Introduction to ggplot2

R Pruim

CVC 2015

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
## 1 1978-01-01   7701         1
## 2 1978-01-02   7527         2
## 3 1978-01-03   8825         3
```

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.

stat: a transformation applied to data before geom gets it

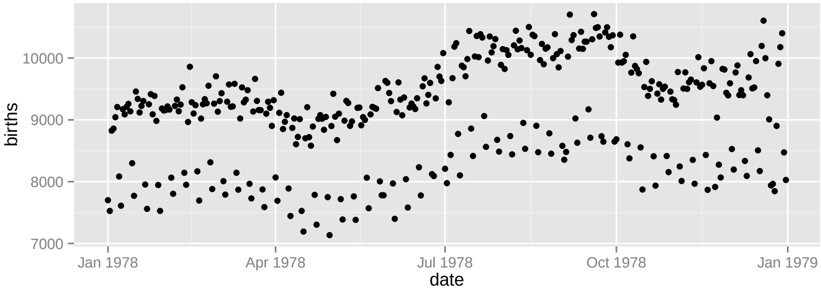
- example: histograms work on binned data

scale: conversion of raw data to visual display

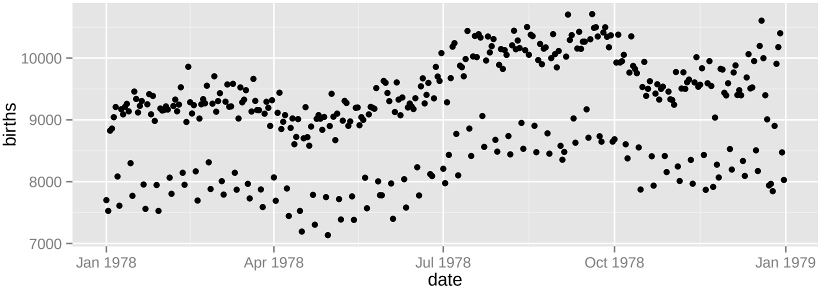
- particular assignment of colors, shapes, sizes, etc.

guide: helps user convert visual data back into raw data (legends, axes)

How do we make this plot?

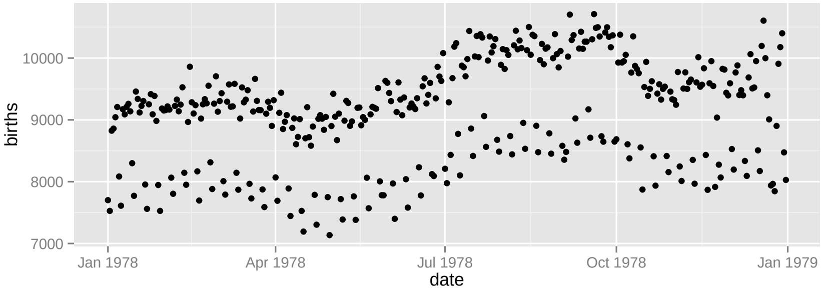


How do we make this plot?



What does R need to know?

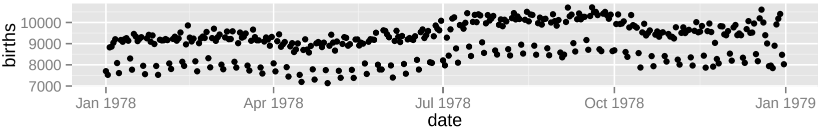
How do we make this plot?



What does R need to know?

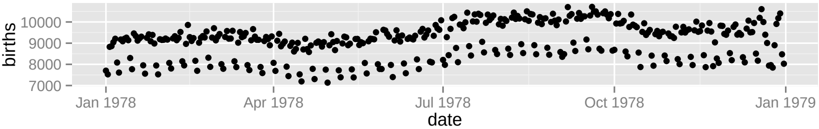
- data source: `Births78`
- geom: points
- aesthetics:
  - `date -> x`
  - `births -> y`
  - default color (same for all points)

How do we make this plot?



What does R need to know?

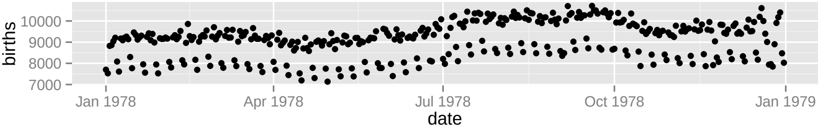
How do we make this plot?



What does R need to know?

- a plot with points: `ggplot() + geom_point()`

How do we make this plot?

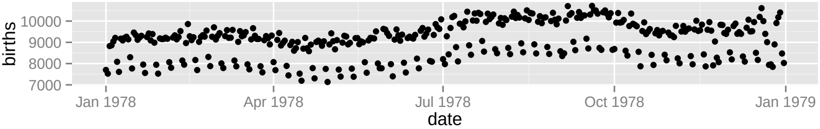


What does R need to know?

- a plot with points: `ggplot() + geom_point()`

- how to map our aesthetics: `aes(x=date, y=births)`

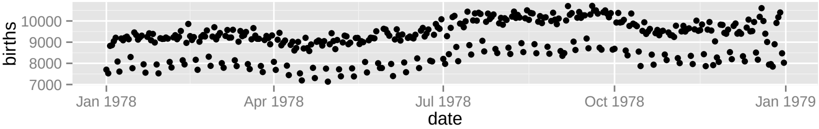
How do we make this plot?



What does R need to know?

- a plot with points: `ggplot() + geom_point()`
- how to map our aesthetics: `aes(x=date, y=births)`
- What data to use: `data = Births78`

How do we make this plot?

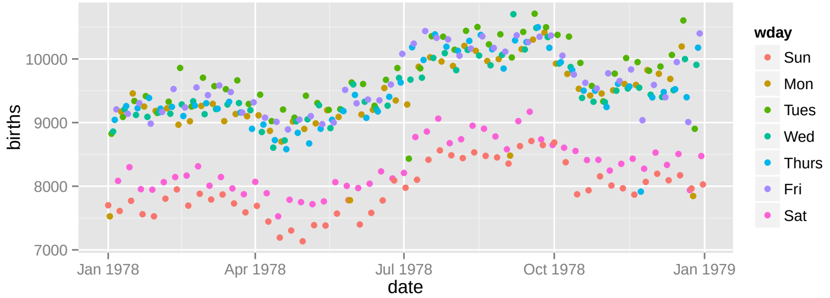


What does R need to know?

- a plot with points: `ggplot() + geom_point()`
- how to map our aesthetics: `aes(x=date, y=births)`
- What data to use: `data = Births78`

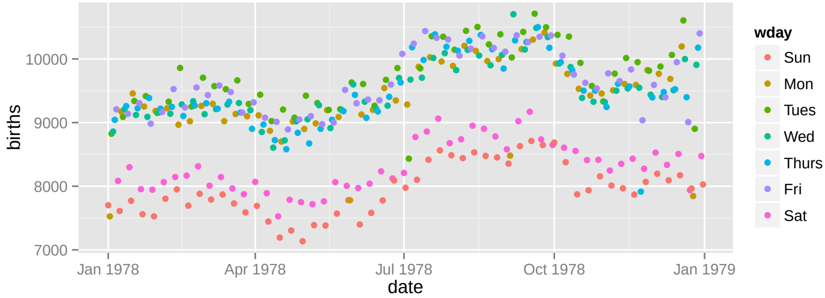
```
ggplot(data = Births78) +
  geom_point(aes(x=date, y=births))
```

How do we make this plot?



What information has changed?

How do we make this plot?

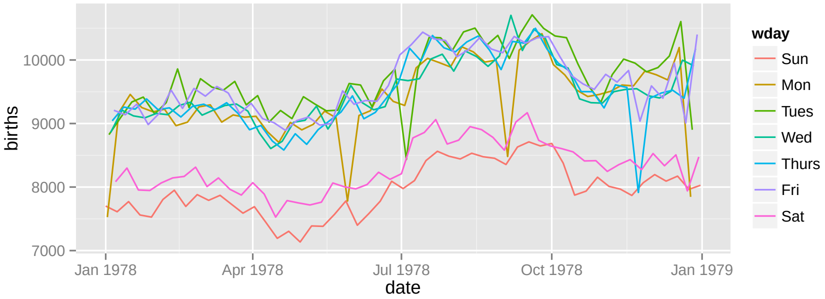


What information has changed?

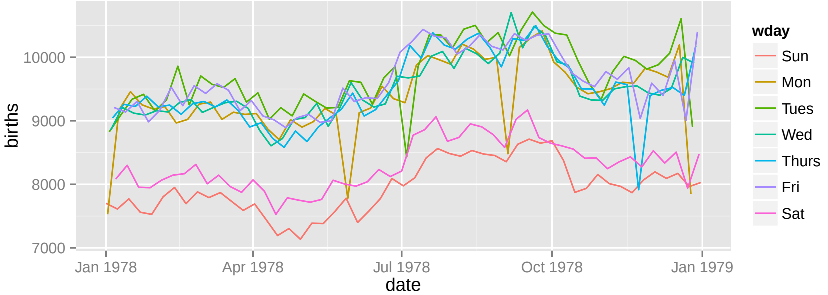
- new aesthetic: mapping color to day of week

