Principles of Data Collection

Prof. Wells

STA 209, 2/10/23

Outline

In this lecture, we will. . .

Outline

In this lecture, we will. . .

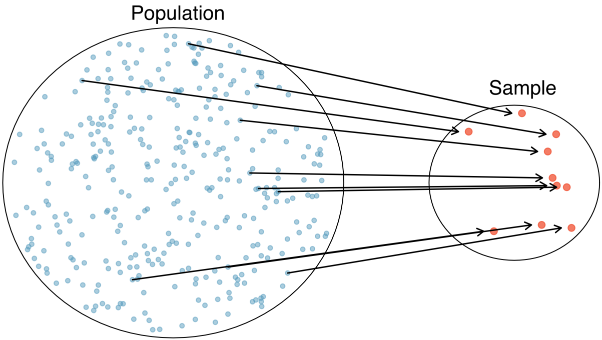
- Discuss principles of data collection
- Compare and contrast observational studies and random experiments

Section 1

Principles of Data Collection

Populations and Samples

- Every statistical investigation must begin by clearly identifying the **population** to be studied, the **variables** to be measured, and the **sample** from which measurements will be taken.



Sampling

"This is a program that intrudes on people's lives, just like the Environmental Protection Agency or the bank regulators. We're spending $70 per person to fill this out. That's just not cost effective, especially since in the end this is not a scientific survey. ***It's a random survey.****"*

— D. Webster, Congressman, on the *American Community Survey*

Sampling

"This is a program that intrudes on people's lives, just like the Environmental Protection Agency or the bank regulators. We're spending $70 per person to fill this out. That's just not cost effective, especially since in the end this is not a scientific survey. ***It's a random survey.****"*

— D. Webster, Congressman, on the *American Community Survey*

- How can a random sample allow us to make justified, scientific conclusions about a population?

Sampling

"This is a program that intrudes on people's lives, just like the Environmental Protection Agency or the bank regulators. We're spending $70 per person to fill this out. That's just not cost effective, especially since in the end this is not a scientific survey. ***It's a random survey.****"*

— D. Webster, Congressman, on the *American Community Survey*

- How can a random sample allow us to make justified, scientific conclusions about a population?
  - Properties of probability allow us to quantify uncertainty.

Sampling

"This is a program that intrudes on people's lives, just like the Environmental Protection Agency or the bank regulators. We're spending $70 per person to fill this out. That's just not cost effective, especially since in the end this is not a scientific survey. ***It's a random survey.****"*

— D. Webster, Congressman, on the *American Community Survey*

- How can a random sample allow us to make justified, scientific conclusions about a population?
  - Properties of probability allow us to quantify uncertainty.
  - In isolation, a single random event may seem arbitrary. But in aggregate, a collection of random events is predictable.

Sampling

"This is a program that intrudes on people's lives, just like the Environmental Protection Agency or the bank regulators. We're spending $70 per person to fill this out. That's just not cost effective, especially since in the end this is not a scientific survey. ***It's a random survey.****"*

— D. Webster, Congressman, on the *American Community Survey*

- How can a random sample allow us to make justified, scientific conclusions about a population?
  - Properties of probability allow us to quantify uncertainty.
  - In isolation, a single random event may seem arbitrary. But in aggregate, a collection of random events is predictable.
- By following basic procedures for randomly selecting a sample, we can be certain that the results fall within a specified margin of the true value a particular percentage of the time.

Simple Random Sampling

- The most basic form of random sampling is **simple random sampling** (SRS), where every member of the population has an equal chance of being selected for the sample.

Simple Random Sampling

- The most basic form of random sampling is **simple random sampling** (SRS), where every member of the population has an equal chance of being selected for the sample.
  - Imagine that a unique ID for each individual is written on a slip of paper and thoroughly shuffled together. IDs are then drawn one-by-one to create a sample.

Simple Random Sampling

- The most basic form of random sampling is **simple random sampling** (SRS), where every member of the population has an equal chance of being selected for the sample.
  - Imagine that a unique ID for each individual is written on a slip of paper and thoroughly shuffled together. IDs are then drawn one-by-one to create a sample.
- Importantly, by construction, there is no inherent correlation between any two members of the sample.

