STAT 200:
Introduction to Data Science with R

Descriptive Statistics and Visualizing Distributions

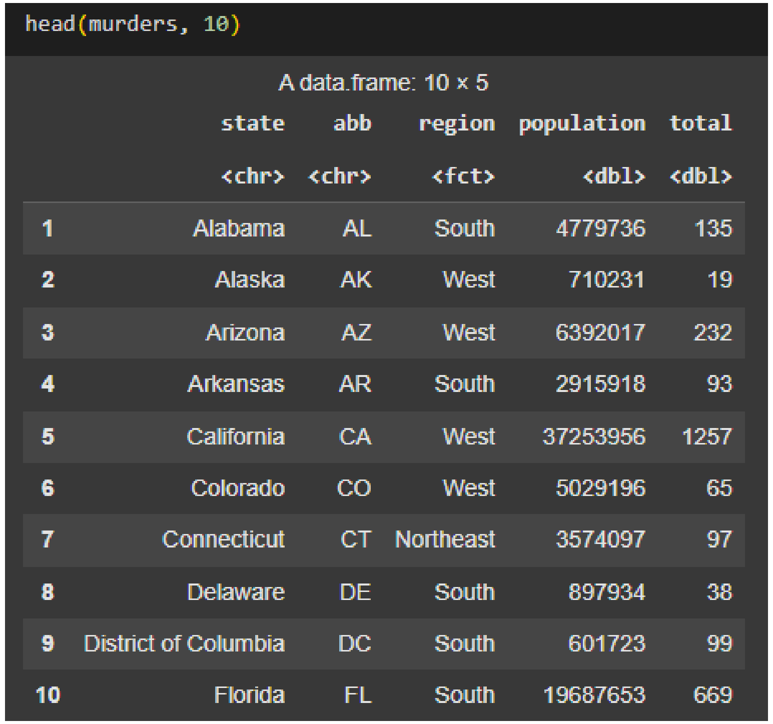
SDSU | San Diego State University

Department | Mathematics and Statistics
Division | Statistics and Data Science

Descriptive Statistics

Descriptive Statistics

- The first step in any data analysis is to gain an understanding of the data itself



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10               Florida    FL      South    19687653    669
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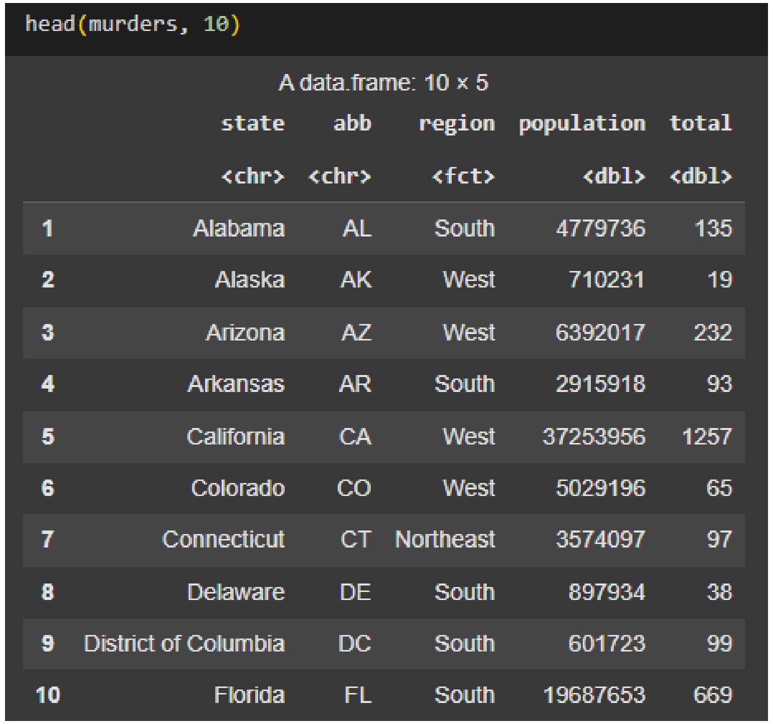
Descriptive Statistics

- The first step in any data analysis is to gain an understanding of the data itself

- We do this by loading our data into some program (e.g., R, Excel) and exploring it various attributes
  - Number of observations
  - Number of variables
  - Identify errors in data entry
  - Identify missing values
  - etc.



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  2. Data visualizations

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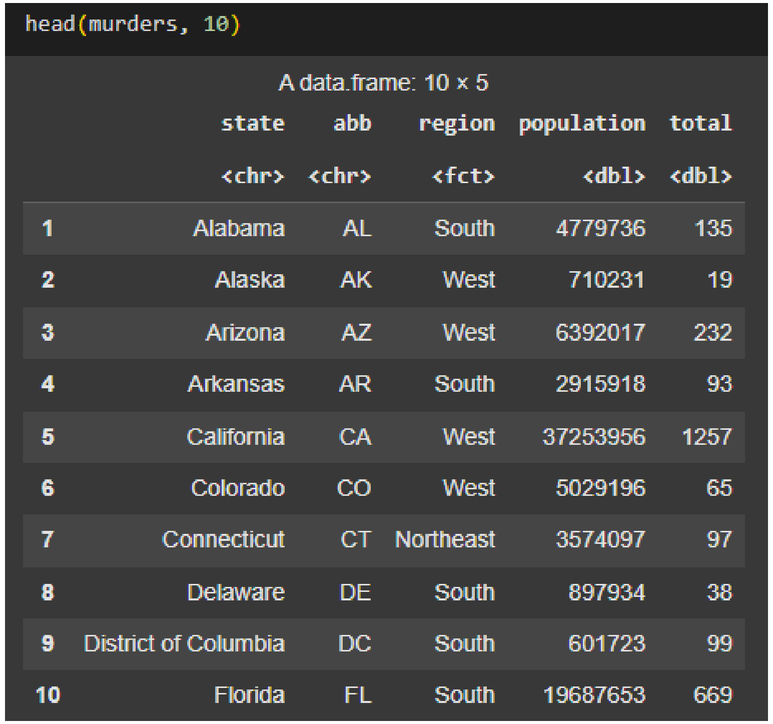
- We use different descriptive statistics and data visualizations for different types of data
  - Numeric data
  - Categorical data

Descriptive Statistics – Types of Data – Numeric

What is numeric data?



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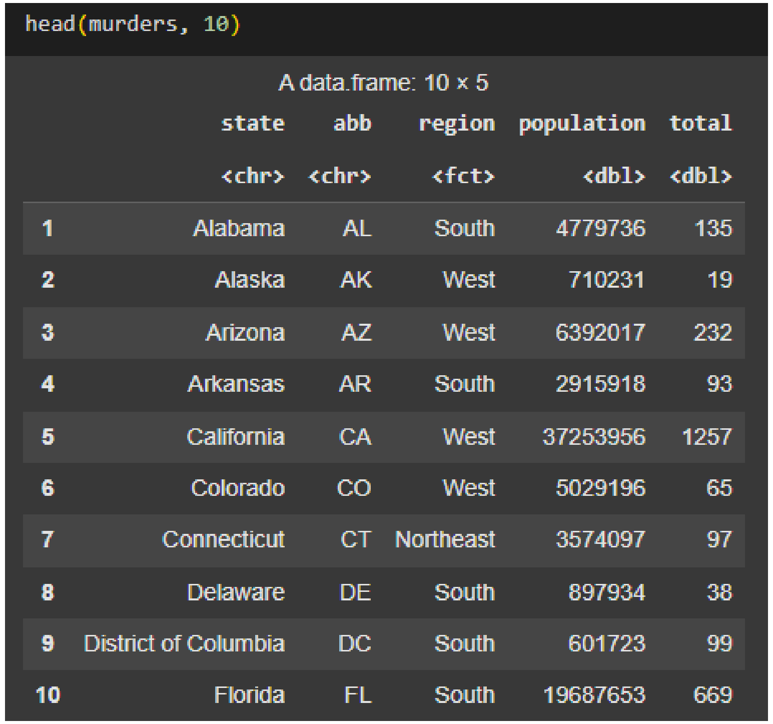
Descriptive Statistics – Types of Data – Numeric

What is numeric data?

- Data consisting of numbers that are either discrete or continuous



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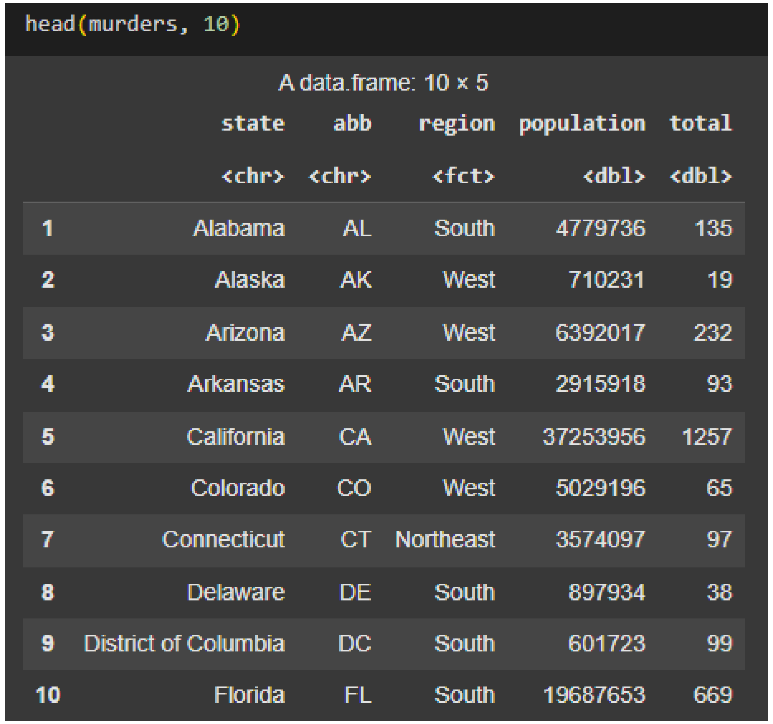
- Data consisting of numbers that are either discrete or continuous
- Discrete data consist of numeric values that are distinct and countable, typically integer-valued data
  - e.g., population
  - e.g., number of students in a classroom



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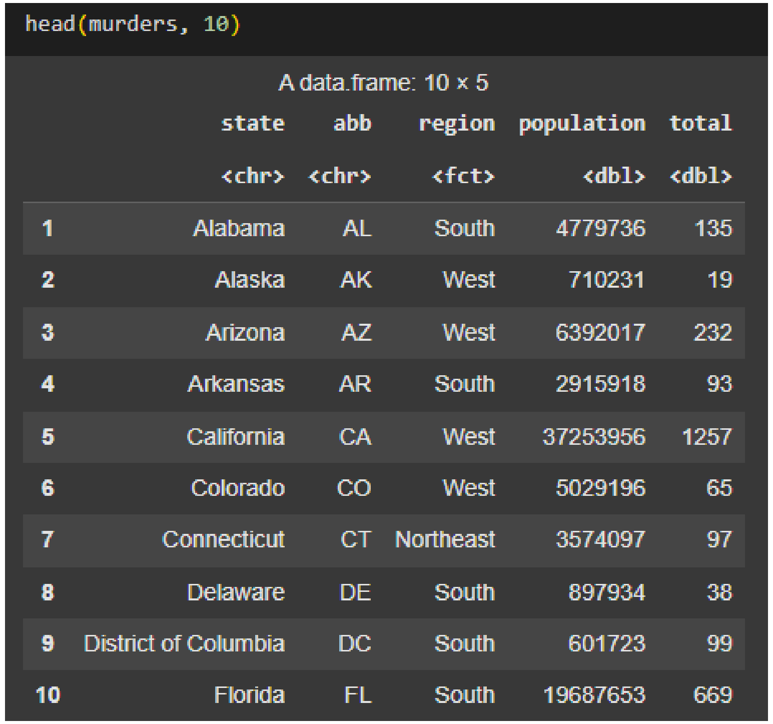
- Data consisting of numbers that are either discrete or continuous
- Discrete data consist of numeric values that are distinct and countable, typically integer-valued data
  - e.g., population
  - e.g., number of students in a classroom
- Continuous numeric data is quantitative data, typically represented by a fraction or decimal
  - e.g., temperature of 98.6 degrees Fahrenheit
  - e.g., time of 2.84 seconds



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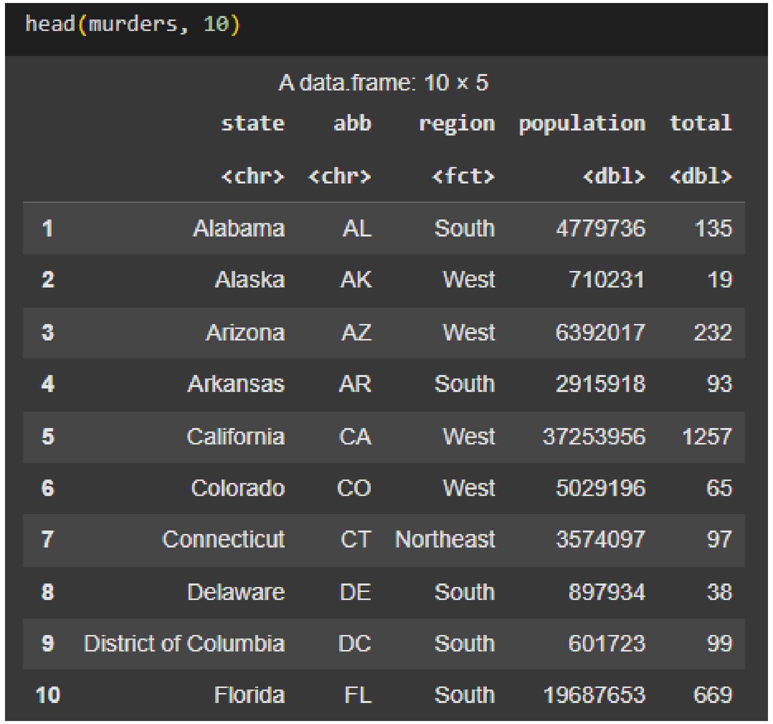
Descriptive Statistics – Types of Data – Categorical

What is categorical data?



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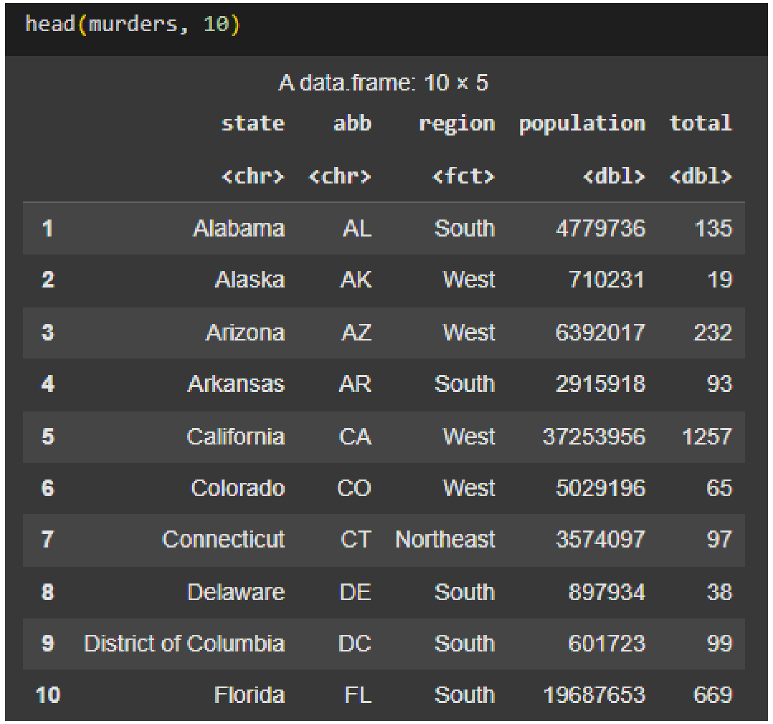

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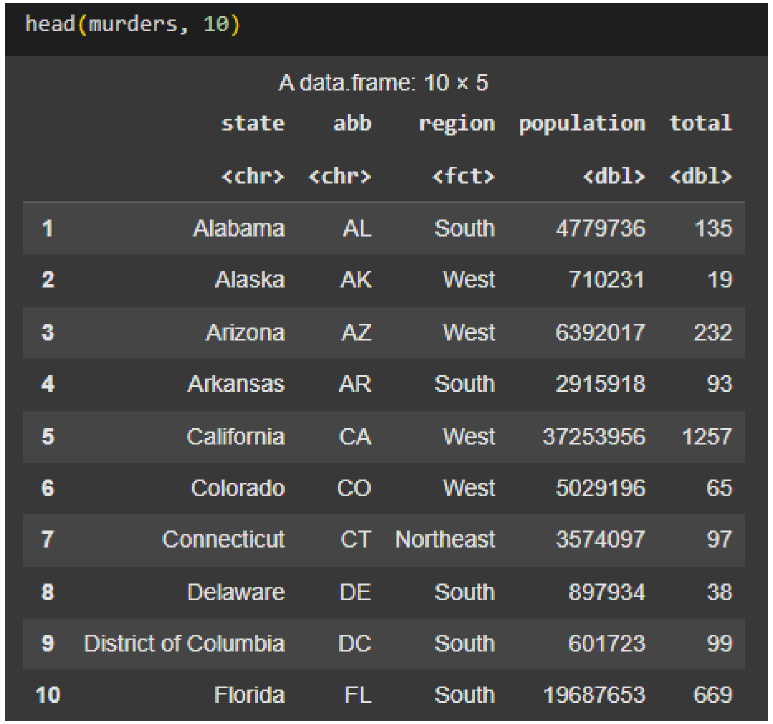
What is categorical data?

