concordance=TRUE

Data Visualization Using R & ggplot2

Naupaka Zimmerman (@naupakaz)
Andrew Tredennick (@ATredennick)

Hat tip to Karthik Ram (@_inundata) for original slides

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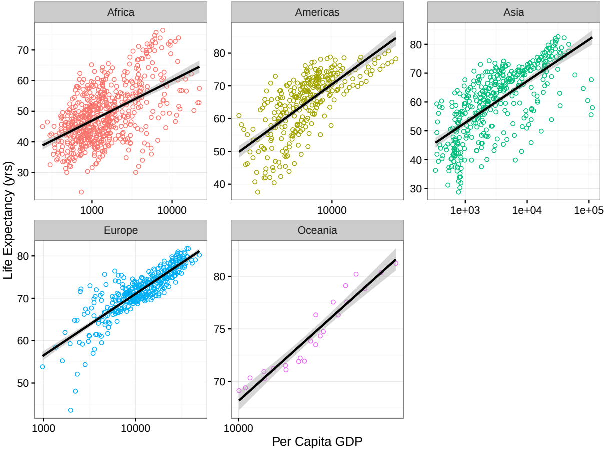
Some housekeeping

Install some packages

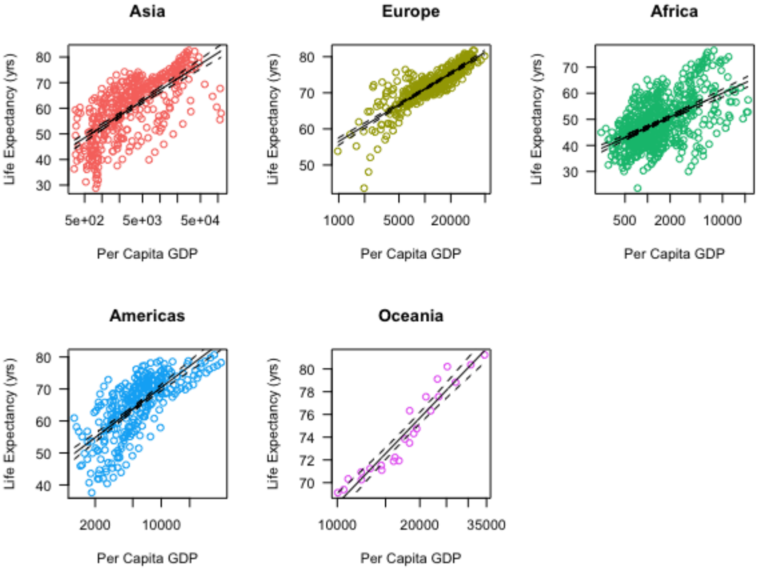
```r
install.packages("ggplot2", dependencies = TRUE)
install.packages("ggthemes")
install.packages("tidyr")
install.packages("dplyr")
```

1 minute


Africa
Americas
Asia
Europe
Oceania
70
60
50
40
30
80
70
60
50
40
80
70
60
50
40
30
80
70
60
50
80
75
70
1000
10000
10000
1e+03
1e+04
1e+05
1000
10000
10000
Life Expectancy (yrs)
Per Capita GDP

```r
ggplot(gapminder, aes(x = gdpPercap, y = lifeExp)) +
  geom_point(shape = 1, aes(color = continent)) +
  stat_smooth(method = "lm", size = 1, color = "black") +
  scale_x_log10() +
  xlab("Per Capita GDP") +
  ylab("Life Expectancy (yrs)") +
  facet_wrap(~continent, scales = "free") +
  theme_bw() +
  guides(color=FALSE)
```

30 minutes


Asia
Life Expectancy (yrs)
80
70
60
50
40
30
5e+02
5e+03
5e+04
Per Capita GDP
Europe
Life Expectancy (yrs)
80
70
60
50
1000
5000
20000
Per Capita GDP
Africa
Life Expectancy (yrs)
70
60
50
40
30
500
2000
10000
Per Capita GDP
Americas
Life Expectancy (yrs)
80
70
60
50
40
2000
10000
Per Capita GDP
Oceania
Life Expectancy (yrs)
80
78
76
74
72
70
10000
20000
35000
Per Capita GDP

```r
conts <- unique(gapminder[,"continent"])
cols <- scales::hue_pal()(length(conts))
par(mfrow = c(2,3))
counter<-1
for (i in conts) {
  plot(gapminder[which(gapminder$continent == i),
      "gdpPercap"],
       gapminder[which(gapminder$continent == i),
          "lifeExp"],
      col = cols[counter],
       xlab = "Per Capita GDP",
 ylab = "Life Expectancy (yrs)",
       main = i, las = 1, log = "x")
  fit <- lm(gapminder[which(gapminder$continent == i),
   "lifeExp"] ~
```

but wait there's more

```
      log(gapminder[which(gapminder$continent == i),
         "gdpPercap"]))
  pred <- predict(fit, interval = "confidence")
  lines(sort(gapminder[which(gapminder$continent == i),
    "gdpPercap"]),
        sort(pred[,1]))
  lines(sort(gapminder[which(gapminder$continent == i),
    "gdpPercap"]),
        sort(pred[,2]), lty = 2)
  lines(sort(gapminder[which(gapminder$continent == i),
    "gdpPercap"]),
        sort(pred[,3]), lty = 2)
  counter <- counter + 1
}
```

Section 1

Why ggplot2?

Why ggplot2?

- More elegant & compact code than with base graphics
- More aesthetically pleasing defaults than lattice
- Very powerful for exploratory data analysis

Why `ggplot2`?

- ‘gg’ is for ‘grammar of graphics’ (term by Lee Wilkinson)
- A set of terms that defines the basic components of a plot
- Used to produce figures using coherant, consistant syntax

Why ggplot2?