Simple Random Sampling

- The most basic form of random sampling is **simple random sampling** (SRS), where every member of the population has an equal chance of being selected for the sample.
  - Imagine that a unique ID for each individual is written on a slip of paper and thoroughly shuffled together. IDs are then drawn one-by-one to create a sample.
- Importantly, by construction, there is no inherent correlation between any two members of the sample.
- Its possible a particular sample may not be "representative" of the population (provided it was not caused by systematic error in sampling).

Simple Random Sampling

- The most basic form of random sampling is **simple random sampling** (SRS), where every member of the population has an equal chance of being selected for the sample.
  - Imagine that a unique ID for each individual is written on a slip of paper and thoroughly shuffled together. IDs are then drawn one-by-one to create a sample.
- Importantly, by construction, there is no inherent correlation between any two members of the sample.
- Its possible a particular sample may not be “representative” of the population (provided it was not caused by systematic error in sampling).
- In fact, it is necessary that such under-representation samples are possible, in order to quantify *extreme* events.

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.
- Some particular sources of statistical bias include:
  - **Non-response**, where an individual selected for a sample cannot or will not contribute.

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.
- Some particular sources of statistical bias include:
  - **Non-response**, where an individual selected for a sample cannot or will not contribute.
  - **Undercoverage**, where some groups of a population are less likely to be included in the sample.

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.
- Some particular sources of statistical bias include:
  - **Non-response**, where an individual selected for a sample cannot or will not contribute.
  - **Undercoverage**, where some groups of a population are less likely to be included in the sample.
  - **Response**, where a sampled individual does not provide accurate or truthful data.

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.
- Some particular sources of statistical bias include:
  - **Non-response**, where an individual selected for a sample cannot or will not contribute.
  - **Undercoverage**, where some groups of a population are less likely to be included in the sample.
  - **Response**, where a sampled individual does not provide accurate or truthful data.
  - **Self-selection**, where membership in the sample is voluntary (leading to correlation between results and traits promoting participation)

Statistial Bias

- Non-random sampling may create **statistical bias**, where certain outcomes are systematically preferred due to sampling technique.
- Some particular sources of statistical bias include:
  - **Non-response**, where an individual selected for a sample cannot or will not contribute.
  - **Undercoverage**, where some groups of a population are less likely to be included in the sample.
  - **Response**, where a sampled individual does not provide accurate or truthful data.
  - **Self-selection**, where membership in the sample is voluntary (leading to correlation between results and traits promoting participation)
  - **Convenience**, where "randomization" is performed by selecting a convenient block of individuals in the population (leading to strong correlation between members of the sample)

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?
  - What sources of bias are present in this sample?

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?
  - What sources of bias are present in this sample?
- Suppose a year later, the restaurant still has 3.5 stars, but now with 2000 reviews. Does the verdict change?

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?
  - What sources of bias are present in this sample?
- Suppose a year later, the restaurant still has 3.5 stars, but now with 2000 reviews. Does the verdict change?
  - Large size cannot correct for bias in the sample.
  - Imagine we polled the entirety of Iowa City (75k people) about their rating of the restaurant. What would we learn from this data about the preferences of people who live in Ames?

Sampling Example

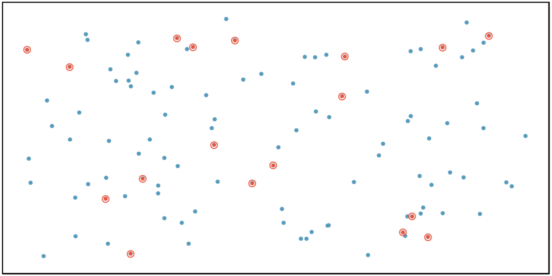
- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?
  - What sources of bias are present in this sample?
- Suppose a year later, the restaurant still has 3.5 stars, but now with 2000 reviews. Does the verdict change?
  - Large size cannot correct for bias in the sample.
  - Imagine we polled the entirety of Iowa City (75k people) about their rating of the restaurant. What would we learn from this data about the preferences of people who live in Ames?
- Small but appropriately random samples tend to be more representative then large but non-random samples.

