Data Analytics
CS301
The Great Review

Fall 2020

Oliver Bonham-Carter

Course Summary

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\subsection*{\textbf{Academic Bulletin Description}}

\begin{quote}
\emph{Special Topics Course:}\\

An introduction to computational and analytical methods for finding
patterns in large data sets. Using statistical procedures that they
design and implement in programming environments, students
extract knowledge from financial, political, scientific, and other data
sources, exploring the issues of power and privilege that emerge from
their discoveries. Students also learn to contrast their own
perspectives with the ones identified by their analyses, reflecting on
the ethical consequences of using the power that originates from
computationally derived knowledge. During a weekly laboratory
session students employ state-of-the-art statistical software to
complete projects, reporting on their findings through both written
documents and oral presentations.

\end{quote}
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Covered Objectives

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\subsection*{\textbf{Course Objectives}}
Students successfully completing this class will have developed:
\begin{enumerate}

  \item A “big-picture” view of data analytics.

  \item An understanding of the objectives and limitations of data
analytics.

  \item An understanding of the main data analytics methods.

  \item Practical skills using relevant software tools and programming
techniques.

  \item An understanding of the contemporary roles of power and
difference as they relate to the knowledge derived from a data set.

  \item An understanding of biases, discrimination and stereotypes that
maybe present during collection, analysis, and reflection on the latent
trends in real-world data sets.