- Supports a continuum of expertise:
- Easy to get started, plenty of power for complex figures

Section 2

The Grammar

Some terminology

- **data**
  - Must be a data.frame
  - Gets pulled into the ggplot() object

The iris dataset

```
head(iris)

##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa
## 3          4.7         3.2          1.3         0.2  setosa
## 4          4.6         3.1          1.5         0.2  setosa
## 5          5.0         3.6          1.4         0.2  setosa
## 6          5.4         3.9          1.7         0.4  setosa
```

tidyr

Help your data play nice with `ggplot`.

tidyr

```
iris[1:2, ]

##   Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1          5.1         3.5          1.4         0.2  setosa
## 2          4.9         3.0          1.4         0.2  setosa

library("tidyr")
df <- gather(iris, key = flower_attribute, value = measurement,
                        -Species)
df[1:2, ]

##   Species flower_attribute measurement
## 1  setosa     Sepal.Length         5.1
## 2  setosa     Sepal.Length         4.9
```

Section 3

Aesthetics

Some terminology

- data
- aesthetics

- **How your data are represented visually**
  - *a.k.a. mapping*
- which data on the x
- which data on the y
- but also: color, size, shape, transparency

Let's try an example

```
myplot <- ggplot(data = iris, aes(x = Sepal.Length,
                        y = Sepal.Width))
summary(myplot)

## data: Sepal.Length, Sepal.Width, Petal.Length,
##   Petal.Width, Species [150x5]
## mapping:  x = Sepal.Length, y = Sepal.Width
## faceting: facet_null()
```

Section 4

Geoms

Some terminology

- data
- aesthetics
- **geom**etry

- **The geometric objects in the plot**
- points, lines, polygons, etc
- shortcut functions: geom_point(), geom_bar(), geom_line()

Basic structure

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width))
    + geom_point()
myplot <- ggplot(data = iris, aes(x = Sepal.Length,
                                  y = Sepal.Width))
myplot + geom_point()
```

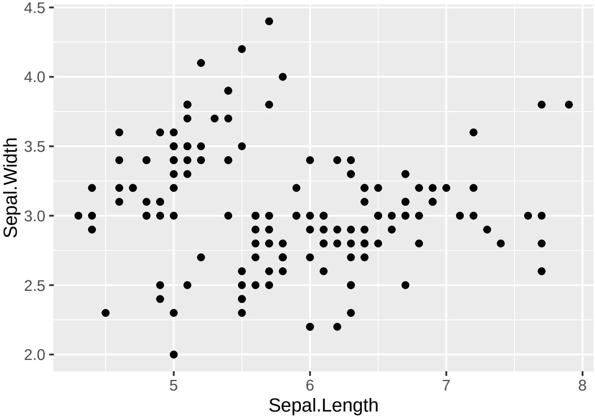
- Specify the data and variables inside the `ggplot` function.
- Anything else that goes in here becomes a global setting.
- Then add layers: geometric objects, statistical models, and facets.

Quick note

- Never use `qplot` - short for quick plot.
- You‘ll end up unlearning and relearning a good bit.

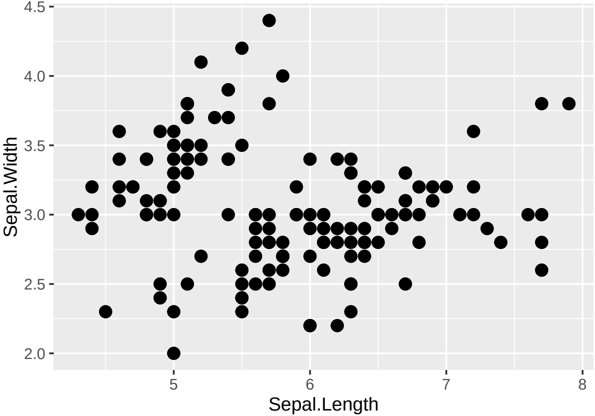
Let's try an example

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
    geom_point()
```



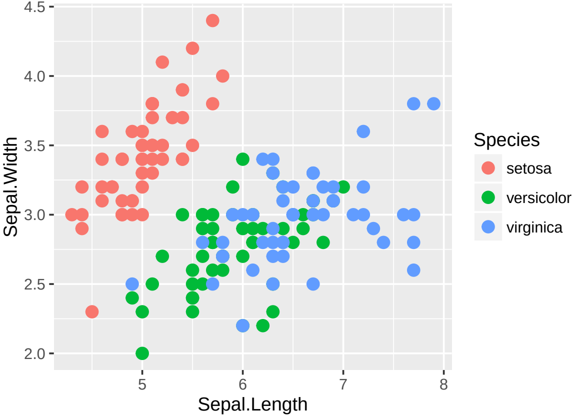
Changing the aesthetics of a geom: Increase the size of points

```
ggplot(data = iris, aes(x = Sepal.Length, y = Sepal.Width)) +
    geom_point(size = 3)
```



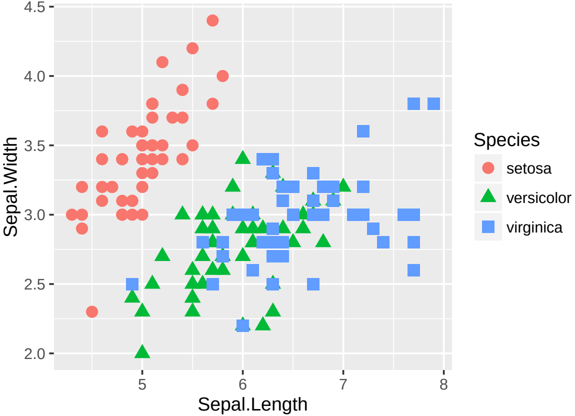
Changing the aesthetics of a geom: Add some color

```
ggplot(iris, aes(Sepal.Length, Sepal.Width,
                 color = Species)) +
    geom_point(size = 3)
```



Changing the aesthetics of a geom: Differentiate points by shape

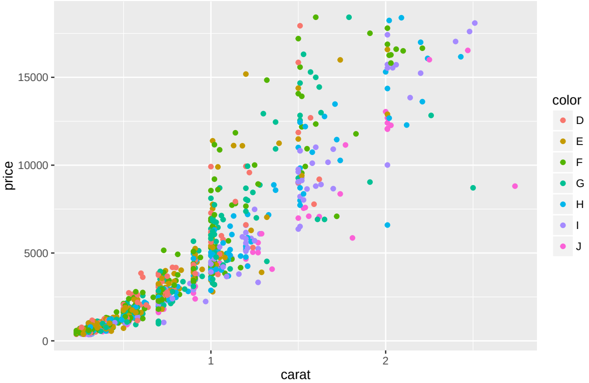
```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(aes(shape = Species), size = 3)
# Why aes(shape = Species)?
```



Exercise 1

```
# Make a small sample of the diamonds dataset
d2 <- diamonds[sample(1:dim(diamonds)[1], 1000), ]
```

Then generate this plot below.



