Week 2: Data/Variable Types and ggplot

and statistics (as Opposed to "Upper Case" Staistics)

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Class Check Round 1

https://pollev.com/sta (6 questions)

Loading Data: Review

```
#install.packages("tidyverse")          <- not required since this is
library(tidyverse)                     # <- preinstalled on jupyterhub
```

```
# http://database.coffeeinstitute.org/
# https://github.com/rfordatascience/tidytuesday/blob/master/
#                     data/2020/2020-07-07
coffee_ratings <- read_csv("coffee_ratings.csv")
# the printout below is normal even though RStudio colors it red
```

```
## Rows: 1338 Columns: 36
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (18): species, owner, country_of_origin, farm_name, mill, company, altit...
## dbl (18): total_cup_points, aroma, flavor, aftertaste, acidity, body, balanc...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Viewing Data: Review

```
coffee_ratings %>% glimpse() # useful printout isn't actually a tibble
```

```
## Rows: 1,338
## Columns: 36
## $ total_cup_points     <dbl> 90.58, 89.92, 89.75, 89.00, 88.83, 88.83, 88.75, ~
## $ species              <chr> "Arabica", "Arabica", "Arabica", "Arabica", "Arab~
## $ owner                <chr> "metad plc", "metad plc", "grounds for health adm~
## $ country_of_origin    <chr> "Ethiopia", "Ethiopia", "Guatemala", "Ethiopia", ~
## $ farm_name            <chr> "metad plc", "metad plc", "san marcos barrancas \~
## $ mill                 <chr> "metad plc", "metad plc", NA, "wolensu", "metad p~
## $ company              <chr> "metad agricultural developmet plc", "metad agric~
## $ altitude             <chr> "1950-2200", "1950-2200", "1600 - 1800 m", "1800-~
## $ region               <chr> "guji-hambela", "guji-hambela", NA, "oromia", "gu~
## $ producer             <chr> "METAD PLC", "METAD PLC", NA, "Yidnekachew Dabess~
## $ in_country_partner   <chr> "METAD Agricultural Development plc", "METAD Agri~
## $ harvest_year         <chr> "2014", "2014", NA, "2014", "2014", "2013", "2012~
## $ grading_date         <chr> "April 4th, 2015", "April 4th, 2015", "May 31st, ~
## $ variety              <chr> NA, "Other", "Bourbon", NA, "Other", NA, "Other",~
## $ processing_method    <chr> "Washed / Wet", "Washed / Wet", NA, "Natural / Dr~
## $ aroma                <dbl> 8.67, 8.75, 8.42, 8.17, 8.25, 8.58, 8.42, 8.25, 8~
```

RStudio + knitter: An aside