Sampling Example

- Suppose we want to know how Iowans feel about a new Pizza restaurant that just opened in Iowa City.
- The particular restaurant has a yelp rating of 3.5 stars with 50 reviews.
  - Can we conclude that that average rating among Iowans is about 3.5 stars?
  - What sources of bias are present in this sample?
- Suppose a year later, the restaurant still has 3.5 stars, but now with 2000 reviews. Does the verdict change?
  - Large size cannot correct for bias in the sample.
  - Imagine we polled the entirety of Iowa City (75k people) about their rating of the restaurant. What would we learn from this data about the preferences of people who live in Ames?
- Small but appropriately random samples tend to be more representative then large but non-random samples.
  - An SRS of size 1000 can estimate a proportion to within 0.03

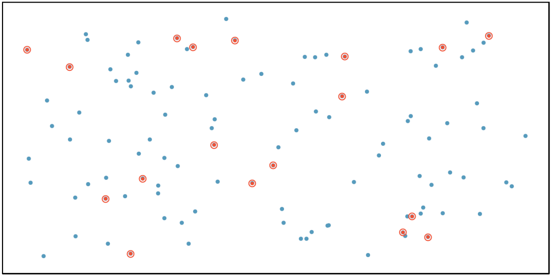
Sampling Methods (SRS)

- **SRS**: Randomly select individuals from the population so that each individual has equal likelihood of being selected.



Sampling Methods (SRS)

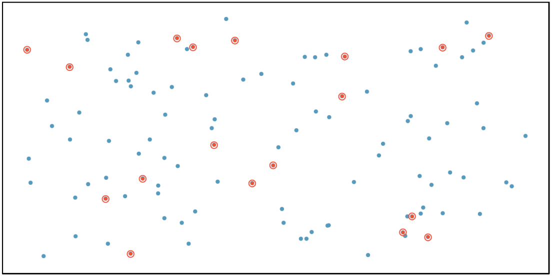
- **SRS**: Randomly select individuals from the population so that each individual has equal likelihood of being selected.



- Advantages:
  - Typically provides better representation compared to larger, non-random samples
  - Relatively simple to implement and analyze
  - Non-biased
  - Provides effective theoretical baseline

Sampling Methods (SRS)

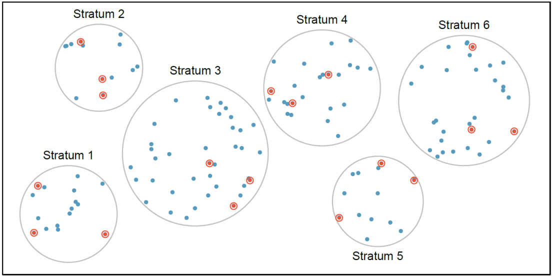
- **SRS**: Randomly select individuals from the population so that each individual has equal likelihood of being selected.



- Disadvantages:
  - May not be as precise as other sampling techniques
  - Can be difficult to perform in practice

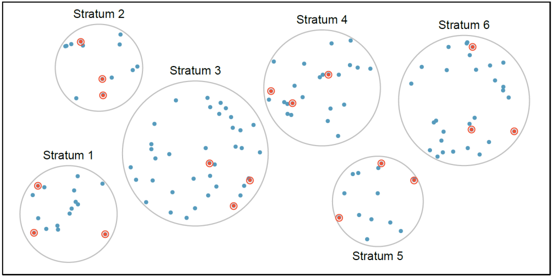
Sampling Methods (Stratified)

- **Stratified**: Strata are made up of similar individuals, then an SRS is taken from each stratum.



Sampling Methods (Stratified)

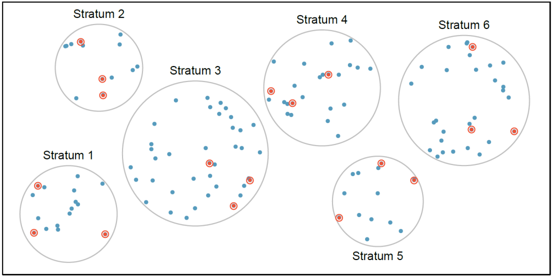
- **Stratified**: Strata are made up of similar individuals, then an SRS is taken from each stratum.