Section 5

Stats

Some terminology

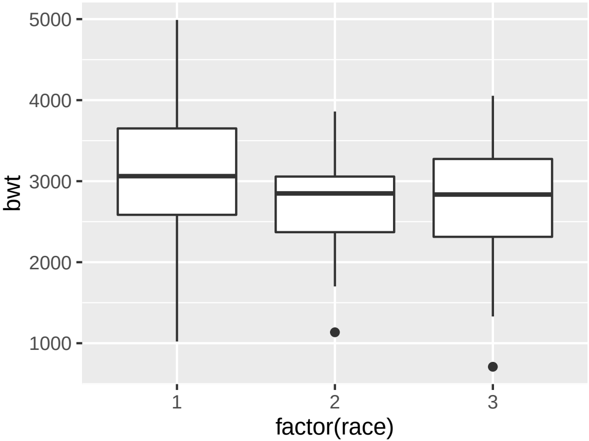
- data
- aesthetics
- geometry
- **stats**

- **Statistical transformations and data summary**
- All geoms have associated default stats, and vice versa
- e.g. binning for a histogram or fitting a linear model

Built-in stat example: Boxplots

See `?geom_boxplot` for list of options

```
library(MASS)
ggplot(birthwt, aes(factor(race), bwt)) + geom_boxplot()
```



Built-in stat example: Boxplots

```
myplot <- ggplot(birthwt, aes(factor(race), bwt)) +
        geom_boxplot()
summary(myplot)

## data: low, age, lwt, race, smoke, ptl, ht, ui, ftv,
##   bwt [189x10]
## mapping:  x = factor(race), y = bwt
## faceting: facet_null()
## -----------------------------------
## geom_boxplot: outlier.colour = NULL, outlier.shape = 19, outlier.siz
## stat_boxplot: na.rm = FALSE
## position_dodge
```

Section 6

Facets

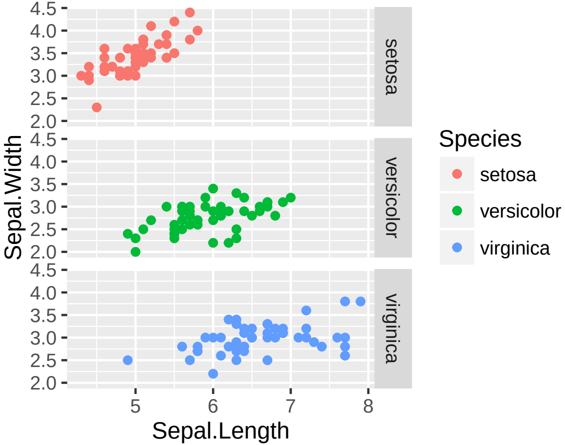
Some terminology

- data
- aesthetics
- geometry
- stats
- facets

- **Subsetting data to make lattice plots**
- Really powerful

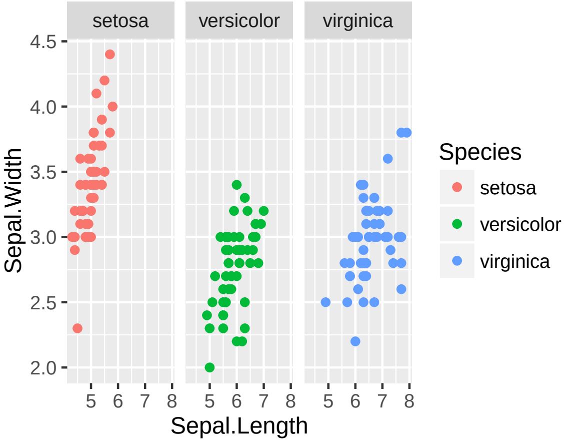
Faceting: single column, multiple rows

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_grid(Species ~ .)
```



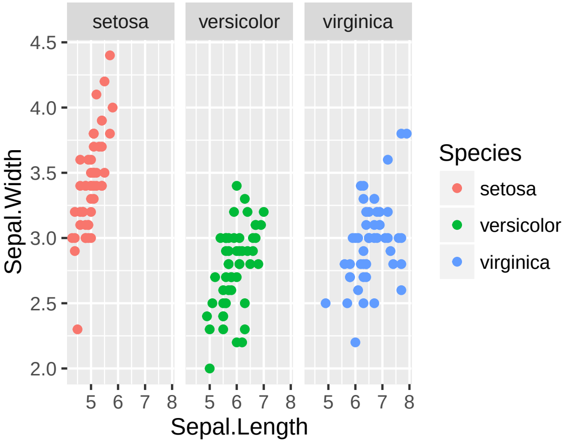
Faceting: single row, multiple columns

```r
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_grid(. ~ Species)
```



or just wrap your facets

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_wrap( ~ Species) # notice lack of .
```



Section 7

Scales

Some terminology

- data
- aesthetics
- geometry
- stats
- facets
- scales

- **Control the mapping from data to aesthetics**
- Often used for adjusting color mapping

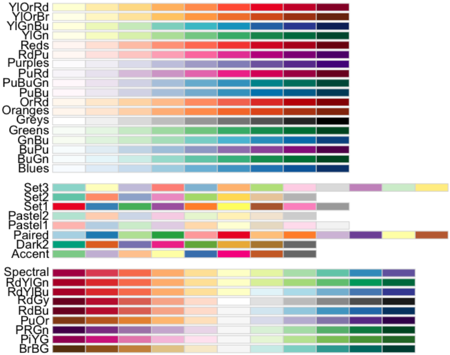
Colors

```
aes(color = variable) # mapping
color = "black" # setting

# Or add it as a scale
scale_fill_manual(values = c("color1", "color2"))
```

