# Probability

## OVERVIEW & PURPOSE

In this session, participants will have an Introduction to probability for data sciences

## OBJECTIVE

- Introduction to Probability
- Basic Probability Rules
- Conditional Probability and Independence
- Discrete Probability Distribution
- Continuous Probability Distributions
- Central Limit Theorem
- Descriptive Statistics and Data Visualization
- Applications in Data Science

## Introduction to Probability:

**Definition:** Probability quantifies the uncertainty or variability of outcomes. Mathematically, it's the ratio of favorable outcomes to all possible outcomes.

**Example:** If you flip a fair coin, the probability of getting heads is 0.5 because there is 1 favorable outcome (heads) and 2 possible outcomes (heads or tails).

**Importance:** In data science, we deal with uncertainty often. Probability provides a foundation to model, measure, and predict uncertain events.

**Basic Terminology:**

**Outcome:** A single result of an experiment.
**Event:** One or more outcomes of interest.
**Sample Space:** The set of all possible outcomes.
**Example:** If you roll a die, the sample space is {1,2,3,4,5,6}. Getting an even number is an event, with outcomes {2,4,6}.

**Importance:** To correctly model uncertainty, you need to understand the elements you are working with and how they relate to each other.

**Fundamental Principle:** The probability of any event lies between 0 (impossible event) and 1 (certain event).

**Importance:** This helps ensure that our probability values make logical sense and keeps our predictions and models grounded.

## Basic Probability Rules:

**Addition Rule:**

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

$P(A \cup B) = P(A) + P(B) - P(A \cap B)$

**Example:** Probability of drawing a heart or a king from a deck of cards.

**Importance:** Helps determine combined probabilities, crucial for evaluating multiple events or conditions.

**Multiplication Rule:**

$$P(A \cap B) = P(A) \cdot P(B \mid A)$$

$P(A \cap B) = P(A) \times P(B \mid A)$

**Example:** Probability of drawing two aces in a row from a deck.

**Importance:** Essential when dealing with dependent events in sequences or processes.

**Complementary Events:**

The complement of A, denoted by $A'$, $A$ or $A^c$, consists of all the outcomes in which the event A does not occur.