- Data divided into distinct groups or categories
- Two types of categorical data
  - Nominal
  - Ordinal



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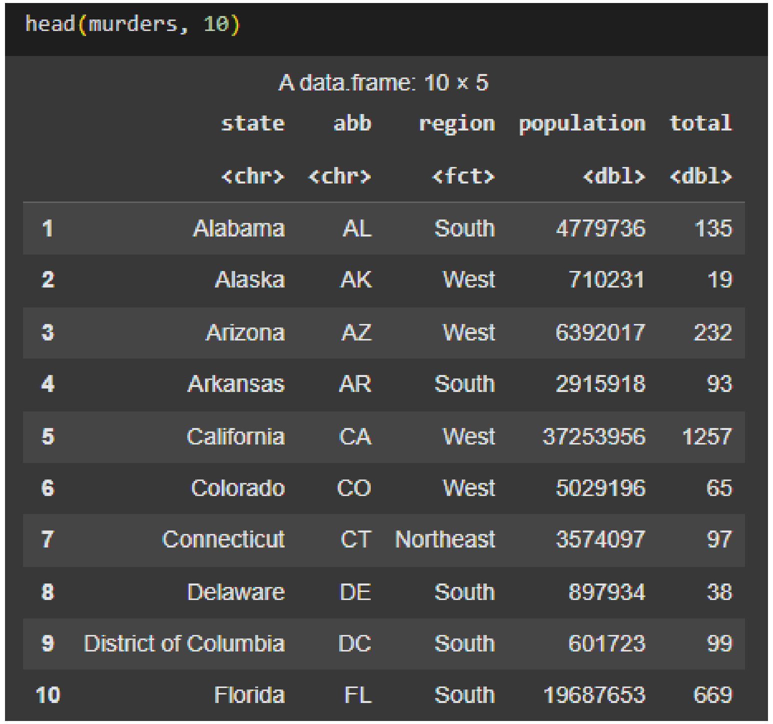

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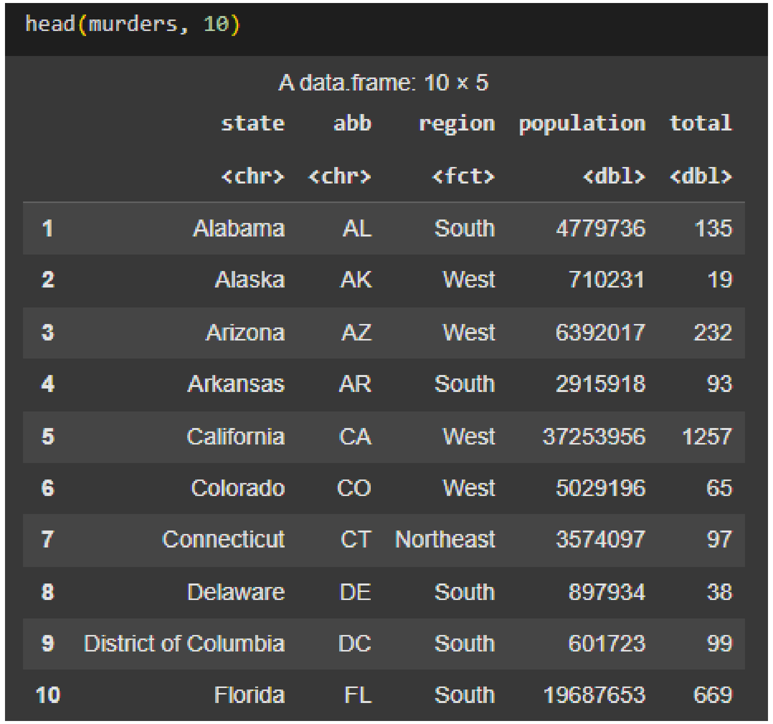

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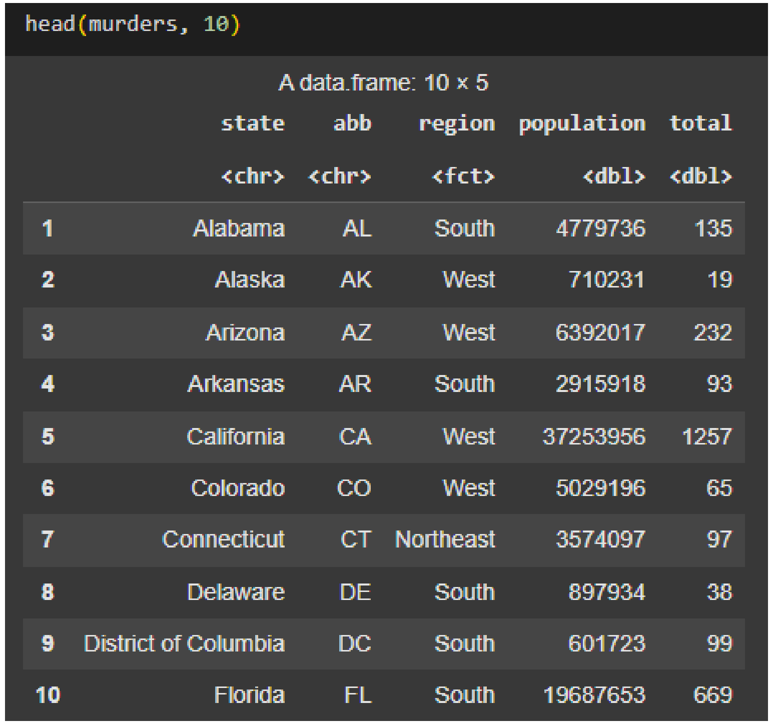

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Note that discrete numeric data can be considered ordinal!

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  - Range
  - Variance
  - Standard deviation
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<u>These were likely covered in your high school courses, but I will review them here!</u>

Descriptive Statistics:

Measures of Central Tendency

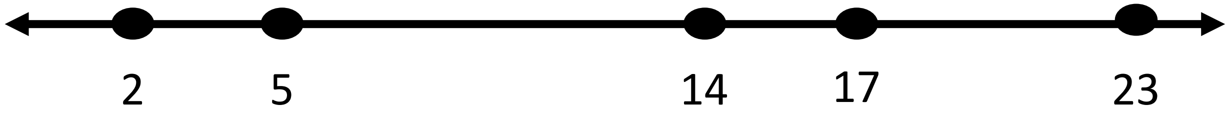
Descriptive Statistics – Numeric Data – Mean

- Consider the following data on the amount of emphysema in the lungs

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

Descriptive Statistics – Numeric Data – Mean

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



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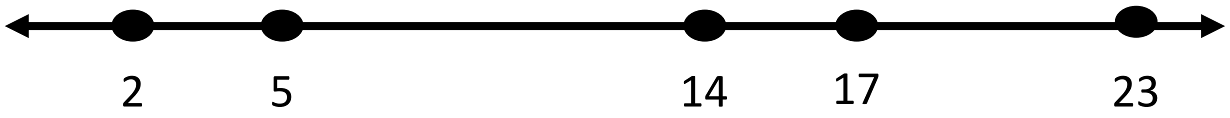

- The mean is a measure of the center of these observations

mean = sum of values / number of values

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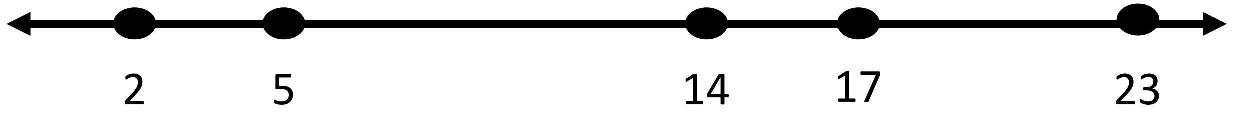

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- What is the mean of the variable percentage emphysema?

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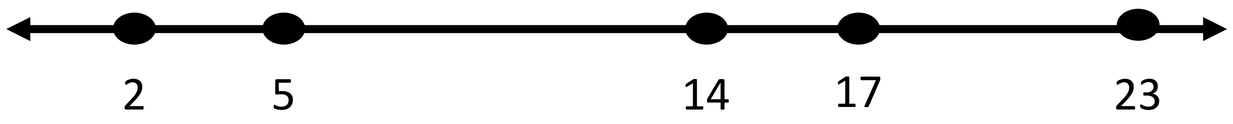

- The mean is a measure of the center of these observations

mean = sum of values / number of values

- What is the mean of the variable percentage emphysema?

(5 + 23 + 2 + 14 + 17 + 14) / 6 = 12.5%

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1	5
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6	14

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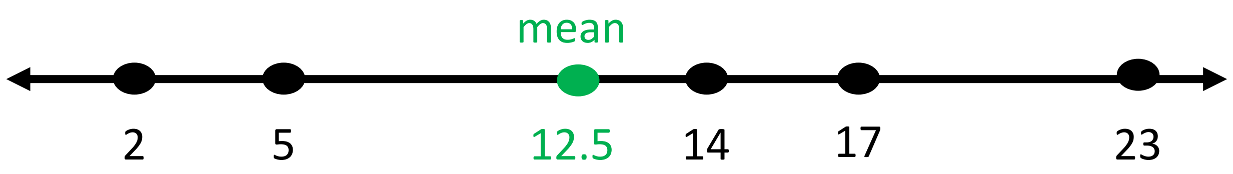

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- What is the mean of the variable percentage emphysema?

(5 + 23 + 2 + 14 + 17 + 14) / 6 = 12.5%

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4	14
5	17
6	14

Descriptive Statistics – Numeric Data – Median

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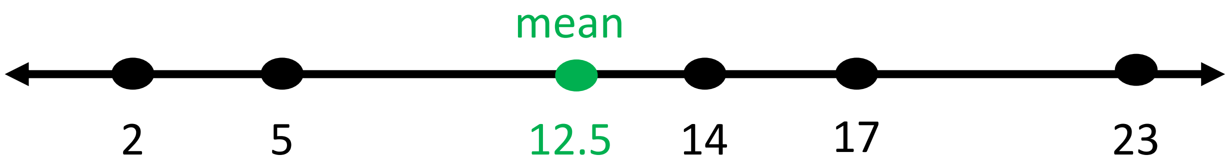

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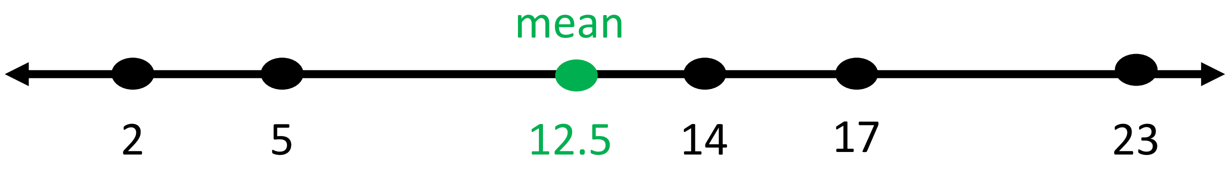

- The median is the value such that half the data is above and half the data is below

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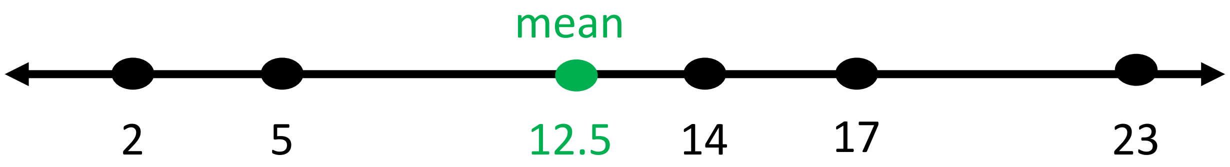

- The median is the value such that half the data is above and half the data is below
- To find the median
  1. Rank the data – 2, 5, 14, 14, 17, 23

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1	5
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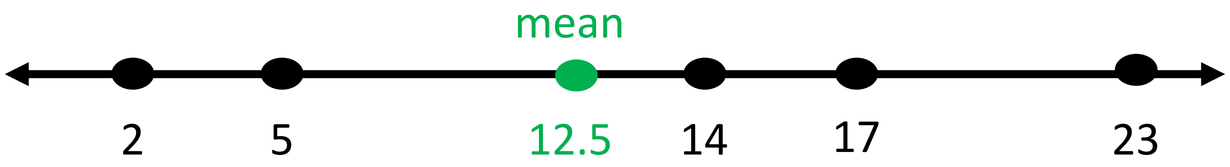

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- To find the median
  1. Rank the data – 2, 5, 14, 14, 17, 23
  2. Find the “middle” number
     - If there is an even number of data points, average the two middle numbers

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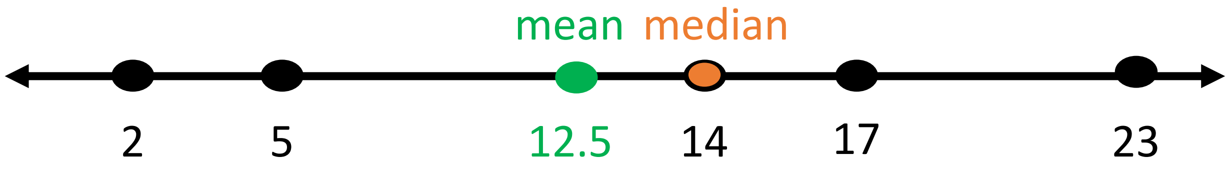

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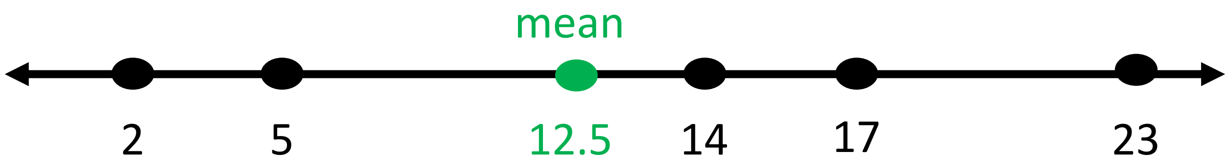
- To find the median
  1. Rank the data – 2, 5, 14, 14, 17, 23
  2. Find the "middle" number
     - If there is an even number of data points, average the two middle numbers

- The median is 14
  - Half the data points are greater than 14 and half are less than 14

Descriptive Statistics – Numeric Data – Mode

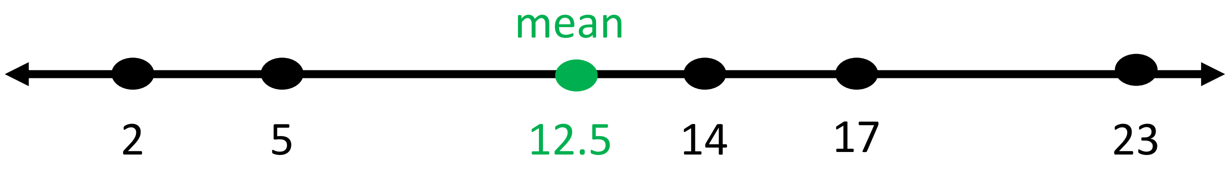
- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

Descriptive Statistics – Numeric Data – Mode

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line

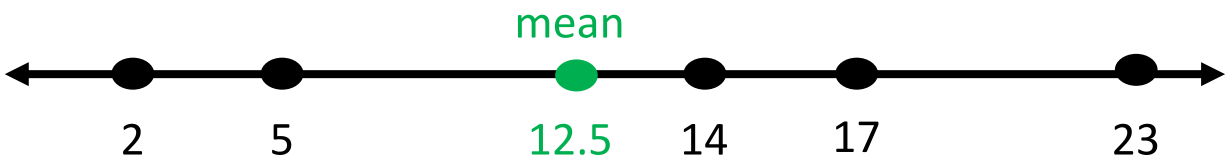


- The mode is the value that appears most often

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

Descriptive Statistics – Numeric Data – Mode

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line

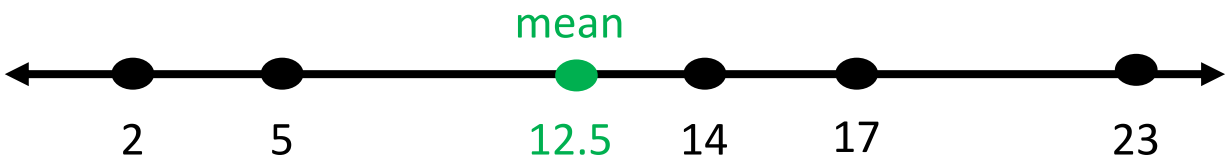


Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

- The mode is the value that appears most often
- To find the mode
  1. Count the occurrence of each value
  2. Choose the value with the largest occurrence

Descriptive Statistics – Numeric Data – Mode

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



- The mode is the value that appears most often

- To find the mode
  1. Count the occurrence of each value
  2. Choose the value with the largest occurrence

- What is the mode of percentage emphysema?