The RColorBrewer package

```r
library("RColorBrewer")
display.brewer.all()
```



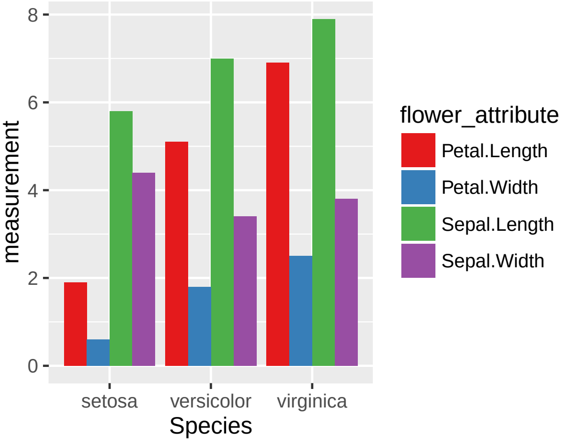
Using a color brewer palette

```
library("RColorBrewer")
df <- gather(iris, key = flower_attribute,
                         value = measurement, -Species)
df[1:2,]

##   Species flower_attribute measurement
## 1  setosa     Sepal.Length         5.1
## 2  setosa     Sepal.Length         4.9
```

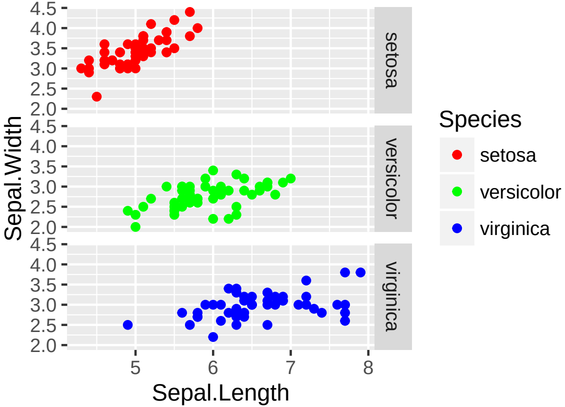
Using a color brewer palette

```
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity", position = "dodge") +
    scale_fill_brewer(palette = "Set1")
```



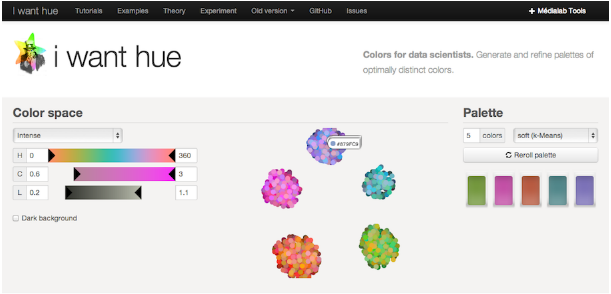
Manual color scale

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point() +
    facet_grid(Species ~ .) +
    scale_color_manual(values = c("red", "green", "blue"))
```



Refer to a color chart for beautful visualizations

`http://tools.medialab.sciences-po.fr/iwanthue/`



Colors for data scientists. Generate and refine palettes of optimally distinct colors.

Color space

Intense

H 0 – 360

C 0.6 – 3

L 0.2 – 1.1

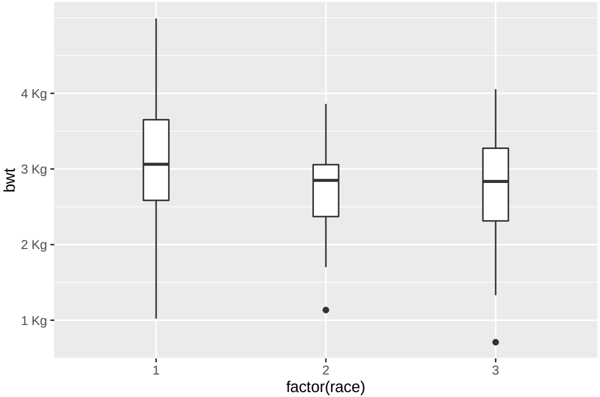
□ Dark background

Palette

5 colors soft (k-Means)

Adding a continuous scale to an axis

```
library(MASS)
ggplot(birthwt, aes(factor(race), bwt)) +
    geom_boxplot(width = .2) +
    scale_y_continuous(labels = (paste0(1:4, " Kg")),
        breaks = seq(1000, 4000, by = 1000))
```



Commonly used scales

```
scale_fill_discrete(); scale_colour_discrete()
scale_fill_hue(); scale_color_hue()
scale_fill_manual();  scale_color_manual()
scale_fill_brewer(); scale_color_brewer()
scale_linetype(); scale_shape_manual()
```

Section 8

Coordinates

Some terminology

- data
- aesthetics
- geometry
- stats
- facets
- scales
- **coord**inates

- Not going to cover this in detail
- e.g. polar coordinate plots

Section 9

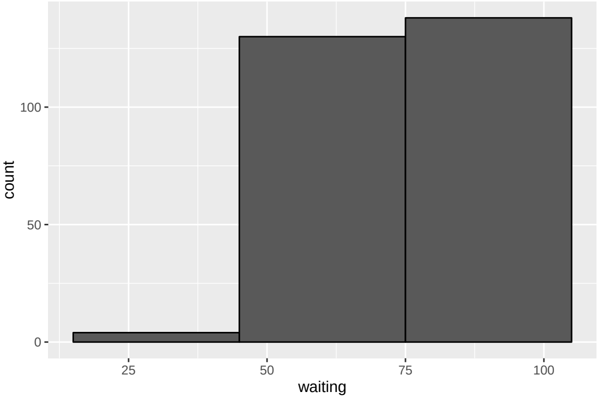
Putting it all together with more examples

Section 10

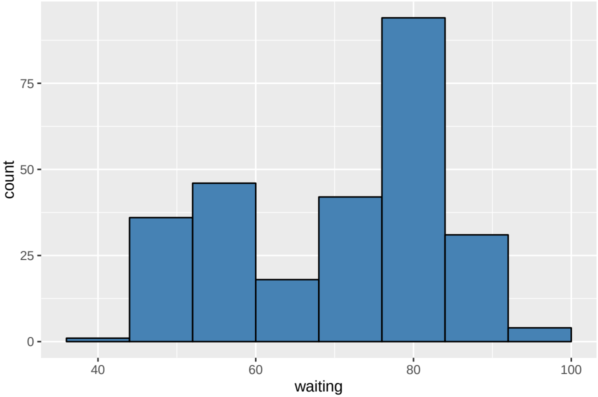
Histograms

See ?geom_histogram for list of options