$$P(A)+P(A')=1$$

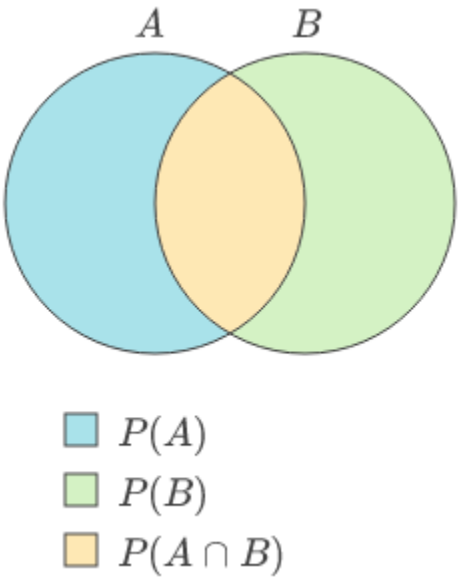
$$P(A)=1-P(A')$$

$P(A')=1-P(A)$

**Importance:** Useful when it's easier to calculate the probability of something not happening.

## Conditional Probability and Independence:

### Conditional Probability:

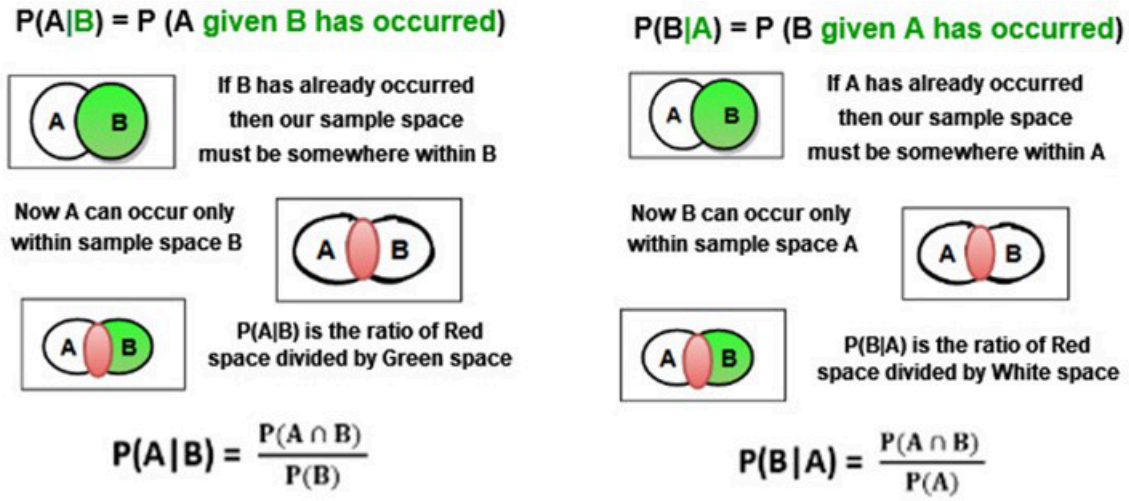



Conditional Probability Formula

$$P(A \mid B) = \frac{P(A \cap B)}{P(B)}$$

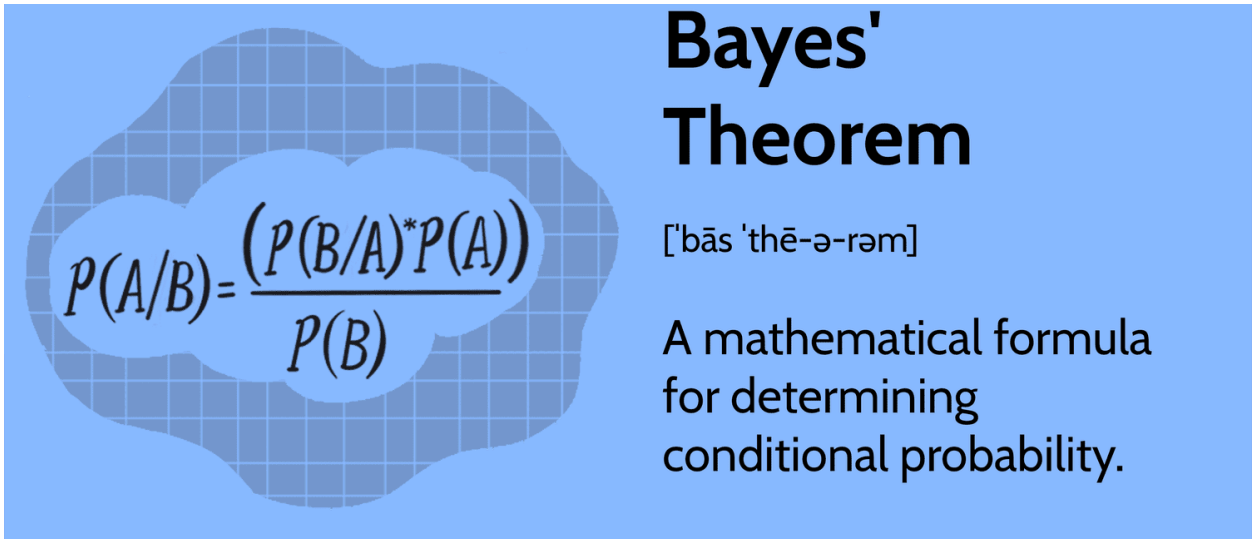
Probability that A occurs given that B has already occured