```
coffee_ratings # %>% head() # %>% knitr::kable()
```

Since we use pdf output in STA130 we won't get into the weeds on this, but...

Table printouts in RStudio are excellent; not so much for pdf output; but for html there's

- https://bookdown.org/yihui/rmarkdown-cookbook/kable.html

  `knitr::kable()`
  you don't actually have to use `library(knitr)` if you use `knitr::`

- https://bookdown.org/yihui/rmarkdown-cookbook/kableextra.html

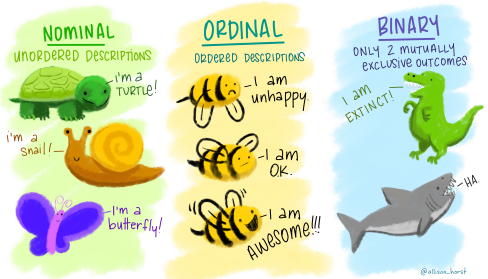
  ```
  library(kableExtra) # for even more control
  ```

Types of Data/Variables

All artwork thanks to @allison_horst!

Numerical/Quanitative

Categorical/Qualitative



What should these be called?

Data or *Variables*?

Binary Data/Variables

- **Binary** just means **two-level** (either/or) **categorical**

Binary can always be represented as **logical** (***boolean***) by just asking "Is it the first category? `TRUE` or `FALSE`?"

- Q: "Is this animal extinct?" A: `TRUE/FALSE`

So **binary/two-level** (either/or) **categorical** variables are equivalent to **logical** `TRUE/FALSE` (***boolean***) variables

Boolean Data/Variables

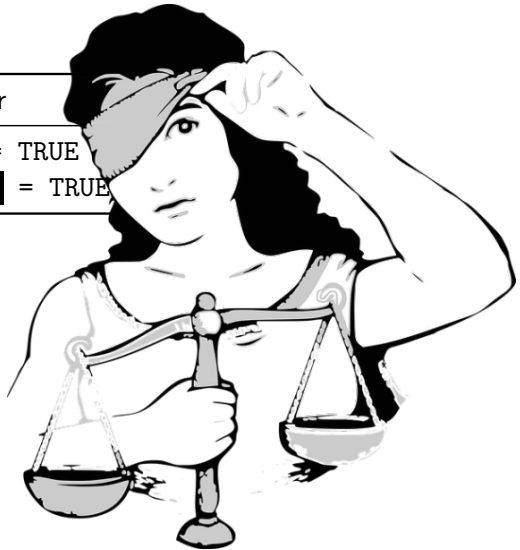
A `logical` type has "&" and "|" rules

"&" (and) operator	"|" (or) operator
`TRUE & TRUE = TRUE`	`TRUE | TRUE = TRUE`
`TRUE & FALSE = FALSE`	`TRUE | FALSE = TRUE`

Comparisons create `logical` types

- < or <= `123 < 1.23`
- > or >= `123 >= 1.23`
- == or != `123 != 1.23`

  `!(123 == 1.23)`
- `!!TRUE = !FALSE = TRUE`

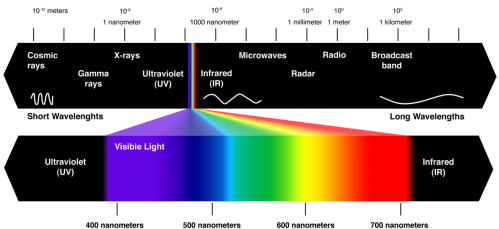


R Data/Variables

ALL R types **ARE** *"numbers"*; but, these exist on a Quantitative-Qualitative spectrum:

	1.23	123	TRUE/FALSE	as.factor("char str")
	Continuous	**Discrete/Ordinal**	**Binary**	**Nominal**
class	numeric	numeric	logical	factor
typeof	double	double	logical	integer
is.integer	FALSE	FALSE	FALSE	FALSE
	"float"	"integer"	"boolean"	"factor"

- 123 and 1.23 aren't different for R
- 123 $\equiv$ **Ordinal**; `factor` $\equiv$ **Nominal**
- R has `logical` **Binary** variables
- **Careful:** `class`, `typeof`, `integer` *have unexpected meanings in R...*



Class Check Round 2

https://pollev.com/sta (6 questions)

Changing R Data/Variables

"R alchemy" to change data types across the "R data type spectrum" is possible when sensible

```
as.character(1.23)   as.logical(as.numeric("0"))   as.numeric(FALSE)
as.numeric("1")      as.logical(as.numeric("1"))   as.numeric(TRUE)
```

which is actually exactly what `as.factor("char str")` **does!**

R does this automatically, sometimes.
When it does it's called ***coercion***:

```
TRUE + 1.23    paste(TRUE + 1.23," = 2.23")
FALSE == 1     paste(TRUE, " = 1")
```

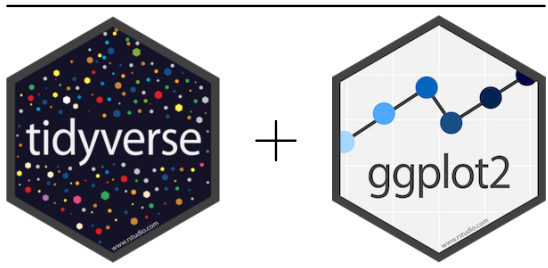
⟵ You can guess/figure out what the `paste` function does, right?

Class Check Round 3

https://pollev.com/sta (3 questions)

Visualizing Different Data Types with ggplot2

`library(ggplot)`



Why care about data types? *So we use the appropriate visualization for each type.*

ggplot2 is part of the tidyverse. Standard usage is based on a grammar of graphics, and there are many learning resources available (including the R4DS textbook, the official cheatsheet, and the DoSS Toolkit)! A big recommendation and hint though (as usaul – but this time from `ggplot2` itself) is to search and find answers online!

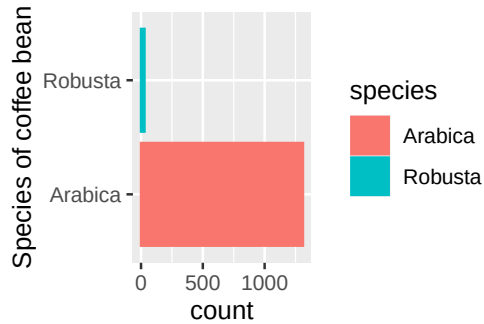
Data Types and their ggplots