```
h <- ggplot(faithful, aes(x = waiting))
h + geom_histogram(binwidth = 30, colour = "black")
```



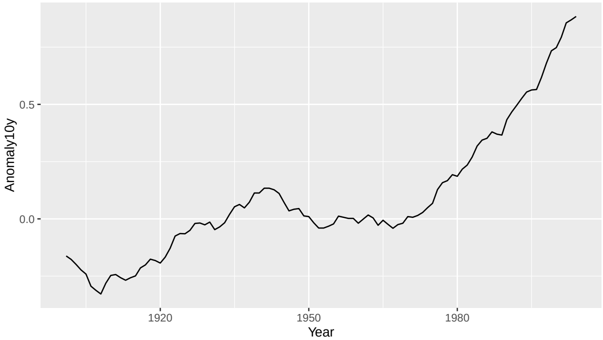
```r
h <- ggplot(faithful, aes(x = waiting))
h + geom_histogram(binwidth = 8, fill = "steelblue",
colour = "black")
```



Section 11

Line plots

```r
climate <- read.csv("../data/climate.csv", header = TRUE)
ggplot(climate, aes(Year, Anomaly10y)) +
    geom_line()
```

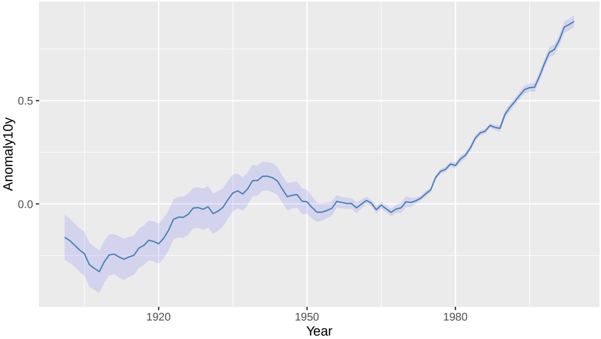


```r
climate <- read.csv(text =

RCurl::getURL('https://raw.github.com/karthikram/ggplot-lecture/master/climate.csv'))
```

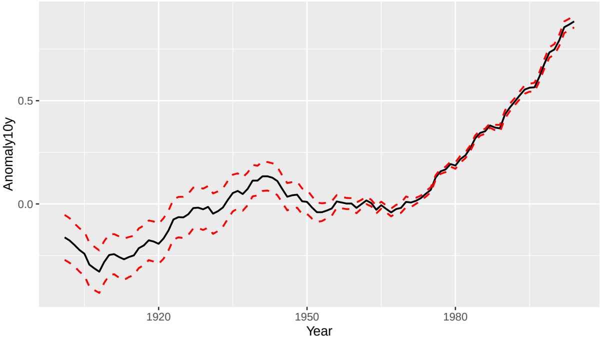
We can also plot confidence regions

```
ggplot(climate, aes(Year, Anomaly10y)) +
    geom_ribbon(aes(ymin = Anomaly10y - Unc10y,
        ymax = Anomaly10y + Unc10y),
        fill = "blue", alpha = .1) +
    geom_line(color = "steelblue")
```



Exercise 2

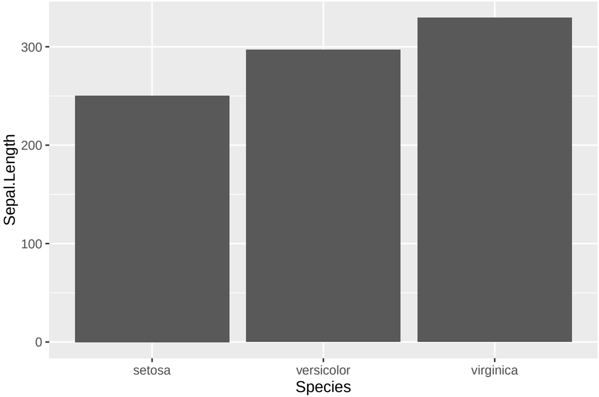
- Modify the previous plot and change it such that there are three lines instead of one with a confidence band.



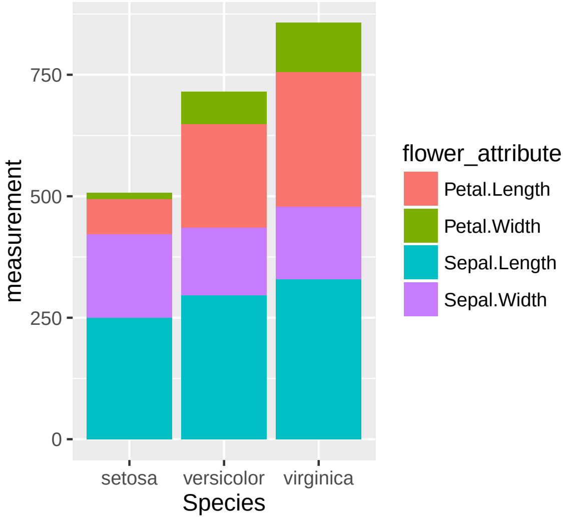
Section 12

Bar plots

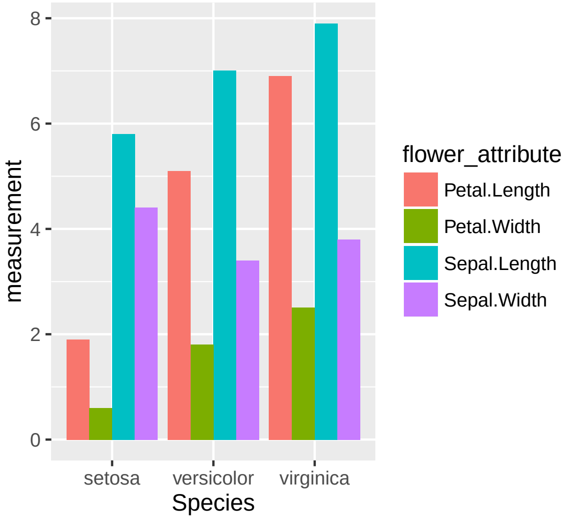
```
ggplot(iris, aes(Species, Sepal.Length)) +
        geom_bar(stat = "identity")
```