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
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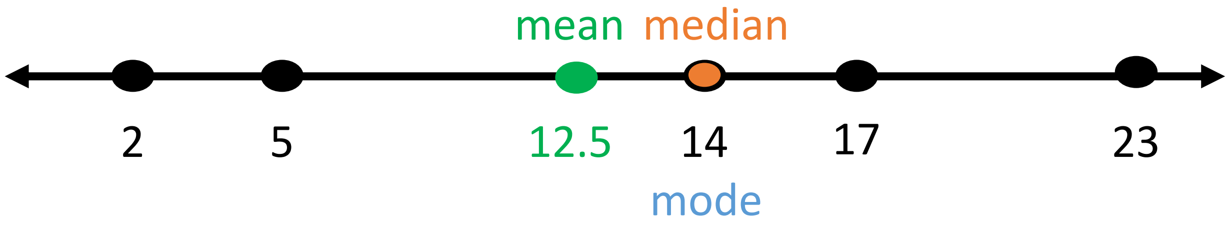
Descriptive Statistics – Numeric Data – Mode

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



- The mode is the value that appears most often

- To find the mode
  1. Count the occurrence of each value
  2. Choose the value with the largest occurrence

- What is the mode of percentage emphysema?
  - 14 since this value occurs 2 times
  - All other values occur less than 2 times

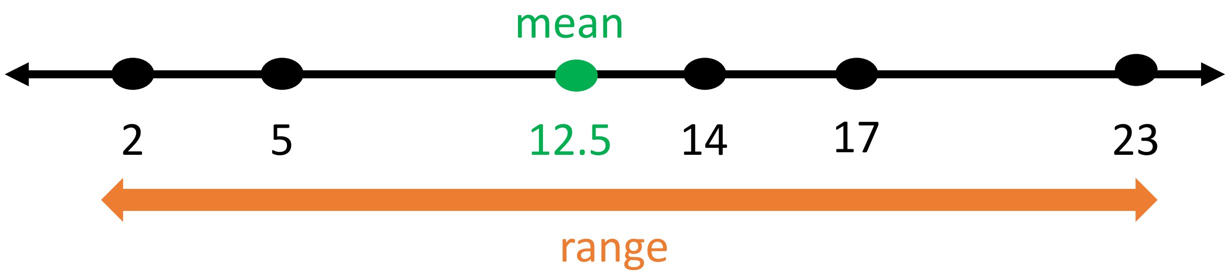
Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

Descriptive Statistics:

Measures of Variability

Descriptive Statistics – Numeric Data – Range

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line

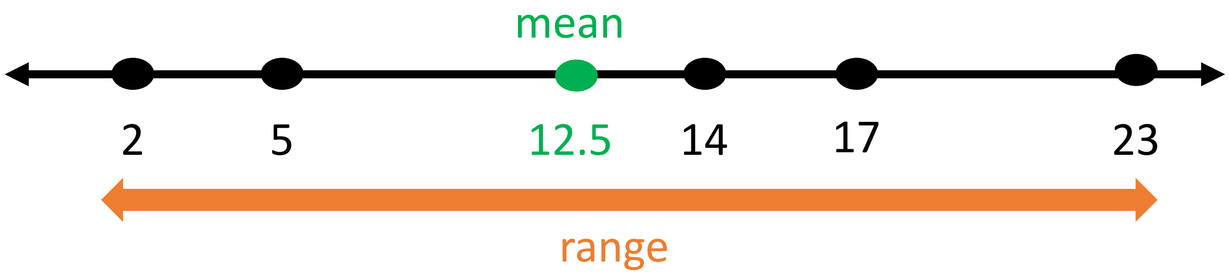


Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17
6	14

- The **range** is the maximum – minimum

Descriptive Statistics – Numeric Data – Range

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



- The **range** is the maximum – minimum
- The range measures the dispersion (spread) of the data

Patient	Percentage Emphysema
1	5
2	23
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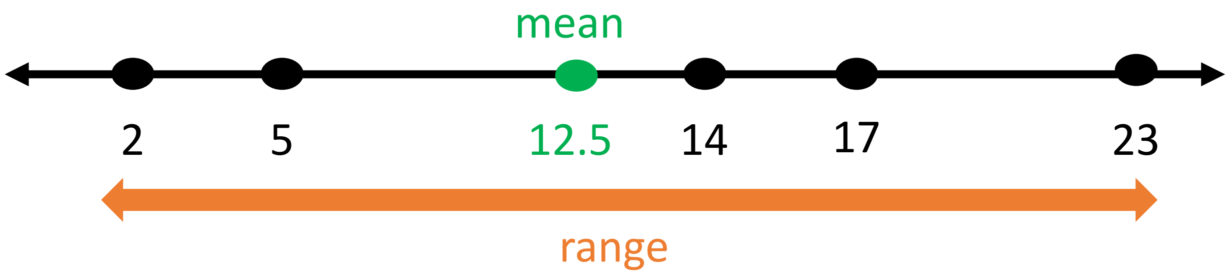
Descriptive Statistics – Numeric Data – Range

- Consider the following data on the amount of emphysema in the lungs
- We can represent the percentage emphysema on the number line



- The **range** is the maximum – minimum
- The range measures the dispersion (spread) of the data
- What is the range of percentage emphysema?

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- Consider the following data on the amount of emphysema in the lungs
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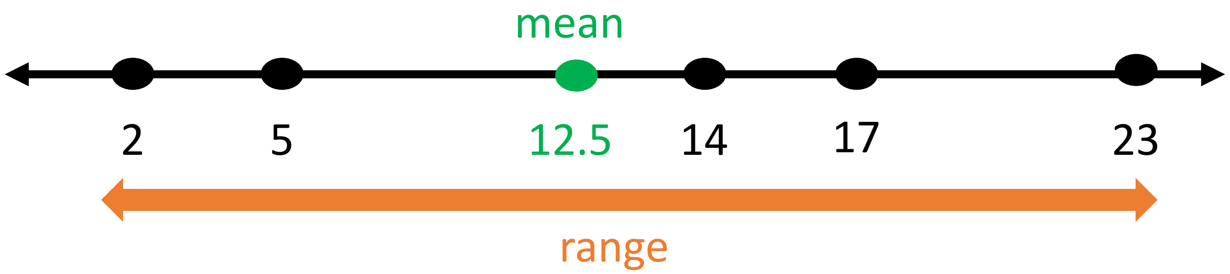

Patient	Percentage Emphysema
1	5
2	23
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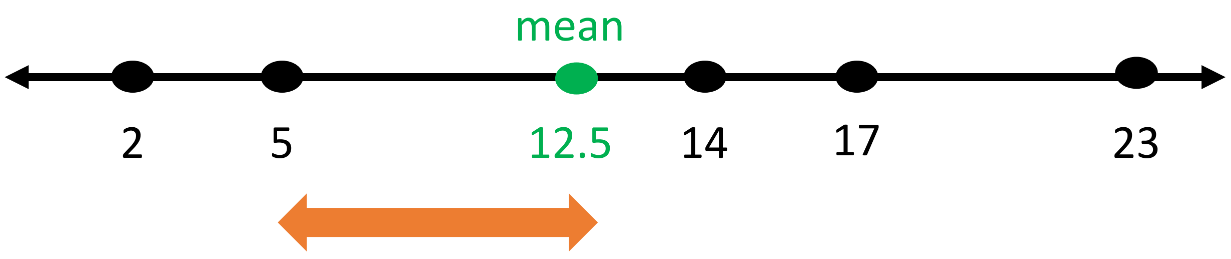
- The **range** is the maximum – minimum
- The range measures the dispersion (spread) of the data
- What is the range of percentage emphysema?

range = max – min = 23 – 2 = 21%

Descriptive Statistics – Numeric Data – Variance

- **Variance** is another measure of dispersion

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
3	2	-10.5	110.25
4	14	1.5	2.25
5	17	4.5	20.25
6	14	1.5	2.25
		Total:	301.5
		Total/(6-1):	60.3



5 – 12.5 = -7.5

Descriptive Statistics – Numeric Data – Variance

- **Variance** is another measure of dispersion
- Unlike range, variance is calculated from all data points (more informative)

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
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4	14	1.5	2.25
5	17	4.5	20.25
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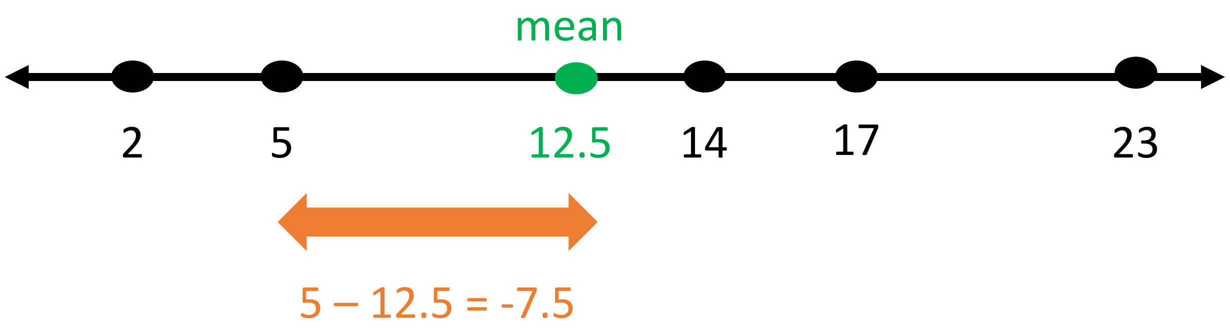

Descriptive Statistics – Numeric Data – Variance

- **Variance** is another measure of dispersion
- Unlike range, variance is calculated from all data points (more informative)
- Variance is the average sum of squared distances from the mean

Patient	%emph	%emph - mean	(%emph – mean)^2
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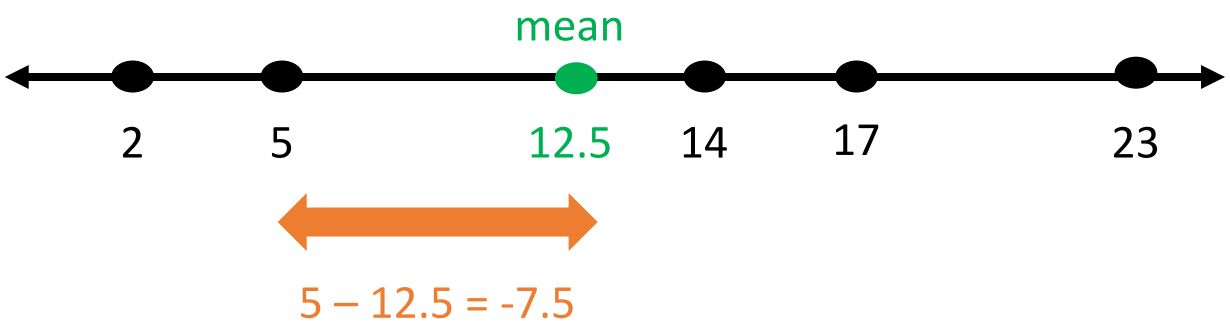

Descriptive Statistics – Numeric Data – Variance

- **Variance** is another measure of dispersion
- Unlike range, variance is calculated from all data points (more informative)
- Variance is the average sum of squared distances from the mean
  1. Subtract the mean from each point

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
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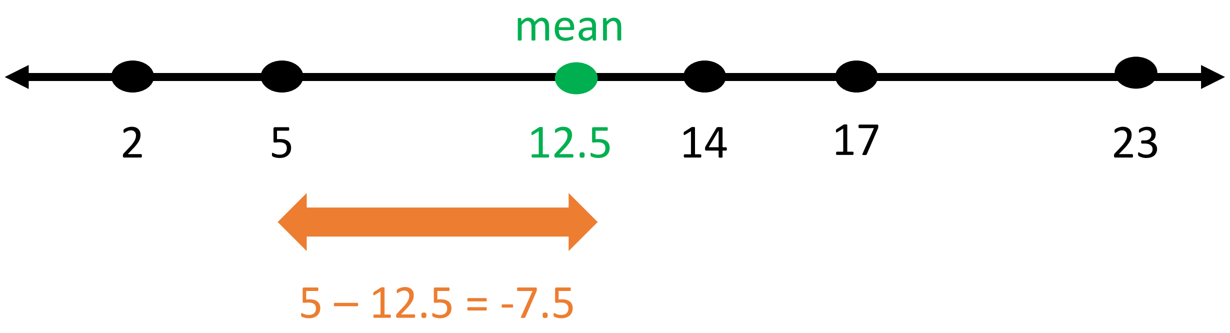

Descriptive Statistics – Numeric Data – Variance

- **<u>Variance</u>** is another measure of dispersion
- Unlike range, variance is calculated from all data points (more informative)
- Variance is the average sum of squared distances from the mean
  1. Subtract the mean from each point
  2. Square each difference

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
3	2	-10.5	110.25
4	14	1.5	2.25
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6	14	1.5	2.25
		Total:	301.5
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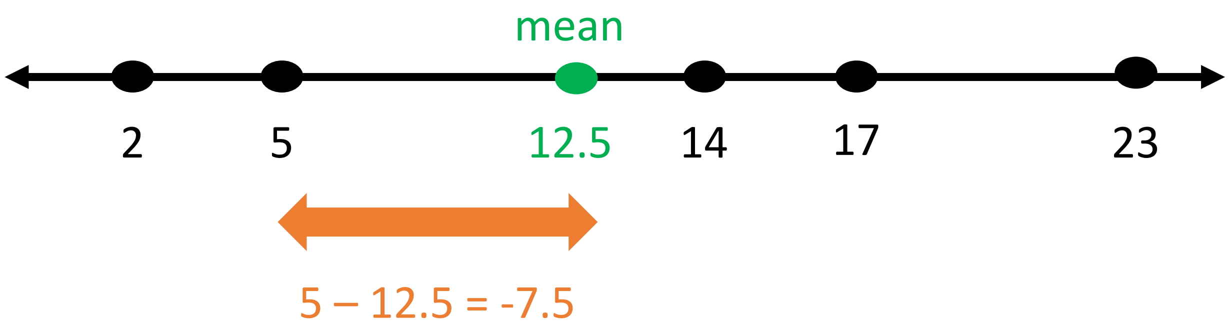

Descriptive Statistics – Numeric Data – Variance

- **<u>Variance</u>** is another measure of dispersion
- Unlike range, variance is calculated from all data points (more informative)
- Variance is the average sum of squared distances from the mean
  1. Subtract the mean from each point
  2. Square each difference
  3. Add the squared differences

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
3	2	-10.5	110.25
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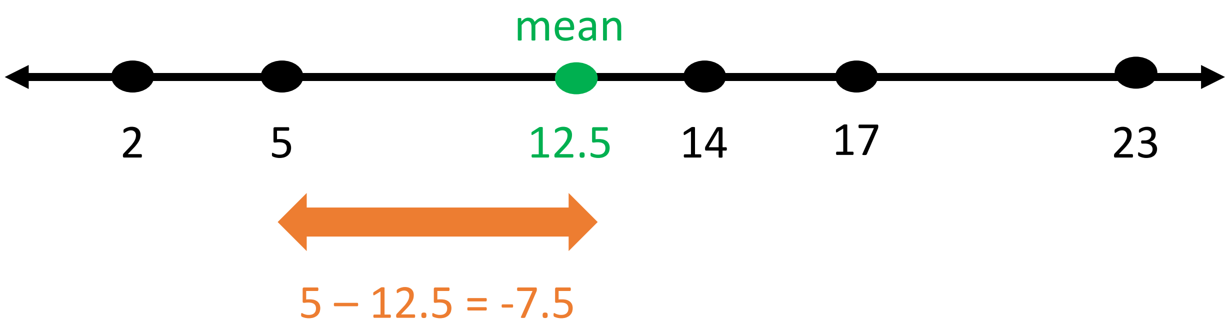

Descriptive Statistics – Numeric Data – Variance

- **Variance** is another measure of dispersion

- Unlike range, variance is calculated from all data points (more informative)

- Variance is the average sum of squared distances from the mean
  1. Subtract the mean from each point
  2. Square each difference
  3. Add the squared differences
  4. Divide the sum by the number of points minus one