```
# Code chunk figure/text ratio options: fig.height=2, fig.width=3
ggplot(data=coffee_ratings, # difference between `color` & `fill`?
       aes(x=species, color=species, fill=species)) +
  geom_bar() + labs(x="Species of coffee bean") + coord_flip()
```

1. What kind of variable is species?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

2. A **barplot** (geom_bar) is NOT an appropriate visualization for what variable type?



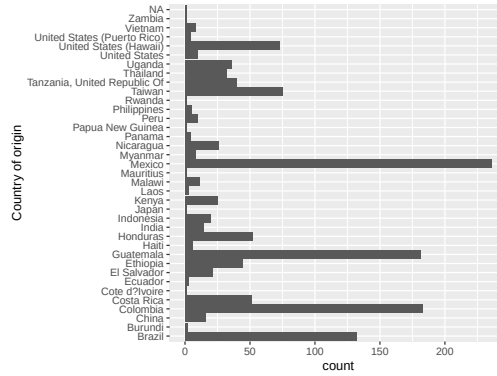
Data Types and their ggplots

```
# Code chunk figure/text ratio options: fig.height=4.5, fig.width=6
coffee_ratings %>% ggplot(aes(x=country_of_origin)) +
  geom_bar() + labs(x="Country of origin") + coord_flip()
# Can this visualization be improved? Hint: google "order geom_bar"
```

1. What kind of variable is `country_of_origin`?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

2. What are interesting features of this **barplot** (`geom_bar`) compared to the last?



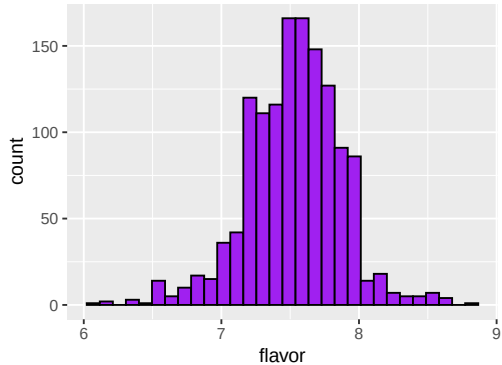
Data Types and their ggplots

```
# Code chunk figure/text ratio options: fig.height=3, fig.width=4
coffee_ratings %>% ggplot(aes(x=flavor)) +
  geom_histogram(bins=30, color="black", fill="blue")
# What's the `bins` parameter do? What's the right choice for `bins`?
```

1. What kind of variable is `flavor`?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

2. A **histogram** (`geom_histogram`) is an appropriate visualization for what variable type?



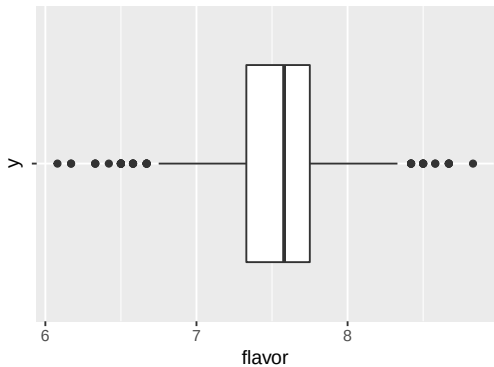
Data Types and their ggplots