```
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity")
```

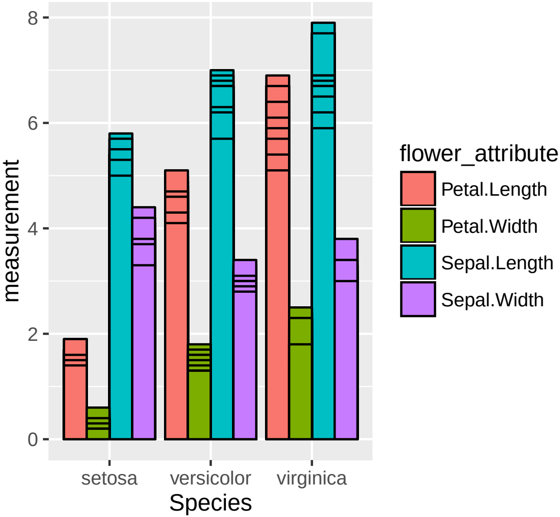


```r
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity", position = "dodge")
```



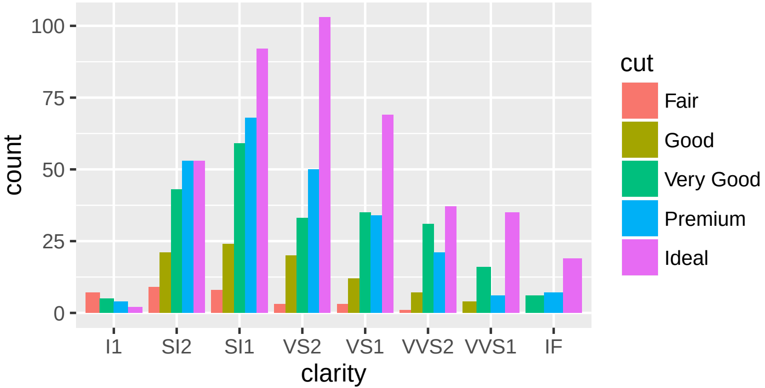
What's going on with the y axis?

```r
ggplot(df, aes(Species, measurement, fill = flower_attribute)) +
    geom_bar(stat = "identity", position="dodge", color="black")
```



Exercise 3

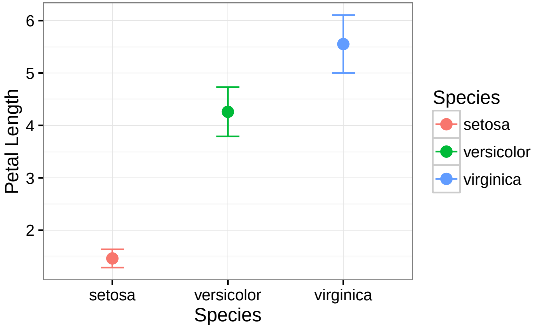
Using the d2 dataset you created earlier, generate this plot below. Take a quick look at the data first to see if it needs to be binned.



Exercise 4

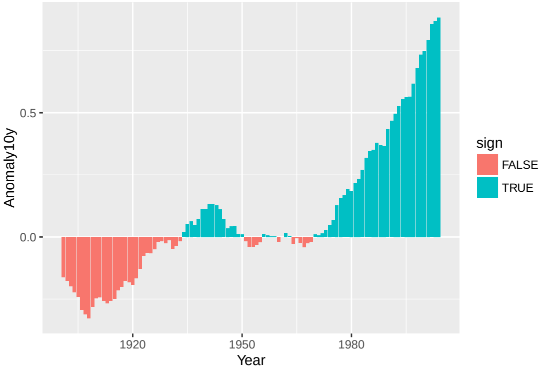
- Use dplyr to calculate the mean and standard deviation of petal length by species.

```
agg <- iris %>%
        group_by(Species) %>%
        summarise(mean.petal.length = mean(Petal.Length),
        sd.petal.length = sd(Petal.Length))
# ?geom_errorbar()
```



Exercise 5

- Using the climate dataset, create a new variable called sign. Make it logical (true/false) based on the sign of Anomaly10y.
- Plot a bar plot and use `sign` variable as the fill.

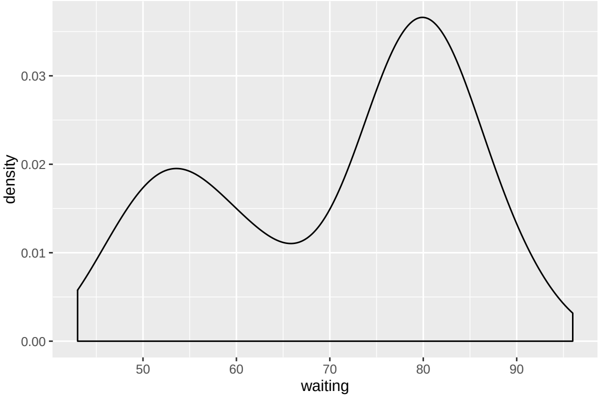


Section 13

Density Plots

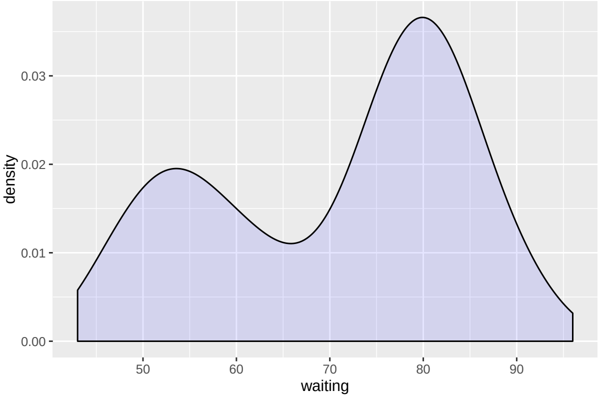
Density plots