```
Births78 <-  Births78 %>%
  mutate(wday = lubridate::wday(date, label=TRUE))
ggplot(data=Births78) +
  geom_point(aes(x=date, y=births, color=wday))
```

How do we make this plot?



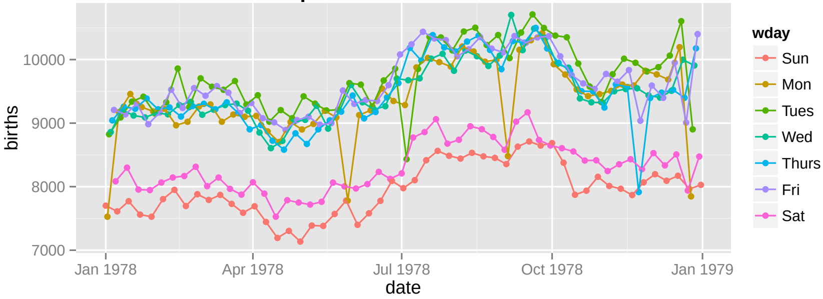
How do we make this plot?



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?



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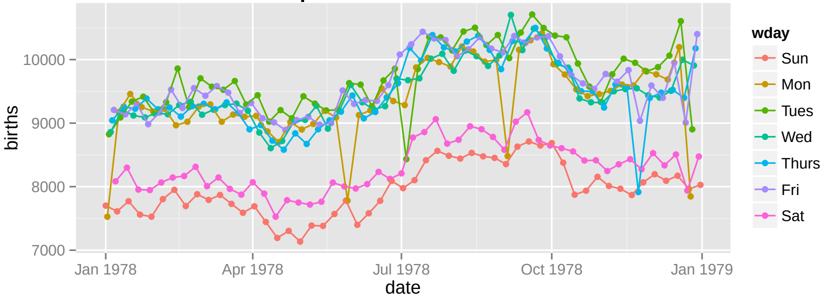
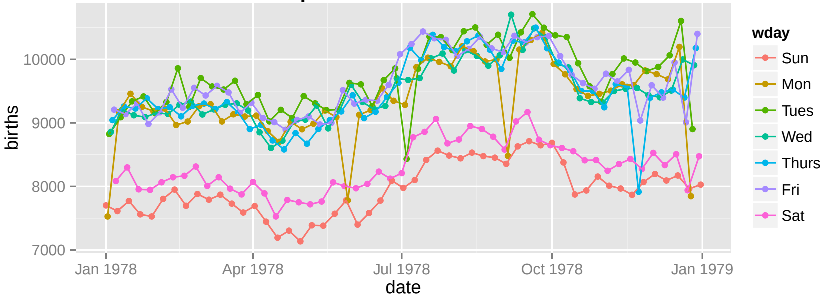


This time we have two **layers**, one with points and one with lines

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

How do we make this plot?



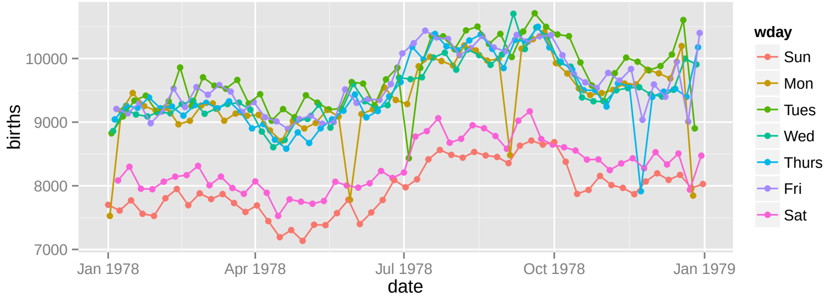
This time we have two **layers**, one with points and one with lines

