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An Introductory Data Analysis: Lecture 1

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Repository Citation
Olaitan O. (2019). An Introductory Data Analysis: Lecture 1. PEER Liberia Project. https://doi.org/10.13028/jz6y-6a35. Retrieved from https://escholarship.umassmed.edu/liberia_peer/22

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University of Massachusetts Medical School

Department of Quantitative Health Sciences

An Introductory Data Analysis

08/12/2019

Dapo Olaitan, Biostatistician

Lecture One

- Introductory Descriptive Statistics
  - Statistical Concepts (Population, Sample, Parameter etc.)
  - Sampling Distribution
- Data Measurement
  - Measures of Central tendency (Location)
  - Measures of Variation
  - Measures of Association

What is Statistics?

Statistics is the **science** of learning from **data**, and of measuring, controlling, and communicating uncertainty; and it thereby provides the navigation essential for controlling the course of scientific and societal advances (*Davidian, M. and Louis, T. A., 10.1126/science.1218685*).

Statistics is also an **ART** … of conducting a study, analyzing the data, and derive useful conclusions from numerical outcomes about real life problems…

What is Biostatistics?

Biostatistics is the application of statistics in medical research,

e.g.:

- Clinical trials
- Epidemiology
- Pharmacology
- Medical decision making
- Comparative Effectiveness Research etc..

Terms in Biostatistics

Data :

All the information we collect to answer the research question

Variables :

Outcome, treatment, study population characteristics

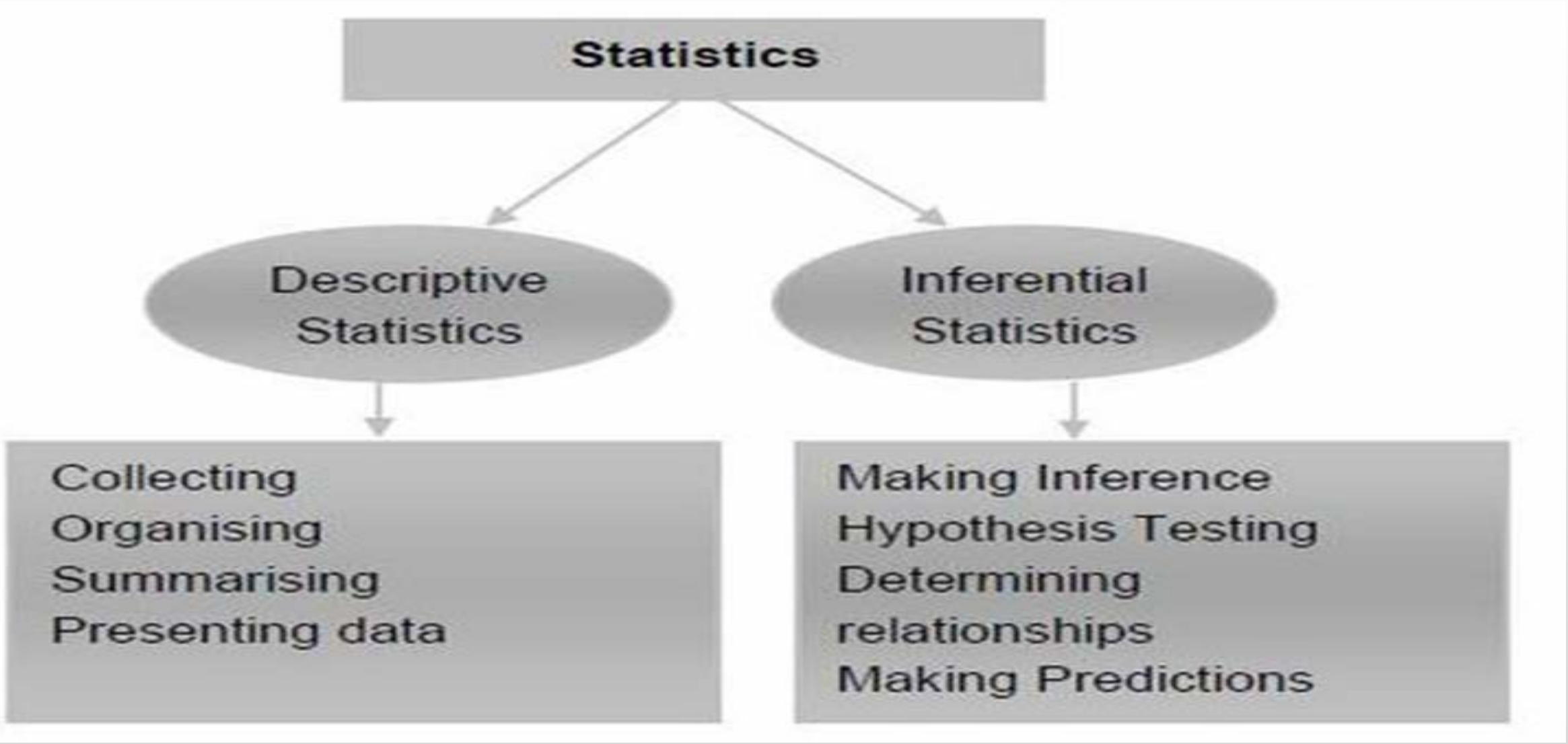
Subjects :