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
3	2	-10.5	110.25
4	14	1.5	2.25
5	17	4.5	20.25
6	14	1.5	2.25
		Total:	301.5
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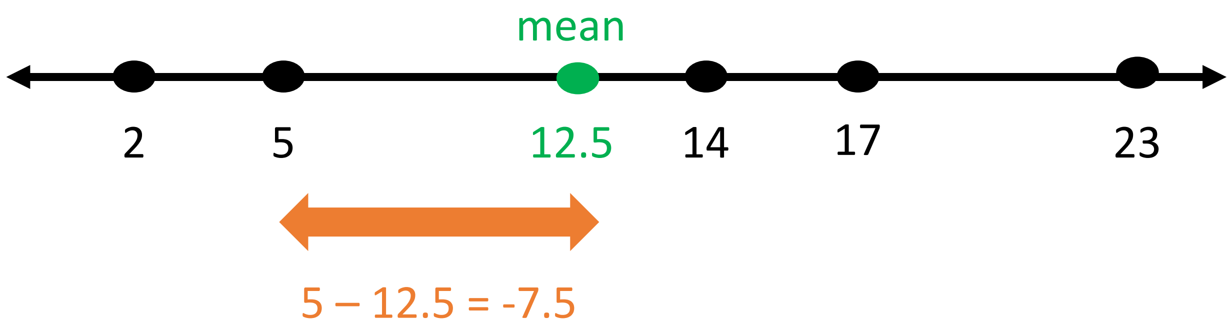

Descriptive Statistics – Numeric Data – Standard Deviation

- **Standard deviation** is the square root of the variance
- Since variance squares the units (%^2 in this case), we take square root to convert back to original units (%)

$$SD = \sqrt{Var} = \sqrt{60.3} = 7.77\%$$

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
3	2	-10.5	110.25
4	14	1.5	2.25
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		Total:	301.5
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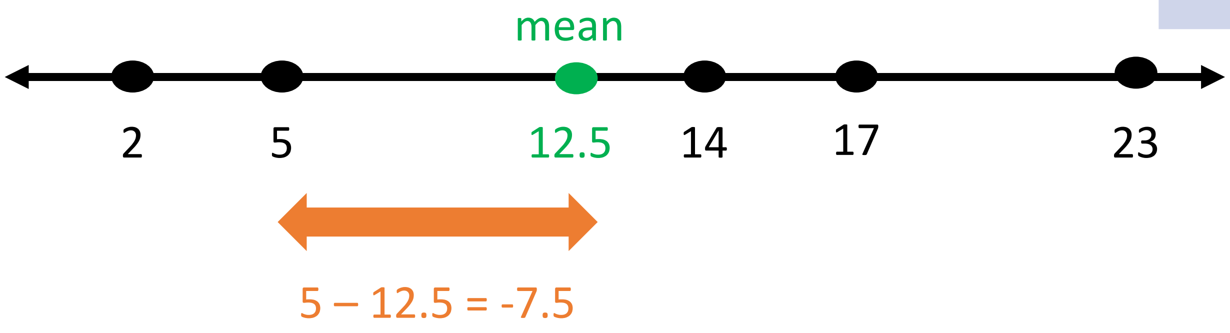
		$SD = \sqrt{60.3}$:	7.77



Descriptive Statistics – Numeric Data

What happens to the variance when points are further from the mean?

A) Variance is larger

B) Variance is smaller

C) Variance stays the same

Patient	%emph	%emph - mean	(%emph – mean)^2
1	5	-7.5	56.25
2	23	10.5	110.25
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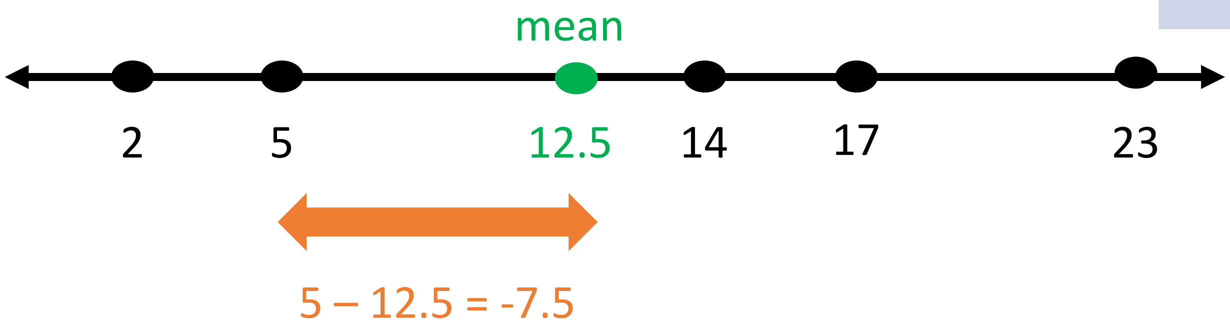
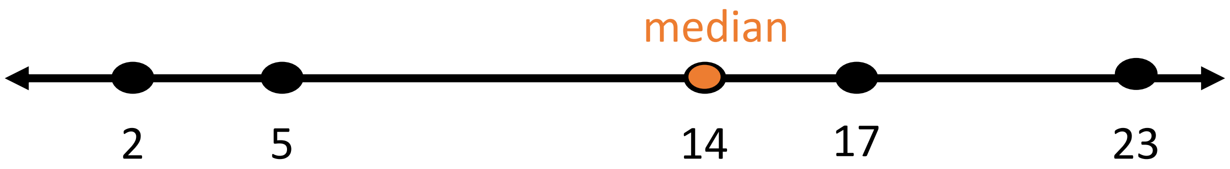


Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Recap: The median is the value such that half the data is above and half the data is below

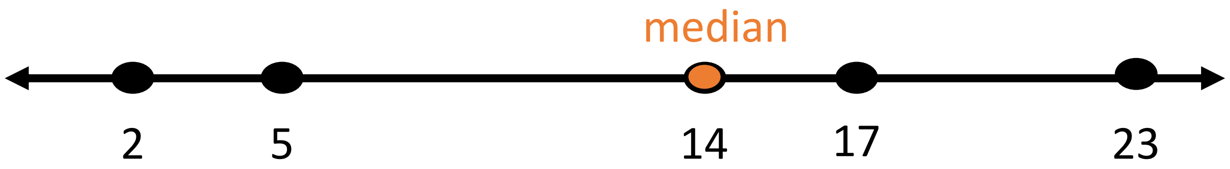
Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17



Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Recap: The median is the value such that half the data is above and half the data is below
- i.e. 50% of data falls below the median and 50% falls above the median

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17



Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Recap: The median is the value such that half the data is above and half the data is below

- i.e. 50% of data falls below the median and 50% falls above the median

- Therefore, other names for the median are the
  - 50% percentile
  - 0.5 quantile

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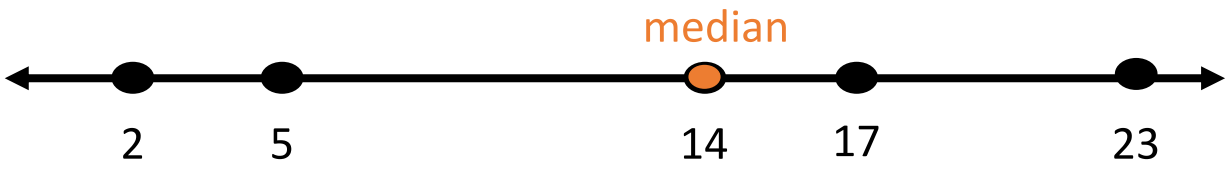
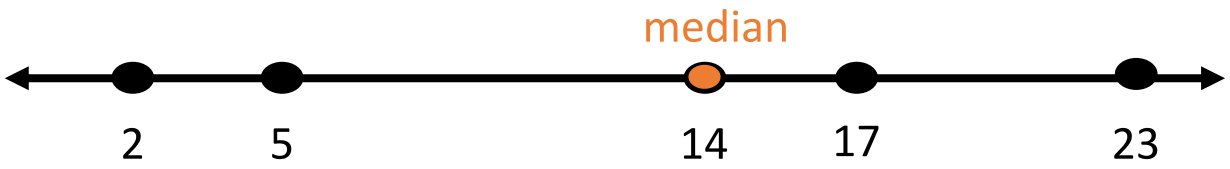


Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Recap: The median is the value such that half the data is above and half the data is below
- i.e. 50% of data falls below the median and 50% falls above the median
- Therefore, other names for the median are the
  - 50% percentile
  - 0.5 quantile
- The pth percentile is the value where
  - p% of data falls below the pth percentile
  - (1-p)% of data fall above the pth percentile

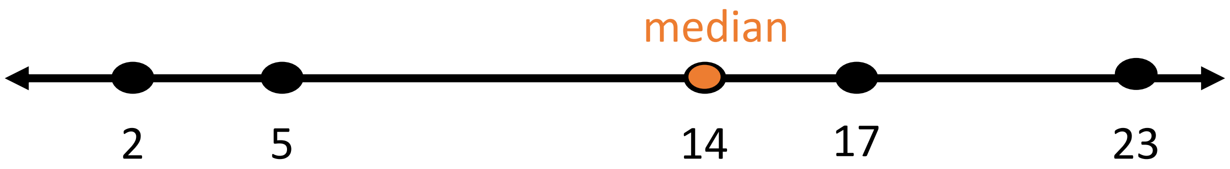
Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17



Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Two common percentiles are the
  - 25th percentile or “lower quartile”
  - 75th percentile or “upper quartile”

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
5	17



Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Two common percentiles are the
  - 25th percentile or “lower quartile”
  - 75th percentile or “upper quartile”
- For the emphysema table on the right,
  - What is the lower quartile?

Patient	Percentage Emphysema
1	5
2	23
3	2
4	14
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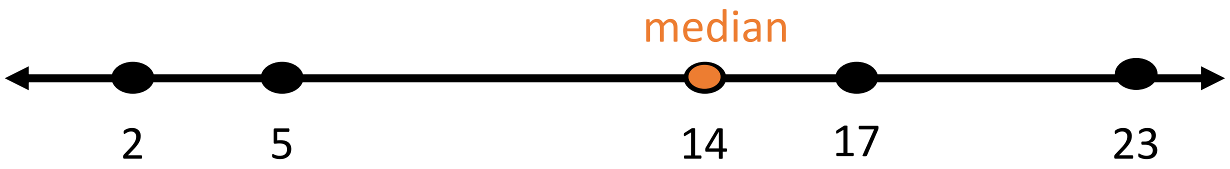

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- For the emphysema table on the right,
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Patient	Percentage Emphysema
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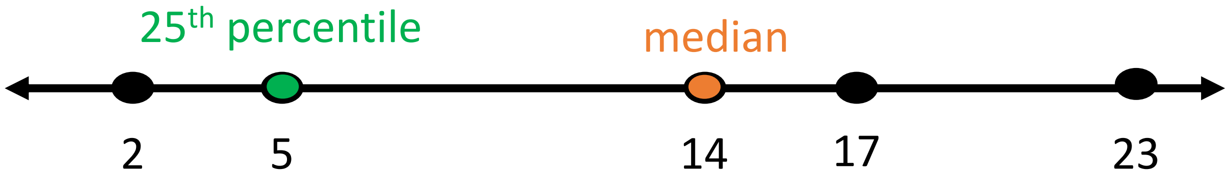

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- For the emphysema table on the right,
  - What is the lower quartile? 5
    - That is, 25% of the data falls below 5
    - 75% of the data falls above 5

Patient	Percentage Emphysema
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2	23
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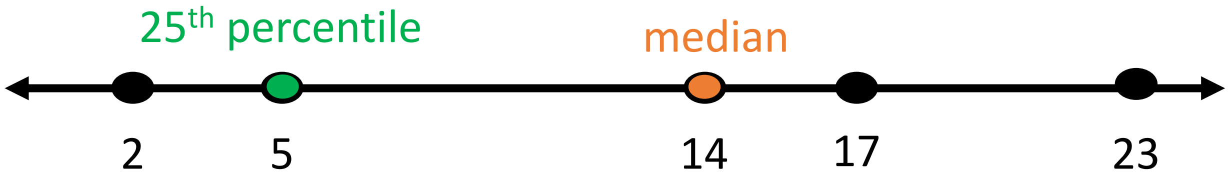
4	14
5	17



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  - What is the upper quartile?

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4	14
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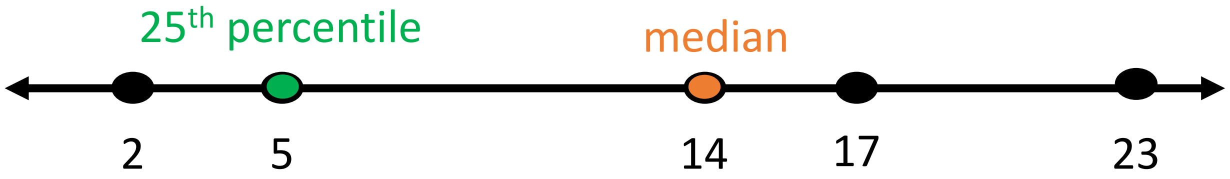

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4	14
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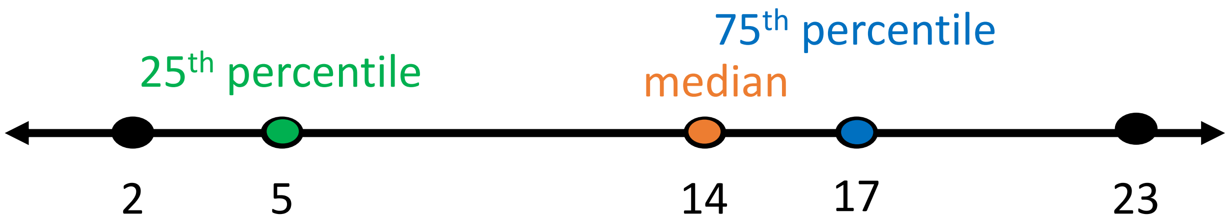

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- For the emphysema table on the right,
  - What is the lower quartile? 5
    - That is, 25% of the data falls below 5
    - 75% of the data falls above 5
  - What is the upper quartile? 17
    - That is, 75% of the data falls below 17
    - 25% of the data falls above 17

Patient	Percentage Emphysema
1	5
2	23
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4	14
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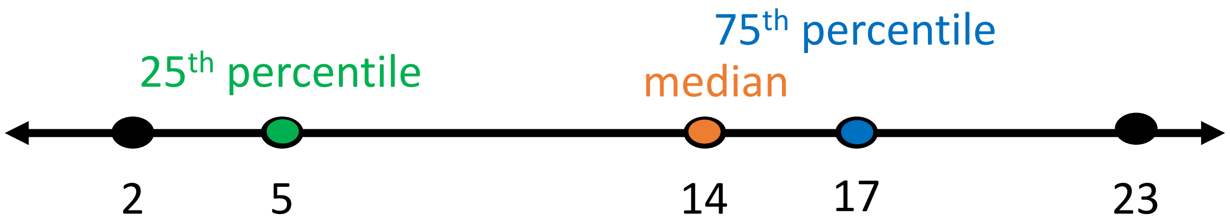

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Patient	Percentage Emphysema
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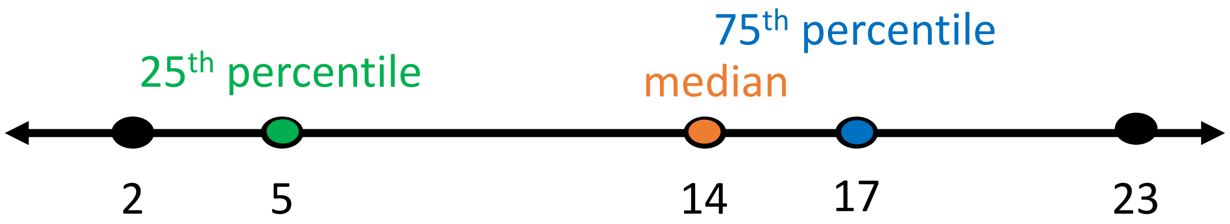
- Note there are variations for calculating percentiles



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    - That is, 75% of the data falls below 17
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Patient	Percentage Emphysema
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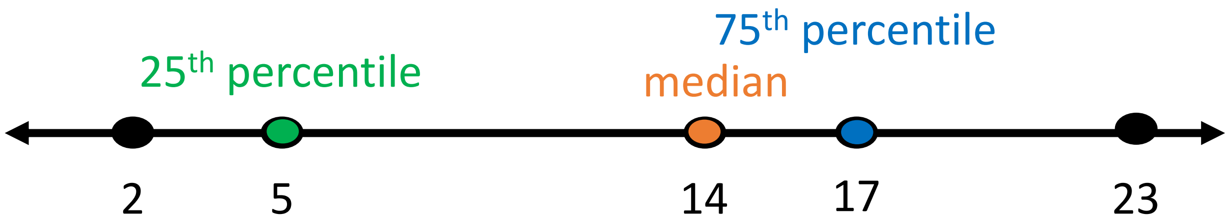
- Note there are variations for calculating percentiles
- For this class, we will use R to calculate percentiles for us