```
ggplot(faithful, aes(waiting)) + geom_density()
```

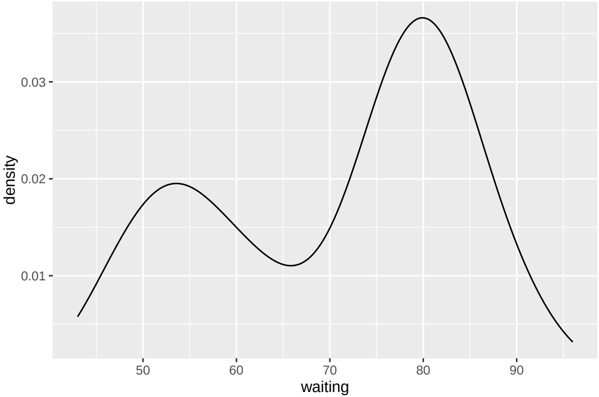


Density plots

```
ggplot(faithful, aes(waiting)) +
    geom_density(fill = "blue", alpha = 0.1)
```



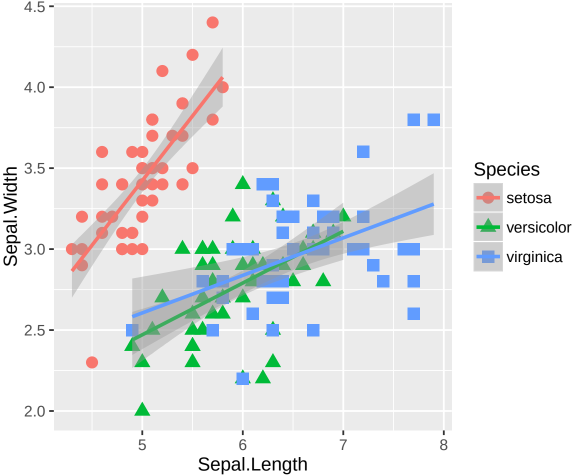
```
ggplot(faithful, aes(waiting)) +
    geom_line(stat = "density")
```



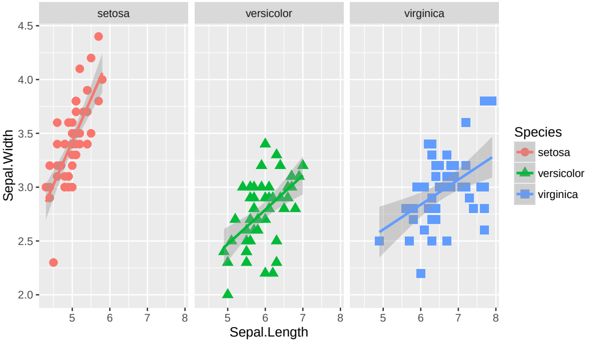
Section 14

Adding smoothers

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(aes(shape = Species), size = 3) +
    geom_smooth(method = "lm")
```



```r
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(aes(shape = Species), size = 3) +
    geom_smooth(method = "lm") +
    facet_grid(. ~ Species)
```



Section 15

Themes

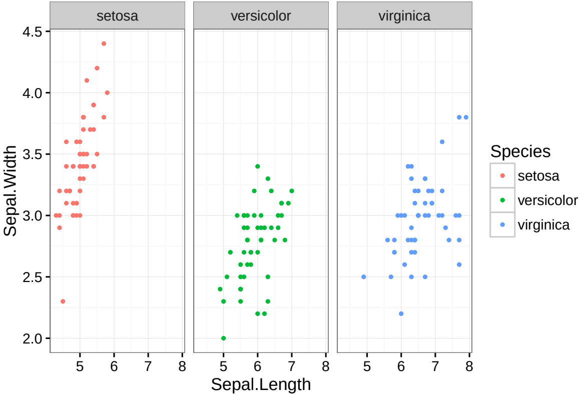
Adding themes

Themes are a great way to define custom plots.

```
+ theme()
# see ?theme() for more options
```

A more basic theme

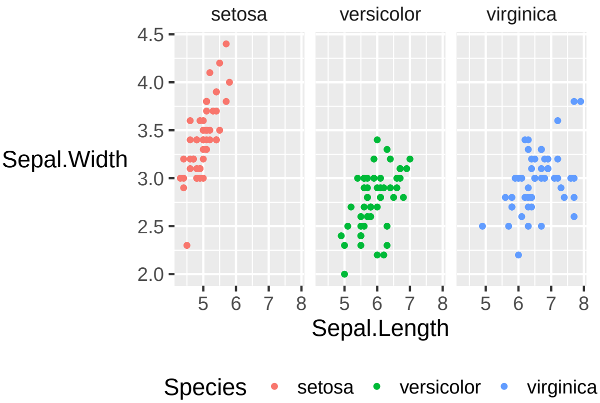
```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(size = 1.2, shape = 16) +
    facet_wrap( ~ Species) +
    theme_bw()
```



A themed plot

```
ggplot(iris, aes(Sepal.Length, Sepal.Width, color = Species)) +
    geom_point(size = 1.2, shape = 16) +
    facet_wrap( ~ Species) +
    theme(legend.key = element_rect(fill = NA),
        legend.position = "bottom",
        strip.background = element_rect(fill = NA),
        axis.title.y = element_text(angle = 0))
```

A themed plot



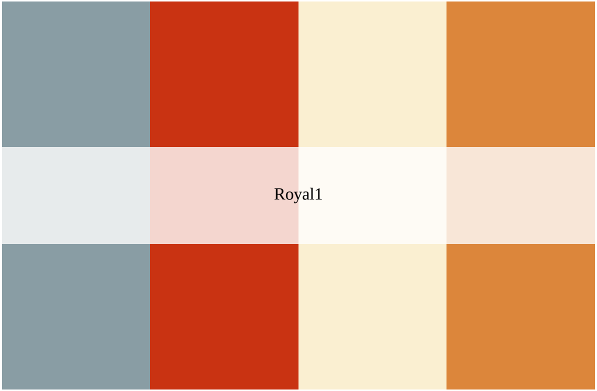
ggthemes library

```r
install.packages('ggthemes')
library(ggthemes)
# Then add one of these themes to your plot
 + theme_stata()
 + theme_excel()
 + theme_wsj()
 + theme_solarized()
```

Fan of Wes Anderson movies?