Units on which characteristics are measured

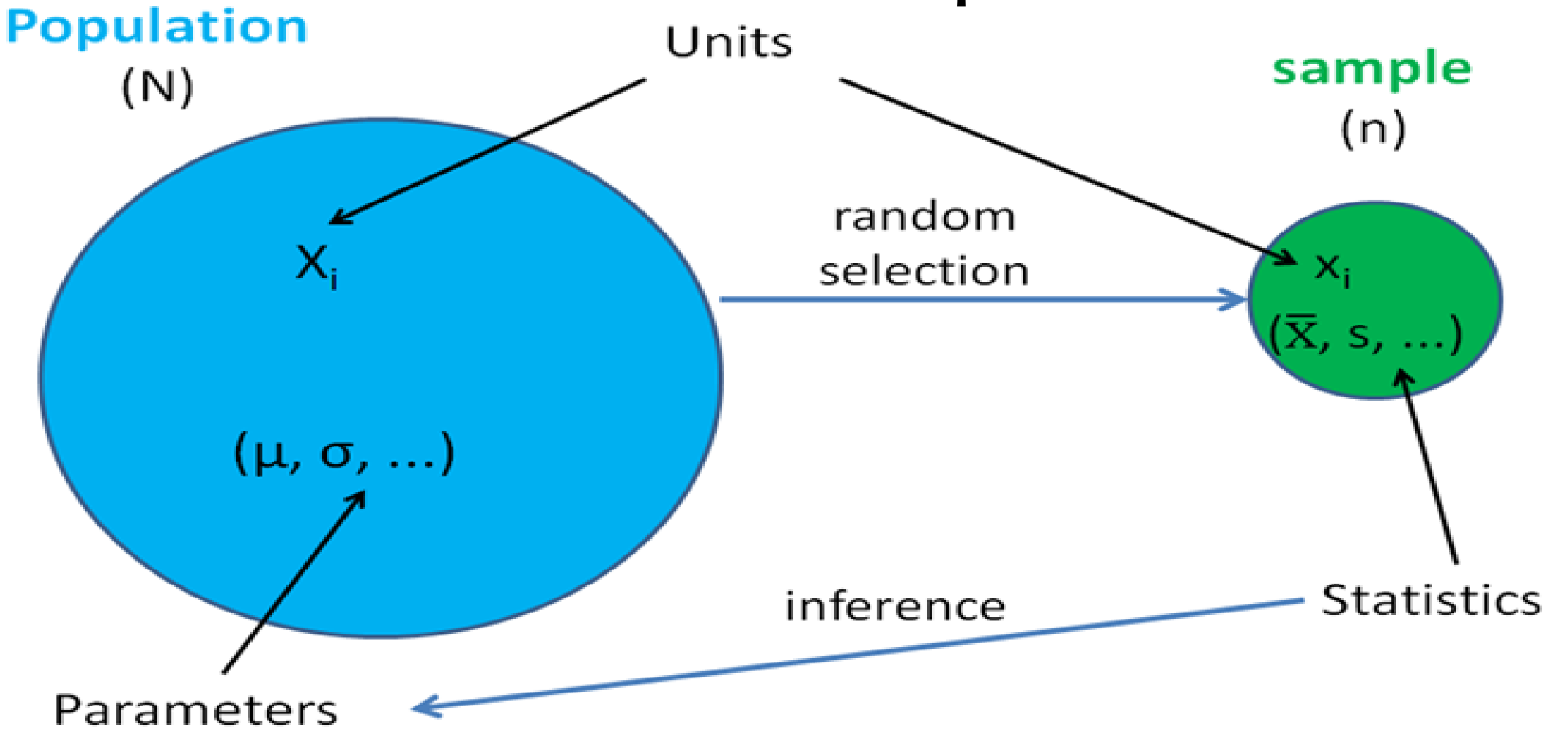
Observations :

