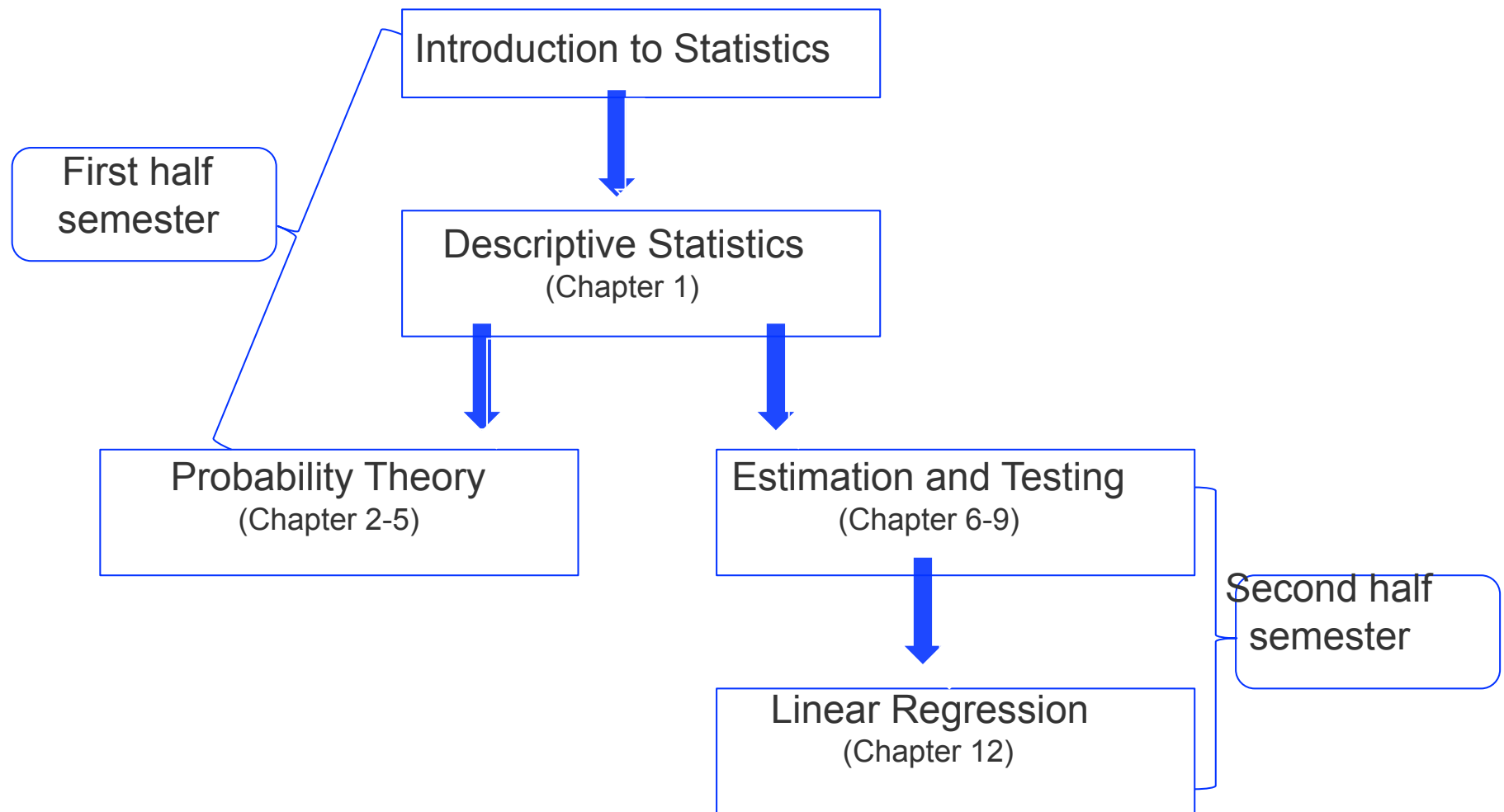


# Overview of the course



# Basic concepts

- **Population:** the whole class of individuals which an investigator is interested in.
- **Census:** the desired information is available for all objects in the population.
- **Sample:** a subset (part) of the population which is examined or observed.
- **Sample Size:** the number of observations in a single sample.
- **Variable:** any characteristic whose value may change from one object to another in the population, including *univariate*, *bivariate*, *multivariate*.