- Advantages:
  - Can be more precise than an SRS, thus requiring lower sample size
  - Hedges against non-representative samples
  - Strata proportions can be adjusted to ensure sufficient data to support analysis

Sampling Methods (Stratified)

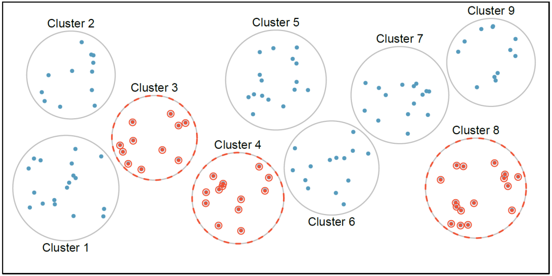
- **Stratified**: Strata are made up of similar individuals, then an SRS is taken from each stratum.



- Disadvantages:
  - Requires more administrative labor in implementation
  - Statistical analysis is more complex
  - Cannot always be implemented

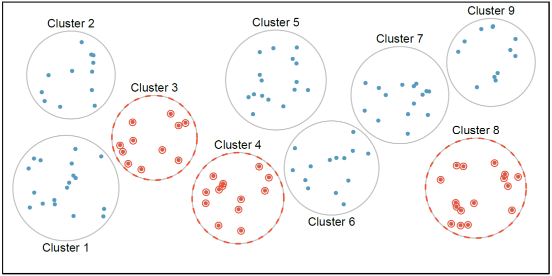
Sampling Methods (Clustered)

- **Clustered**: An SRS is taken of non-homogeneous clusters. A sample is formed from all observations in those clusters.



Sampling Methods (Clustered)

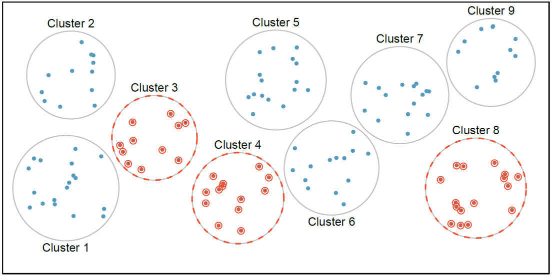
- **Clustered**: An SRS is taken of non-homogeneous clusters. A sample is formed from all observations in those clusters.



- Advantages:
  - Can be used when it is difficult or impossible to create complete list of population
  - Useful when population is naturally concentrated in heterogeneous groups
  - Often more cost/time effective per sample size than alternatives

Sampling Methods (Clustered)

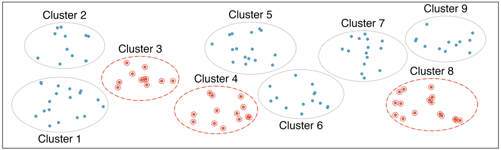
- **Clustered**: An SRS is taken of non-homogeneous clusters. A sample is formed from all observations in those clusters.

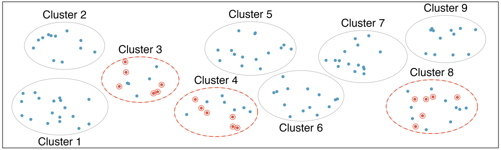


- Disadvantages:
  - Is less precise than simple or stratified sampling
  - Statistical analysis is more complex
  - Cannot always be implemented

Sampling Methods (Multistaged)

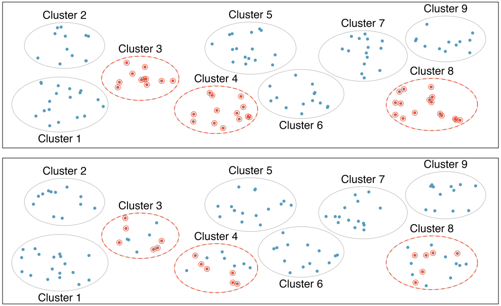
- **Multistaged**: An SRS is taken of non-homogeneous clusters. Then, an SRS is then performed within each cluster.





Sampling Methods (Multistaged)

- **Multistaged**: An SRS is taken of non-homogeneous clusters. Then, an SRS is then performed within each cluster.