Data elements

Statistical Analysis

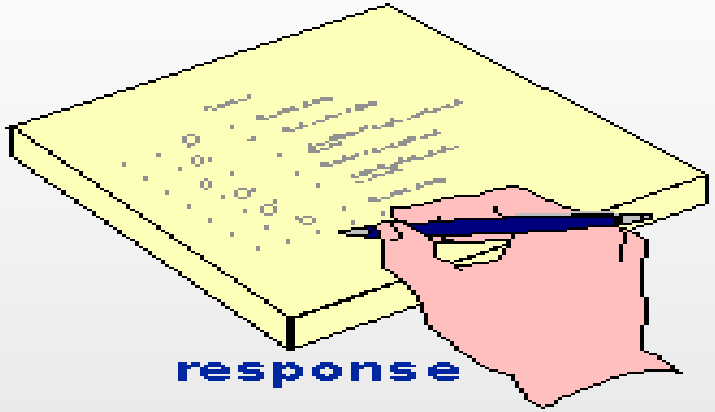


Statistical Concepts



Sampling

Variable



1 2 3 (4) 5

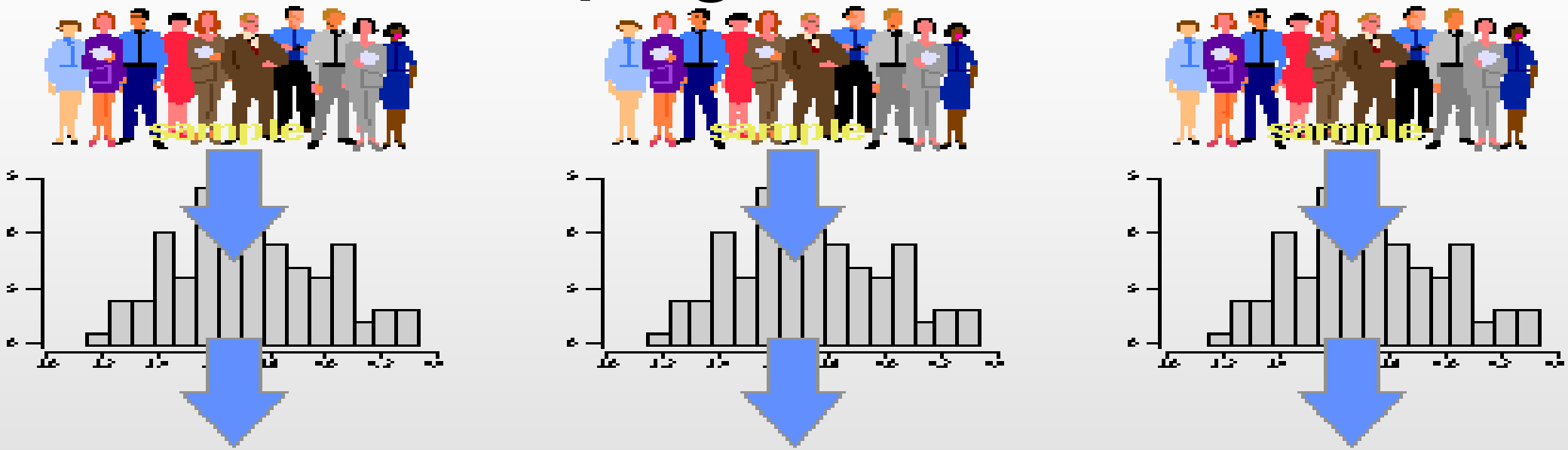
Statistic

Average = 3.75

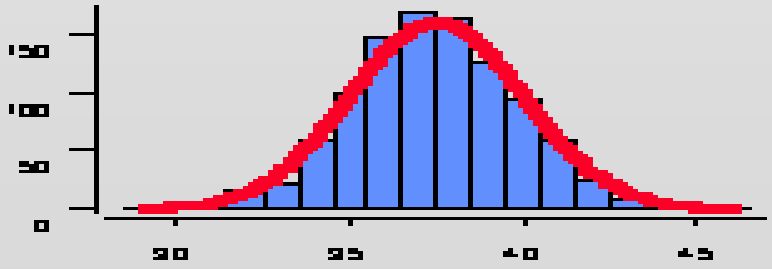
Parameter

Average = 3.72

Sampling Distribution



The Sampling Distribution...



...is the distribution of a statistic across an infinite number of samples

Sampling Error

Sample :

A sample is just one of a potentially infinite number of samples.

Standard Deviation :

The standard deviation of the sampling distribution shows how different samples would be distributed.