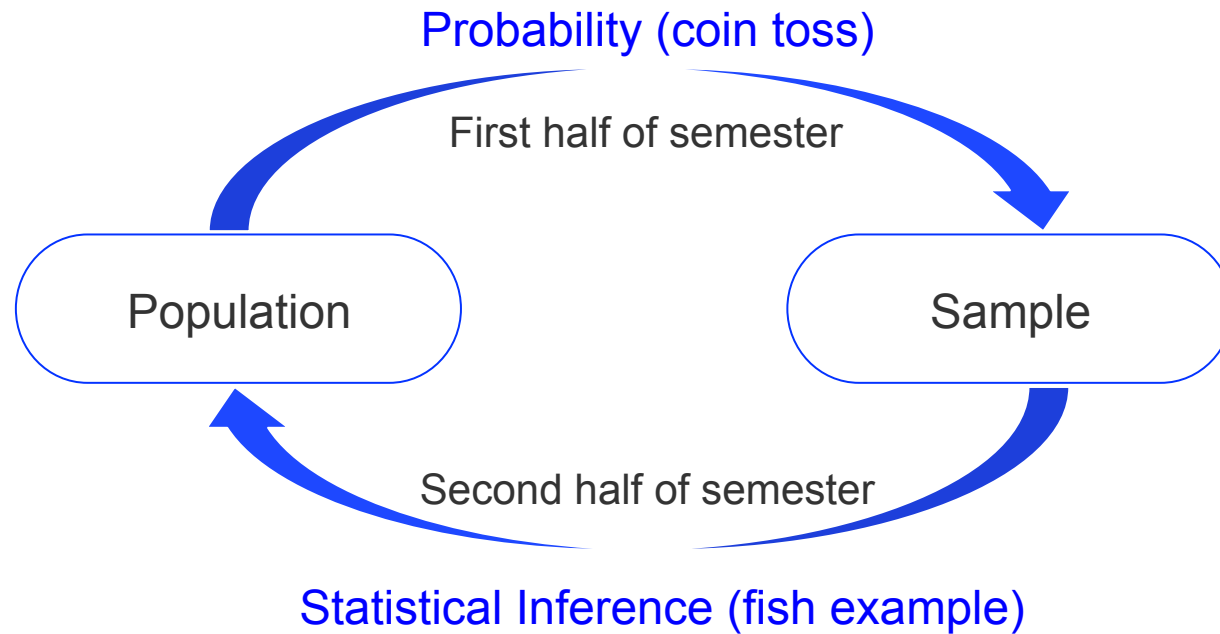
# Probability

- What are random variables? Example: coin tosses.
- To describe random variables: *distribution*. This course will cover a variety of commonly used probability distributions.
  - Discrete distributions: Binomial, Poisson, etc.
  - Continuous distributions: Exponential, Normal (Gaussian), etc.
- Conditional probability.

# Statistical Inference

- Estimation:
  - Point estimation. Example: What is the total number of fish in a lake?
  - Interval estimation.
- Hypothesis testing:
  - One sample testing.
  - Two sample testing. Example: Is there a significant improvement in the new drug?
- Estimation and hypothesis testing are just two different ways of looking at the same problem.

# Probability and Inference



# Descriptive Statistics

- Pictorial methods:
  - Stem-and-Leaf Displays.
  - Dotplots.
  - Histograms.
- All these methods convey information about the following aspects of the data:
  - Identification of a typical or representative value
  - Extent of spread about the typical value
  - Presence of any gaps in the data
  - Extent of symmetry in the distribution of values
  - Number and location of peaks
  - Presence of any outlying values

# Stem-and-Leaf displays

- Steps for constructing a Stem-and-Leaf Display:
  1. Select one or more leading digits for the stem values. The trailing digits become the leaves.
  2. List possible stem values in a vertical column.
  3. Record the leaf for every observation beside the corresponding stem value.
  4. **Indicate the units for stems and leaves someplace in the display.**
- R demo for Stem-and-Leaf:
  - Command: `>stem(x)`
  - Option: `scale=...`, `scale` has to be a positive number. It controls the plot length. A value of `scale=2` will cause the plot to be roughly twice as long as the default (`=1`).