Yup, that's a thing

```r
# install.packages('wesanderson')
library("wesanderson")
# display a palette
wes_palette("Royal1")
```



Section 16

Create functions to automate your plotting

Write functions for day to day plots

```
my_custom_plot <- function(df, title = "", ...) {
    ggplot(df, ...) +
    ggtitle(title) +
    whatever_geoms() +
    theme(...)
}
```

Then just call your function to generate a plot. It's a lot easier to fix one function that do it over and over for many plots

```
plot1 <- my_custom_plot(dataset1, title = "Figure 1")
```

Section 17

Publication quality figures

- If the plot is on your screen

```
ggsave('~/path/to/figure/filename.png')
```

- If your plot is assigned to an object

```
ggsave(plot1, file = "~/path/to/figure/filename.png")
```

- Specify a size

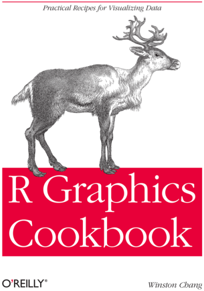
```
ggsave(file = "/path/to/figure/filename.png", width = 6,
height =4)
```

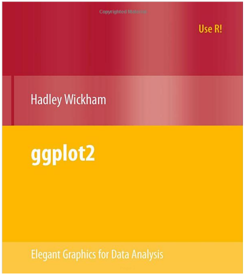
- or any format (pdf, png, eps, svg, jpg)

```
ggsave(file = "/path/to/figure/filename.eps")
ggsave(file = "/path/to/figure/filename.jpg")
ggsave(file = "/path/to/figure/filename.pdf")
```

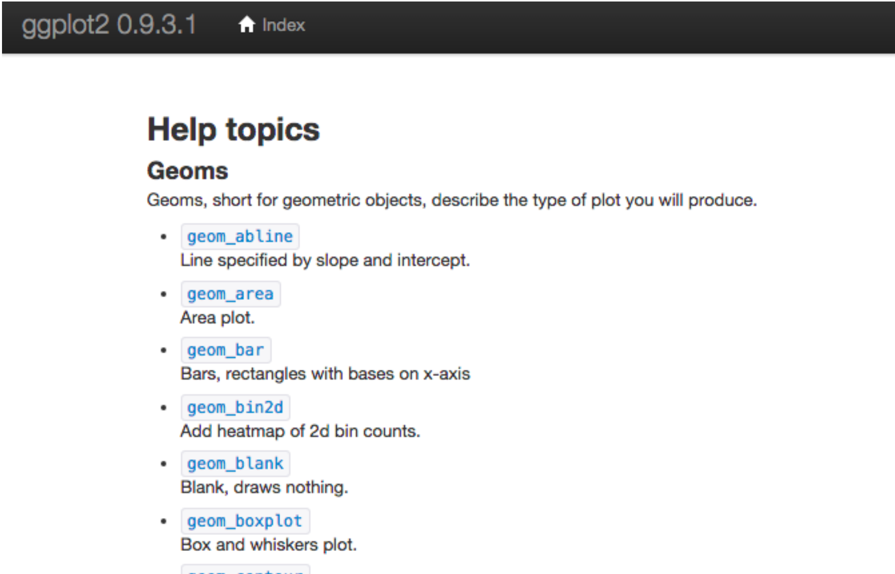
Further help

- You've just scratched the surface with ggplot2.
- Practice
- Read the docs (either locally in `R` or at `http://docs.ggplot2.org/current/`)
- Work together





ggplot2 Help Pages



ggplot2 0.9.3.1 Index

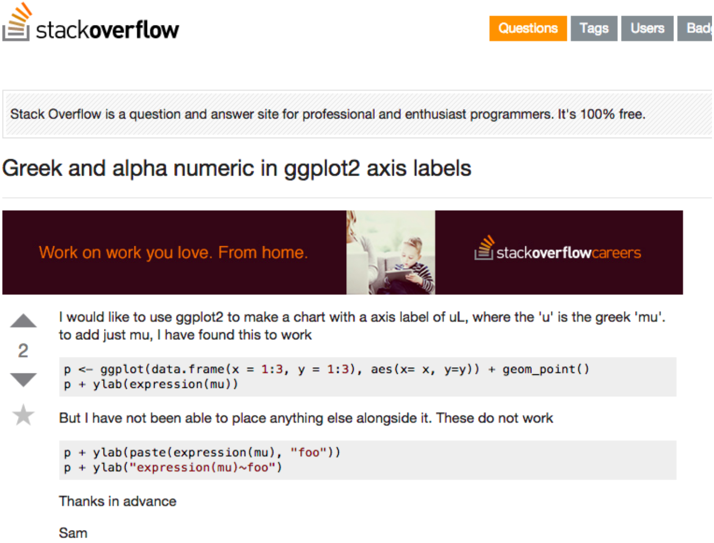
Help topics

Geoms

Geoms, short for geometric objects, describe the type of plot you will produce.

- `geom_abline`
  Line specified by slope and intercept.
- `geom_area`
  Area plot.
- `geom_bar`
  Bars, rectangles with bases on x-axis
- `geom_bin2d`
  Add heatmap of 2d bin counts.
- `geom_blank`
  Blank, draws nothing.
- `geom_boxplot`
  Box and whiskers plot.

StackOverflow



Stack Overflow is a question and answer site for professional and enthusiast programmers. It's 100% free.

Greek and alpha numeric in ggplot2 axis labels

Work on work you love. From home.

stackoverflowcareers

I would like to use ggplot2 to make a chart with a axis label of uL, where the 'u' is the greek 'mu'. to add just mu, I have found this to work

```
p <- ggplot(data.frame(x = 1:3, y = 1:3), aes(x= x, y=y)) + geom_point()
p + ylab(expression(mu))
```

But I have not been able to place anything else alongside it. These do not work

```
p + ylab(paste(expression(mu), "foo"))
p + ylab("expression(mu)~foo")
```

Thanks in advance

Sam