```
# Code chunk figure/text ratio options: fig.height=3, fig.width=4
coffee_ratings %>% ggplot(aes(x=flavor, y="")) + geom_boxplot()
# How does this code differ from the code for `geom_histogram()`?
```

1. A **boxplot** (geom_boxplot) is an appropriate visualization for what variable type?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

2. Why is the middle line of the box plot located more towards the right?

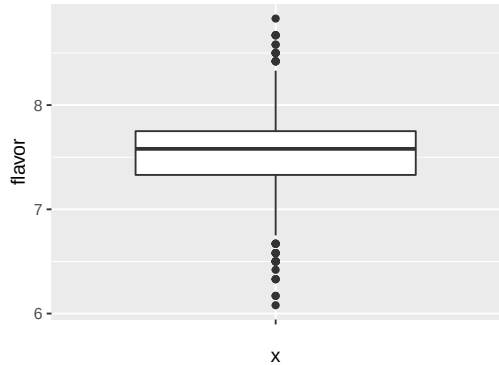


Data Types and their ggplots

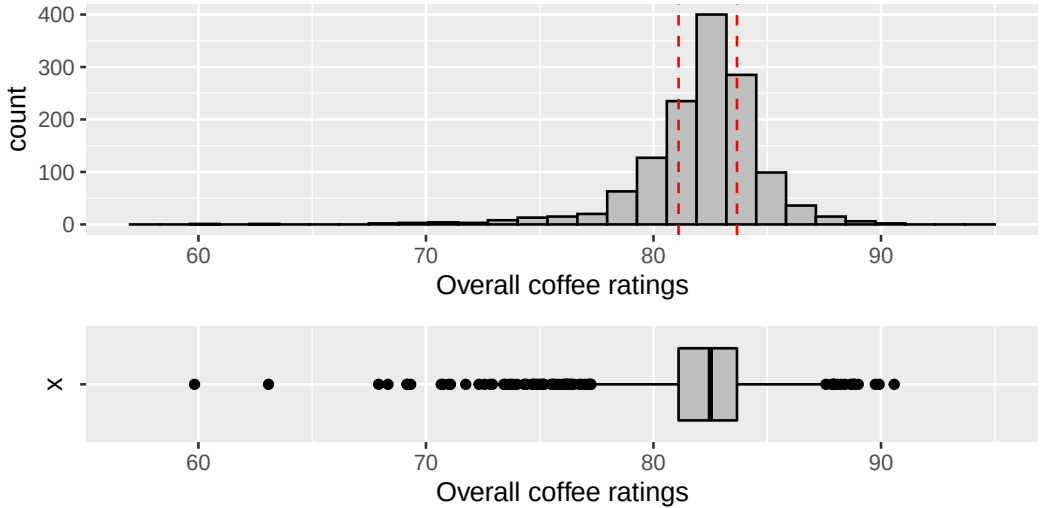
```
# Code chunk figure/text ratio options: fig.height=3, fig.width=4
coffee_ratings %>% ggplot(aes(x="", x=flavor)) + geom_boxplot()
# Something changed? What? And do you like it better? Why or why not?
```

Boxplot (geom_boxplot) components

1. Median (50th data percentile)