# Dotplots

- When to use? *When the data is reasonably small or there are relatively few distinct data values, and have ties.*
- Each observation is represented by a dot above the corresponding location on a horizontal measurement scale. When a value occurs more than once, there is a dot for each occurrence, and these dots are stacked vertically.
- There are no built-in functions in R that can plot dotplots. One has to write his own function to do the job.
  - R demo. Define new functions.
  - Function: `>dotplot(x)`



# More basic concepts

- **Discrete Variable:** Its set of possible values is either finite or else can be listed in an infinite sequence. (Gender, Age, etc.)
- **Continuous Variable:** Its possible values consist of an entire interval on the real number line. (Height, Weight, etc.)
- **Frequency:** Number of times a value occurs in the data set.
- **Relative Frequency:**  $\text{Frequency} / (\text{Sample size})$ .

# Histogram

- Most commonly used tool in descriptive statistics.
- Histogram for discrete data:
  - Determine the frequency and relative frequency of each  $x$  value.
  - Mark possible  $x$  values on a horizontal scale.
  - Above each value, draw a rectangle whose height is the relative frequency (or the frequency) of that value.
- Histogram for continuous data:
  - Divide the range of the data into classes (5-10) of *equal width*. (It can also be unequal.)
  - Determine the frequency and relative frequency for each class.
  - Mark the class boundaries on a horizontal measurement axis.
  - Above each class interval, draw a rectangle whose height is the corresponding relative frequency (or frequency).

# Constructing histogram

- **Example:** The maximum daily temperature in degrees Fahrenheit measured from May to September 1973 at La Guardia Airport. (154 observations)

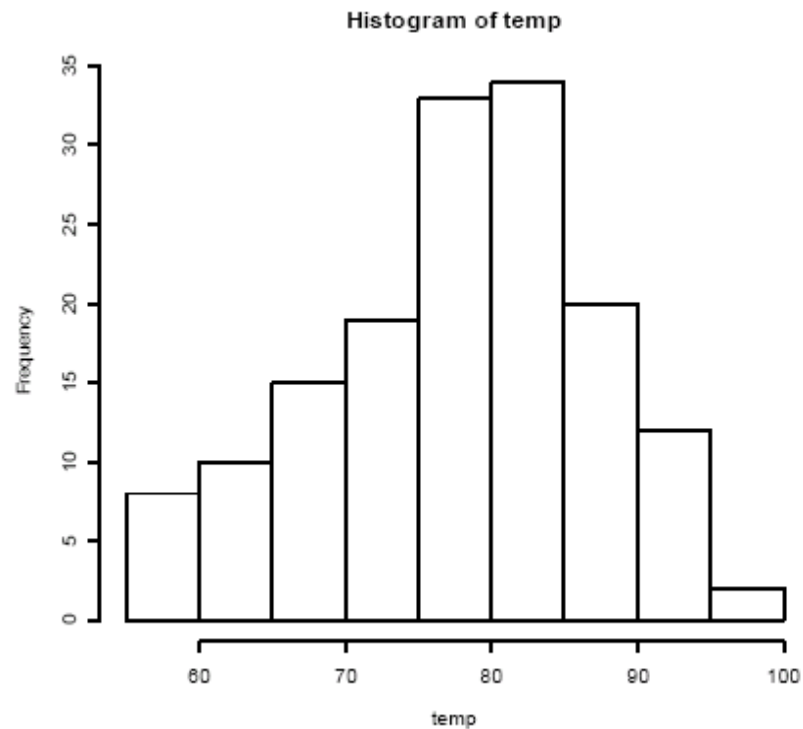
Data

{67 72 74 62 56 66 65 59 61 69 74 69 66 68 58 64 66 57 68 62 59 73 61 61 57  
58 57 67 81 79 76 78 74 67 84 85 79 82 87 90 87 93 92 82 80 79 77 72 65 73  
76 77 76 76 76 75 78 73 80 77 83 84 85 81 84 83 83 88 92 92 89 82 73 81 91  
80 81 82 84 87 85 74 81 82 86 85 82 86 88 86 83 81 81 81 82 86 85 87 89 90  
90 92 86 86 82 80 79 77 79 76 78 78 77 72 75 79 81 86 88 97 94 96 94 91 92  
93 93 87 84 80 78 75 73 81 76 77 71 71 78 67 76 68 82 64 71 81 69 63 70 77  
75 76 68}

Draw a histogram.