- Advantages / Disadvantages:
  - Allows for clusters contain large number of observations.
  - Statistical analysis more complex
  - Compared to cluster sampling, has higher variability.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.
  - A random sample of 10 liberal arts colleges could be selected. All students at each campus could be interviewed.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.
  - A random sample of 10 liberal arts colleges could be selected. All students at each campus could be interviewed.
- Describe how to implement *multistage sampling*.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.
  - A random sample of 10 liberal arts colleges could be selected. All students at each campus could be interviewed.
- Describe how to implement *multistage sampling*.
  - A random sample of 10 liberal arts colleges could be selected. A random subset of 100 students at each campus could be interviewed.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.
  - A random sample of 10 liberal arts colleges could be selected. All students at each campus could be interviewed.
- Describe how to implement *multistage sampling*.
  - A random sample of 10 liberal arts colleges could be selected. A random subset of 100 students at each campus could be interviewed.
- Within a college, describe how to implement *stratified sampling*.

Examples of Sampling Methods

Suppose we are interested in the relationship between alcohol consumption and academic outcomes among undergraduates at 50 liberal arts colleges in the US. We intend to conduct face-to-face interviews.

- What are some challenges posed by the *simple random sampling* method?
  - Since data collection requires face-to-face interviews, it can be expensive to visit potentially 50 different colleges.
- Describe how to implement *cluster sampling*.
  - A random sample of 10 liberal arts colleges could be selected. All students at each campus could be interviewed.
- Describe how to implement *multistage sampling*.
  - A random sample of 10 liberal arts colleges could be selected. A random subset of 100 students at each campus could be interviewed.
- Within a college, describe how to implement *stratified sampling*.
  - We could stratify students by year in school, sampling 25 students of each year.

Section 2

Experiments and Observational Studies

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:
  1. **Controlling**: Treatments of interest are compared to a control group receiving no treatment.

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:
  1. **Controlling**: Treatments of interest are compared to a control group receiving no treatment.
  2. **Randomized**: Subjects are randomly assigned into treatment / control groups to minimize influence of variables that cannot be controlled.

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:
  1. **Controlling**: Treatments of interest are compared to a control group receiving no treatment.
  2. **Randomized**: Subjects are randomly assigned into treatment / control groups to minimize influence of variables that cannot be controlled.
  3. **Replicable**: Methodology should be thoroughly documented so that later researchers can replicate study to verify findings.

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:
  1. **Controlling**: Treatments of interest are compared to a control group receiving no treatment.
  2. **Randomized**: Subjects are randomly assigned into treatment / control groups to minimize influence of variables that cannot be controlled.
  3. **Replicable**: Methodology should be thoroughly documented so that later researchers can replicate study to verify findings.
  4. **Blocking**: If variables are suspected to affect response variable, subjects are first grouped into blocks based on these variables.

Principles of Experiment Design

- The randomized experiment is the standard tool used to demonstrate causal relationship between variables.
- Modern randomized experiments are built on 5 principles:
    1. **Controlling**: Treatments of interest are compared to a control group receiving no treatment.
    2. **Randomized**: Subjects are randomly assigned into treatment / control groups to minimize influence of variables that cannot be controlled.
    3. **Replicable**: Methodology should be thoroughly documented so that later researchers can replicate study to verify findings.
    4. **Blocking**: If variables are suspected to affect response variable, subjects are first grouped into blocks based on these variables.
    5. **Blind**. When possible, neither experimenters nor subjects should know whether subjects are in treatment or control group.

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.
  - Explanatory variable: nitrate content of diet.
  - Response variable: exhaustion measured by O2 saturation.

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.
  - Explanatory variable: nitrate content of diet.
  - Response variable: exhaustion measured by O2 saturation.

  - Treatment: nitrate dietary supplement (powdered beet)
  - Control: No supplement

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.
  - Explanatory variable: nitrate content of diet.
  - Response variable: exhaustion measured by O2 saturation.

  - Treatment: nitrate dietary supplement (powdered beet)
  - Control: No supplement
- It is suspected that nitrate supplements may effect professional and amateur athletes differently,
  - We are concerned that imbalance in number of pro / amateur athletes between treatment and control groups could influence results.