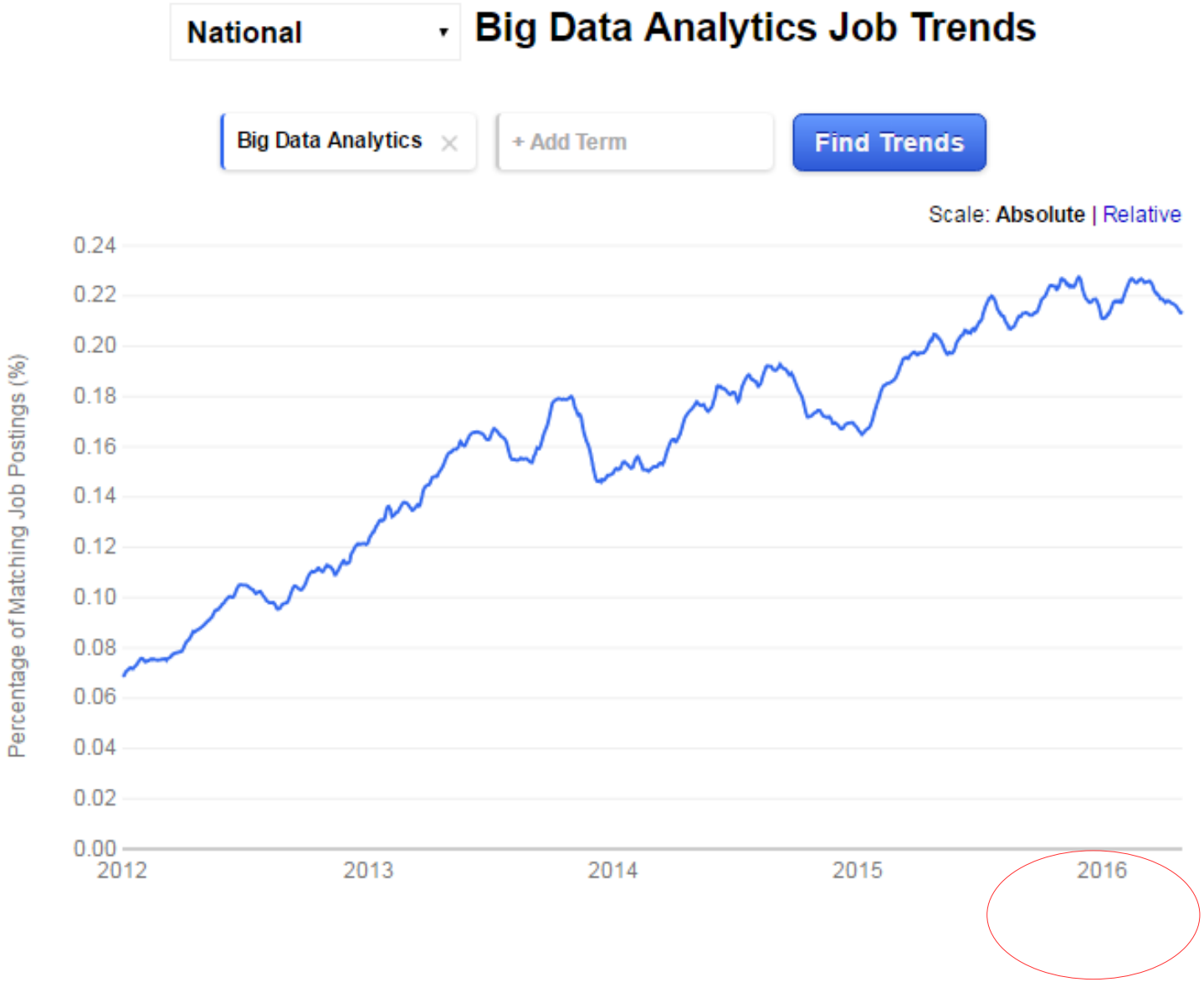
\end{enumerate}
```

How Did We Achieve These Objectives?

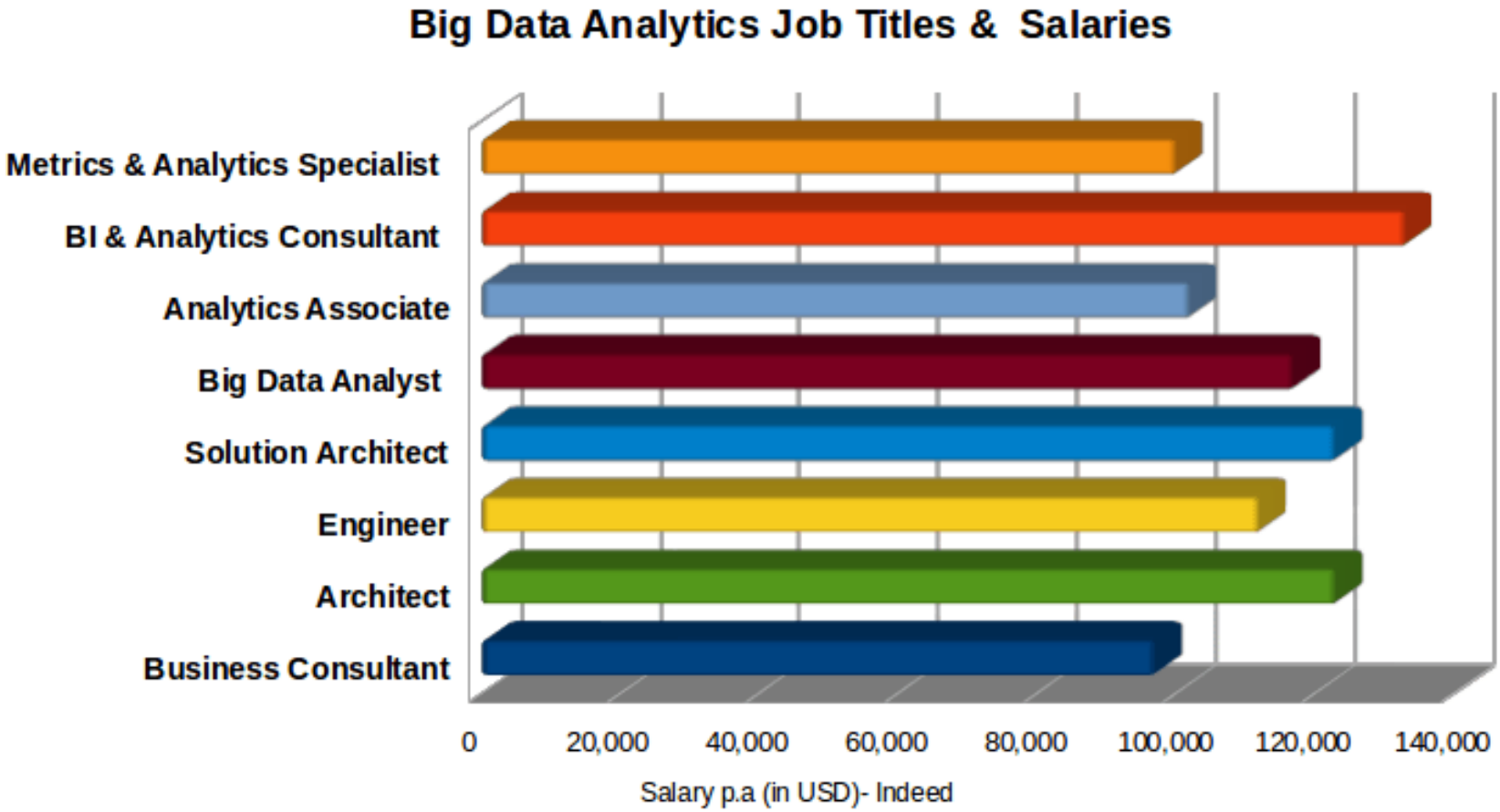
- Class lessons with activities using R to explore data sets
- Labs where students were given opportunity to apply classroom learning to data sets to uncover own researches
- Guest speakers who came to discuss how their own research involves DA
  - Ron Mattocks
  - Lydia Eckstein, PhD
  - Yee Mon Thu, PhD
  - Steven Onyeiwu, PhD

Jobs and Careers

- Many more job posting where analytics is absolutely required



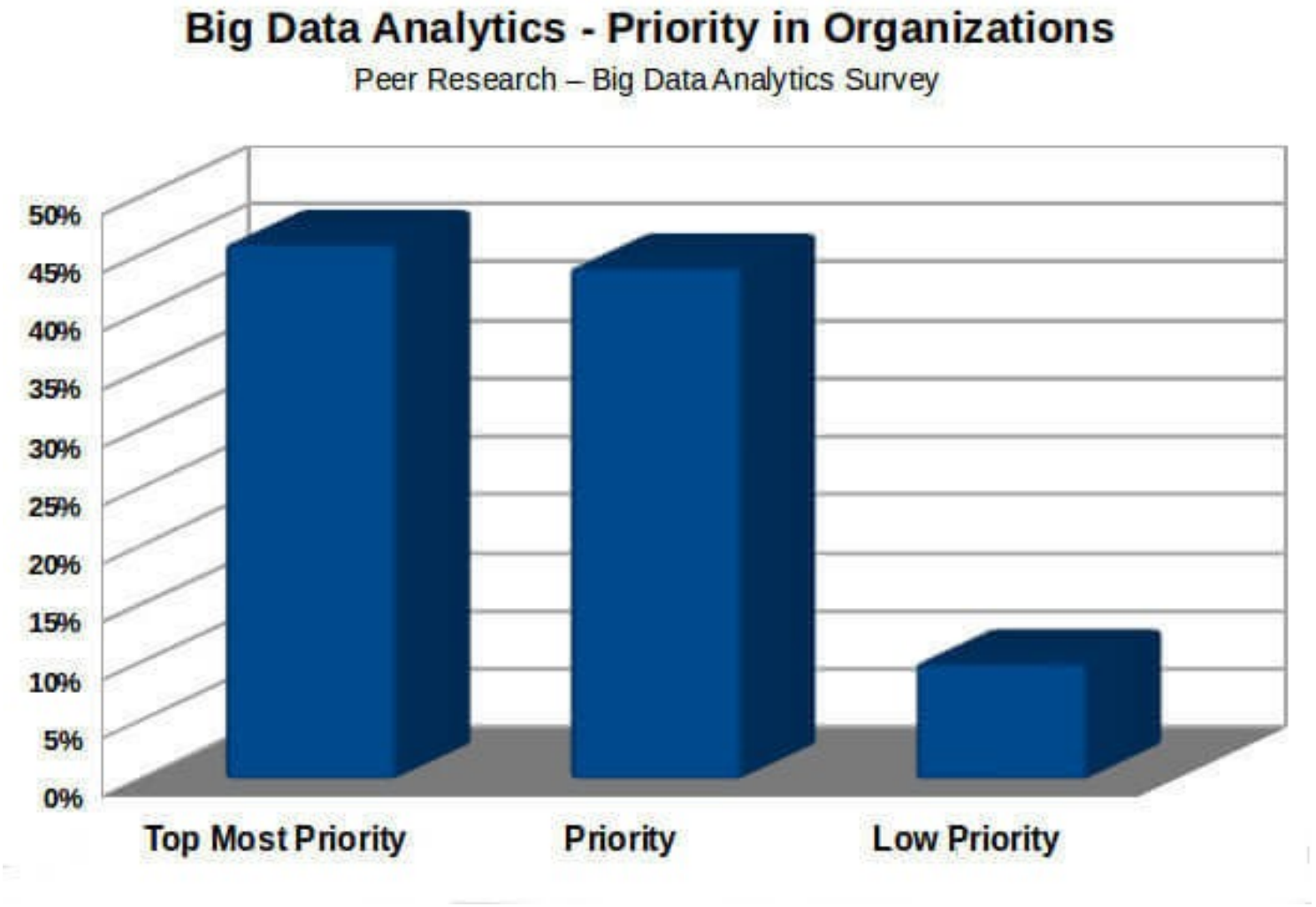
Money to Be Made



- High-paying salaries DA
- These careers have security due to the ever-presence of data in research, industry and everywhere else.

https://www.edureka.co/blog/10-reasons-why-big-data-analytics-is-the-best-career-move

More Important Each Day



- Organizations are looking for people to help them process, understand what is in their data to make decisions.

Helping Business Development

- Organizations realize that data drives their business.
- When will your career in DA begin?!

Forbes

- ***“75% of firms are prioritizing big data and analytics expertise in their hiring decisions****, stating that having these skills is critical for any candidate to be considered an IoT (Internet of Things) expert.”*

https://www.forbes.com/sites/louiscolumbus/2017/08/21/big-data-analytics-is-the-most-wanted-expertise-by-75-of-iot-providers/#52082a4e5188

Computers and Information

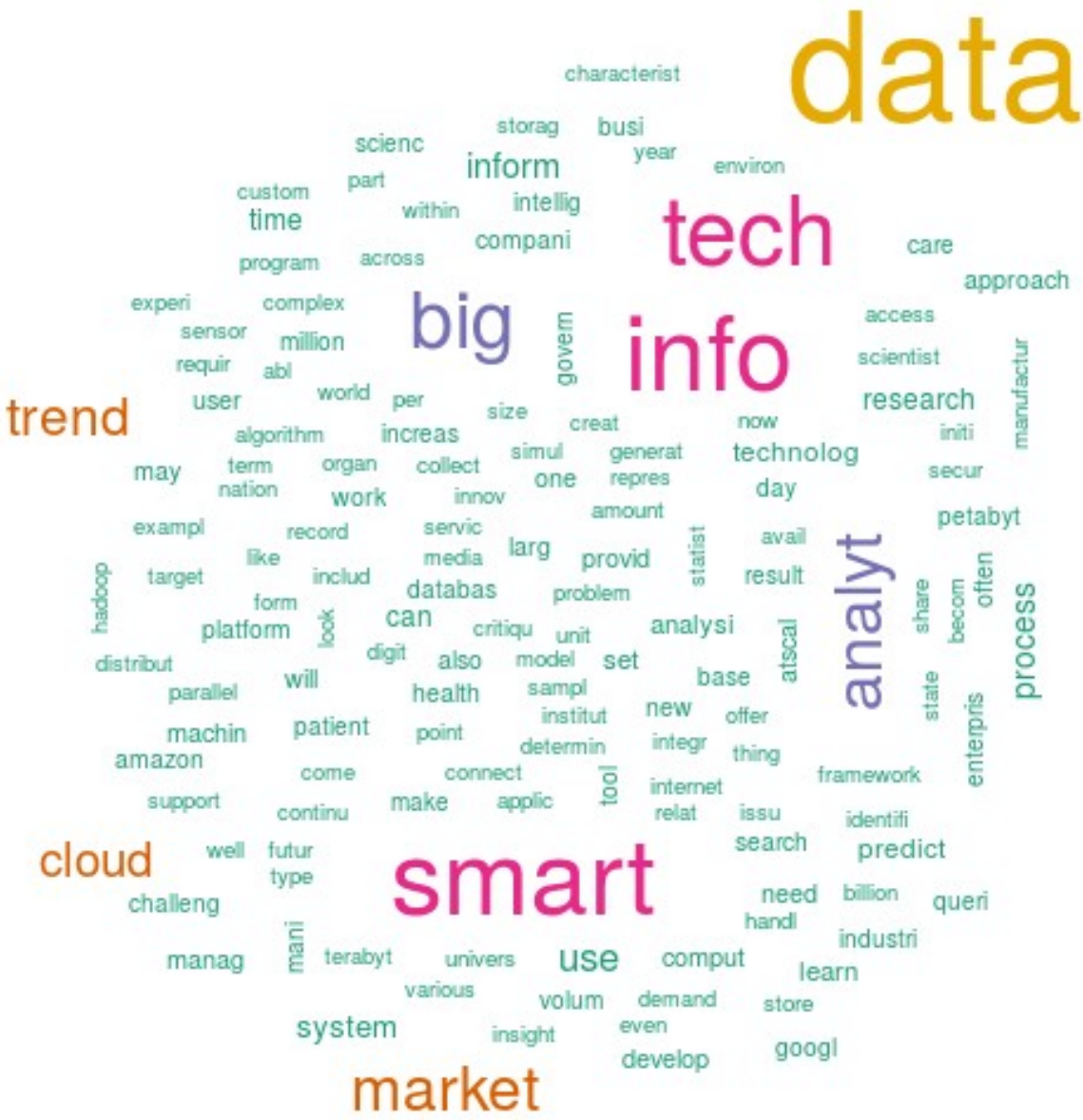
- In this class, you learned how to use machines to harness the power of data.

Raw Data

Meaningful Information

How to Analyze Data?

- How do we harness this power of data analytics?



Topics Covered

- **Google Analytics**
  - Web traffic Information: terms and plots
- **Visualizations: types and meanings**
- **R Statistics**
  - Basic syntax and methods
- **Library features**
  - Tidyverse, nycflights13, lubridate
- **Concepts**
  - Exploratory data analysis
  - Tidy data manipulation
  - Managing date and time
  - Others from recent lessons

We Have Ethical Backbone

