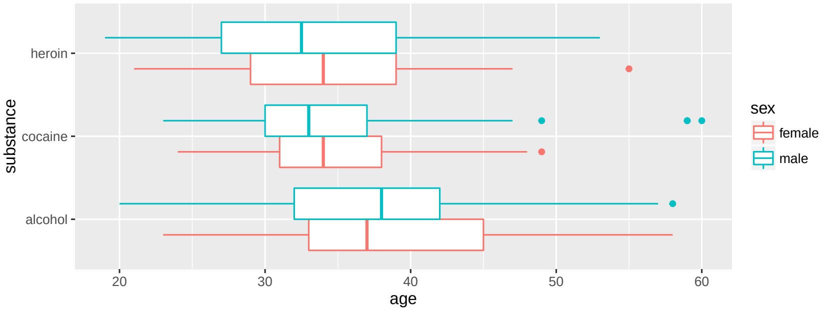
```r
HELPrct %>%
  ggplot(aes(x = substance, y = age, color = sex)) +
  geom_boxplot()
```



Horizontal boxplots

Horizontal boxplots are obtained by flipping the coordinate system:

```
HELPrct %>%
  ggplot(aes(x = substance, y = age, color = sex)) +
  geom_boxplot() +
  coord_flip()
```

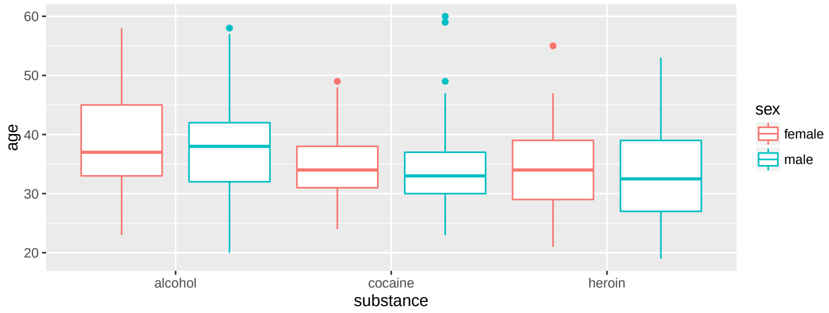


- `coord_flip()` may be used with other plots as well to reverse the roles of `x` and `y` on the plot.

Give me some space

We've triggered a new feature: `dodge` (for dodging things left/right). We can control how much if we set the dodge manually.

```
HELPrct %>%
  ggplot(aes(x = substance, y = age, color = sex)) +
  geom_boxplot(position = position_dodge(width = 1))
```

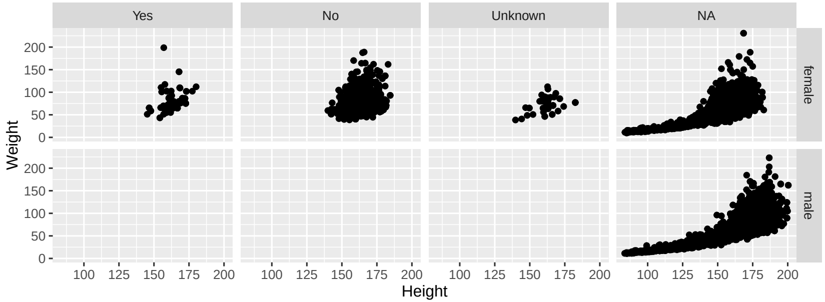


Issues with bigger data

```r
require(NHANES)
dim(NHANES)
```

```
## [1] 10000    76
```

```r
NHANES %>%  ggplot(aes(x = Height, y = Weight)) +
  geom_point() + facet_grid( Gender ~ PregnantNow )
```

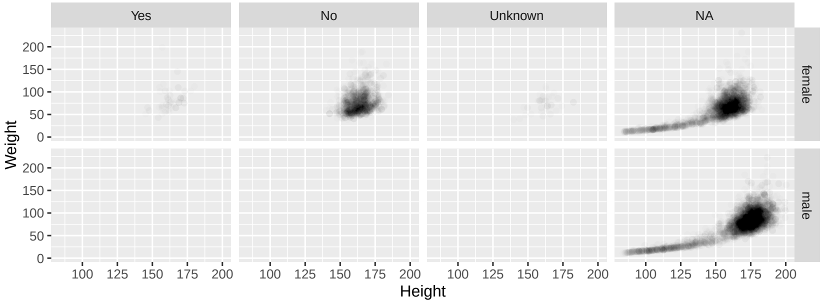


- Although we can see a generally positive association (as we would expect), the overplotting may be hiding information.

Using alpha (opacity)

One way to deal with overplotting is to set the opacity low.