Sampling (Standard) Error :

The sampling error gives some idea of the precision of a statistical estimate.

Sampling Distribution

Population :

A group of persons, objects, or items from which samples are taken for measurement.

Sample :

A measurable portion of a population whose properties are studied in other to gain information about the population.

	Population	Sample	
Descriptive Measure	Parameter	statistic	Summary of a characteristic
Size	N	n	Total number of subjects
Mean	μ	$\bar{x}$	Average
Variance	σ^2	s^2	Variance

Count

Frequency (f) :

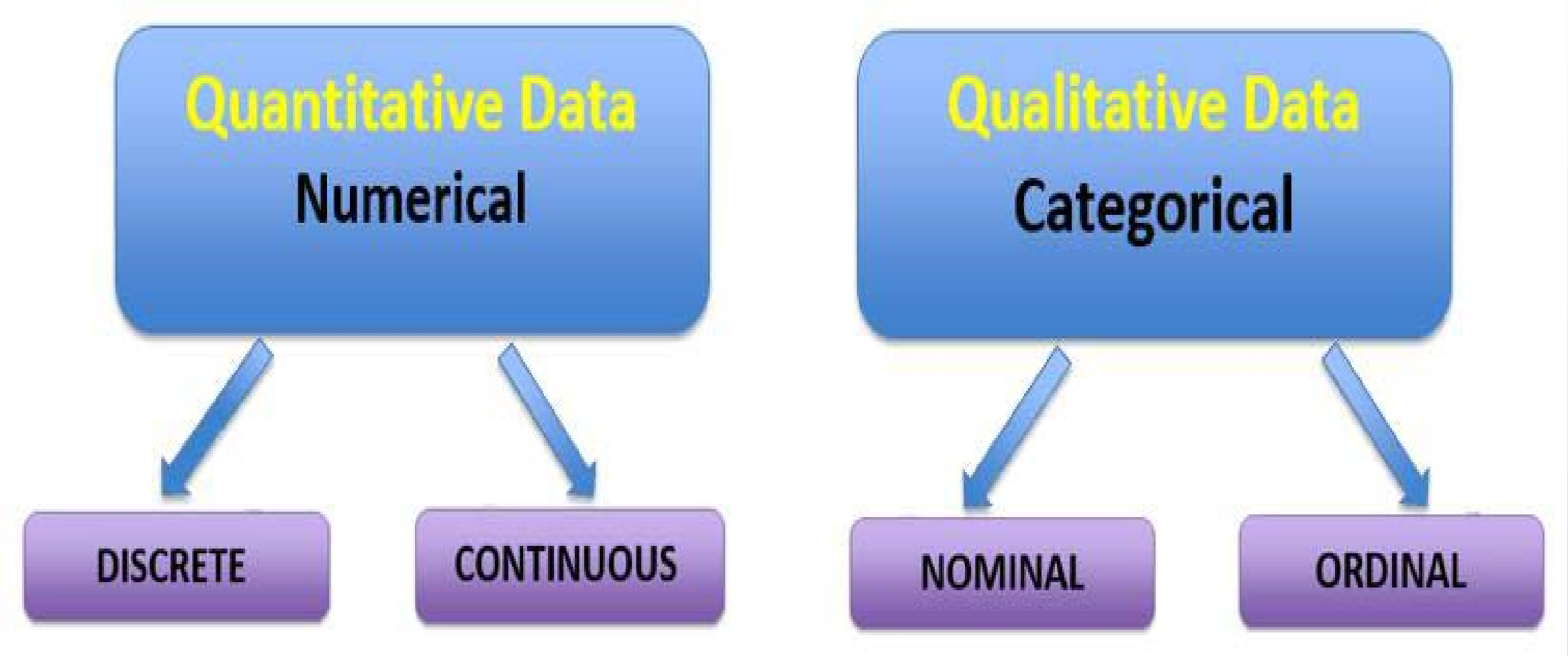
This is the number (#) of subjects in each category.