- We discussed ethical concepts.
- For example: *Twelve Million Phones, One Dataset, Zero Privacy,* A New York Times opinion piece
- Link: https://www.nytimes.com/interactive/2019/12/19/opinion/location-tracking-cell-phone.html

Opinion | THE PRIVACY PROJECT

Twelve Million Phones, One Dataset, Zero Privacy

By Stuart A. Thompson and Charlie Warzel

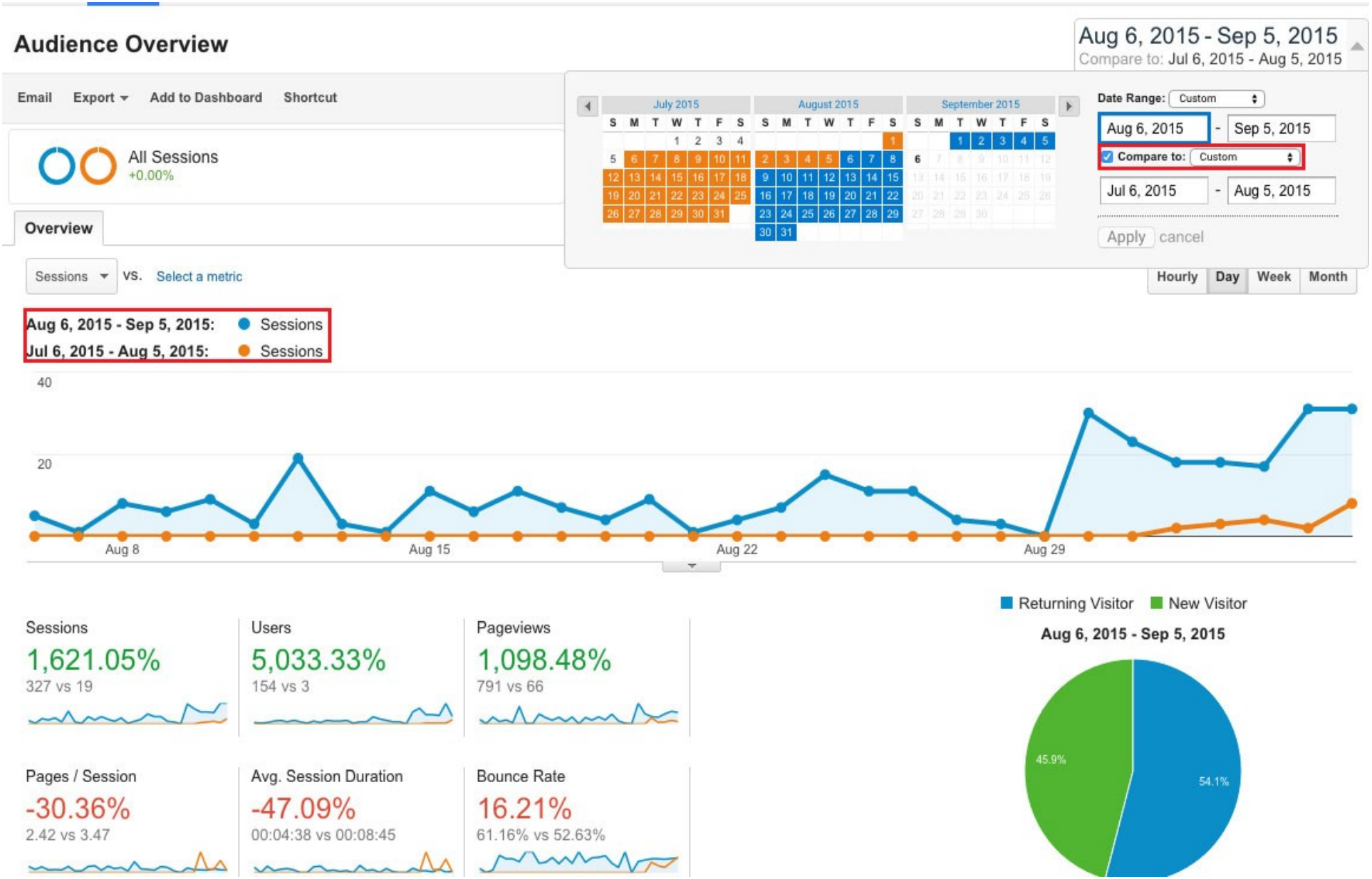
DEC. 19, 2019

We Learned Analysis: Google Analytics

- An introduction to computational and analytical methods for finding patterns in large data sets.
- Google Analytics and web page data analysis
  - Page views?
  - How many users clicked on purchase buttons?
  - How many user downloaded (read, viewed) your hand-out newsletter?
  - How long to land on “check-out” page? Time to decide to buy?

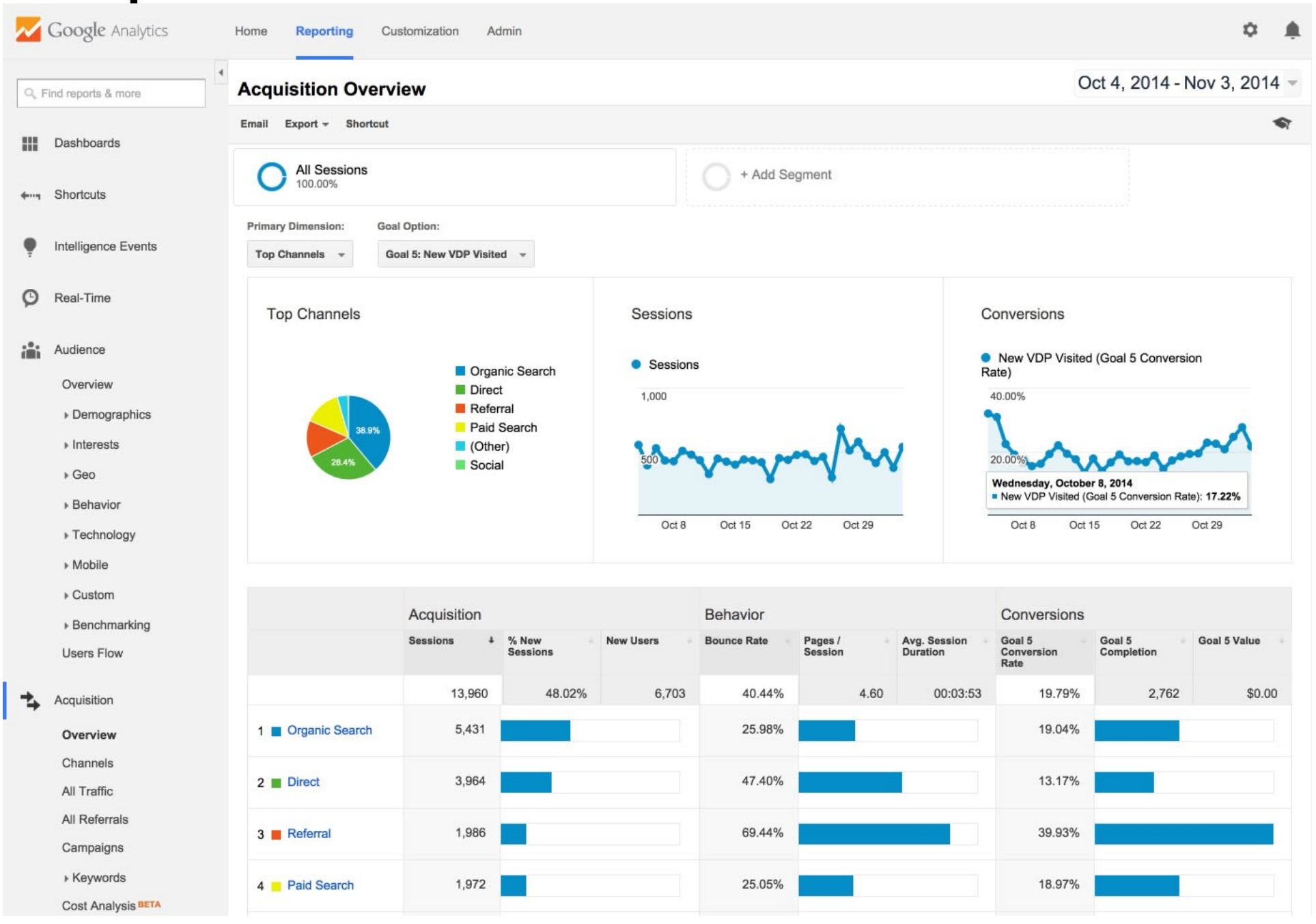
Audience

- Who are your users?
- When was that?



Acquisition

- How do these users get to your site?



Where To Now?

- Google Analytics is a tool allowing for convenient analysis of web sites
- The code was written by developers for this purpose.
- What if you need tools and there are no current developers to create them?

Develop Your Own Tools!!

Questions to Ask?

- No rules about which questions to ask to guide your research.
- Two types of general questions for making discoveries
  - What type of variation occurs within my variables?
  - What type of covariation occurs between my variables?

Terms To Know

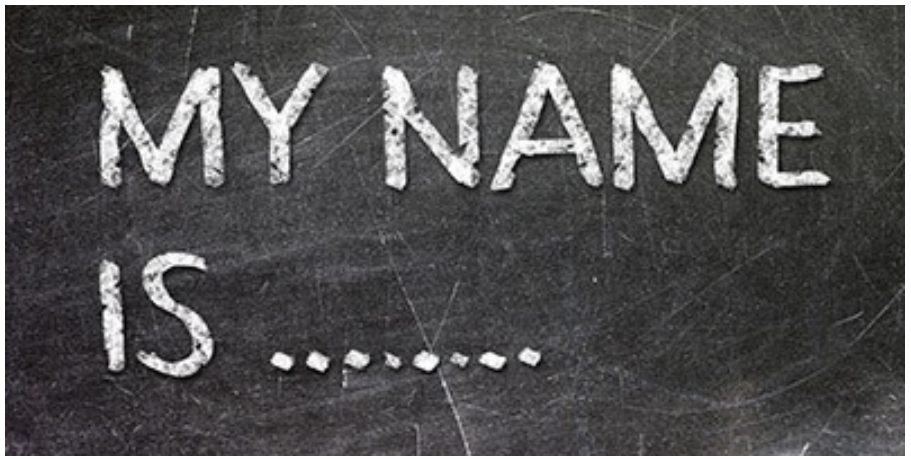
- A **variable** is a quantity, quality, or property that you can measure.
- A **value** is the state of a variable when you measure it. The value of a variable may change from measurement to measurement.
- An **observation** is a set of measurements made under similar conditions (you usually make all of the measurements in an observation at the same time and on the same object). An observation will contain several values, each associated with a different variable. I'll sometimes refer to an observation as a data point.