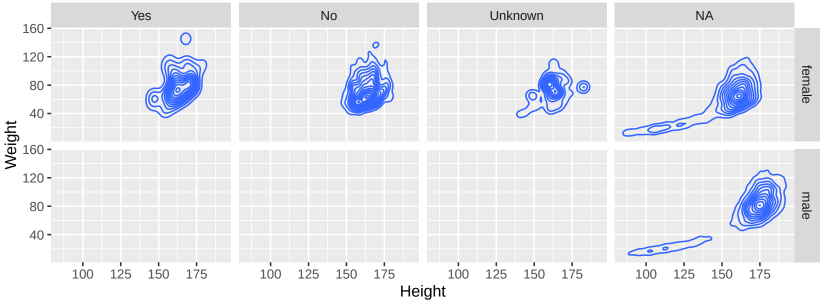
```
NHANES %>%
  ggplot(aes(x = Height, y = Weight)) +
  geom_point(alpha = 0.01) + facet_grid( Gender ~ PregnantN
```



geom_density2d

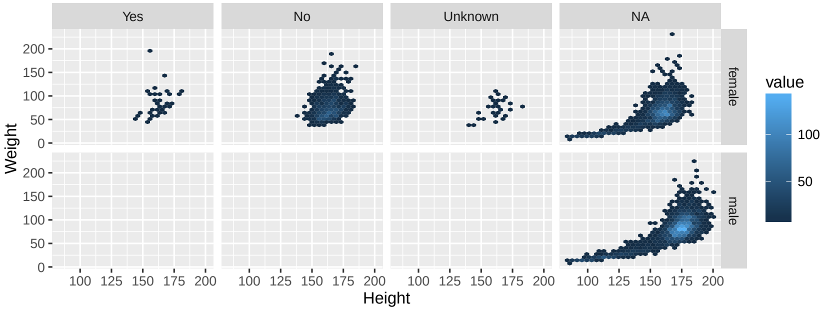
Alternatively (or simultaneously) we might prefere a different geom altogether.

```
NHANES %>%
  ggplot(aes(x = Height, y = Weight)) +
  geom_density2d() + facet_grid( Gender ~ PregnantNow )
```



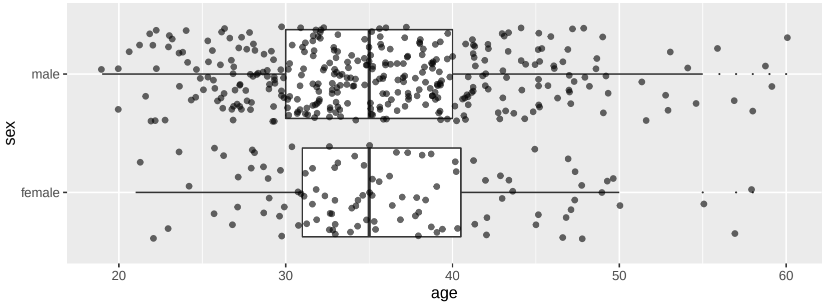
geom_hex

```r
NHANES %>%
  ggplot(aes(x = Height, y = Weight)) +
  geom_hex() + facet_grid(Gender ~ PregnantNow)
```



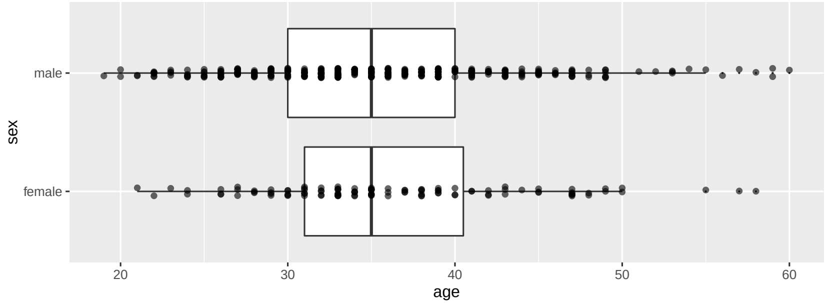
Multiple layers

```
ggplot( data = HELPrct, aes(x = sex, y = age)) +
  geom_boxplot(outlier.size = 0) +
  geom_jitter(alpha = .6) +
  coord_flip()
```



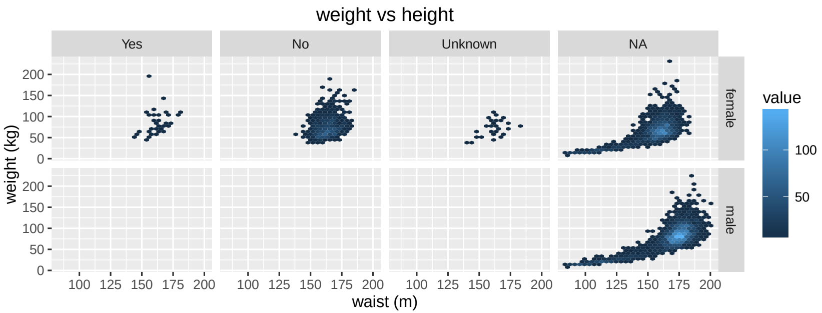
Multiple layers

```
ggplot( data = HELPrct, aes(x = sex, y = age)) +
  geom_boxplot(outlier.size = 0) +
  geom_point(alpha = .6, position = position_jitter(width =
  coord_flip()
```