2. Interquartile range (IQR) box (25th to 75th data percentiles)
3. Whiskers cover farthest "outliers" <= 1.5*IQR from the "IQR box"
4. "Outliers" are the data points more extreme than the above rule

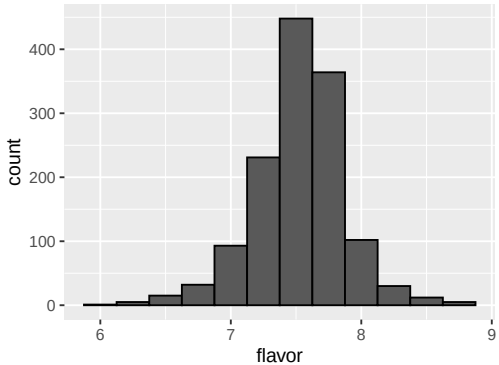


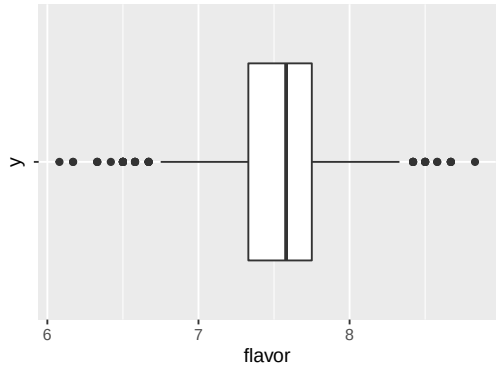
Histograms Versus Boxplots



Histograms Versus Boxplots

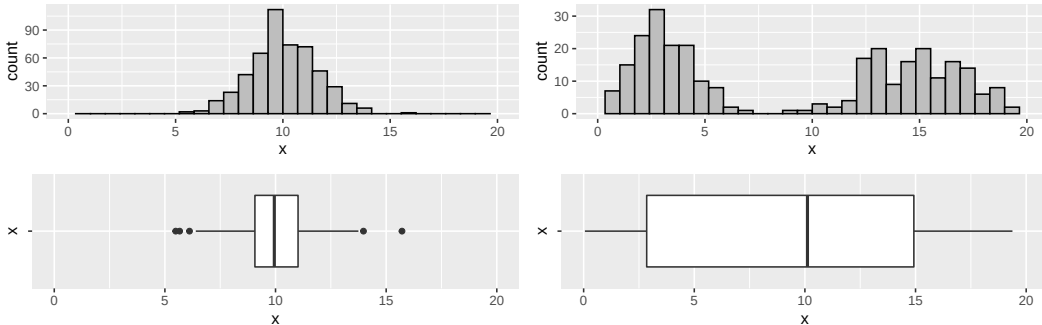
```
# Code chunk figure/text ratio options: fig.height=3, fig.width=4
geom_histogram(bins=12, color="black") VERSUS geom_boxplot()
# What reasons are there to prefer boxplots over histograms, if any?
```





Which do you like better?

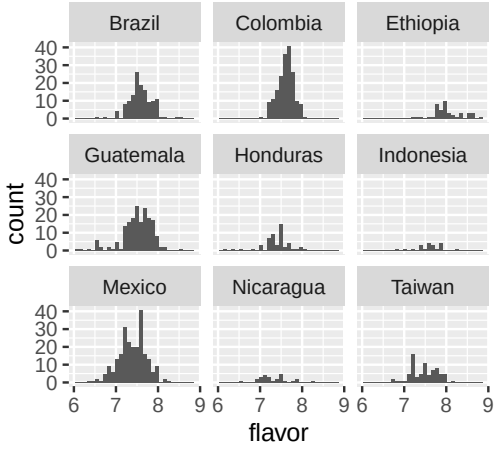
```
# Code chunk figure/text ratio options: fig.height=3.2
geom_histogram(bins=30, color="black", fill="gray") VERSUS geom_boxplot()
```



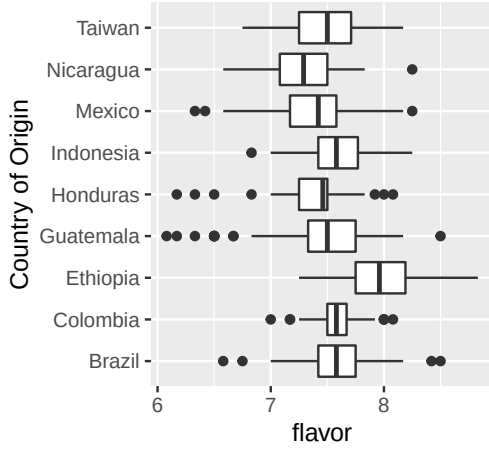