- **Tabular data** is a set of values, each associated with a variable and an observation. Tabular data is tidy if each value is placed in its own "cell", each variable in its own column, and each observation in its own row.

The R Programming Language

- https://www.r-project.org/
- What is the R language?
  - An open source, well-developed programming platform for work in statistics, mathematics and data analytics
  - Built-in libraries to simplify programming
  - Language includes conditionals, loops, user-defined recursive functions and input and output facilities.
- Community Blogs:
  - https://www.r-bloggers.com/
  - https://twitter.com/rstudiotips

Simple Steps: R Programming

- Strings
  - “Hello World”
- Concatenation of strings
  - H <- “Hello”
  - W <- “world”
  - paste(H,W, sep = “ ”)
    - What is the result here??



- You try: print your full name!
  - name <- first-*name*,
  - Lastname <- *last-name*

Code for a Simple GGPlot

- **library(tidyverse) or if not present,**
- **install.packages("tidyverse")**
- **ggplot(data = mpg) + geom_point(mapping = aes(x = displ, y = hwy))**

- Establish the *canvas* (where the plot is shown)
- **Ggplot()**

- Link to the data (set is called, 'mpg')
  - **ggplot(data = mpg)**

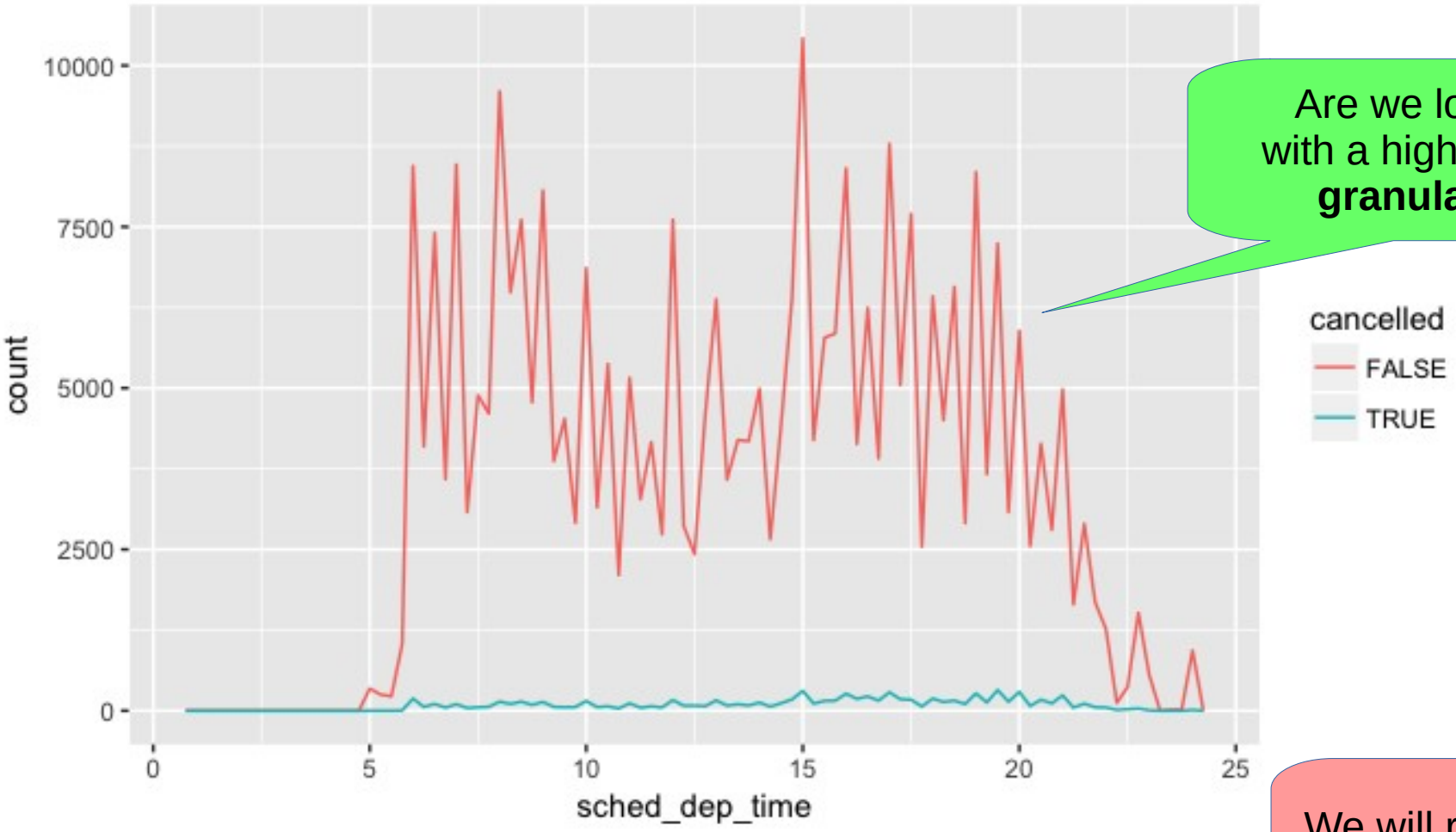
- Compute the geometery of point placement on canvas
  - **geom_point(mapping = …)**

- Compute the aesthetics of the plot (titles, color, point type, etc)
  - **aes(x = displ, y = hwy)**

dplyr Basics

- Five key dplyr functions
  - Pick observations by their values (**filter()**).
  - Reorder the rows (**arrange()**).
  - Pick variables by their names (**select()**).
  - Create new variables with functions of existing variables (**mutate()**).
  - Collapse many values down to a single summary (**summarise()**).
- Find help for each: ?keyword

Potential Pitfalls in Theory



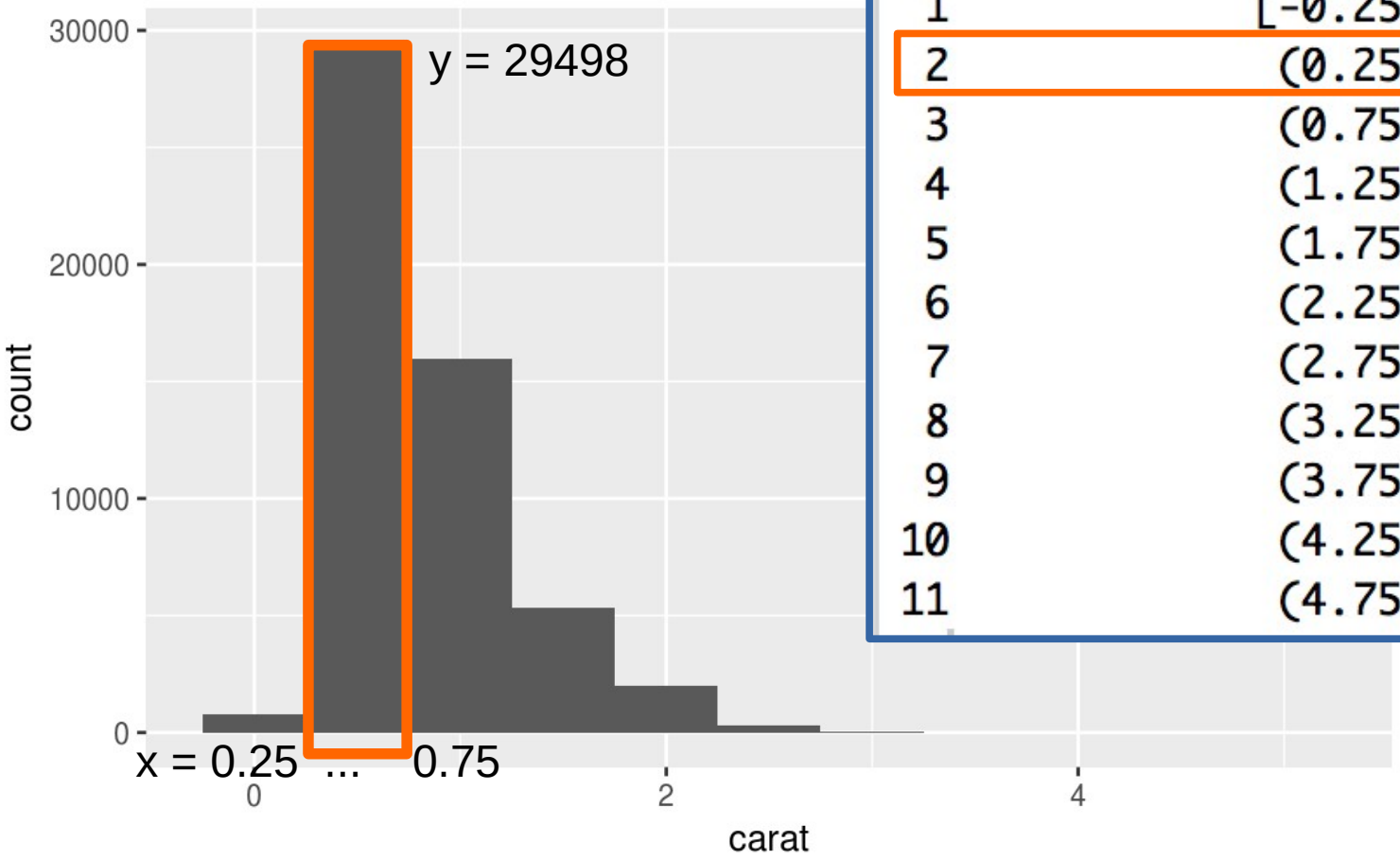
Are we looking with a high-enough **granularity**?

We will return to visual comparisons

- We get an slight idea of cancellations
- But many more non-cancelled flights than cancelled flights

Histogram as Text

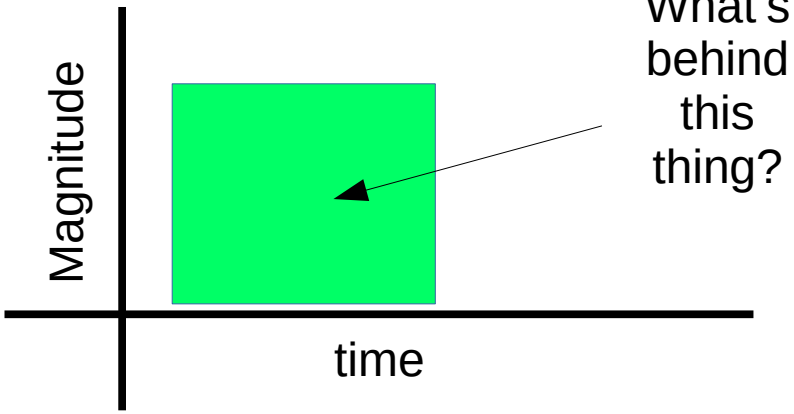
- The cut_width() gives a textual representation of the histogram.