Descriptive Statistics – Numeric Data – Quantiles and Percentiles

- Two common percentiles are the
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- For the emphysema table on the right,
  - What is the lower quartile? 5
    - That is, 25% of the data falls below 5
    - 75% of the data falls above 5
  - What is the upper quartile? 17
    - That is, 75% of the data falls below 17
    - 25% of the data falls above 17

Patient	Percentage Emphysema
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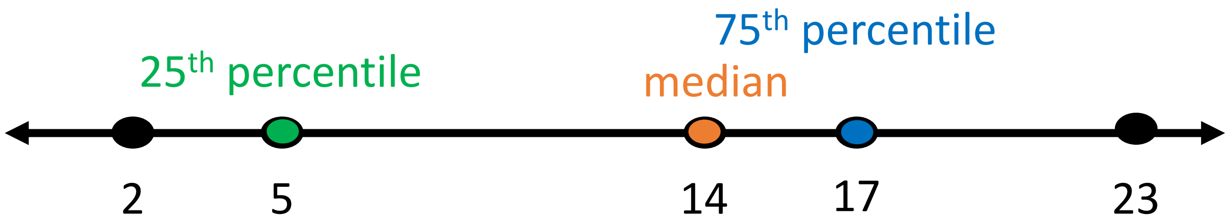
5	17

- Note there are variations for calculating percentiles
- For this class, we will use R to calculate percentiles for us
- I primarily want you to know how to interpret these values



Descriptive Statistics:

Categorical Variables

Descriptive Statistics – Categorical Data

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- For example, we can categorize % emphysema into three ordinal categories
  - >0, ≤10
  - >10, ≤ 20
  - >20

Patient	Percentage Emphysema	Emphysema Category
1	5	>0, ≤10
2	23	>20
3	2	>0, ≤10
4	14	>10, ≤ 20
5	17	>10, ≤ 20
6	14	>10, ≤ 20

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- For example, we can categorize % emphysema into three ordinal categories
  - $>0, \leq 10$
  - $>10, \leq 20$
  - >20
- We then count the number of observations per category

Patient	Percentage Emphysema	Emphysema Category
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3	2	$>0, \leq 10$
4	14	$>10, \leq 20$
5	17	$>10, \leq 20$
6	14	$>10, \leq 20$

Frequency Table

Emphysema Category	Frequency
$>0, \leq 10$	2
$>10, \leq 20$	3
>20	1

Distributions and Histograms

Histograms to Visualize Data Distributions

Measures of central tendency

- Mean (average)
- Median (50th percentile, 0.50 quantile)
- Mode (value that occurs most often)

Measures of variability

- Range
- Variance
- Standard deviation
- Quantiles/Percentiles

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Comparing groups using information about their data distributions is ***statistics!***

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- Consider the following data set:
    - You collect data on 9 students on the number of years a student has played an instrument

Person	Years Playing Music
1	8
2	6
3	5
4	7
5	6
6	7
7	8
8	7
9	9

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  - You collect data on 9 students on the number of years a student has played an instrument
  - How many times does 5 occur?
  - How many times does 7 occur?
- The plot of these frequencies vs the data values is a **histogram**

Person	Years Playing Music
1	8
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3	5
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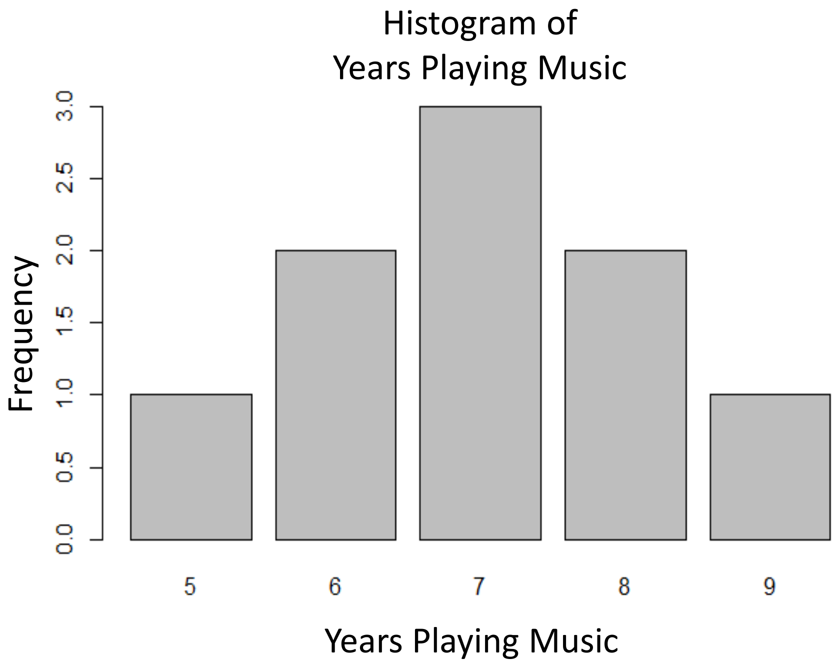

Histograms to Visualize Data Distributions

- But what if the data are continuous (decimals) and not discrete (integer-valued)?

Person	Years Playing Music
1	8.2
2	6.1
3	5.5
4	7.8
5	6.4
6	7.6
7	8.2
8	7.3
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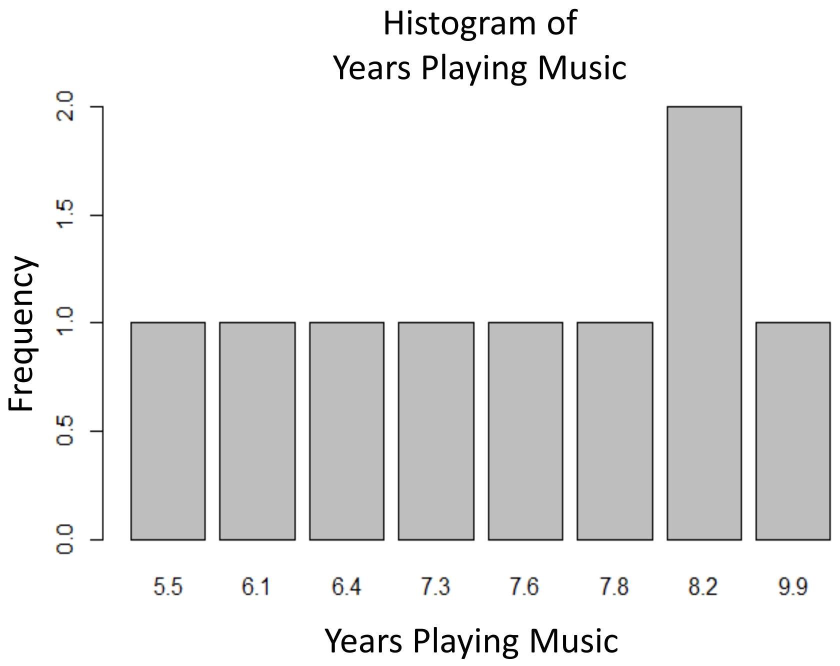

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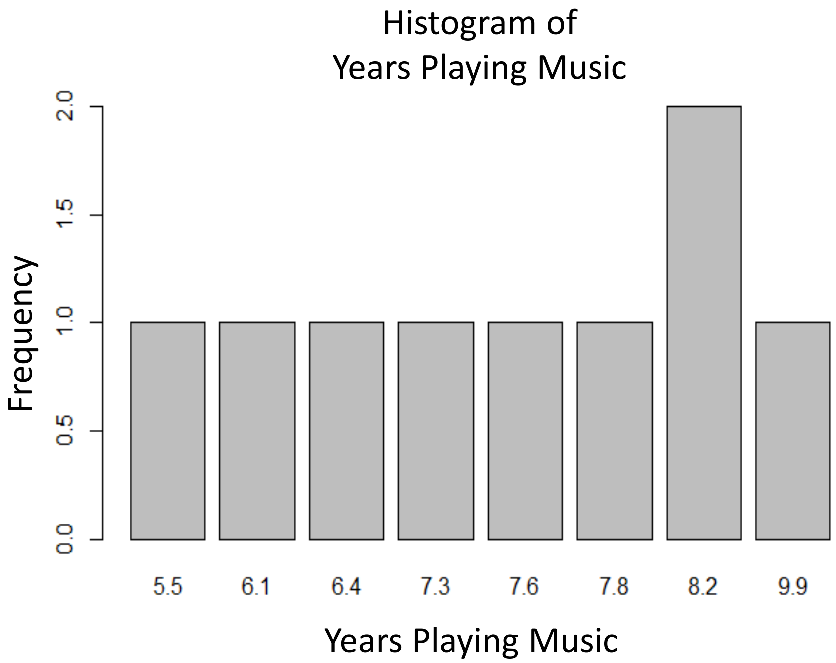

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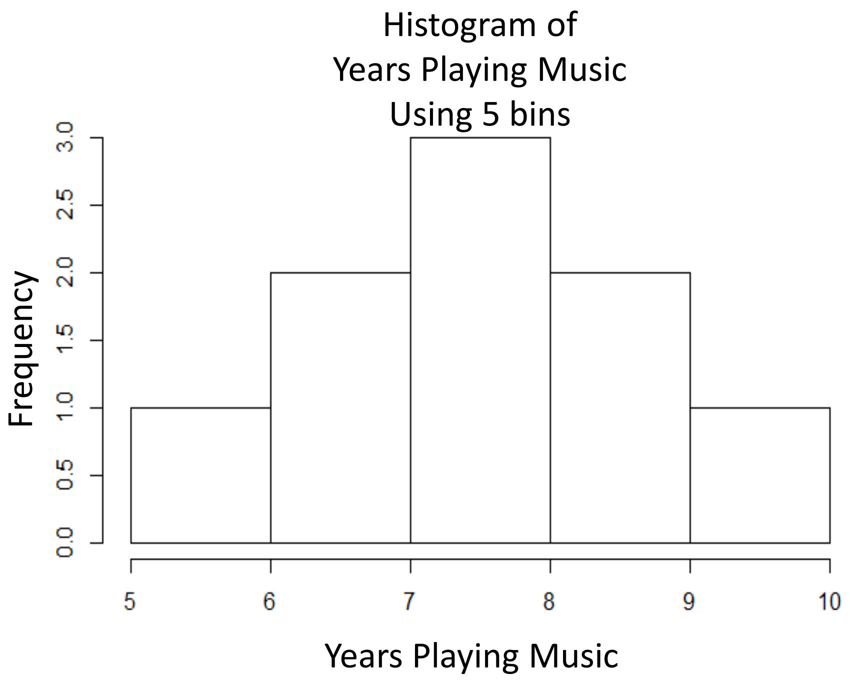

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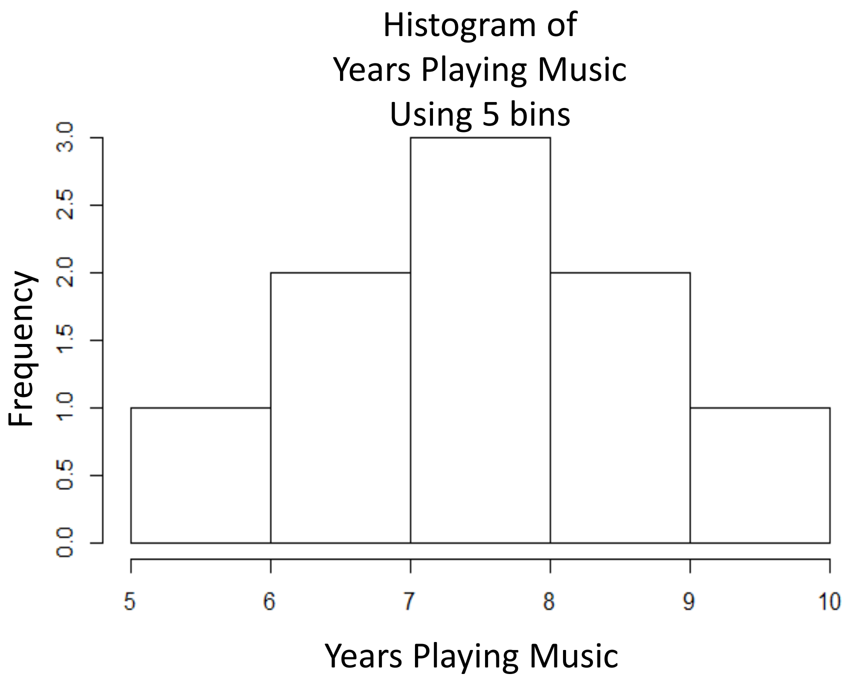

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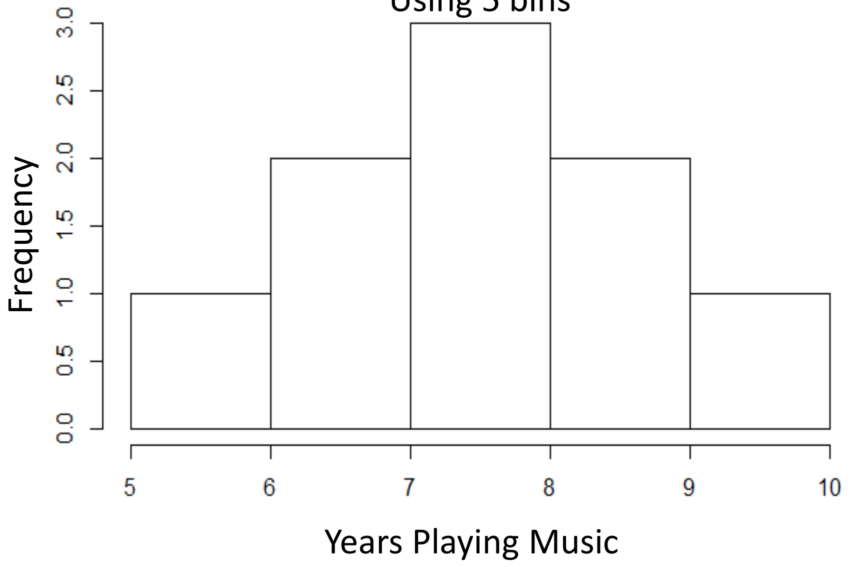
Histogram of
Years Playing Music
Using 5 bins



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    - e.g., 4-5, 5-6, 6-7
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- The best number of bins is subjective
- You may need to try a few times before acquiring a useful histogram

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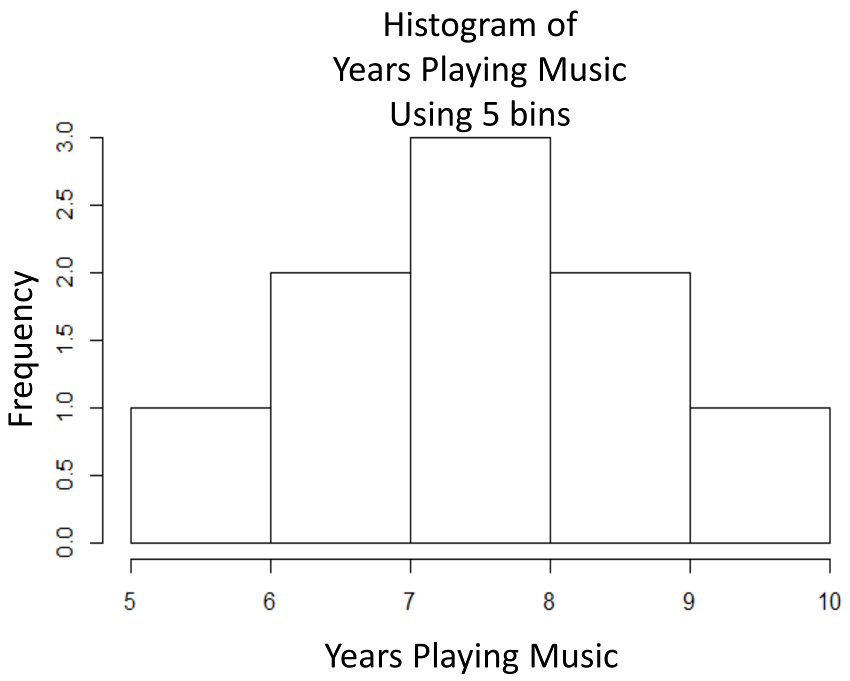