**Example:** Probability of someone being a smoker given that they have lung cancer.



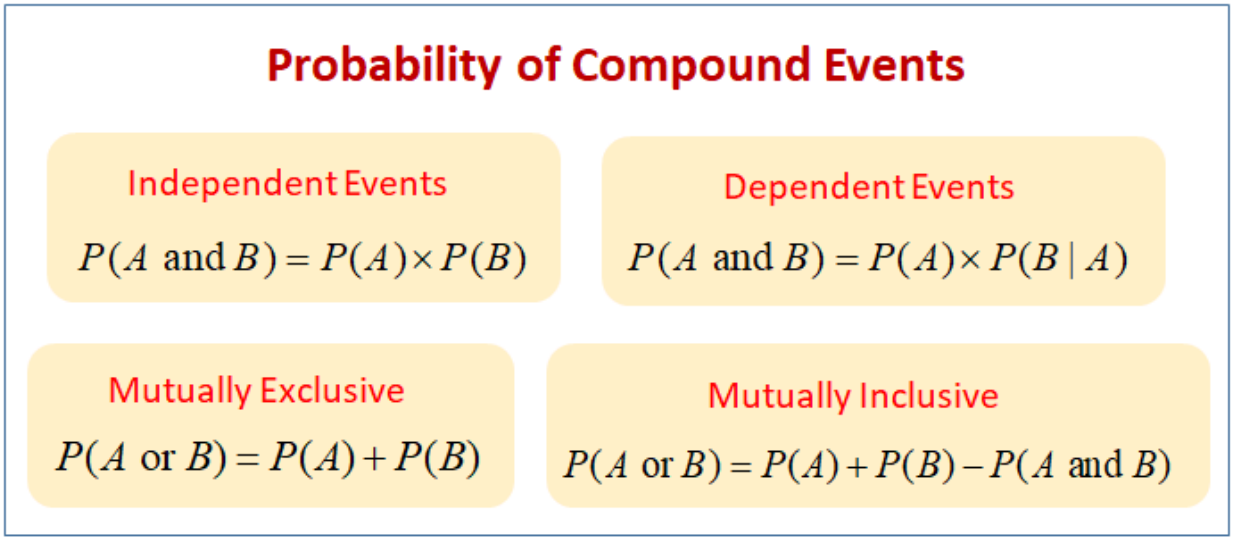

**Importance:** Key for understanding dependencies and relationships between events.

**Bayes' Theorem:**



**Importance:** Essential in many machine learning algorithms and for updating probabilities with new information.

**Independence:** If

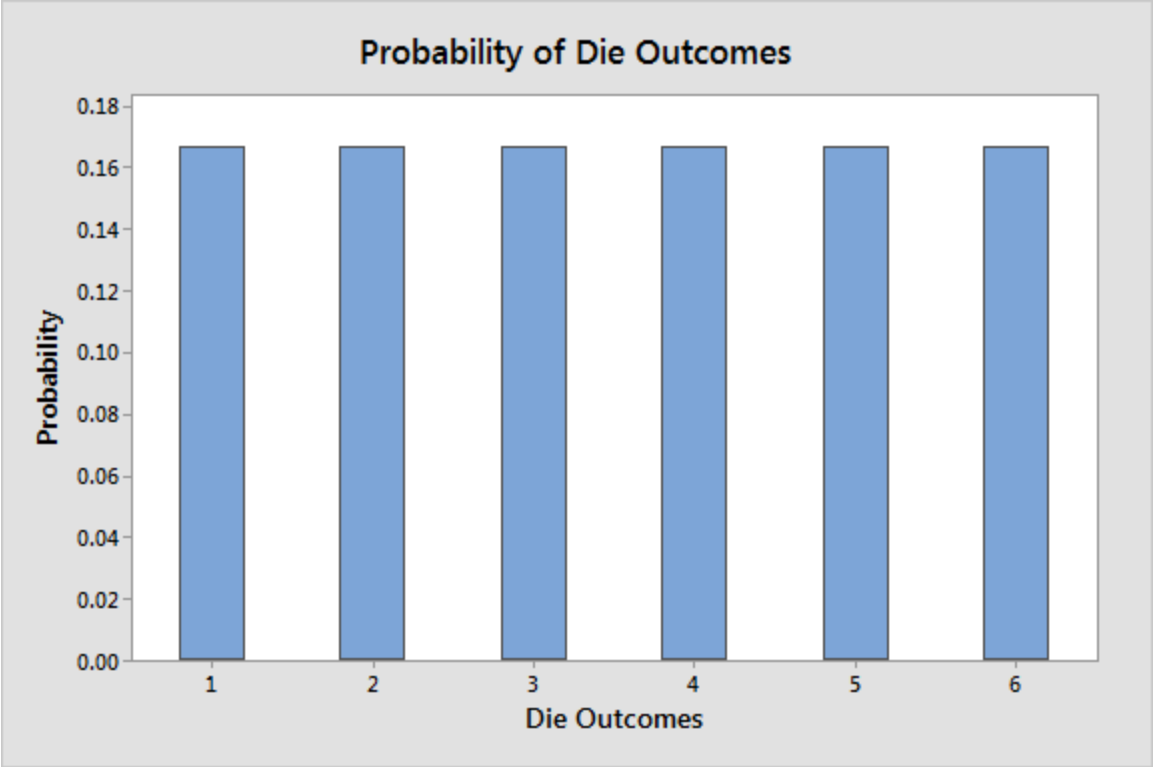



$P(A \cap B) = P(A) \times P(B)$, A and B are independent.