Relative frequency (%) :

This is the proportion (%) of subjects in each category.

Period	Frequency (f)	Relative Frequency (%)	Cumulative Relative Frequency (%)
1	450	(450 ÷ 1450) × 100 = 31	31
2	750	52	83
3	250	17	100
Total	**1450**	**100**	

Types Of Data



Data Measurement

There are three basic measurement methods primarily used in descriptive statistics.

Types :

- Measures of Central Tendency or Location
- Measures of Dispersion
- Measures of Association

Measures of Central Tendency or Location

The Measures of Central Tendency components are powerful tools when summarizing and comparing data.

- Mean or Arithmetic Average
- Median
- Mode

Mean or Arithmetic Average

$$\text{Mean} = \frac{\text{Sum of all data values}}{\text{Number of data values}}$$

Definition	Formula
• Average value. • A typical value for the variable of interest.	$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n}$

Measures of Central Tendency or Location

Median (The middle item of a data)

Definition	Formula
• The middle value of the variable of interest. • 50% of the collected values are less and 50% are greater than the median.	• If n odd: the $\frac{(n+1)^{th}}{2}$ observation • If n even: mean of the $\frac{n^{th}}{2}$ and the $(\frac{n}{2}+1)^{th}$ observations in the **ordered** sample

Median

Example :

If there is an odd number of values in the data set, then the median is the middle value

Data : **6, 9, 1, 2, 6, 5, 1**

Arrange from lowest to highest : **1, 1, 2, 5, 6, 6, 9**

Median = **5**

Median

Example :

If there is an even number of values in the data set, then the median is the mean of the two middle values

Data : **6, 9, 1, 2, 6, 1**

Arrange from lowest to highest : **1, 1, 2, 6, 6, 9**

$$\text{Median} = \frac{2 + 6}{2} = 4$$

Quartiles

Definition

- First (**Q_1**): 25% of the collected values are less than Q_1.
- Second (**Q_2**): 50% of the collected values are less than Q_2 (**median**).
- Third (**Q_3**): 75% of the collected values are less than Q_3.

Percentiles

Definition

- **q_p**: p% of the collected values are less than q_p.
- E.g., q_1 is that value of the population (or sample) with 1% of the observed values being less and 99% being grater than it.

Mode / Min / Max

Definition

- **Min**: the minimum of the collected values ($X_{(1)}$).
- **Max**: the maximum of the collected values ($X_{(n)}$).
- **Mode**: the most frequent of the collected values.