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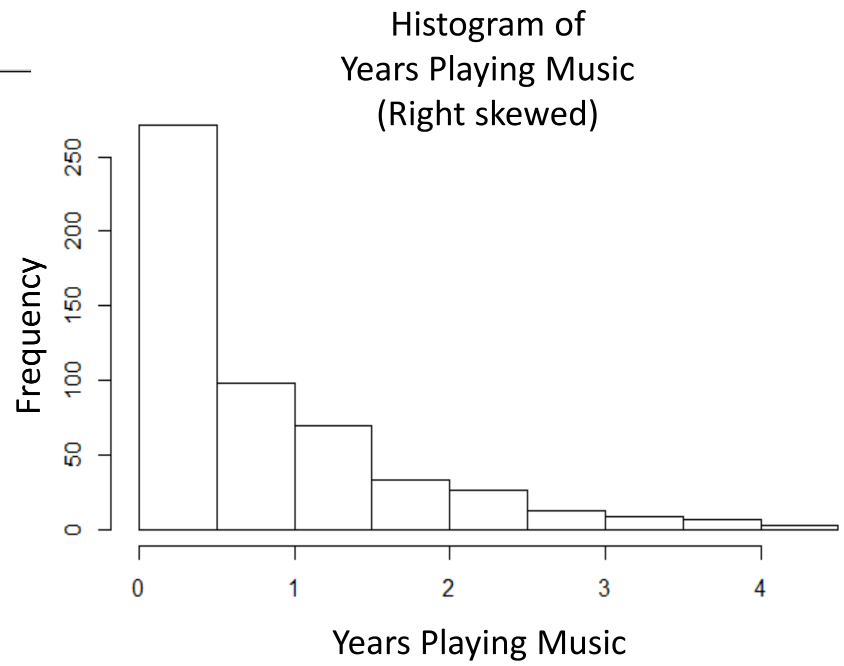

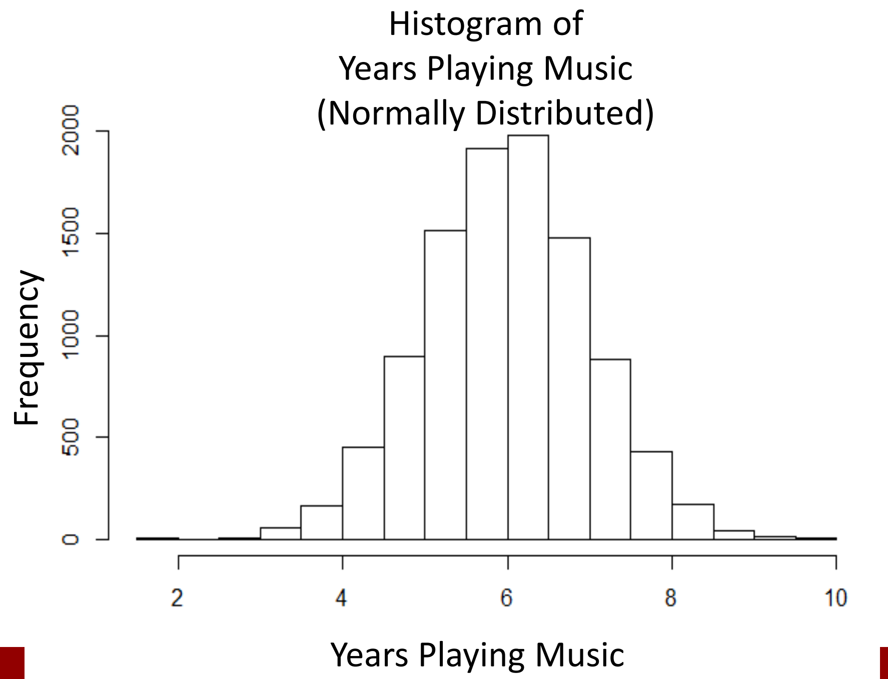

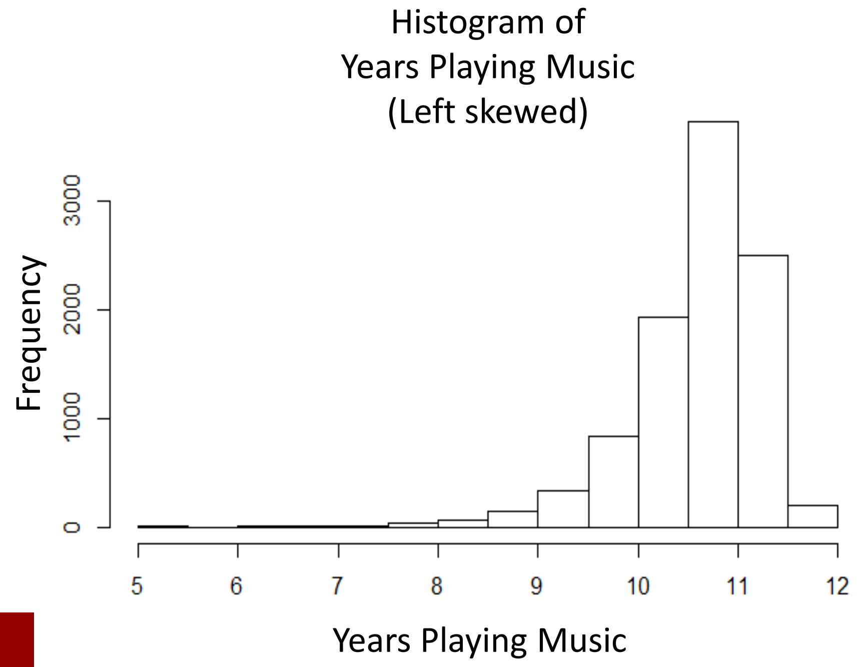

Histograms to Visualize Data Distributions

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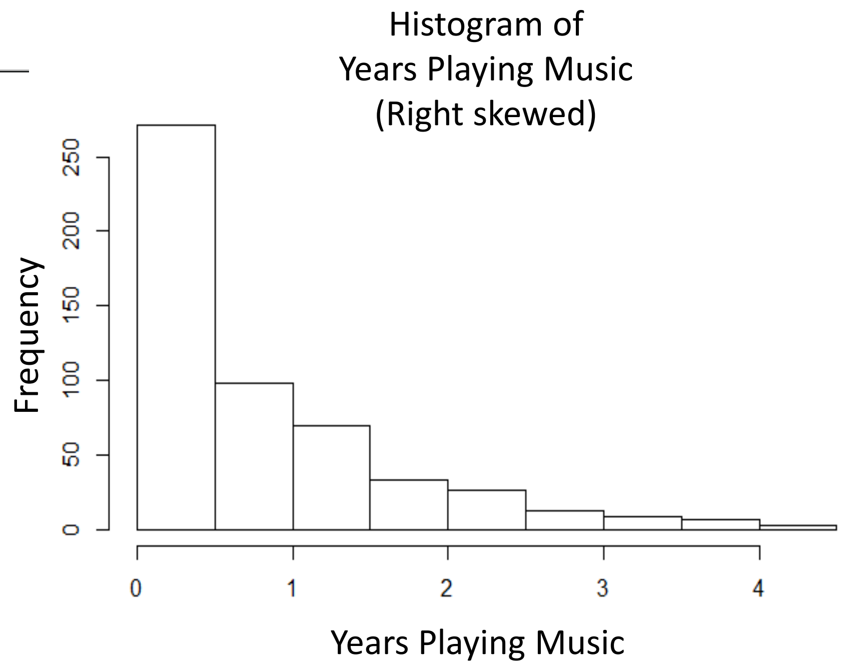
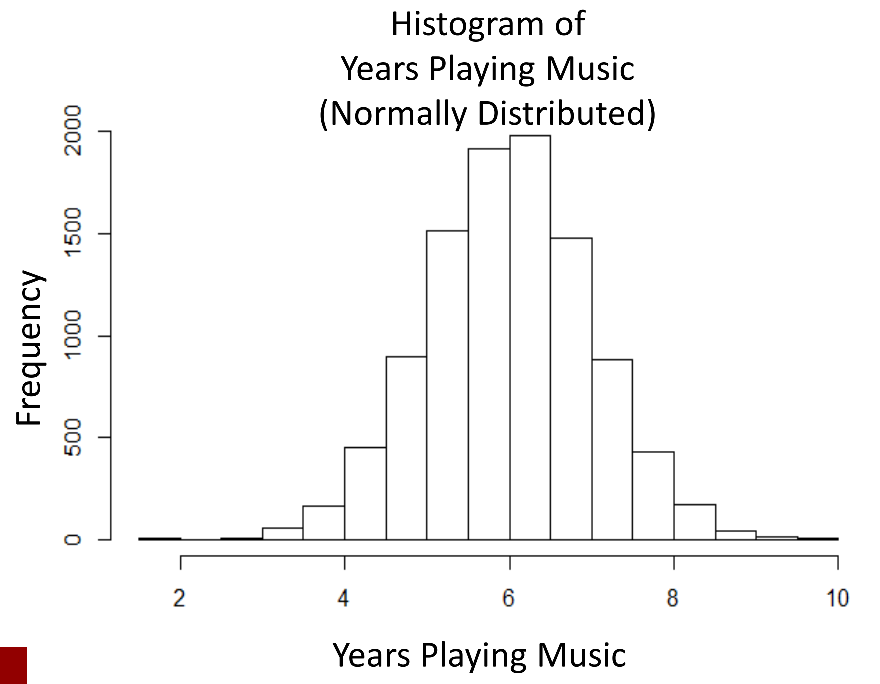
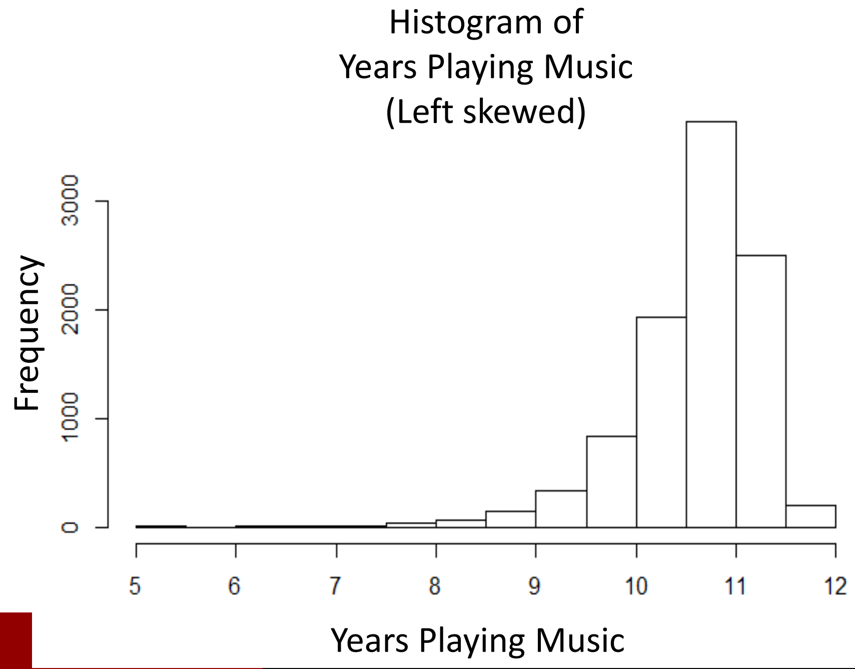
- Data distributions can take on many, many different shapes

- However, the most common is a bell-shaped curve called the normal distribution

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$





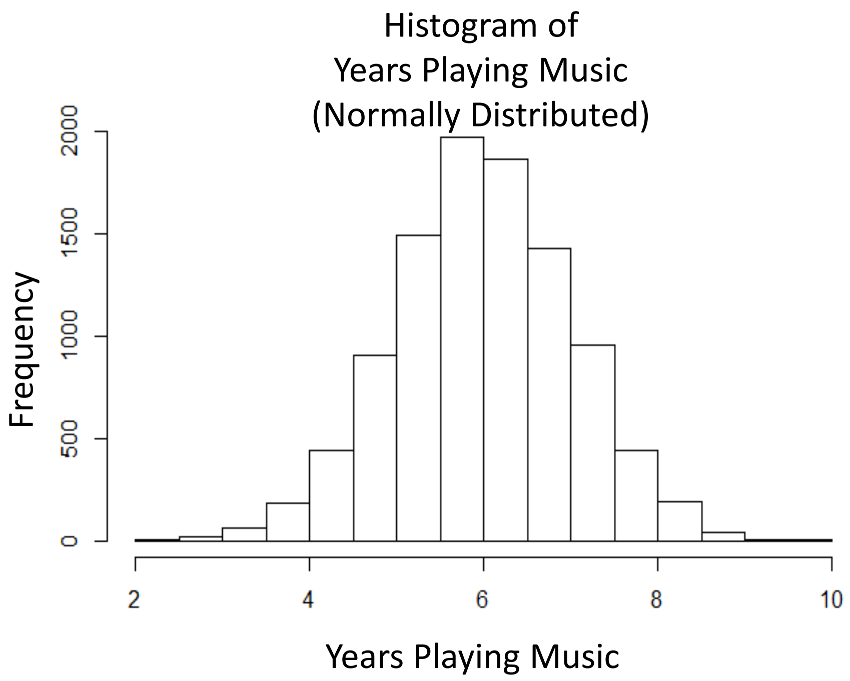


Distributions and Descriptive Statistics

Histograms to Descriptive Statistics

- Descriptive statistics describe different aspects of the distribution

- Central tendency – Where is the center of the distribution?



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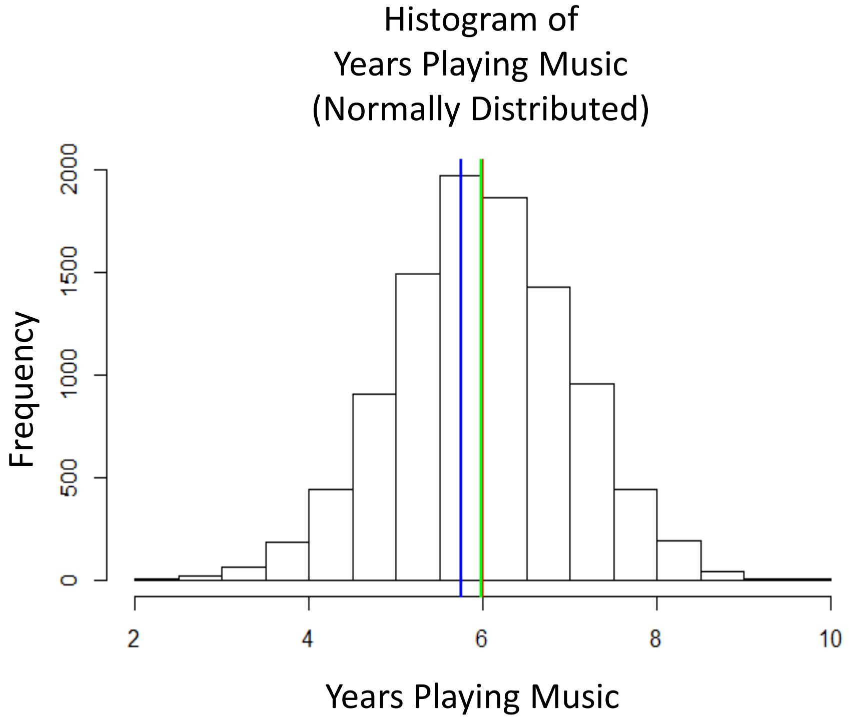

Histograms to Descriptive Statistics

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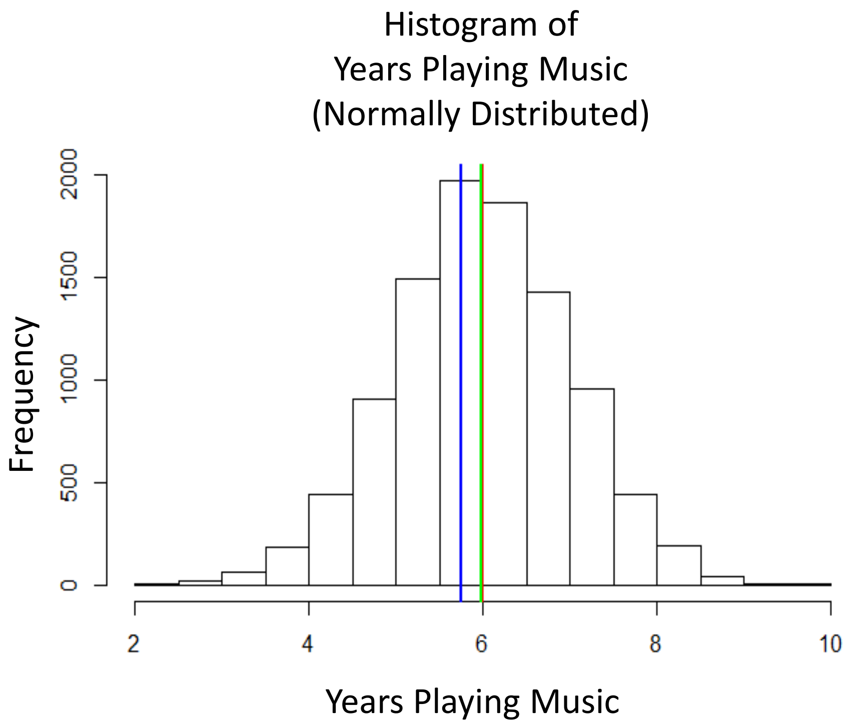
  - Mean = 5.99, Median = 5.98, Mode = ~5.75