```
> diamonds %>%
+     count(cut_width(carat, 0.5))
# A tibble: 11 x 2
   `cut_width(carat, 0.5)`     n
                    <fctr> <int>
 1          [-0.25,0.25]   785
 2           (0.25,0.75] 29498
 3           (0.75,1.25] 15977
 4           (1.25,1.75]  5313
 5           (1.75,2.25]  2002
 6           (2.25,2.75]   322
 7           (2.75,3.25]    32
 8           (3.25,3.75]     5
 9           (3.75,4.25]     4
10           (4.25,4.75]     1
11           (4.75,5.25]     1
```

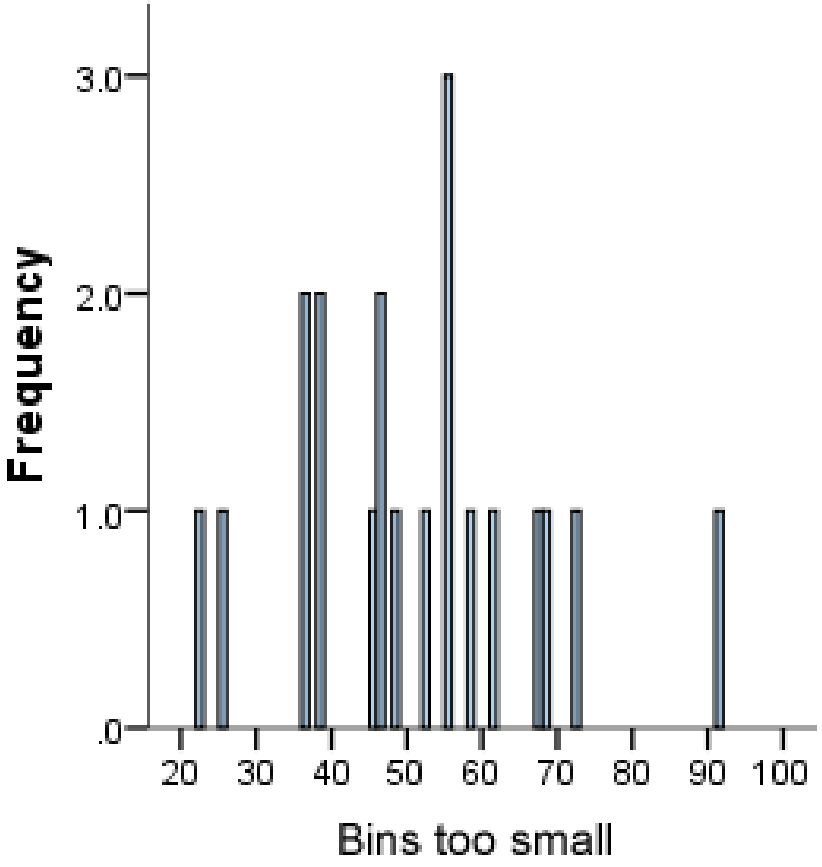
This Plot May Make It Hard To See The Phenomenon

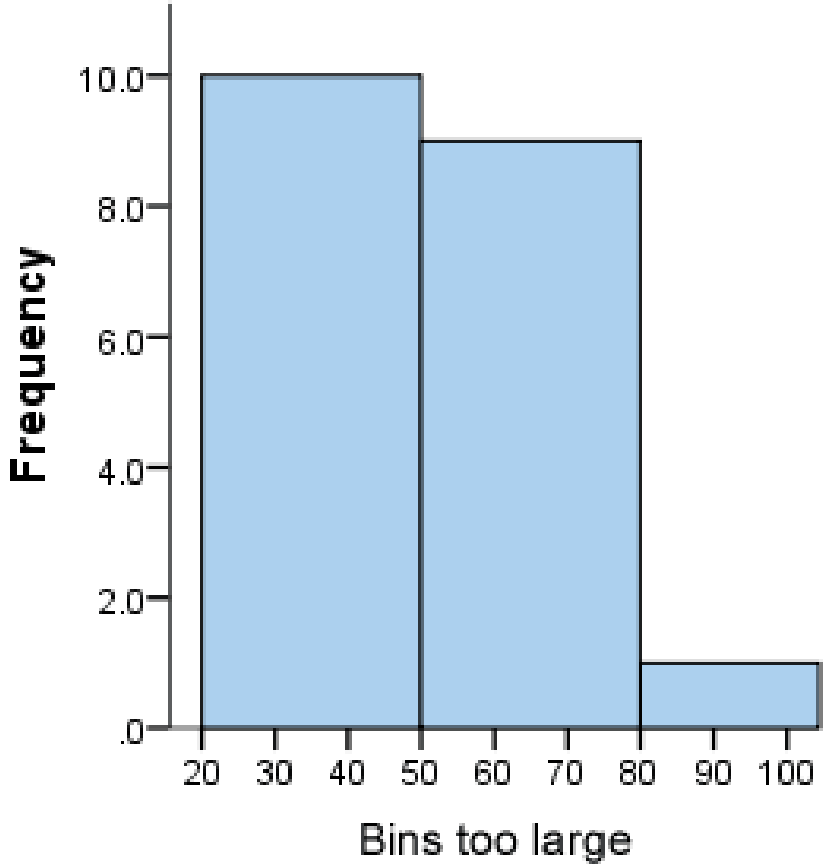
- The counts variable seems to have values from all over the range.
- This is noise in our plot
- If one group is much smaller than the others, then it is hard to see the differences in its distribution.



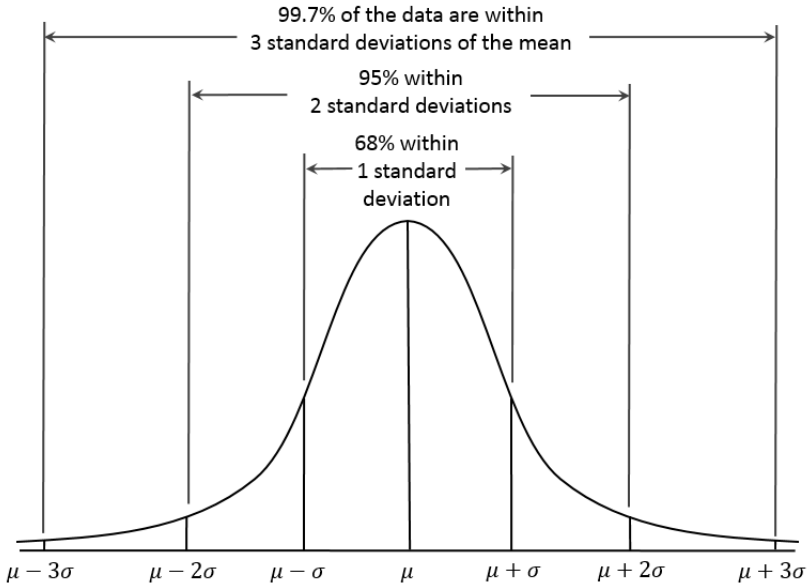
Different Bin Widths

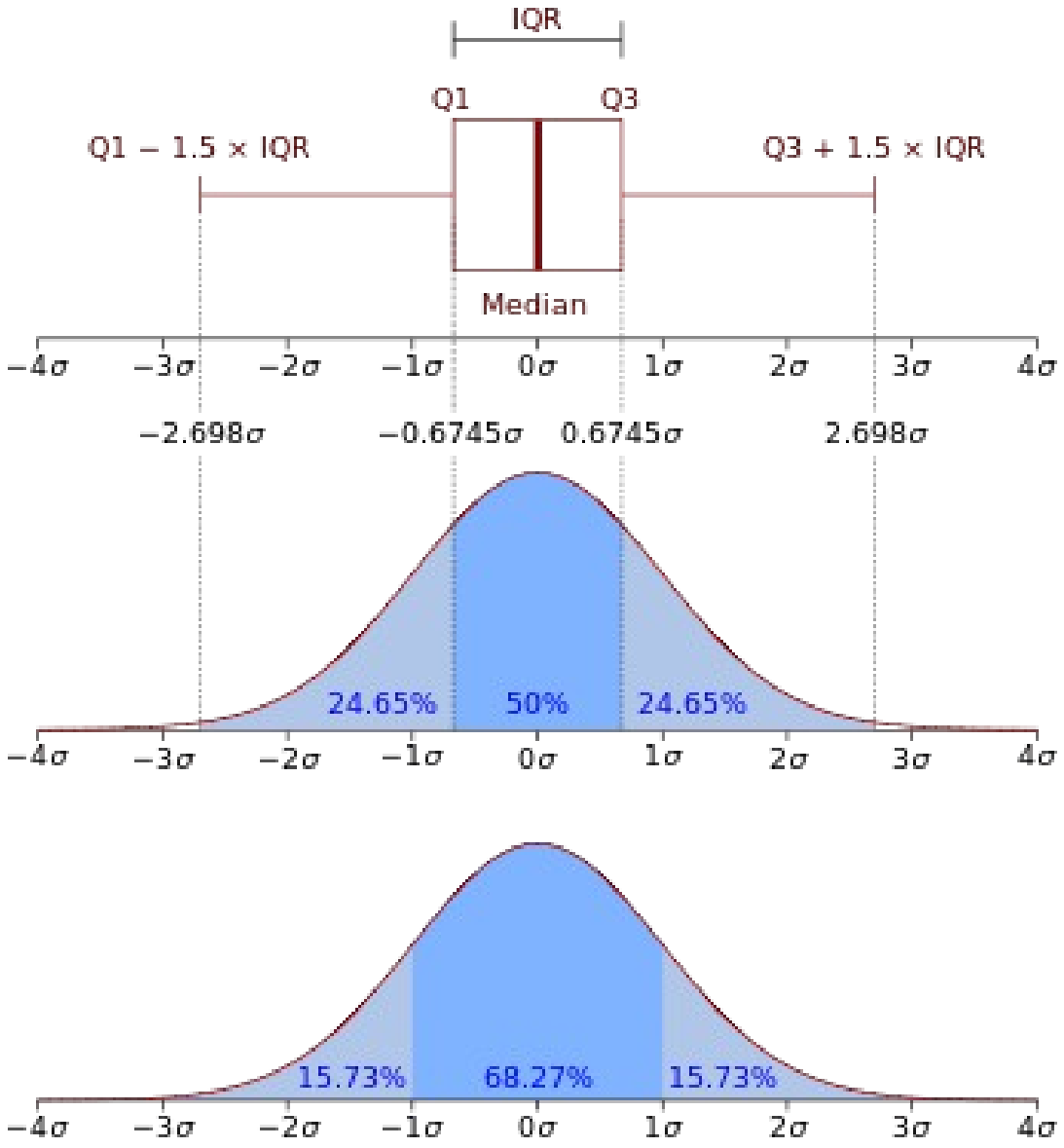
- Set the width of the intervals in a histogram with the binwidth argument, which is measured in the units of the *x* variable.
- Left histogram: bins are too small, too much individual data and hides underlying pattern (frequency distribution).
- Right histogram: bins are too large, hard to spot trends in the data.





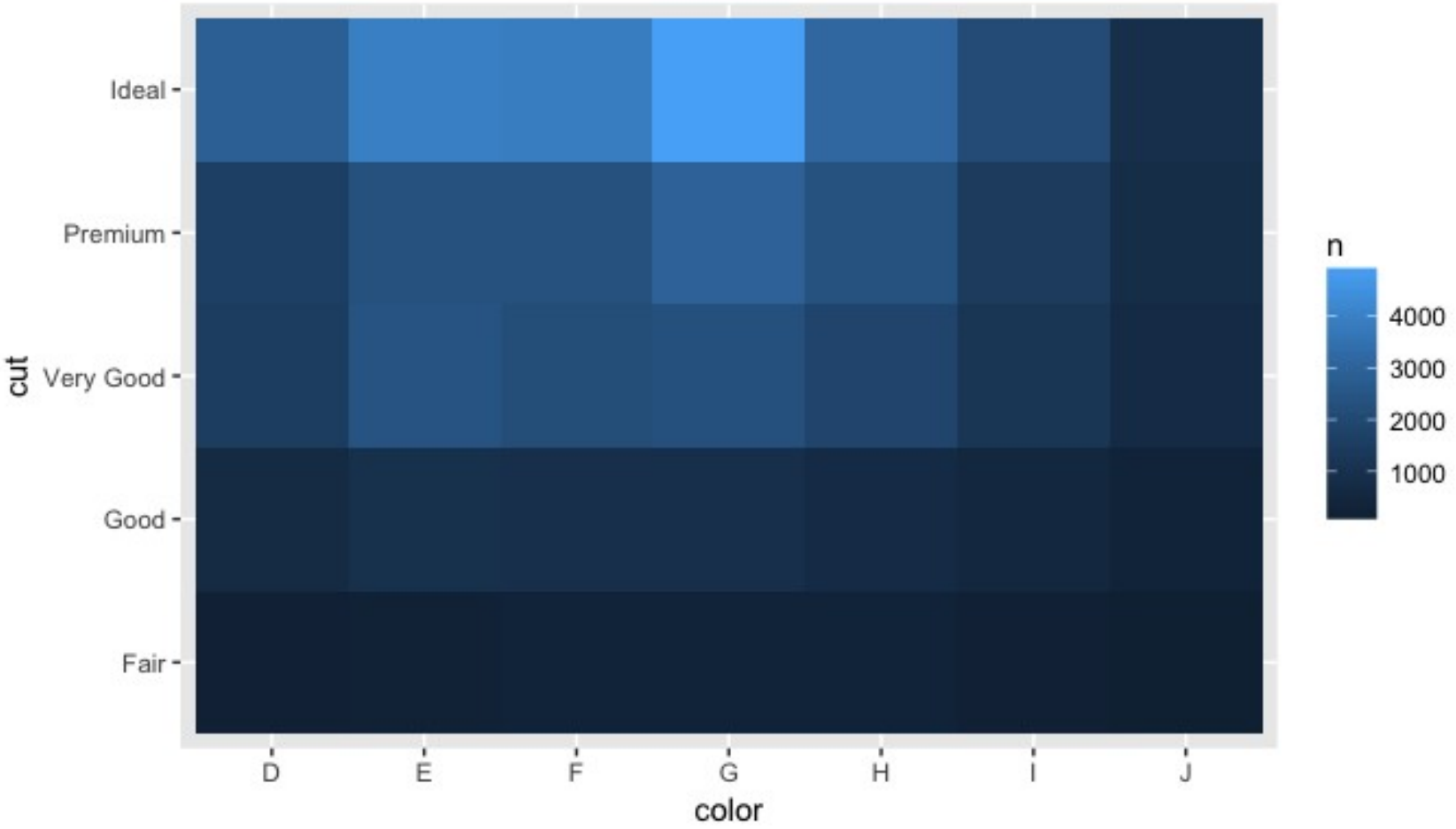
Box Plots





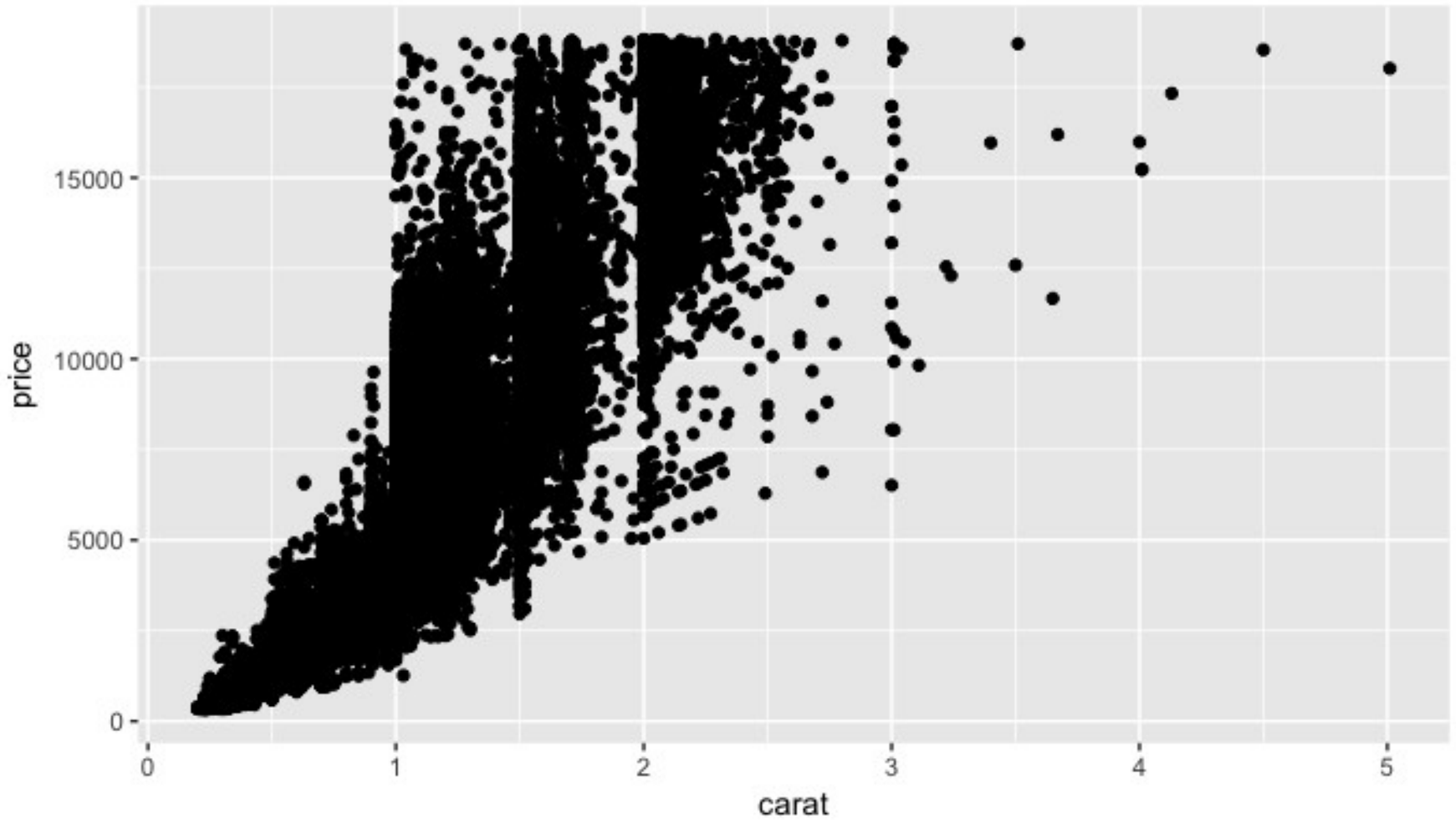
- For the normal distribution, the values less than one standard deviation away from the mean account for 68.27% of the set; while two standard deviations from the mean account for 95.45%; and three standard deviations account for 99.73%.

Visualization - Mini Distributions: Cut vs Color



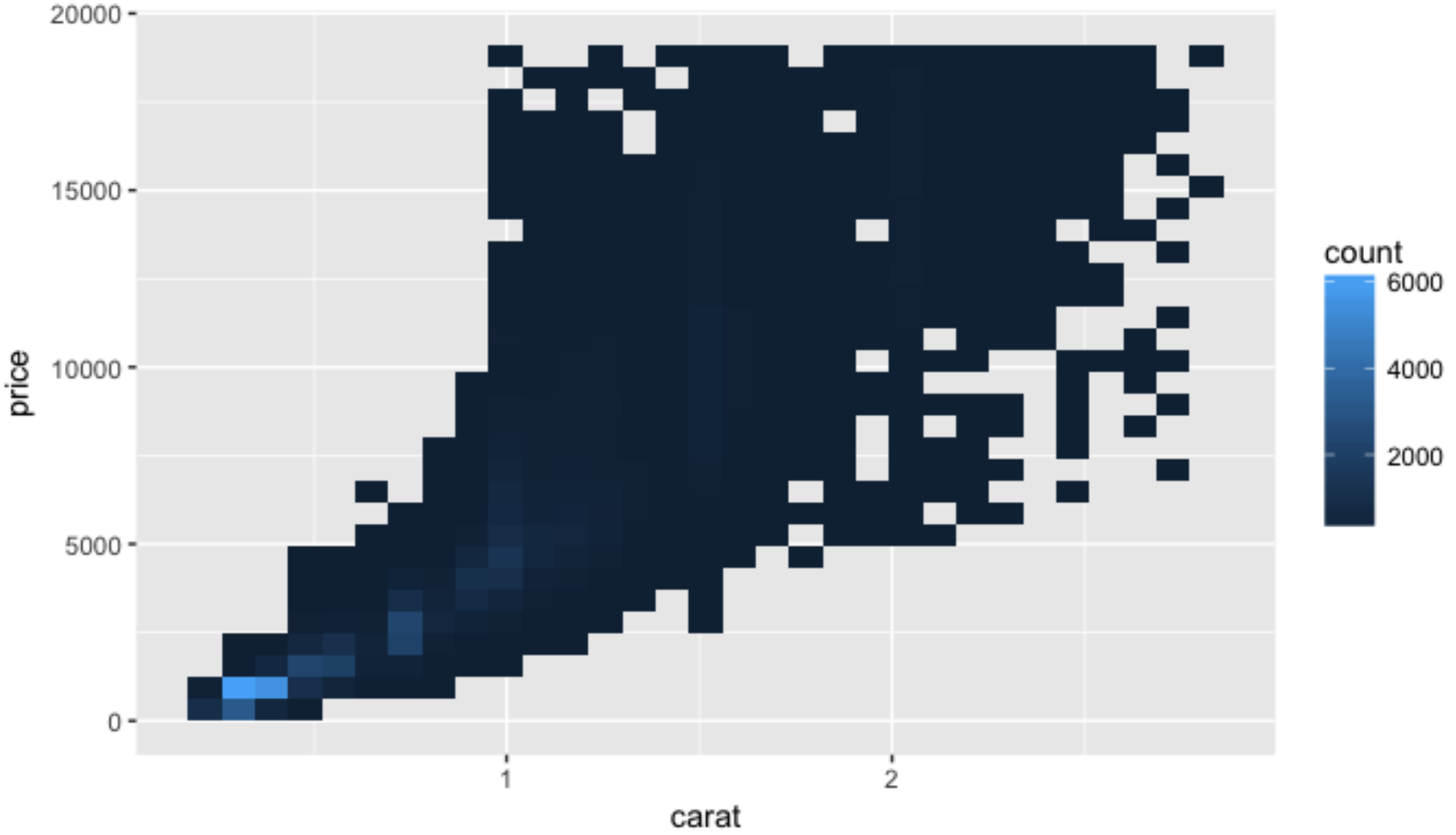