```
library(gridExtra) # gives functionality to arrange the plots as above
library(egg) # also gives functionality to arrange the plots as above
```

Which do you like better?

(Google "free yaxis facet_wrap")



(But what is this missing?)



Why would this be important?

(First Order) Distributional Characteristics: Center/Location statistics

Median: 50^{th} percentile of the data

- Half of the data is less than or equal to the median
- Half of the data is greater than or equal to the median

Mean: the average value in the data

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Mode: the most frequent data value

1. What happens to the **Median**/**Mean** as the largest data point increases? *Is the **Median** or **Mean** more "robust" relative to the largest data point?*

2. For which type of variable is the **Mode** the least meaningful? Why?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

(Second Order) Distributional Characteristics: Spread/Scale statistics

IQR (from the **boxplot**):
75^{th} percentile $-$ 25^{th} percentile

Range:
$\max_{i=1,\cdots,n} x_i \quad - \quad \min_{i=1,\cdots,n} x_i$

Variance: (almost)
average squared distance from mean

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

Standard Deviation:
Square root of the **Variance**

$$s = \sqrt{s^2}$$

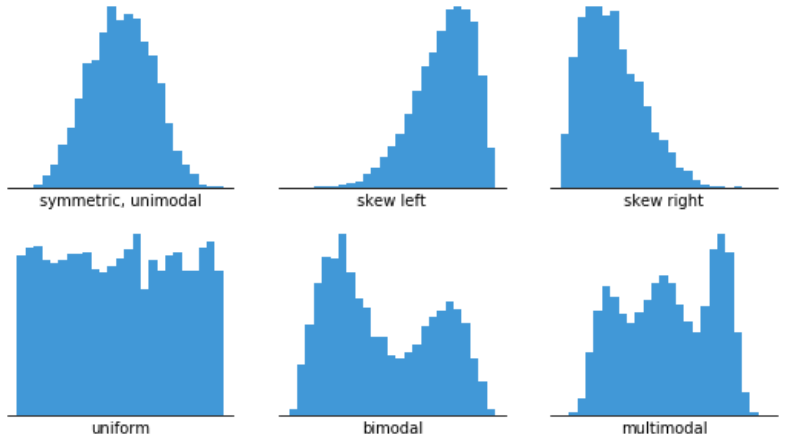
Squared Units... don't mean much

"Average 'squared distance' "?

Original Units... are interpretable

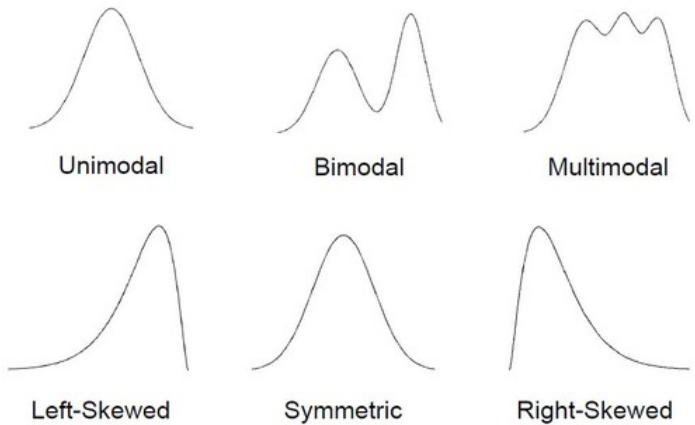
& range is often $\sim$ 5 standard deviations

(Higher Order) Distributional Characteristics: Skewness + Modality



https://chartio.com/learn/charts/histogram-complete-guide/

(Higher Order) Distributional Characteristics: Skewness + Modality



https://quizlet.com/au/178077005/mm2-stats-flash-cards/

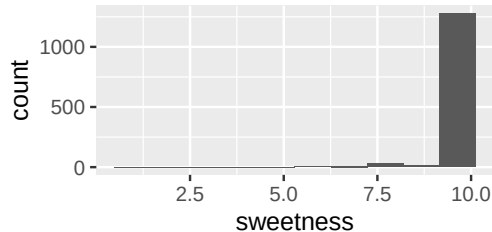
Review Quiz

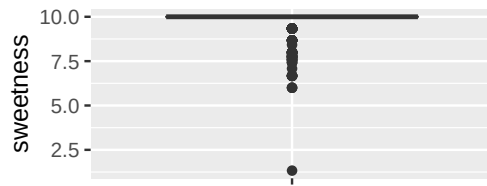
1. What kind of variable is `sweetness`?

   A. Nominal Categorical
   B. Ordinal Categorical
   C. Continuous
   D. Boolean

   Is it

2. **symmetric**, **left**, or **right-skewed**?
3. **unimodal**, **bimodal**, or **multimodal**?
4. What's the approximate distributional **Median**, **Mean**, and **Mode**?





Self-Quiz

Ask Yourself...

1. What's the difference between continuous numerical / discrete numerical / nominal categorical / ordinal categorical / binary / logical (boolean) Data types?
2. What's the difference between data and a variable?
3. What's the difference between data and a distribution?
4. What is the difference between `geom_`'s `bar`, `histogram`, and `boxplot`?
5. Do you know how to make them in R, and place (and size them) in RStudio?
6. Do you know how to put multiple `boxplots` in the same `ggplot2` figure?
7. Do you know the `mean`, `median`, `range`, `IQR`, `var`, and `sd` statistics R functions?
8. Can you visually describe data distributions based on their data types, visualizations, the above statistics (or their rough approximations), and characterizations of their ***modality***, ***skewness*** and, ***outliers***?

Describing Numerical/Categorical Distributions

Focus of this weeks Problem Set and TUT

- What is the shape of the data and where is it located? Where is it's center?
- For categorical data, which category occurred the most and least frequently?
- Is the observed data concentrated near a particular value or category?
- What are the mean, median, mode of data or a distribution, and what makes them different?
- Is it symmetric, with the data centered in the middle?
- What is the standard deviation and interquartile range of data or a distribution?
- Is it left-skewed (with a long left tail and the data mostly to the right of this)?
- Is it right-skewed (with a long right tail and the data mostly to the left of this?)
- How much spread is there in the data (and relative to what)?
- Are the tails of the distribution heavy-tailed, potentially producing lots of outliers?
- Are there any outliers, i.e., extreme values in a data set?
- Are the tails of the distribution thin-tailed, so the data doesn't really produce outliers?
- Is the data or distribution unimodal, bimodal, multimodal, or uniform?
- If there are modes, how many are there and where are they?

Rstudio Demo

1. Click this jupyterhub repo launcher link