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.
  - Explanatory variable: nitrate content of diet.
  - Response variable: exhaustion measured by O2 saturation.
  - Treatment: nitrate dietary supplement (powdered beet)
  - Control: No supplement
- It is suspected that nitrate supplements may effect professional and amateur athletes differently,
  - We are concerned that imbalance in number of pro / amateur athletes between treatment and control groups could influence results.
- To minimize this risk, we block subjects by pro / amateur status:

Blocking Example

- Suppose we would like to design an experiment to investigate if a diet high in nitrates improves lung function.
  - Explanatory variable: nitrate content of diet.
  - Response variable: exhaustion measured by O2 saturation.

  - Treatment: nitrate dietary supplement (powdered beet)
  - Control: No supplement
- It is suspected that nitrate supplements may effect professional and amateur athletes differently,
  - We are concerned that imbalance in number of pro / amateur athletes between treatment and control groups could influence results.
- To minimize this risk, we block subjects by pro / amateur status:
  1. Divide SRS into pro and amateur blocks.
  2. Randomly assign pro athletes to treatment and control groups.
  3. Similarly, randomly assign amateur athletes to treatment and control groups.
  4. This ensure pro/amateur status is equally represented in treatment and control groups.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?
  - Sometimes, observational studies are the *only* tool available for assessing the state of the world in order to make decisions.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?
  - Sometimes, observational studies are the *only* tool available for assessing the state of the world in order to make decisions.
- Experiments may be unethical
  - To study whether smoking causes cancer, we cannot randomly force participants to smoke or to not smoke.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?
  - Sometimes, observational studies are the *only* tool available for assessing the state of the world in order to make decisions.
- Experiments may be unethical
  - To study whether smoking causes cancer, we cannot randomly force participants to smoke or to not smoke.
- Experiments may be temporally impossible
  - To study whether gender influenced survival rate on the Titanic, we only have historical records to look at.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?
  - Sometimes, observational studies are the *only* tool available for assessing the state of the world in order to make decisions.
- Experiments may be unethical
  - To study whether smoking causes cancer, we cannot randomly force participants to smoke or to not smoke.
- Experiments may be temporally impossible
  - To study whether gender influenced survival rate on the Titanic, we only have historical records to look at.
- Experiments may not be manufacturable
  - To study whether high unemployment rate leads to presidential losses for the incumbent party, we cannot create new presidential races.

Observational Studies and Association

- Generally, data in observational studies are collected only by monitoring what occurs. Thus, they are usually only sufficient to show associations between variables.
- So why conduct observational studies at all?
  - Sometimes, observational studies are the *only* tool available for assessing the state of the world in order to make decisions.
- Experiments may be unethical
  - To study whether smoking causes cancer, we cannot randomly force participants to smoke or to not smoke.
- Experiments may be temporally impossible
  - To study whether gender influenced survival rate on the Titanic, we only have historical records to look at.
- Experiments may not be manufacturable
  - To study whether high unemployment rate leads to presidential losses for the incumbent party, we cannot create new presidential races.
- Experiments of appropriate size may be prohibitively expensive
  - Experiments of small or moderate size often include uncontrolled confounding variables

Random Sampling vs. Random Assignment

- Statistical investigations can incorporate two sources of randomization:

Random Sampling vs. Random Assignment

- Statistical investigations can incorporate two sources of randomization:

		Assignment of Explanatory Variable			
		Random allocation of explanatory variable	Individual decides explanatory variable (non-random)		
Selection of Observational Units from the Population	Random sample	The observational units are randomly selected from the population; then the explanatory variable (treatment) is randomly assigned.	The observational units are randomly selected from the population, but the value of the explanatory variable is not randomly assigned by the researcher.	→	Conclusions generalize directly to the population.
	Other sampling method (non-random)	The observational units are observed (somehow!) and then randomly allocated to the levels of the explanatory variable.	The observational units are observed (somehow!) and the value of the explanatory variable is not randomly assigned by the researcher.	→	Conclusions might not be generalizable because of volunteer bias.
		↓	↓		
		Significant conclusions are considered to be cause and effect.	Significant conclusions must be framed with possible confounding variables.		