```
diamonds %>%
  count(color, cut) %>%
  ggplot(mapping = aes(x = color, y = cut)) +
    geom_tile(mapping = aes(fill = n))
```

Visualization - Mini Distributions: Carat vs Price




```
ggplot(data = diamonds) +
  geom_point(mapping = aes(x = carat, y = price))
```

Visualization - Mini Distributions: Carat vs Price




```
ggplot(data = smaller) +
  geom_bin2d(mapping = aes(x = carat, y = price))
```

Dates and Times in R

- How do we deal when time or dates are a part of our analysis?
- How do we determine if our data spreads across a leap year?
- What if we measures our observations using a minute-by-minute time frame for some series of years? If there is a leap year, is there a problem?

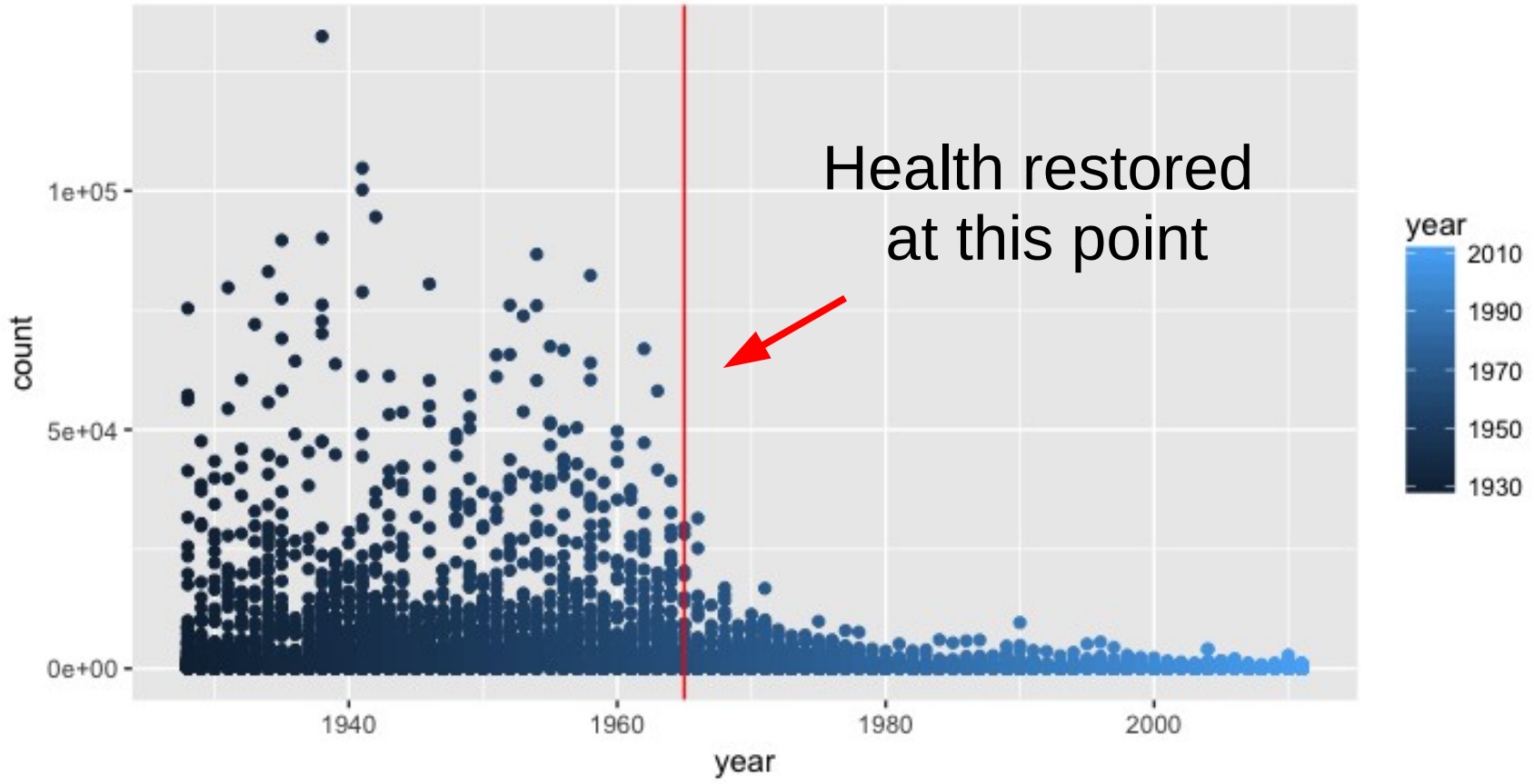
Vaccine Lab 3: What Does Our Data Say About (All) Vaccines of Data?