**Importance:** Helps simplify complex probability calculations and understand relationships.

## Discrete Probability Distributions:

**Uniform Distribution:** Each outcome is equally likely.




**Importance:** Serves as a baseline model for comparison.

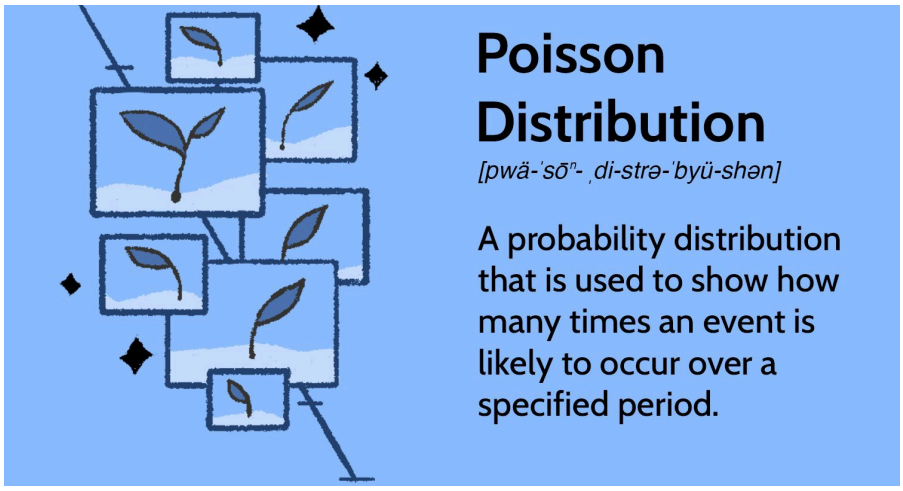
**Binomial Distribution:**

$$P(x) = \binom{n}{x} p^x q^{n-x} = \frac{n!}{(n-x)!x!} p^x q^{n-x}$$

where
$n$ = the number of trials (or the number being sampled)
$x$ = the number of successes desired
$p$ = probability of getting a success in one trial
$q$ = 1 - p = the probability of getting a failure in one trial