Unordered	X_1	X_2	X_3	X_4	X_5	X_6	X_7
	121	110	114	100	160	130	130
Ordered	$X_{(1)}$	$X_{(2)}$	$X_{(3)}$	$X_{(4)}$	$X_{(5)}$	$X_{(6)}$	$X_{(7)}$
	100	110	114	121	130	130	160

Min

Max

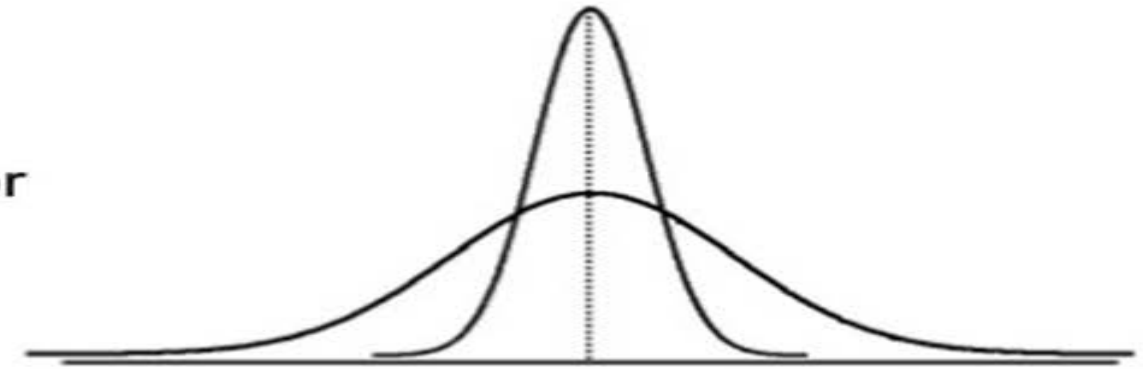
Mode = 130

Measures of Dispersion (Variation)

Measures of Variation

- **Variation**
  - **Range**
  - **Interquartile Range**
  - **Variance**
  - **Standard Deviation**
  - **Coefficient of Variation**

- Measures of variation give information on the **spread** or **variability** of the data values.



Same center, different variation

Measures of Dispersion (Variation)

Range

largest value minus smallest value

Interquartile Range (IQR)

difference between 75^{th} percentile and 25^{th} percentile values

Variance (s^2)

$$\frac{1}{n-1}\sum(x-\bar{x})^2$$

Standard deviation (s)

$$\sqrt{variance}$$

Variance (s^2)

Definition	Formula
• Average squared deviation from the mean.	$S^2 = \frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}$

X_1	X_2	X_3	X_4	X_5	X_6	X_7
121	110	114	100	160	130	130

$\bar{X} = 123.6$

$$S^2 = \frac{(X_1 - \bar{X})^2 + \cdots + (X_7 - \bar{X})^2}{n-1} = \frac{(121 - 123.6)^2 + \cdots + (130 - 123.6)^2}{7-1}$$