```
library(tidyverse)

library(dslabs)

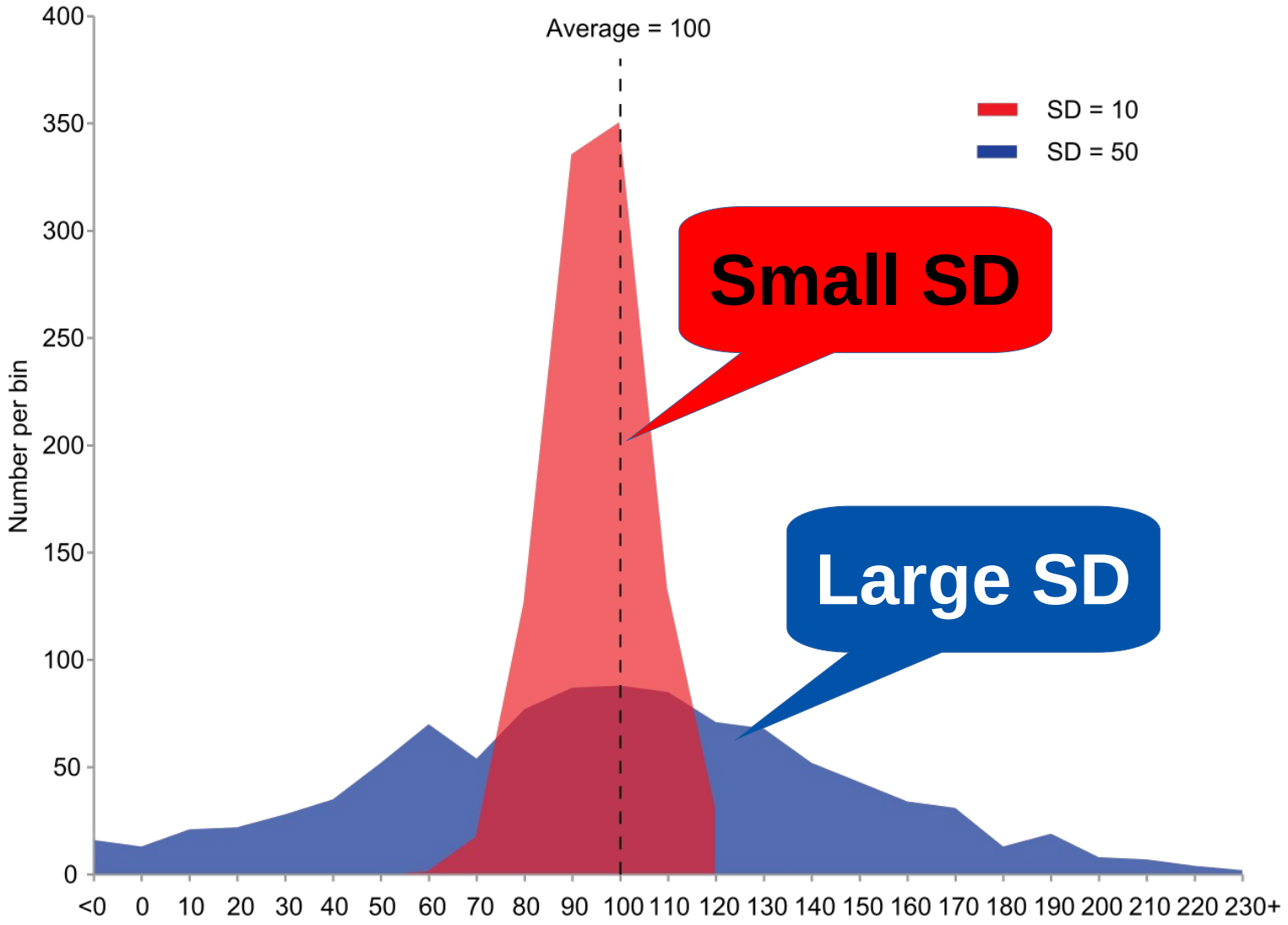
library(dplyr)

ggplot(data = us_contagious_diseases) +  geom_point(mapping = aes(x = year, y = count, color = year)) + geom_vline(xintercept = 1965, color = "red")
```



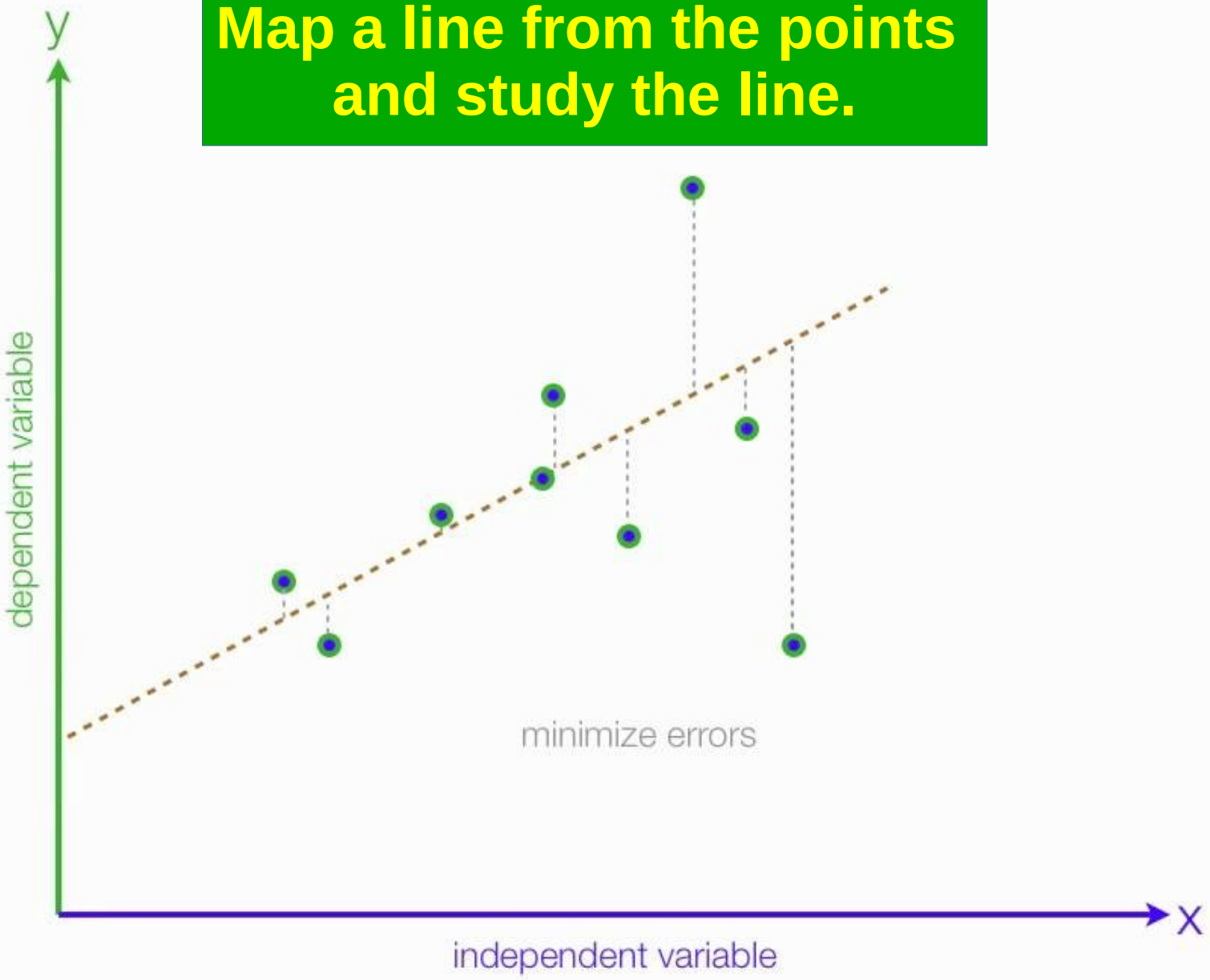
Basic Stats
Standard Deviation

- A quantity calculated to indicate the extent of deviation for a group as a whole.

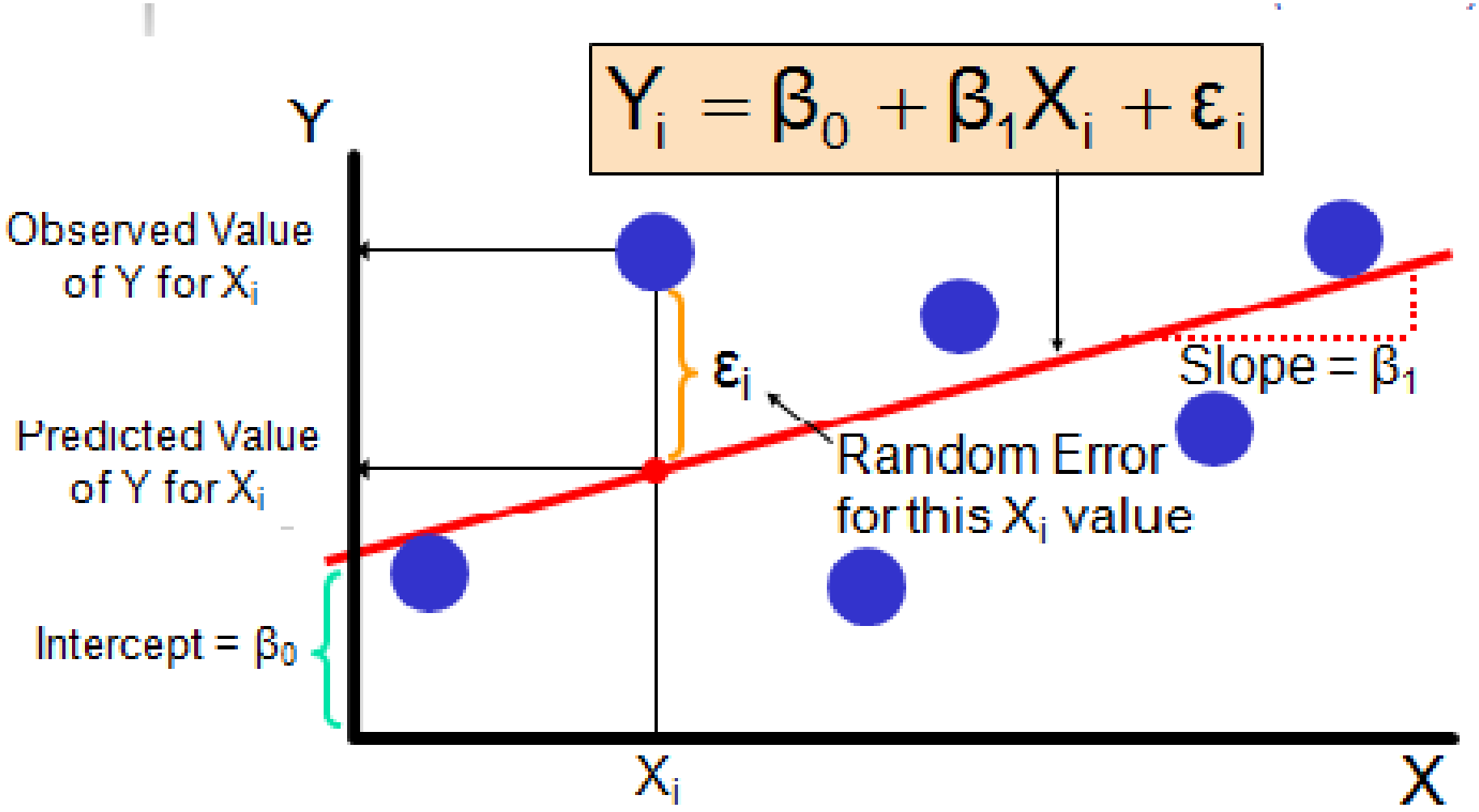


Linear Regression

Map a line from the points and study the line.



Let's Talk Linear Models

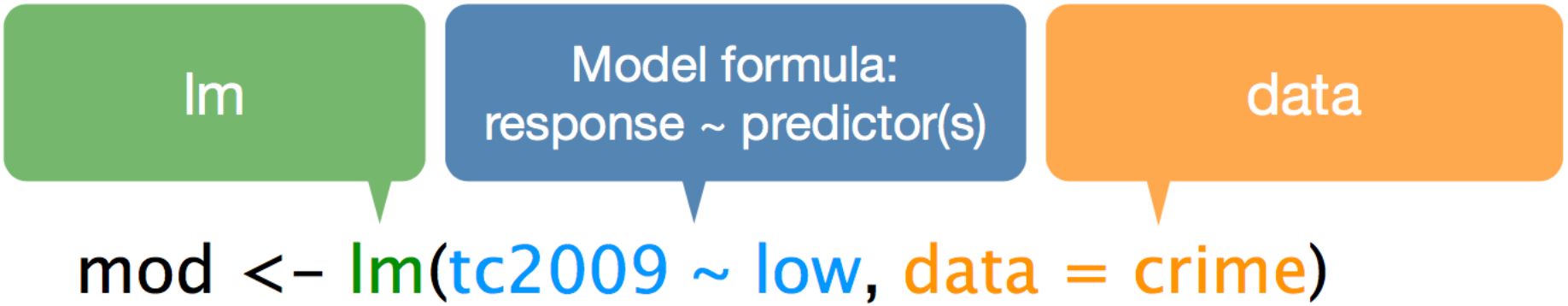


Linear Regression

- Is one thing able to influence another thing?
- A linear approach for modeling the relationship between a scalar dependent variable ***y*** and one or more explanatory variables, or independent variables, denoted by ***x***.
- *Simple linear regression*: Single explanatory variable; **models x and y**
- *Multiple linear regression*: More than one explanatory variable (***y's***); **models x and y1, y2**

Let's Hit the Code

- Linear model syntax



Linear Regression: Code