**Importance:** Useful in situations with two outcomes, like pass/fail, win/lose.

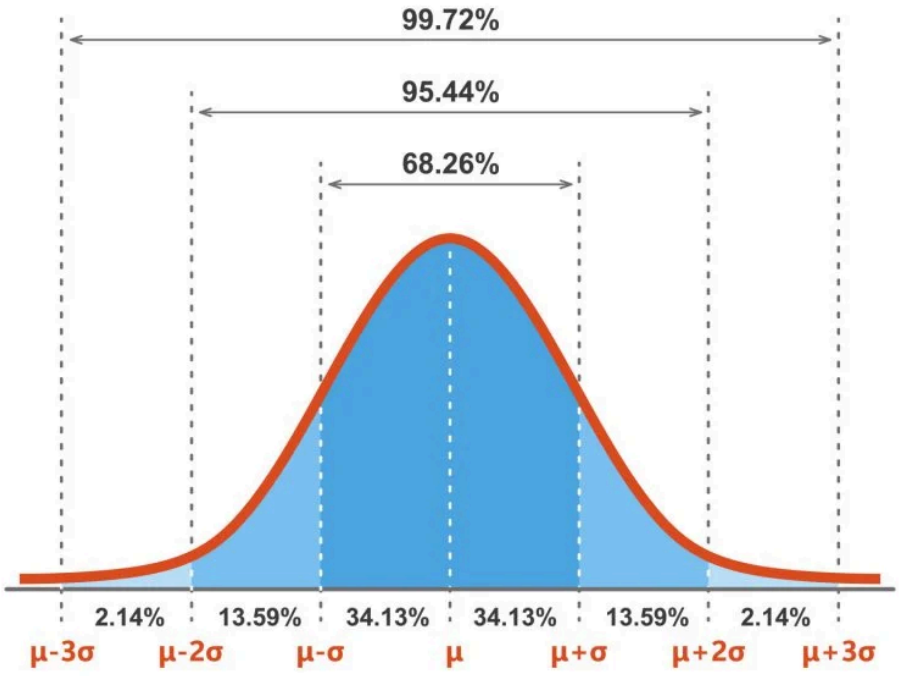
**Poisson Distribution:**




**Importance:** Great for modeling rare events over time or space.

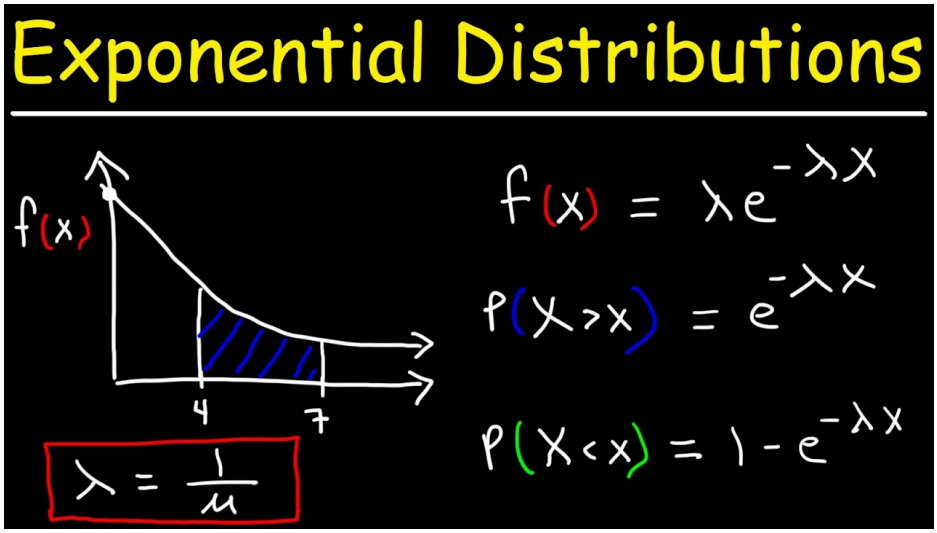
## Continuous Probability Distributions:

**Normal Distribution:** Characterized by mean $\mu$ and standard deviation $\sigma$.



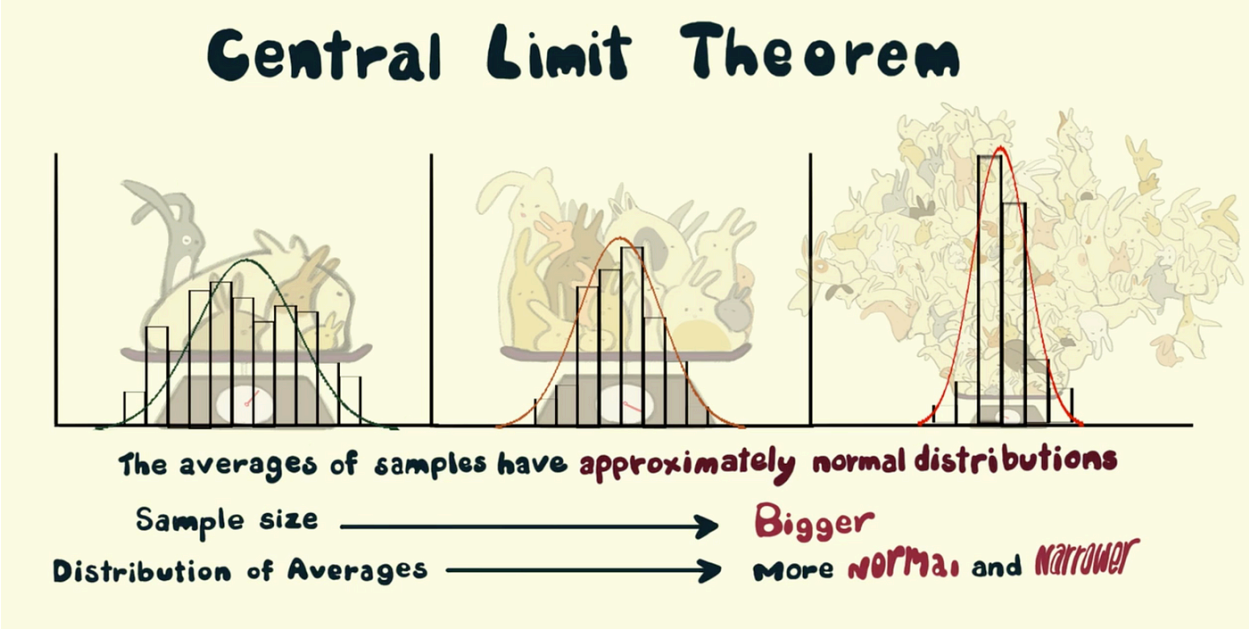

**Importance:** The foundation for many statistical methods and hypothesis tests.

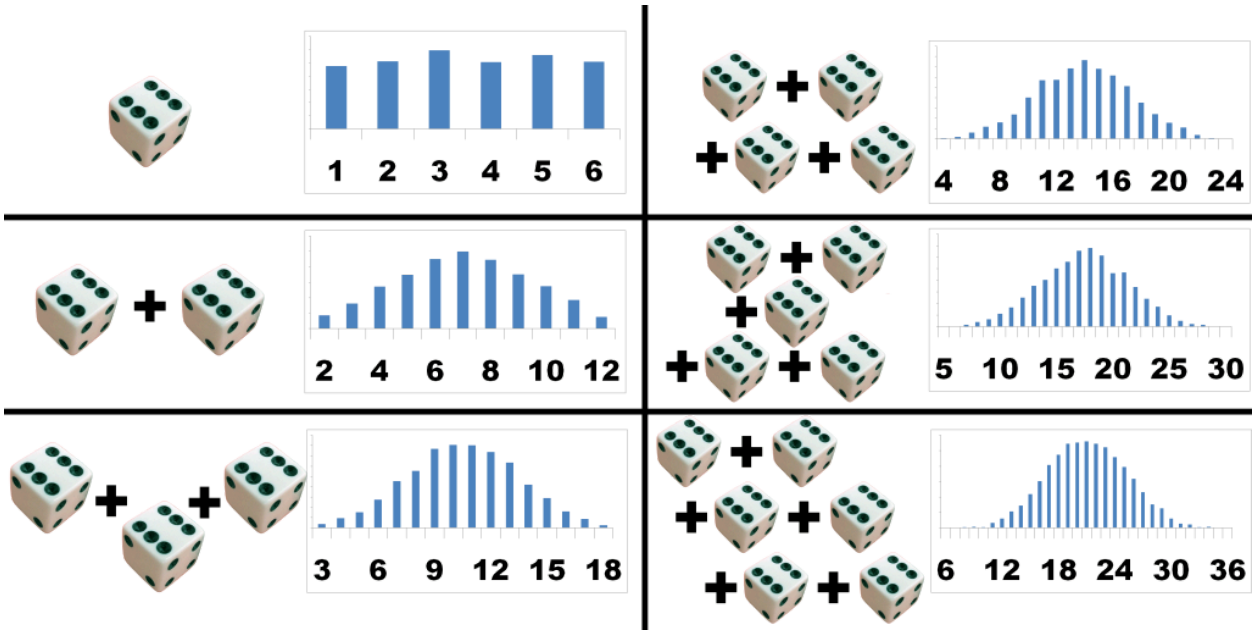
**Exponential Distribution:** Models time between events.