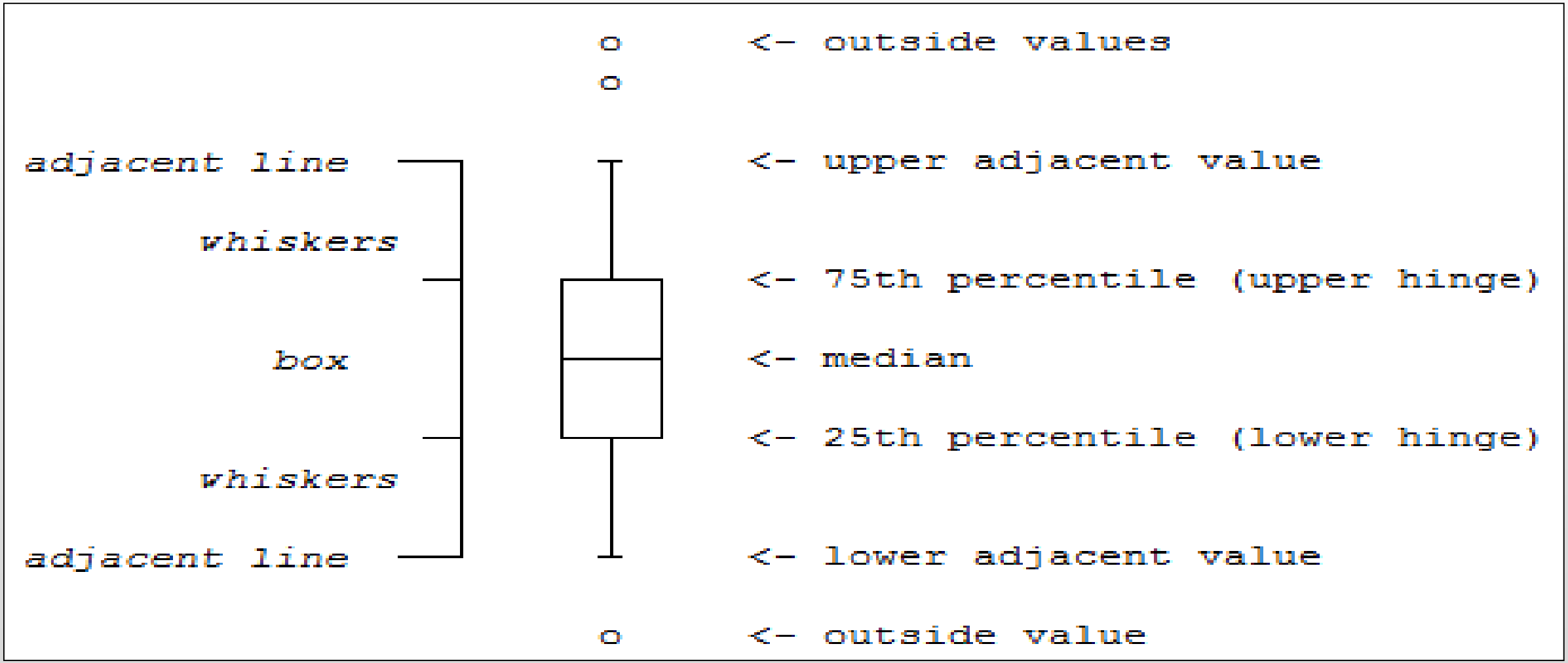
$$= \frac{2247.72}{6} = 374.62 \approx 374.6$$

Other Measures of Dispersion

Definition	Formula
• Standard deviation	$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}}$
• Mean Absolute Deviation (MAD)	$MAD = \frac{\sum_{i=1}^{n}\lvert X_i - \bar{X}\rvert}{n}$
• Range	Max – Min
• Interquartile Range (IQR)	$Q_3 - Q_1$
• Coefficient of variation	$\frac{s}{\bar{X}}$

Graphical Methods for Continuous variables

Box - Plot (Continuous Data):



Outliers

- Observations above **Q3 + 1.5IQR** or below **Q1 – 1.5IQR** are called, "**outliers**", in the box plot.
- Outliers are not caused by typo or errors.
- Outliers are simply part of data, which can not be ignored.
- Outliers explain how many extreme values are located at tails of a distribution.

Measures of Association

The measures of association helps to determine the outcomes of epidemiological studies, and also explains the strength of association between two categorical research variable indicators.

Types of Measures

1. Relative Risk (RR) or Risk Ratio,
2. Rate Ratio,
3. Odds Ratio (OR).

1. Relative Risk (RR) or Risk Ratio

The relative risk (risk ratio) quantifies a population's risk of disease from a particular exposure.