Labeling

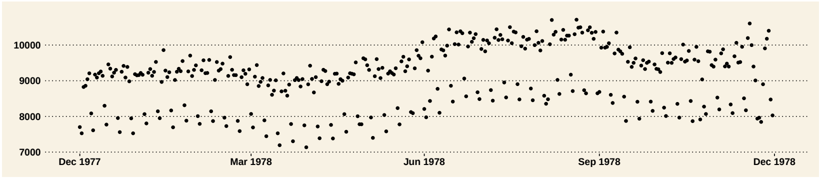
```
NHANES %>%
  ggplot(aes(x = Height, y = Weight)) +
  geom_hex() + facet_grid( Gender ~ PregnantNow ) +
  labs(x = "waist (m)", y = "weight (kg)",
       title = "weight vs height")
```



Things I haven't mentioned (much)

- scales (fine tuning mapping from data to plot)
- guides (so reader can map from plot to data)
- coords (`coord_flip()` is good to know about)
- themes (for customizing appearance)

```r
require(ggthemes)
ggplot(data = Births78, aes(x = date, y = births)) +
      geom_point() + theme_wsj() # wall street journal
```



Things I haven't mentioned (much)

- scales (fine tuning mapping from data to plot)
- guides (so reader can map from plot to data)
- coords (`coord_flip()` is good to know about)
- themes (for customizing appearance)

```
require(xkcd)
ggplot(data = Births78, aes(x = date, y = births, colour =
       geom_smooth(se = FALSE) + theme_xkcd()
```

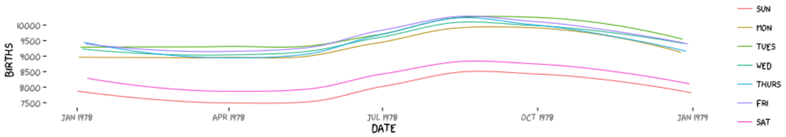
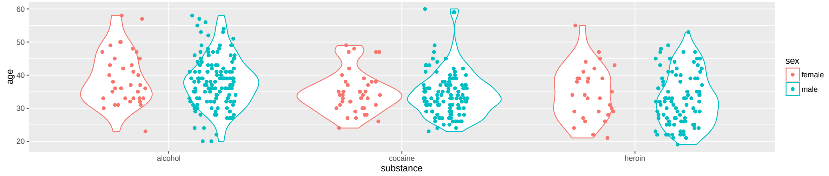


Figure 1: births

Things I haven't mentioned (much)

- scales (fine tuning mapping from data to plot)
- guides (so reader can map from plot to data)
- coords (`coord_flip()` is good to know about)
- themes (for customizing appearance)
- position (`position_dodge()` can be used for side by side bars)

```
ggplot(data = HELPrct,
       aes(x = substance, y = age, color = sex)) +
  geom_violin(position = position_dodge()) +
  geom_point(aes(color = sex, fill = sex),
             position = position_jitterdodge())
```

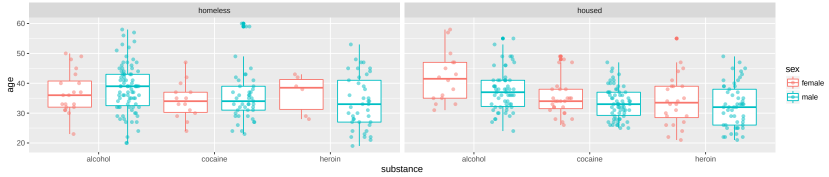


Things I haven't mentioned (much)

- scales (fine tuning mapping from data to plot)
- guides (so reader can map from plot to data)
- themes (for customizing appearance)
- position (`position_dodge()`, `position_jitterdodge()`, `position_stack()`, etc.)

A little bit of everything

```r
ggplot(data = HELPrct,
       aes(x = substance, y = age, color = sex)) +
  geom_boxplot(position = position_dodge(width = 1)) +
  geom_point(aes(fill = sex), alpha = .5,
    position = position_jitterdodge(dodge.width = 1)) +
  facet_wrap(~homeless)
```



A short cut

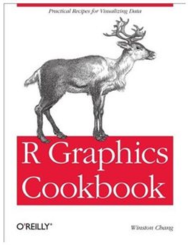
`mplot(dataframe)` provides an interactive plotting tool

```
mplot(HELPrct)
```

- quickly make several plots from a data frame
- can show the expression so you can learn how to do it or copy and paste into another document
- `ggplot2` or `lattice`

Want to learn more?

- docs.ggplot2.org/
- Winston Chang's: *R Graphics Cookbook*



What's around the corner?

`ggvis`

- dynamic graphics (brushing, sliders, tooltips, etc.)
- uses Vega (D3) to animate plots in a browser
- similar structure to `ggplot2` but different syntax and names

Dynamic documents

- combination of `RMarkdown`, `ggvis`, and `shiny`