## Example cont.

Class	Count	Percent
55-59.9	8	5.2
60-64.9	10	6.5
65-69.9	15	9.8
65-74.9	19	12.4
75-79.9	33	21.6
80-84.9	34	22.2
85-89.9	20	13.1
90-94.9	12	7.9
95-99.9	2	1.3



- R demo. `>hist(x)` (option: `breaks=...`)

# Unequal class widths

- For unequal class widths, the rectangle height is determined by the formula,

$$\text{rectangle height} = \frac{\text{relative frequency of the class}}{\text{class width}}$$

the resulting rectangle height is called *densities*.

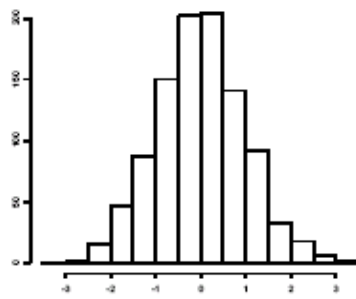
- The areas under densities sum up to 1.
- In R, we use `breaks` to define the unequal class widths. Setting `freq = FALSE` to switch from frequencies to densities.

# Examining distributions

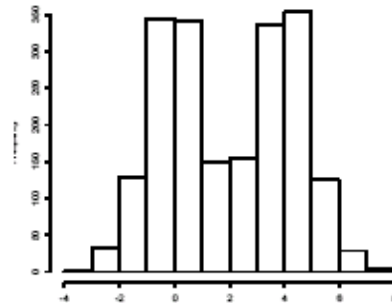
- When examining a distribution, look at its **shape**, **center** and **spread**. Look for clear deviations from the overall shape.
- We are interested in whether it is symmetric or skewed, as well as the number of modes.
- **Outliers** are observations that lie outside of the overall pattern of a distribution.

# Examining distributions

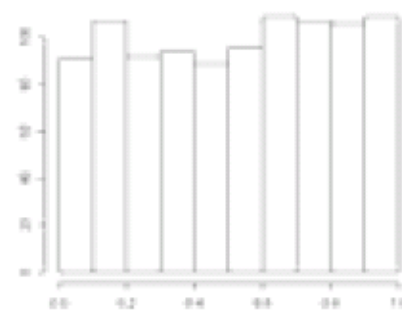
(a) Symmetric, unimodal



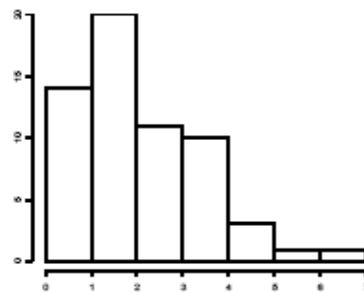
(b) bimodal



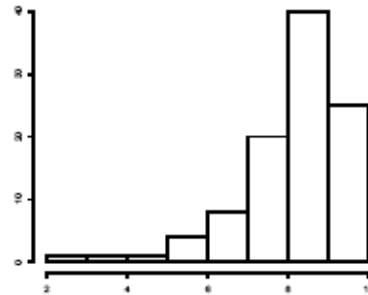
(c) Uniform



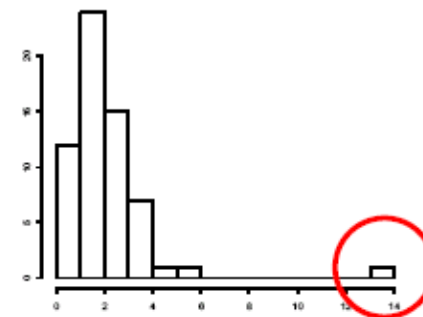
(d) right skewed



(e) left skewed



(f) Outlier



# Examining a new data set

1. Examine each variable by itself.
2. Study the relationship between variables.

For both steps 1 and 2 we want to:

- Display the data graphically.
- Summarize the data numerically (Statistics).
- Construct a mathematical model.