```
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*. Sometimes the order of the layers can be important because of overplotting.

Alternative Syntax

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

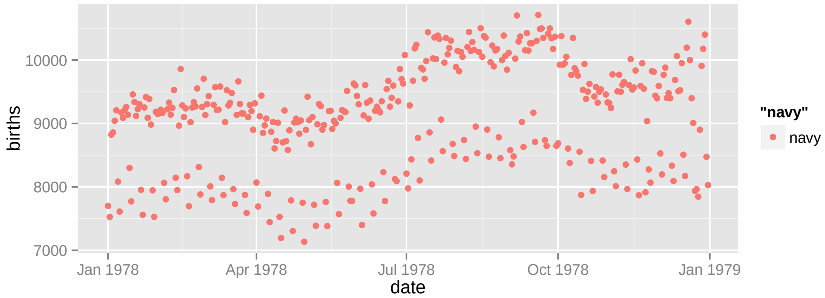


What does this do?

```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()
```

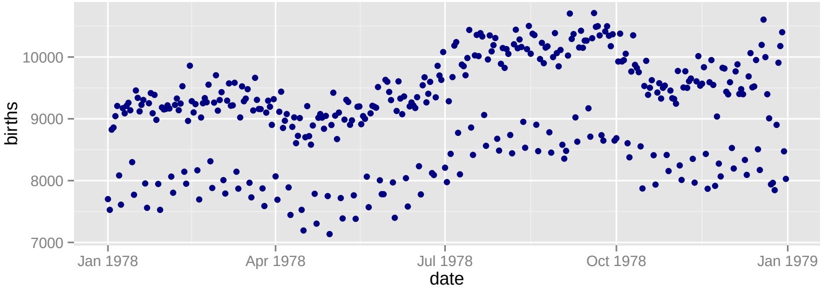


This is *mapping* the color aesthetic to a new variable with only one value (“navy”).
So all the dots get set to the same color, but it’s not navy.