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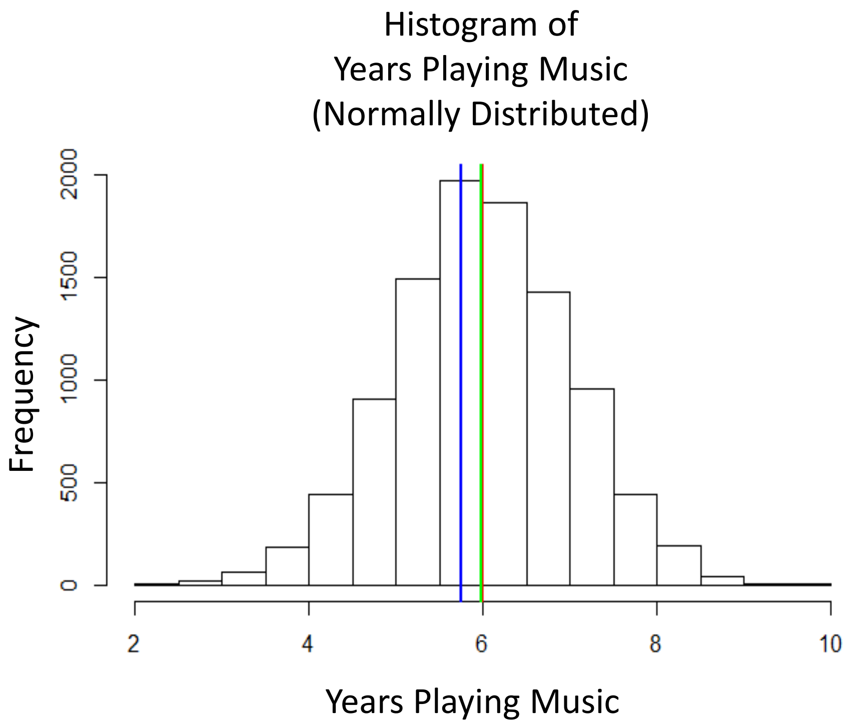

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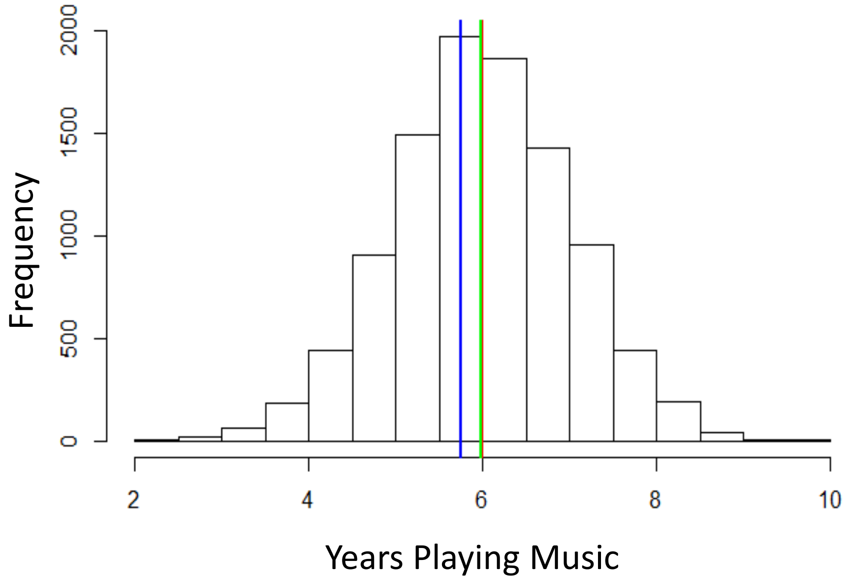
- **Note:** For the theoretical normal distribution, the mean = median = mode

Histogram of
Years Playing Music
(Normally Distributed)



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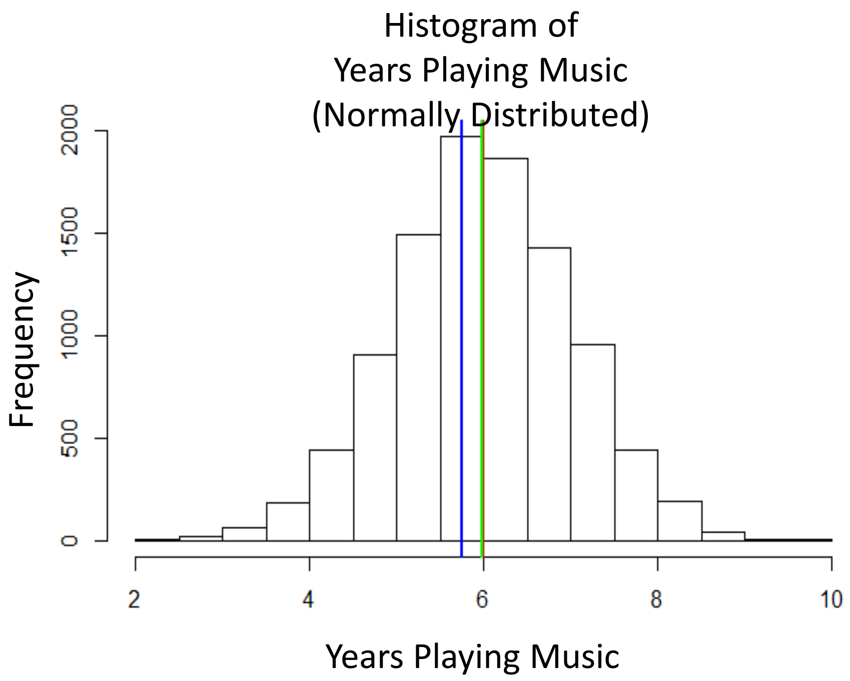

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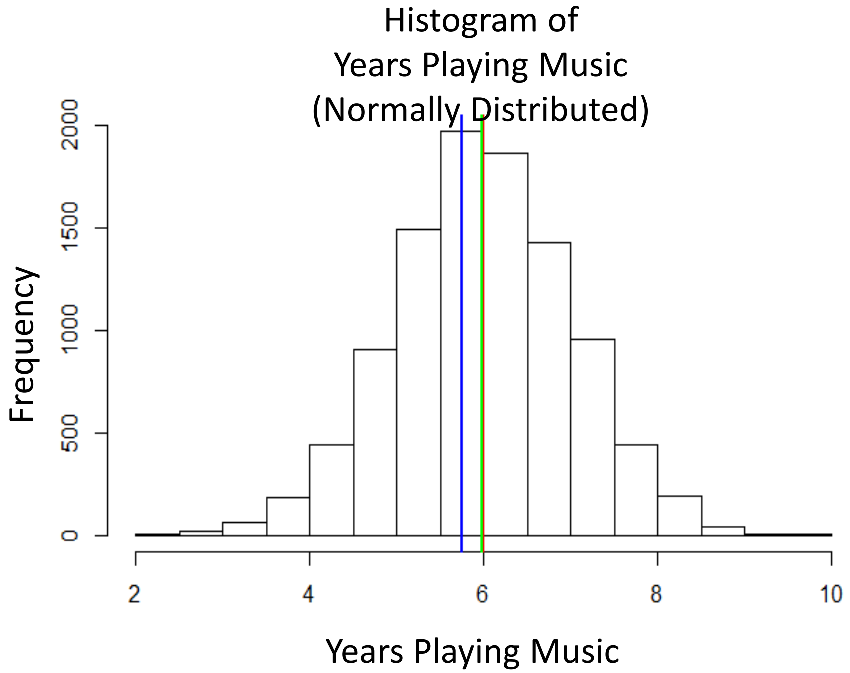

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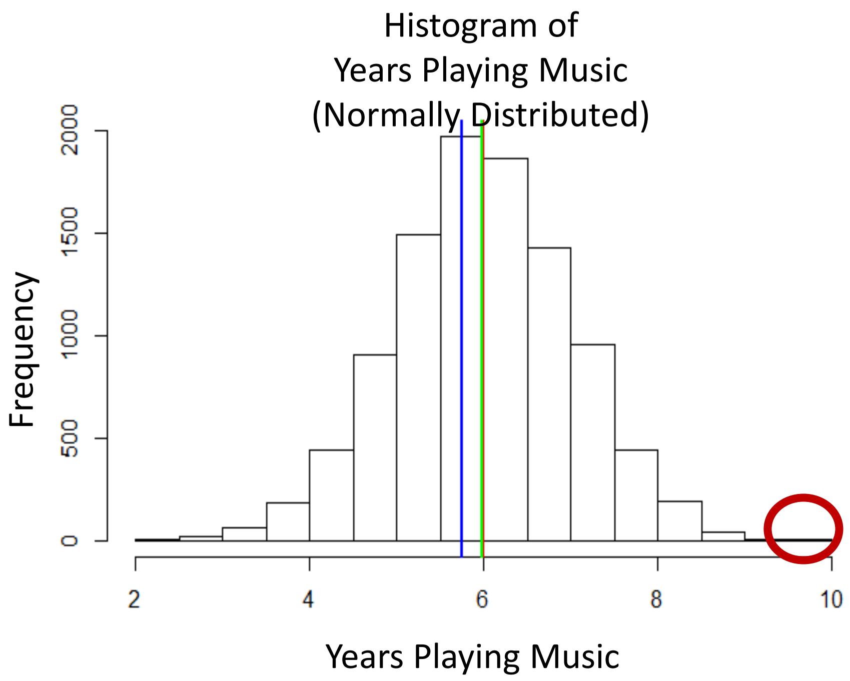

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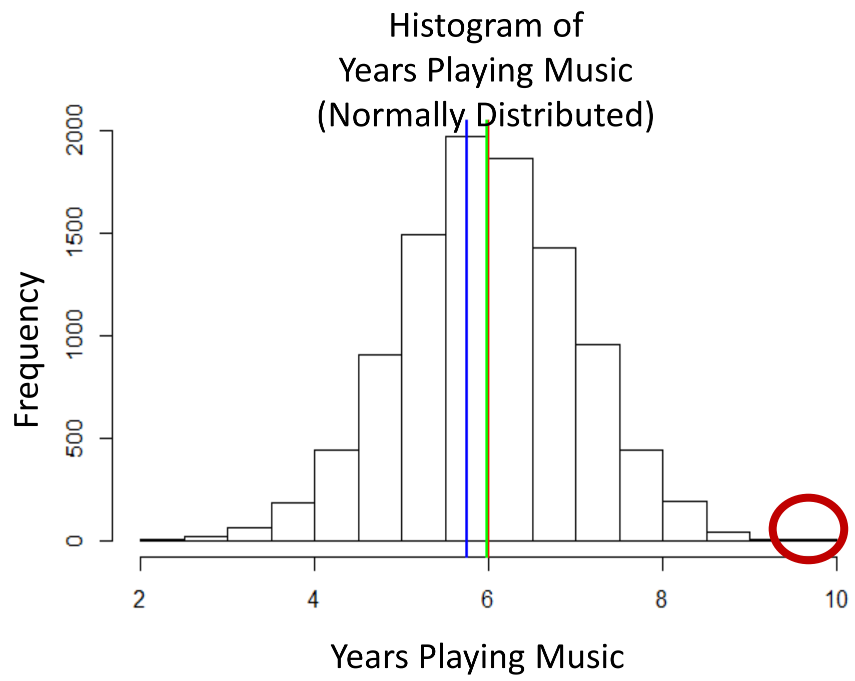
- Descriptive statistics describe different aspects of the distribution
- Dispersion – What is the range of years of music played?
  - 2 to 10 years
- What can we say about this student?
- Where is the student with the least amount of experience playing music?

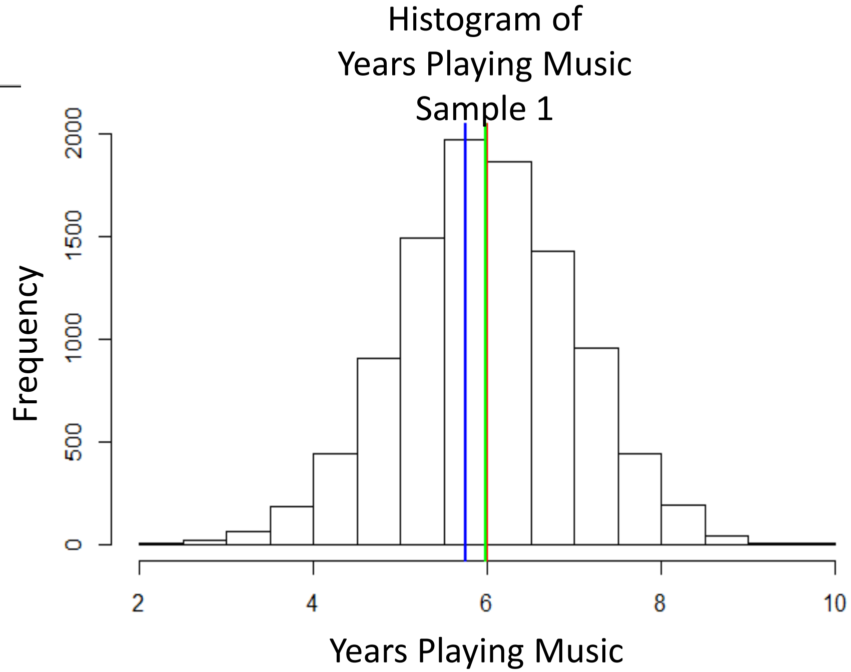


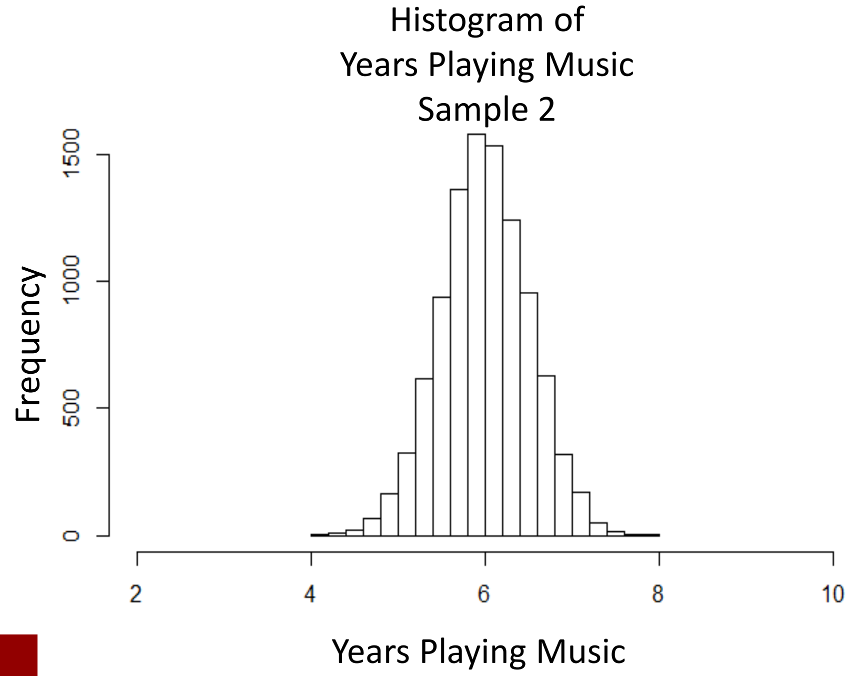
Histograms to Descriptive Statistics

- Imagine we collect data on two different groups of students (shown on the right)
- Which sample (1 or 2) has a smaller standard deviation in years of playing music?