It is primarily associated with the;

- Cohort study
- Cumulative Incidence (disease frequency by comparing ratio)
- Probabilities comparison in terms of their ratio **(p1 / p2)**
- Strength of association of categorical indicators

Relative Risk :

	Disease		
Exposure	**Yes**	**No**	**TOTAL**
Yes	a	b	**a + d**
No	c	d	**c + d**
TOTAL	**a + c**	**b + d**	**n**

Formula :

Risk in exposed group = $a / (a + b)$

Risk in un-exposed group = $c / (c + d)$

Relative Risk (RR) = $[a / (a + b)] / [c / (c + d)]$

Rules

Relative Risk (Risk Ratio) :

- **RR = 1.0** (suggests no difference or little difference in risk : incidence in each group is the same).
- **RR > 1.0** (suggests an increased risk of that outcome in the exposed group).
- **RR < 1.0** (suggests a reduced risk in the exposed group).

Prevalence Ratio (PR) :

- Measures prevalence rather than incidence (measured by risk ratio)

- Usually from a cross-sectional study

	Disease		
Exposure	**Yes**	**No**	**TOTAL**
Yes	a	b	**a + d**
No	c	d	**c + d**
TOTAL	**a + c**	**b + d**	**n**

Prevalence Ratio (PR) = $[a / (a + b)] / [c / (c + d)]$

2. Rate Ratio :

The rate ratio Compares the rates of disease in two groups that differ by demographic characteristics or exposure history.

Formula ;

$$\text{Rate Ratio} = \frac{\text{Rate for group of primary interest}}{\text{Rate for comparison group}}$$

3. Odds Ratio (OR) :

The odds ratio helps in the study of rare diseases and the multiple exposures that may be related to an healthcare outcome.

The odds ratio is associated with ;

- the case - control studies,
- the 'Odds' , and helps to indicate how **much higher** the odds of exposure among cases of a disease compared with controls.

Odds Ratio (OR) :

Formula :

Exposed	Case	Control
Yes	a	b
No	c	d

Odds of being exposed among the cases = **a / c**

Odds of being exposed among the control = **b / d**

Exposure odds ratio = odds of exposure (cases) / odds of exposure (con)

= **(a/c) / (b/d)**

= **(a*d) / (b*c)** (Cross-product ratio)

Rules

Odds Ratio (OR) :

OR = 1 (Odds of exposure among cases **'Equals'** Odds of exposure among controls **: Exposure is not associated with the disease**).

OR > 1 (Odds of exposure among cases **'Is Greater'** than Odds of exposure among controls **: Exposure may be a risk factor for the disease**).

OR < 1 (Odds of exposure among cases **'Is Lower'** than the Odds of exposure among controls **: Exposure may be protective against the disease**).

Prevalence Odds Ratio (POR):

- Similar to odds ratio from case control study

- Usually from a cross-sectional study

	Disease		
Exposure	**Yes**	**No**	**TOTAL**
Yes	a	b	**a + d**
No	c	d	**c + d**
TOTAL	**a + c**	**b + d**	**n**

Prevalence Odds Ratio (POR) = (a*d) / (c*b)

Chi - square Test for Independence

The Chi-squared test is applied when ;

- A single population has two categorical variables.
- We are about to determine whether there is a significant association between the two categorical variables.
- We are about to determine whether results are statistically significant.

Chi Square ($\chi 2$) Test - Assumptions

The following assumptions or fundamentals must be met prior to carrying out a Chi-square test ;

- The expected value of a cell count must be equal to, or greater than 5 in a contingency table.
- The observations within a sample must be independent of one another.
- The sample is a random sample of categorical observations from a large population.

Chi-square – Formula :

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}.$$

where $\mathbf{O_{i,j}}$ is the observed frequency count at level ***i*** of Variable **A** and level ***j*** of Variable **B**,

$\mathbf{E_{i,j}}$ is the expected frequency count at level ***i*** of Variable **A** and level ***j*** of Variable **B**.

Chi-square – Hypothesis :

Chi-square hypothesis states that ;

The Null $\mathbf{H_o}$: variable **1** and variable **2** are independent

(Assumes that there is no association between the two variables).

The Alternative $\mathbf{H_a}$: variable **1** and variable **2** are not independent

(Assumes that there is an association between the two variables).

Thank you