Setting vs. Mapping

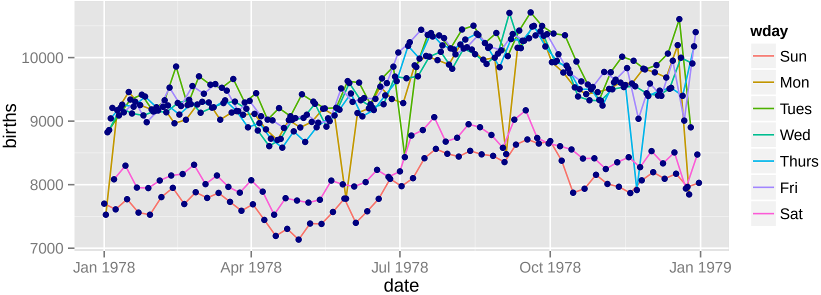
If we want to *set* the color to be navy for all of the dots, we do it this way:

```
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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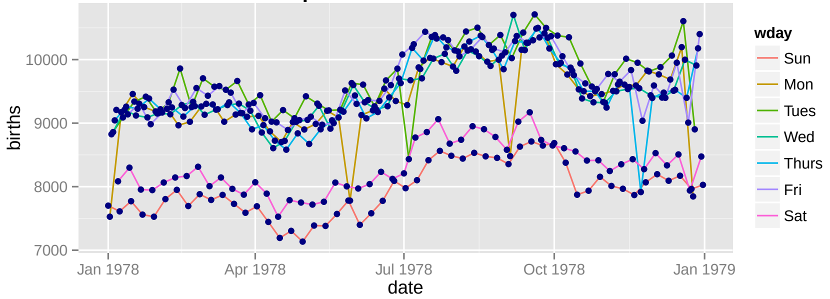


```
Births78 %>%
  ggplot(aes(x=date, y=births)) +
  geom_line(aes(color=wday)) +        # map color here
  geom_point(color="navy")            # set color here
```

- 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

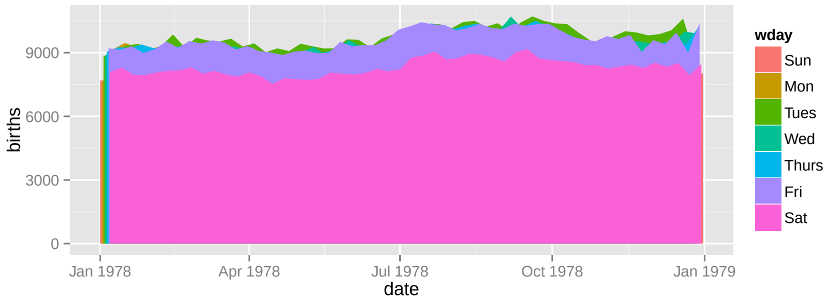
```r
apropos("^geom_")
```

```
 [1] "geom_abline"       "geom_area"        "geom_bar"
 [4] "geom_bin2d"        "geom_blank"       "geom_boxplot"
 [7] "geom_contour"      "geom_crossbar"    "geom_density"
[10] "geom_density2d"    "geom_dotplot"     "geom_errorbar
[13] "geom_errorbarh"    "geom_freqpoly"    "geom_hex"
[16] "geom_histogram"    "geom_hline"       "geom_jitter"
[19] "geom_line"         "geom_linerange"   "geom_map"
[22] "geom_path"         "geom_point"       "geom_pointran
[25] "geom_polygon"      "geom_quantile"    "geom_rangefra
[28] "geom_raster"       "geom_rect"        "geom_ribbon"
[31] "geom_rug"          "geom_segment"     "geom_smooth"
[34] "geom_step"         "geom_text"        "geom_tile"
[37] "geom_tufteboxplot" "geom_violin"      "geom_vline"
```

help pages will tell you their aesthetics and default stats

Let's try geom_area

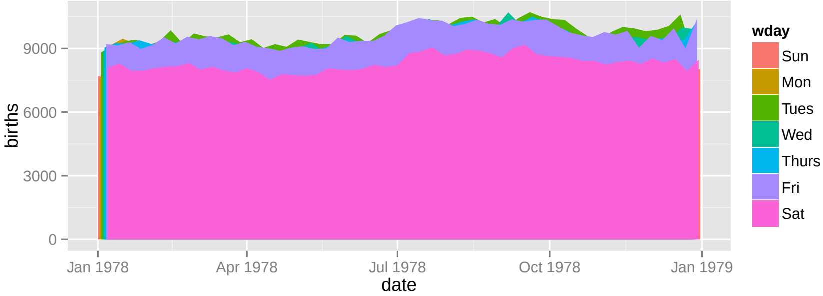
```
Births78 %>%
  ggplot(aes(x=date, y=births, fill=wday)) +
  geom_area()
```



This is not a good plot

Let's try geom_area