# Describing distributions numerically

- For single variables, We are interested in summaries that provide information about the **center** and **spread** of the distribution.
- A **statistic** is a numerical summary of data.
- The two most common measures of center are the **mean** and **median**.
- “generous” vs. “selfish”.

# Mean

- If we have  $n$  ,observations, their **mean** is defined by,

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

or

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

Ex. Calculate the mean of the data set: {1,2,3,4,5}.

$$\bar{x} = \frac{1 + 2 + 3 + 4 + 5}{5} = \frac{15}{5} = 3$$

Ex. Calculate the mean of the data set: {1,2,3,4,30}.

$$\bar{x} = \frac{1 + 2 + 3 + 4 + 30}{5} = \frac{40}{5} = 8$$

# Mean cont.

- The mean is **non-resistant**, meaning that it is influenced by very large or very small data points that are extreme values for the data set.



# Median

The **median**, written as  $M$ , is defined as the middle value of a data set.

1. List all  $n$  observations in order of size.
2. If  $n$  is odd, the median is the center value of the ordered list.
3. If  $n$  is even, the median is the average of the two center observations.

# Median Cont.

Ex. Calculate the median of {6,2,5,19,12,10}.

2 5 6 | 10 12 19

M is the average of 6 and 10, hence  $M=8$ .

Ex. Calculate the median of {1,2,3,4,5} and {1,2,3,4,30}.

1 2 3 | 4 5       $M=3$ .

1 2 3 | 4 30       $M=3$ .

# Median cont.

- The median is **resistant** (**robust**) to the extremes in the data set. Extremely large or small values do NOT influence the median.

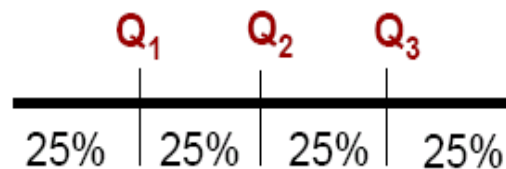


# Measures of variability

- Mean and median provide measures of **location** (**center**).
- One also needs some measures of **variability** to further describe the **spread** of the data set.
- Commonly used numerical values that can summarize the spread of a distribution.
  - Range
  - Interquartile Range (IQR)
  - Standard deviation

# Quartiles

- The median divides the data into two groups of equal size.
- The quartiles divide the data into four groups of equal size.





# Quartiles cont.

To find the quartiles:

1. Find the median.
2. Find the first quartile (Q1, or the *lower fourth*) by finding the median of the lower half of the data.
3. Find the third quartile (Q3, or the *upper fourth*) by finding the median of the upper half of the data.

*(When  $n$  is odd include the median in both halves in steps 2 and 3.)*

Ex. Find the quartiles for the data set {2,4,6,8,12,14,18,19,41}.

2 4 6 8 **12** 14 18 19 41

2 4 **6** 8 12

12 14 **18** 19 41

M = 12   Q1 = 6   Q3 = 18

# IQR

- The Interquartile Range, IQR, is the distance between the first and third quartiles,

$$\text{IQR} = Q3 - Q1.$$

- The IQR measures the spread of the middle 50% of the data.
- An observation is a suspected **outlier** if it falls more than  $1.5 \times \text{IQR}$  from the closest fourth. An outlier is **extreme** if it is more than  $3 \times \text{IQR}$  from the nearest fourth, and it is **mild** otherwise.

Ex. Can any of the observations in the data set  $\{2, 4, 6, 8, 12, 14, 18, 19, 41\}$  be considered outliers?

Recall we had  $M = 12$ ,  $Q1 = 6$ ,  $Q3 = 18$ . Therefore,  $\text{IQR} = 18 - 6 = 12$ .

$1.5 \times \text{IQR} = 1.5 \times 12 = 18$ .  $Q3 + 18 = 36$ ,  $Q1 - 18 = -12$ . Since  $41 > 36$ , 41 is classified as a potential outlier.