```
ctl <- c(4.17,5.58,5.18,6.11,4.50,4.61,5.17,4.53,5.33,5.14)
trt <- c(4.81,4.17,4.41,3.59,5.87,3.83,6.03,4.89,4.32,4.69)
group <- gl(2, 10, 20, labels = c("Ctl","Trt"))
weight <- c(ctl, trt)
lm.D9 <- lm(weight ~ group)
lm.D90 <- lm(weight ~ group - 1) # omitting intercept
summary(lm.D9)
```

- H0: there is no relationship between vars, m =0
- Ha: There is a relationship between vars, m!=0

  # Check the p-value:

  - If p-val =< alpha = 0.05: reject H0.
  - If p-val > alpha = 0.05: do not reject H0.

So, Are My Models Made From Sampling Full Data Set Any Good?

- Use *Parametric statistics* to check your model before you use it!

```
> summary(mod)

Call:
lm(formula = earn ~ height, data = pWages)

Residuals:
   Min     1Q Median     3Q    Max
-49392 -17589  -4448  10236 108209

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -138901.1    50897.3  -2.729 0.007530 **
height         2607.4      760.6   3.428 0.000891 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 29100 on 98 degrees of freedom
Multiple R-squared:  0.1071,    Adjusted R-squared:  0.09795
F-statistic: 11.75 on 1 and 98 DF,  p-value: 0.0008909
```

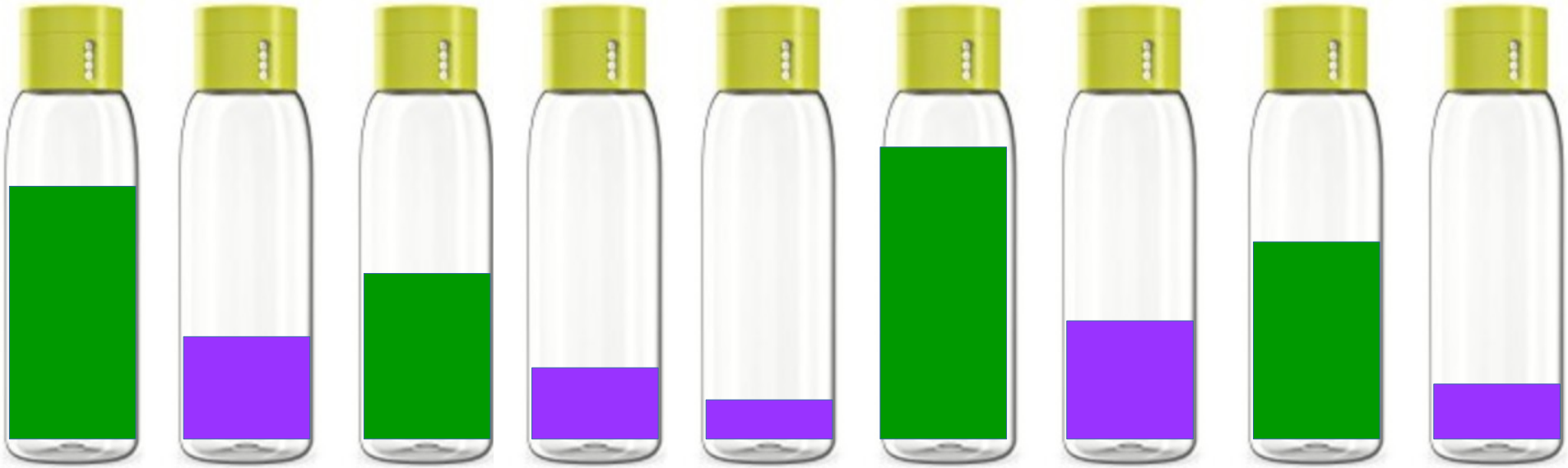
mod = lm(earn ~ height, data = pWages)

Basic Stats: T-Tests

- Suppose: We are the producers of two kinds o drinks: green and purple. Each drink comes in a bottle and we would like to know whether the green and the purple drink are filled to the same levels.
- We randomly select 9 bottles from our entire set of 100000 bottles

Basic Stats: T-Tests

- By inspection,
  - **Purple bottles seem a little under-filled**
  - **Green bottles seem a little over-filled**
- Can we use a statistical test to conclude whether the whole batch is under- or over-filled?



T-Test: Hypotheses

- We want to know: **Is there a statistically significant difference between the two groups in terms of the average extent to which the bottles are filled?**
  - **Null hypothesis (Ho)**: The bottles are filled the same
  - **Alternative hypothesis (Ha)**: There is a difference between the filling of bottles.
- Remember: we have a sample of only nine bottles from the super set of 100000 bottles. Statistics is used to extrapolate from the small set to the larger set.

Use *p*-Values

- The p-Value says that we are sure that our sample size that we randomly selected if a very good representation of our larger super set.
- 95 confidence interval range: Our selected bottled fit within 95 per cent of the entire set → a good representation of the whole set of 100000 bottles.
- **Reject the Null Hypothesis when p < 0.05** (when *p* is close to zero.)

Basic Stats: T-Tests

```
data_drinks <- data_drinks %>%
    select(Colour, percentFull)
#Run the t-test: a comparison of means.
t.test(data = data_drinks, percentFull ~ Colour)
```

 # Check the p-value:

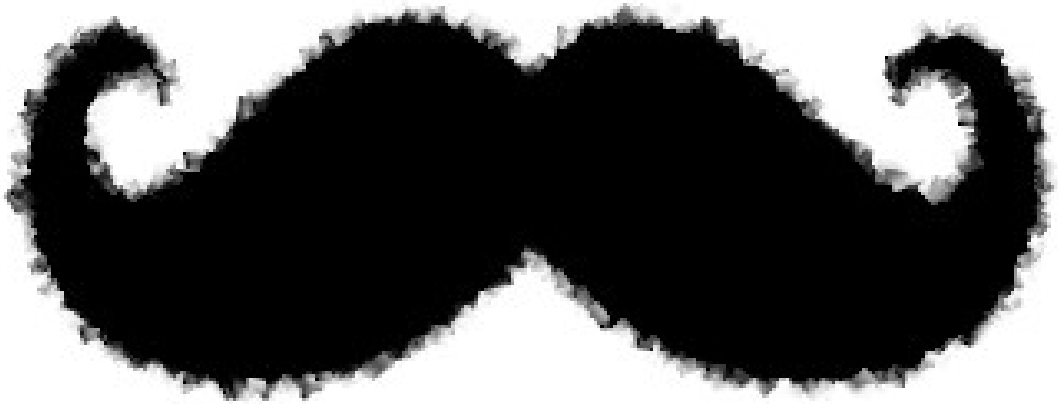
- **If p-val =< alpha = 0.05: reject H0.**
- **If p-val > alpha = 0.05: do not reject H0.**

- **What do we conclude about our *data_drinks*?**

What Did We NOT Cover!?

Now, Go Decorate Your Resume!!

It's Your Turn!



Now, Go Decorate Your Resume!!

We Would Have Covered Machine Learning...

- **Good Tutorials below**
- **Machine Learning in R for beginners**
  - https://www.datacamp.com/community/tutorials/machine-learning-in-r#five
- **Your First Machine Learning Project in R Step-By-Step**
  - https://machinelearningmastery.com/machine-learning-in-r-step-by-step/
- **Intro to Machine Learning with R & caret**
  - https://www.youtube.com/watch?v=z8PRU46I3NY
- **Machine learning with the "diabetes" data set in R**
  - https://towardsdatascience.com/machine-learning-with-the-diabetes-data-set-in-r-11fa7ae944d0

Files: `src/ML1.R` and `src/ML2.R`