```
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

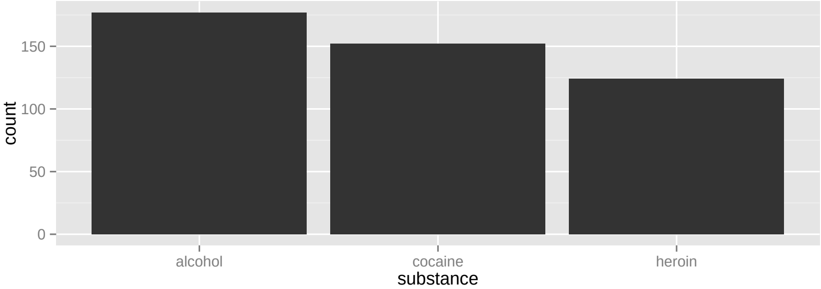
HELPrct: Health Evaluation and Linkage to Primary care randomized clinical trial

```
?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?

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HELPrct %>%
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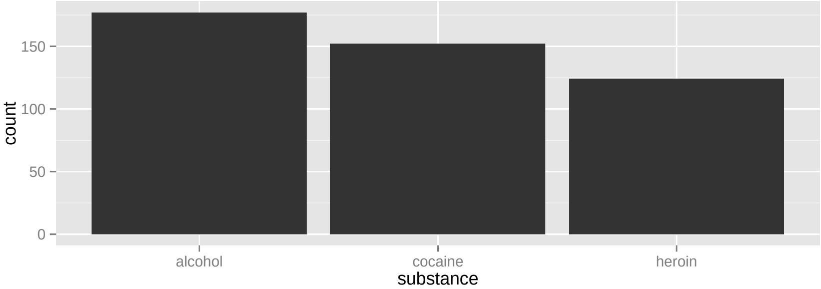

- Hmm. What's up with `y`?

Why are these people in the study?

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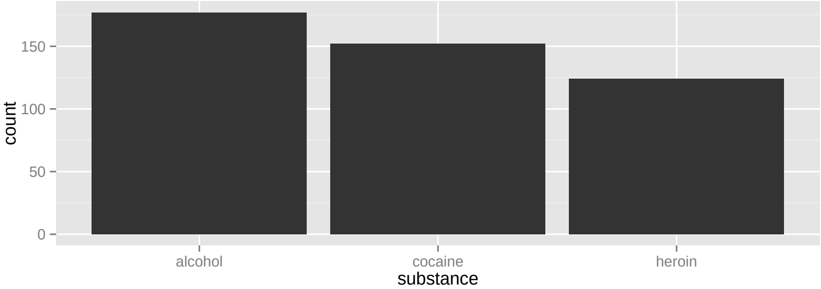


- Hmm. What's up with `y`?
  - `stat_bin()` is being applied to the data before the `geom_bar()` gets to do its thing. Binning creates the `y` values.

Data Flow

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

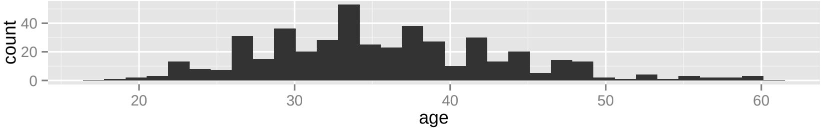
Simplifications:

- 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?

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

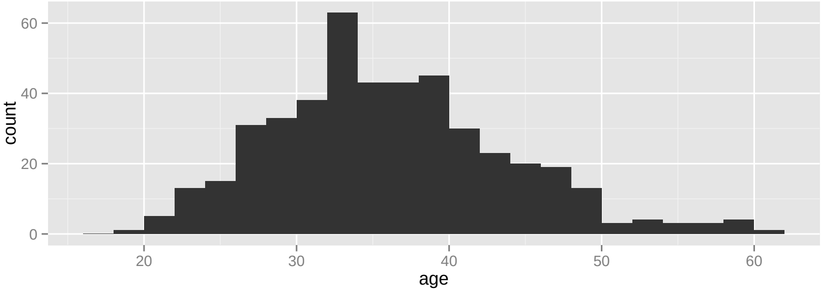


Notice the messages

- 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.

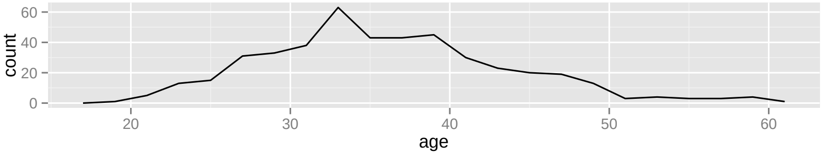
Setting the binwidth manually

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

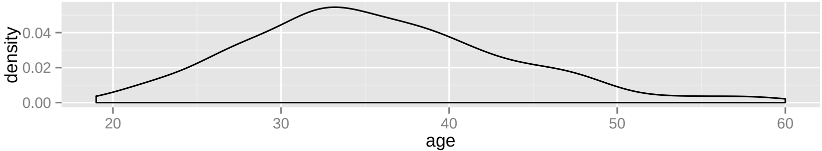


How old are people in the HELP study? – Other geoms

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



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

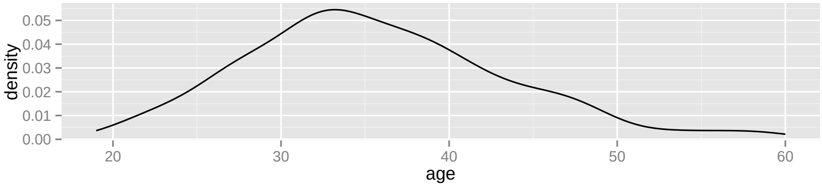


Selecting stat and geom manually

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

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

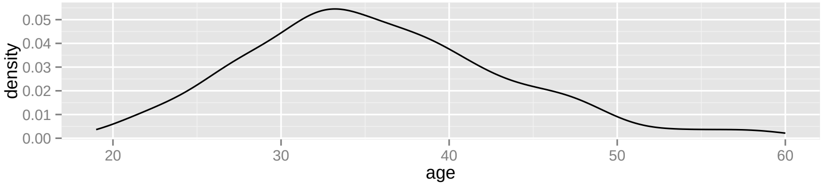


Selecting stat and geom manually

Every stat comes with a default geom

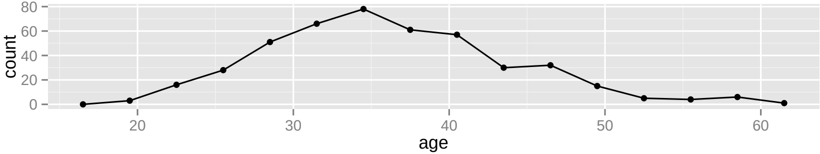
- we can specify stats instead of geom, if we prefer
- we can mix and match geoms and stats however we like

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

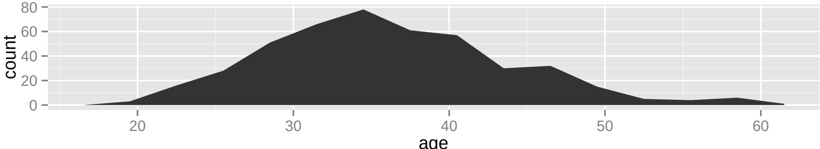


More combinations