A) Sample 1

B) Sample 2





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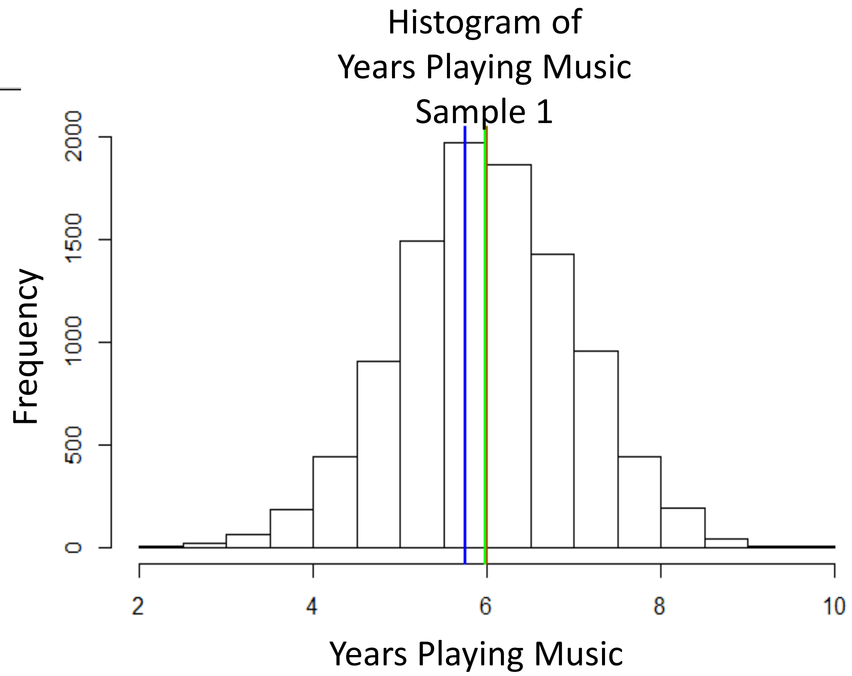
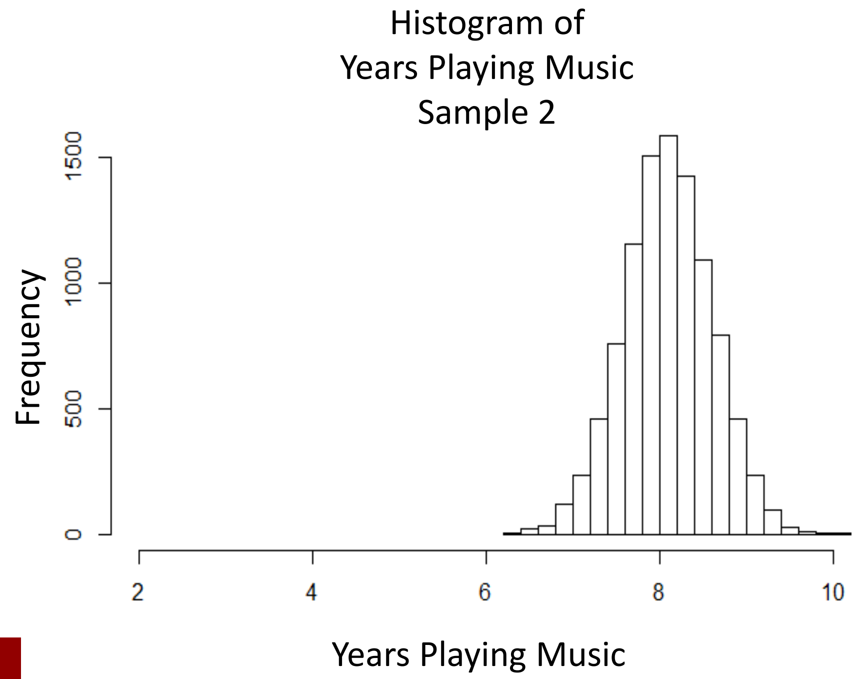


Histogram of Years Playing Music Sample 1

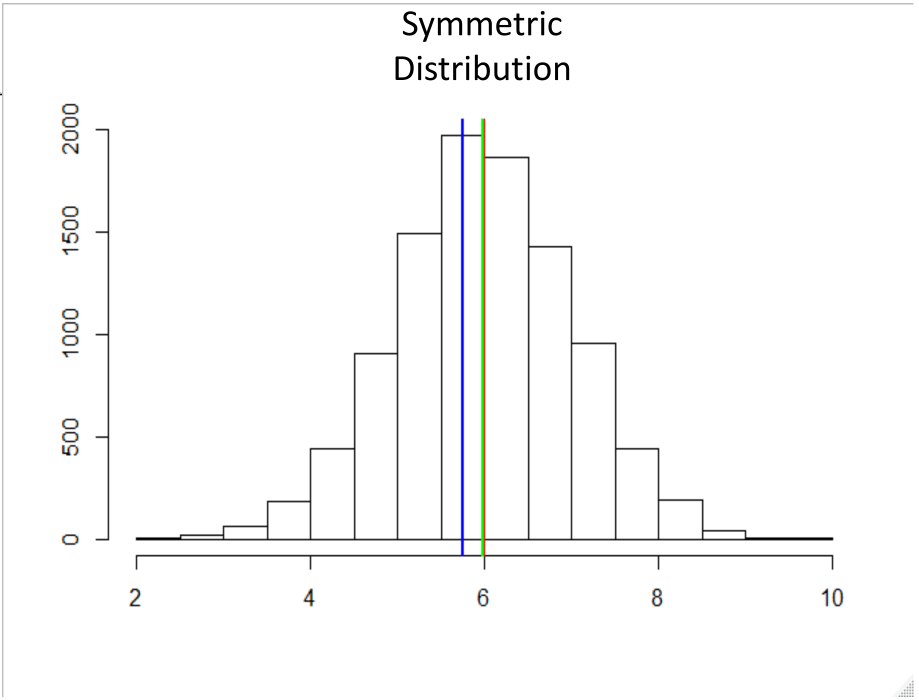


Histogram of Years Playing Music Sample 2

Histograms to Visualize Data Distributions

- When the distribution is close to symmetric the

  mean ≈ median



Histograms to Visualize Data Distributions

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- Left skewed distributions

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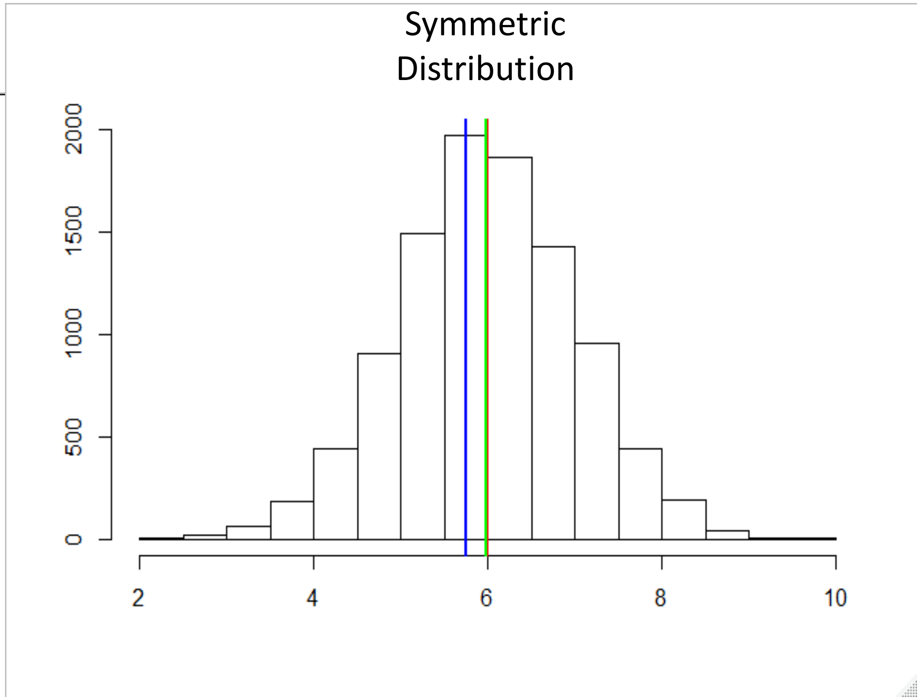

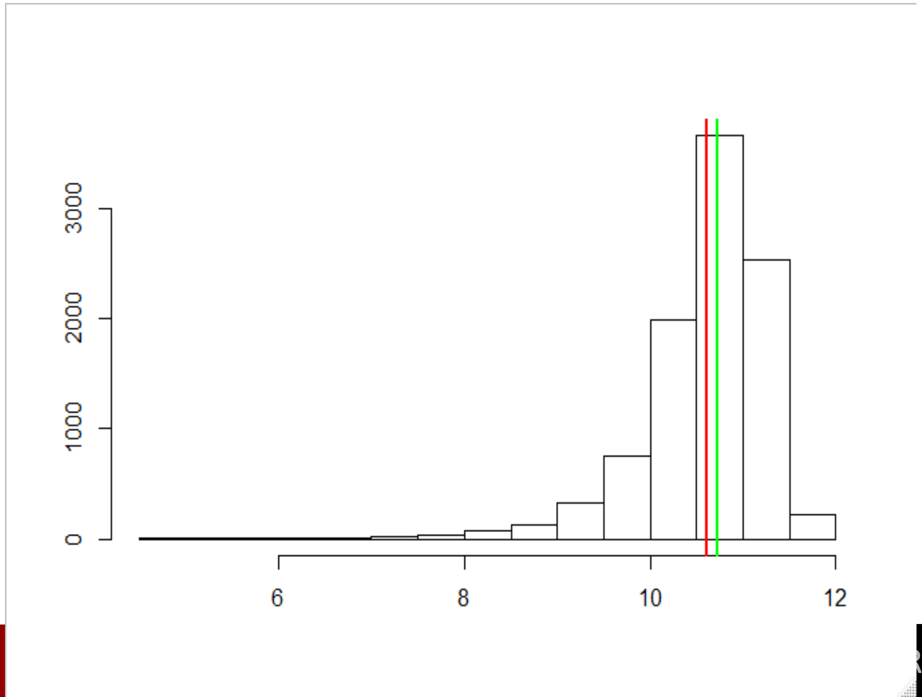

Histograms to Visualize Data Distributions

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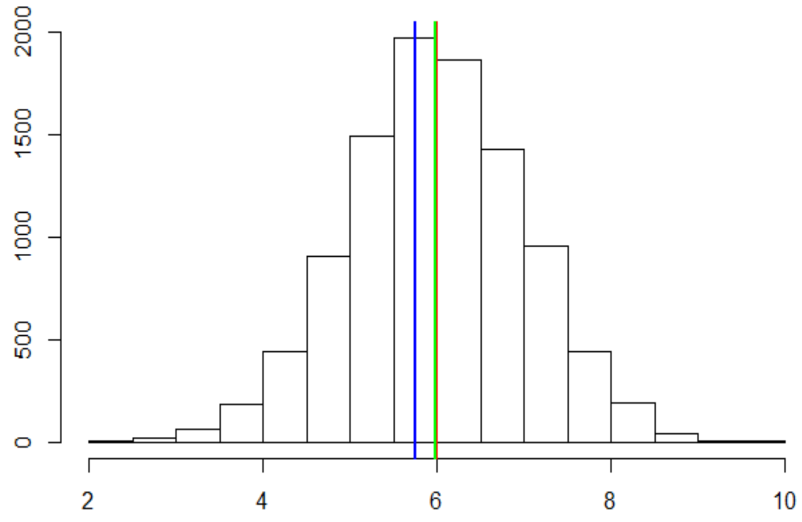
Symmetric Distribution



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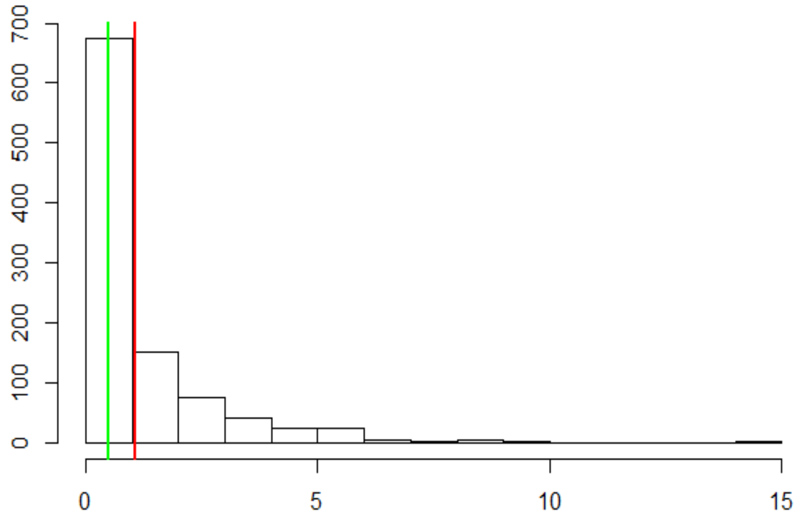

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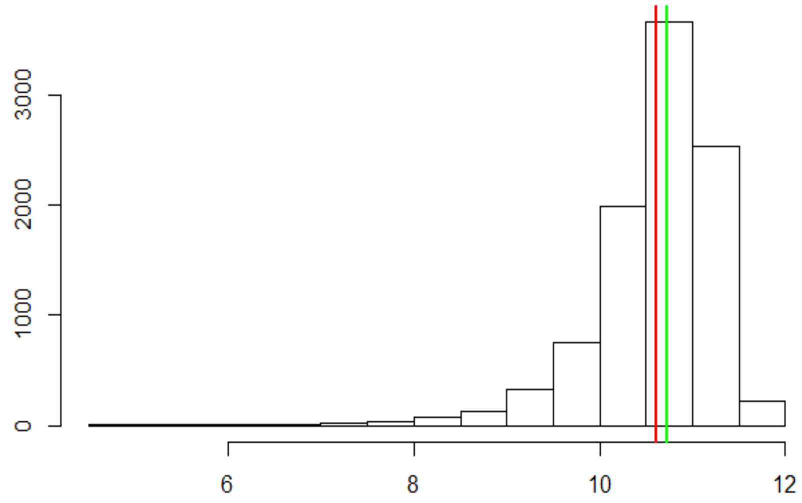

Histograms to Visualize Data Distributions

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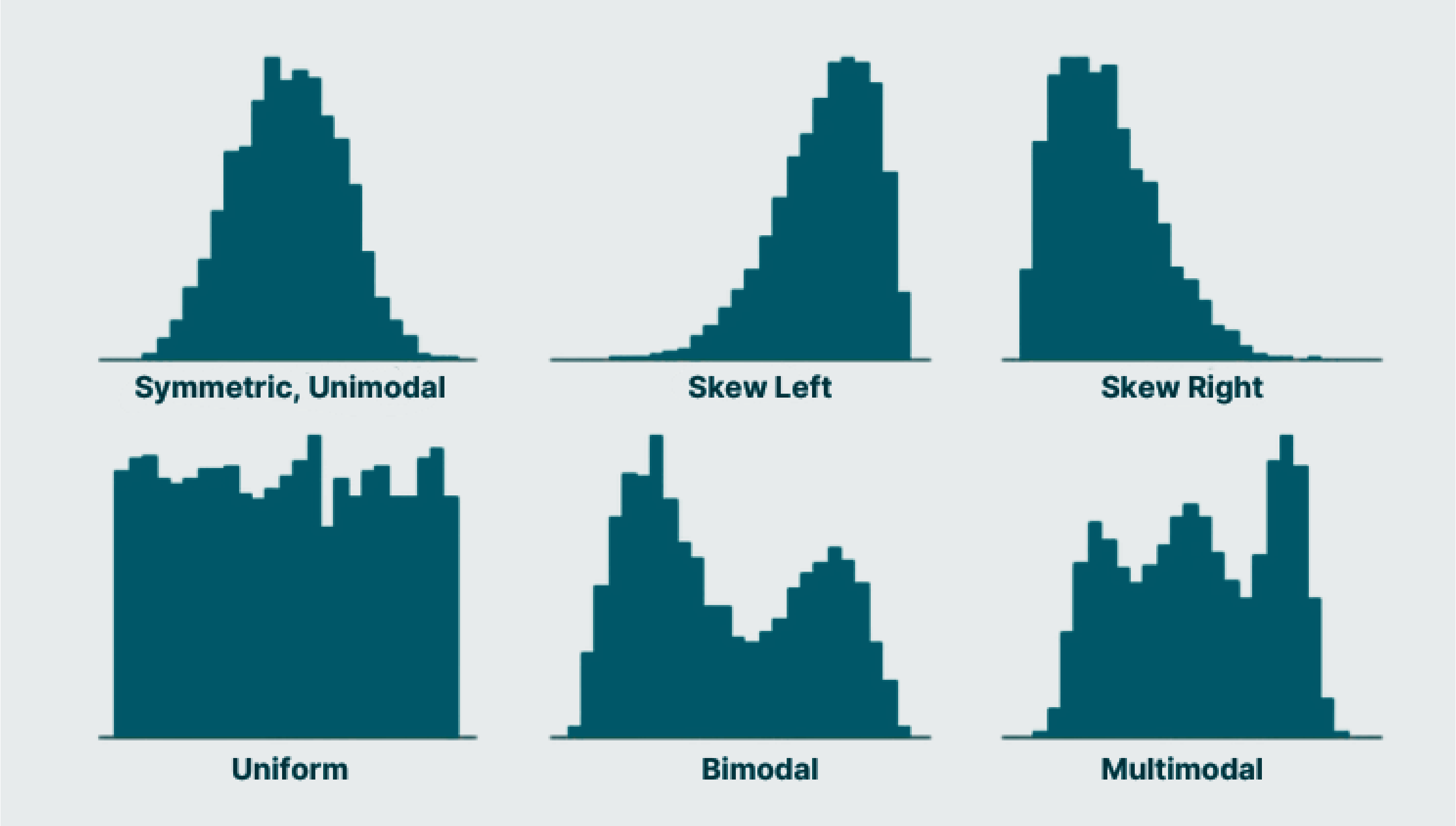

R Code Covered in Practice Assignment