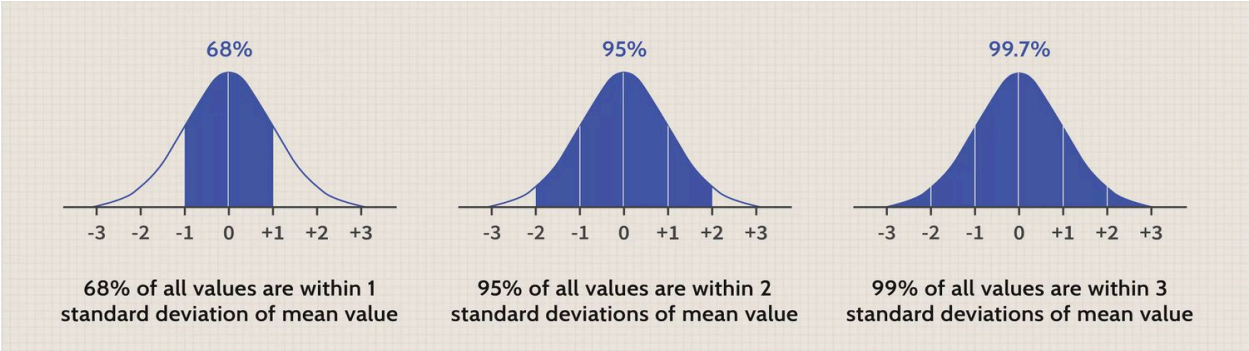

**Importance:** Useful for modeling lifetimes or decay.

## Central Limit Theorem:



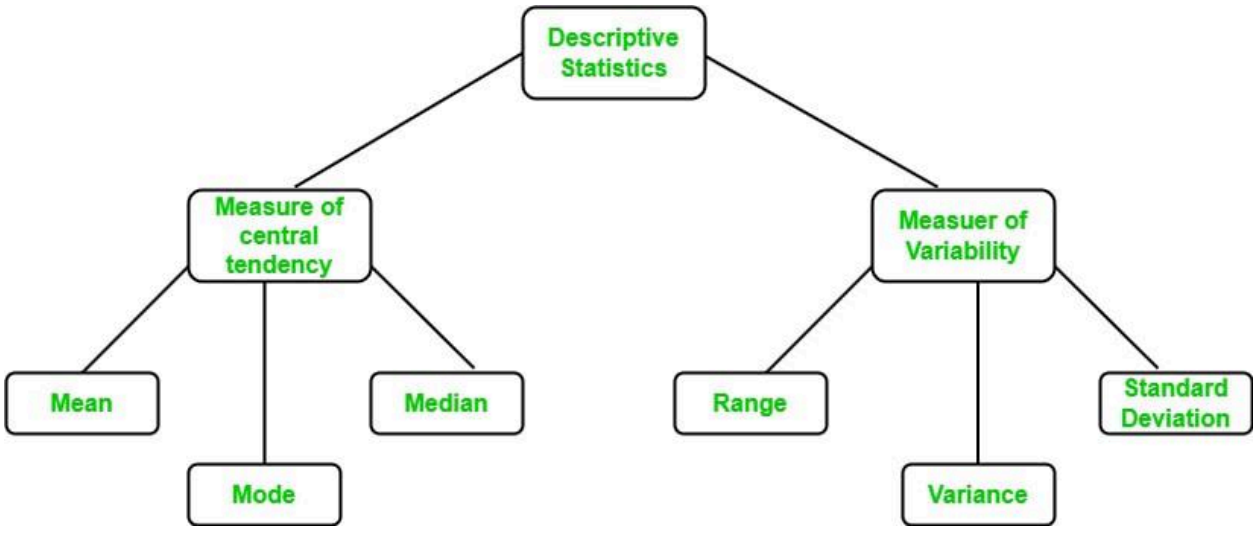

Even if initial data isn't normal, the distribution of sample means becomes more normal as sample size increases.



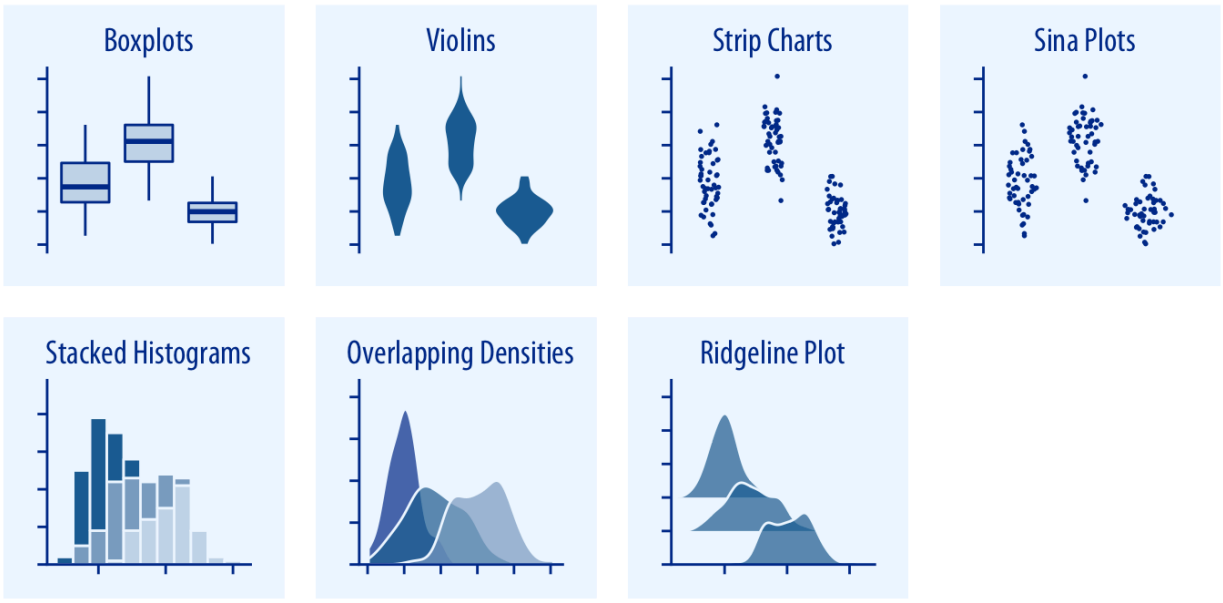

Importance: Underpins many statistical methods and hypothesis tests.

## Descriptive Statistics and Data Visualization:

**Metrics** like mean, median, mode, variance, and standard deviation provide summary statistics.




**Histograms and Box** Plots help visualize and understand data distributions.




**Importance:** Provides initial insights, helps spot trends, outliers, and anomalies.

## Applications in Data Science:

**Hypothesis Testing:** Test assumptions or hypotheses about a dataset.

**Importance:** Crucial for making informed decisions based on data.

**Regression Analysis:** Understand relationships and predict outcomes.

**Importance:** Core technique in predictive modeling.

**Bayesian Thinking:** Combine prior knowledge with observed data.

**Importance:** Offers a flexible framework for modeling and prediction, especially with limited data.

Understanding these concepts in depth provides a strong foundation for anyone diving into the realm of data science and statistical analysis.