```
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)
```

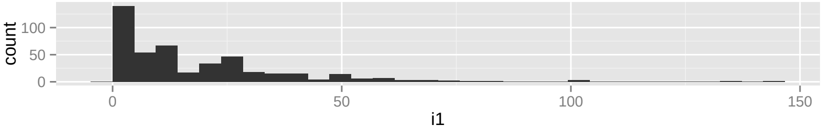


Your turn: How much do they drink? (i1)

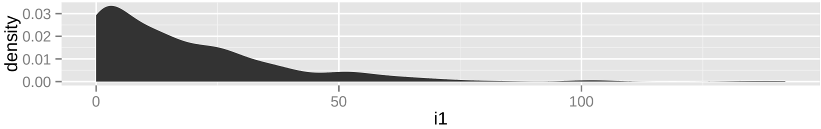
Create a plot that shows the distribution of the average daily alcohol consumption in the past 30 days (`i2`).

How much do they drink? (i1)

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



```
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?

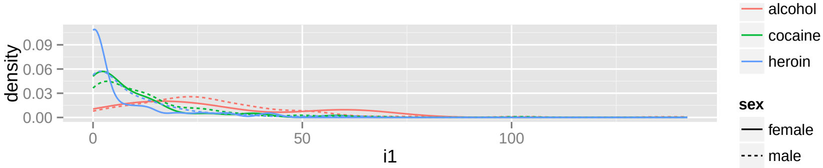
Give it a try.

- 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

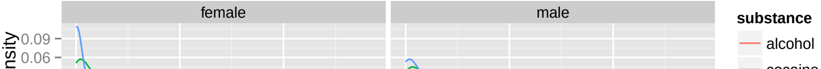
Using color and linetype:

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



Using color and facets

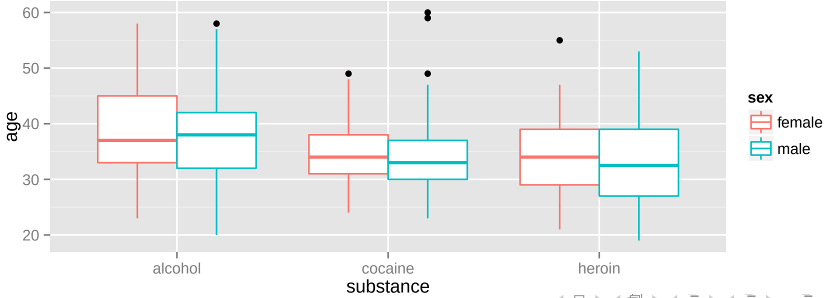
```
HELPrct %>%
  ggplot(aes(x=i1, color=substance)) +
  geom_line(stat="density") + facet_grid( . ~ sex )
```



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.

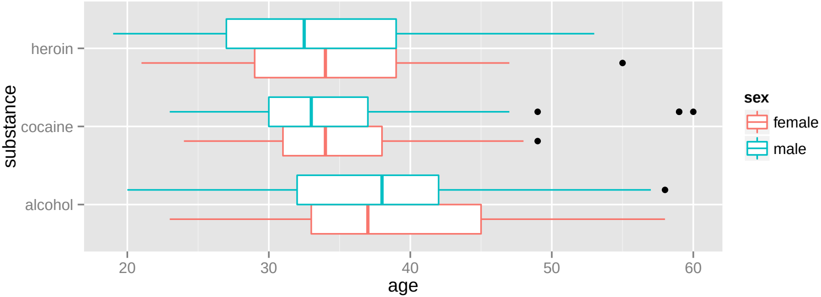
```
HELPrct %>%
  ggplot(aes(x=substance, y=age, color=sex)) +
  geom_boxplot()
```



Horizontal boxplots

Horizontal boxplots are obtained by flipping the coordinate system:

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

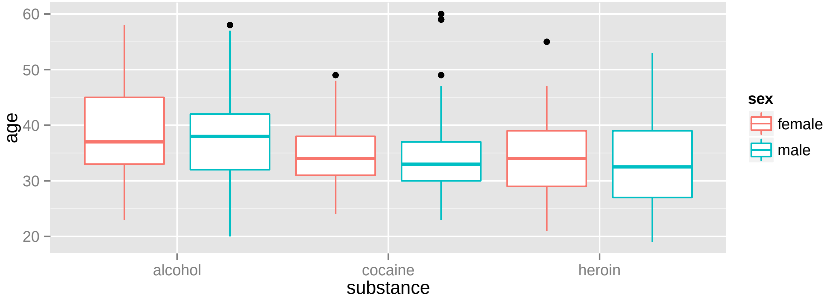


- `coord_flip()` may be used with other plots as well to reverse the roles of `x` and `y` on the plot.

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))
```

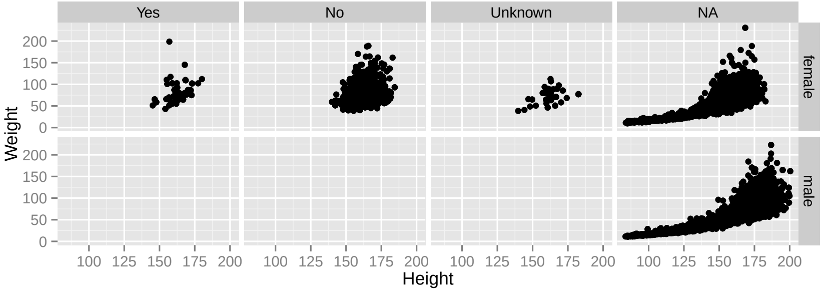


Issues with bigger data

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

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

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

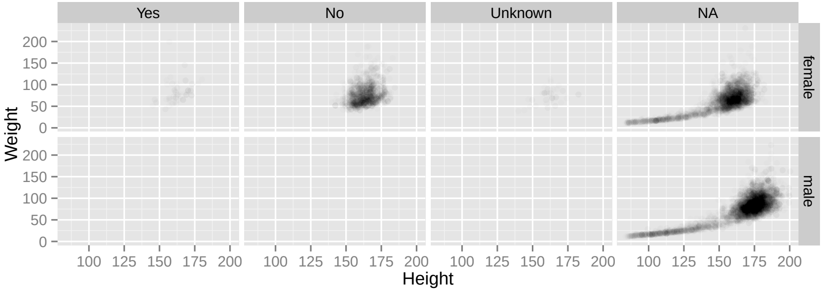


- Although we can see a generally positive association (as we

Using alpha (opacity)

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

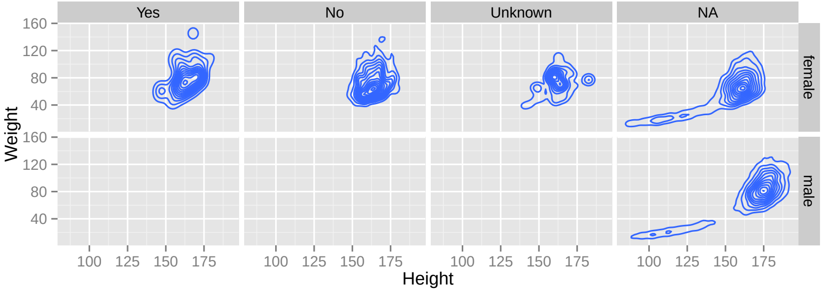
```
NHANES %>%
  ggplot(aes(x=Height, y=Weight)) +
  geom_point(alpha=0.01) + facet_grid( Gender ~ PregnantNow
```



geom_density2d

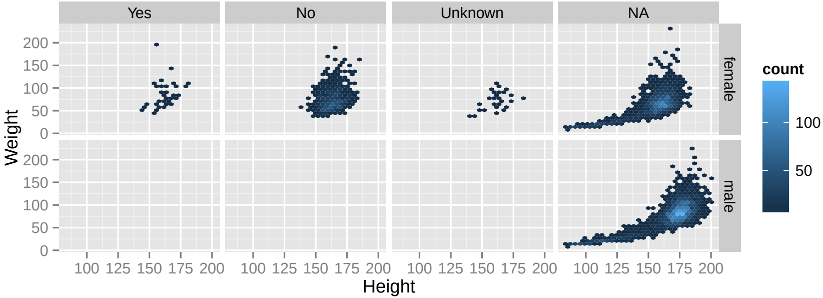
Alternatively (or simultaneously) we might prefere a different geom altogether.

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



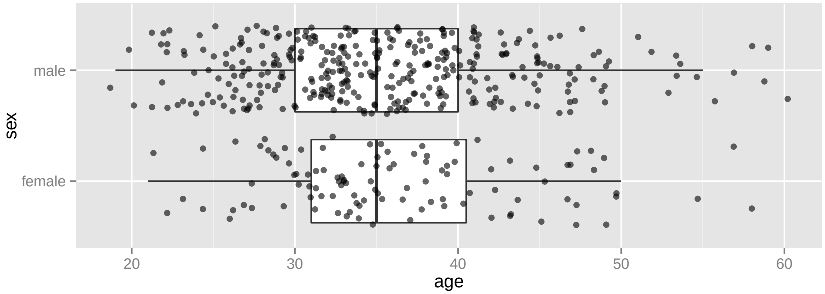
geom_hex

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



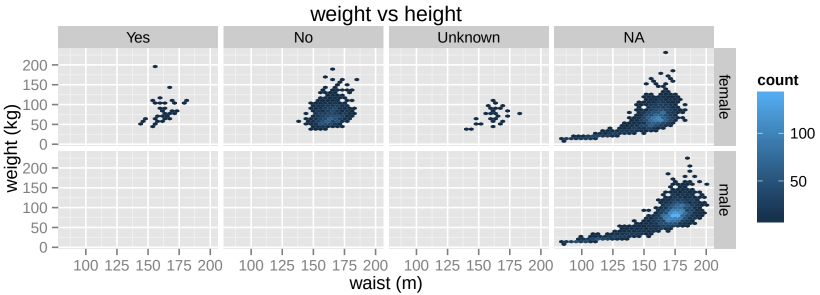
Multiple layers

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



Labeling

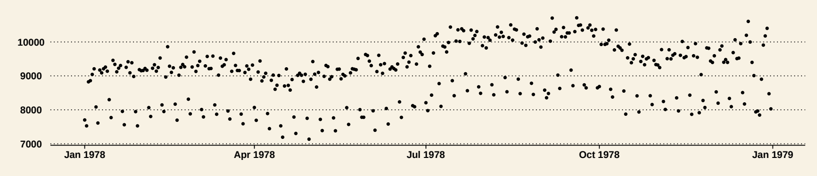
```
NHANES %>%
  ggplot(aes(x=Height, y=Weight)) +
  geom_hex() + facet_grid( Gender ~ PregnantNow ) +
  labs(x="waist (m)", y="weight (kg)", title="weight vs he
```



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)

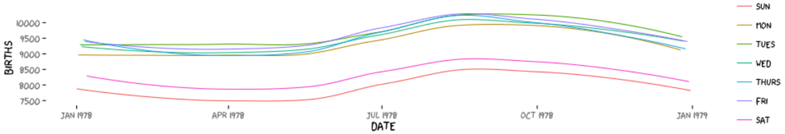
```
require(ggthemes)
qplot( x=date, y=births, data=Births78) + theme_wsj()
```



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)

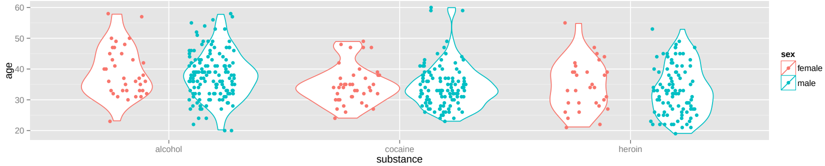
```r
require(xkcd)
qplot( x=date, y=births, data=Births78, color=wday,
       geom="smooth", se=FALSE) +
  theme_xkcd()
```



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(coef = 10, position=position_dodge()) +
  geom_point(aes(color=sex, fill=sex), position=position_j
```

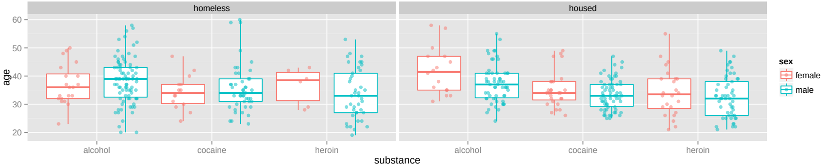


Things I haven't mentioned (much)

- 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

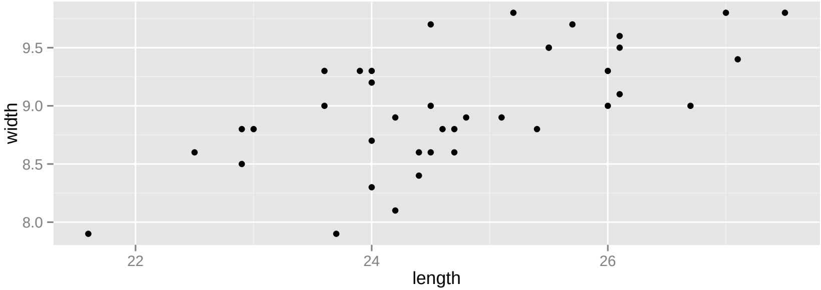
```
ggplot( data=HELPrct, aes(x=substance, y=age, color=sex)) +
  geom_boxplot(coef = 10, position=position_dodge(width=1))
  geom_point(aes(fill=sex), alpha=.5,
             position=position_jitterdodge(dodge.width=1))
  facet_wrap(~homeless)
```



Some short cuts

1. `qplot()` provides "quick plots" for `ggplot2`

```
qplot(length, width, data=KidsFeet)
```



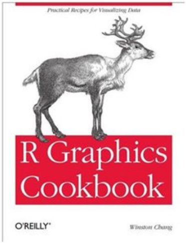
2. `mplot(dataframe)` provides an interactive plotting tool for both `ggplot2` and `lattice`.

```
mplot(HELPrct)
```

- quickly make several plots from a data frame

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`