OpenIntro

# Chapter 1: Introduction to data

OpenIntro Statistics, 4th Edition

Slides developed by Mine Çetinkaya-Rundel of OpenIntro.

# Data basics

# Classroom survey

A survey was conducted on students in an introductory statistics course. Below are a few of the questions on the survey, and the corresponding variables the data from the responses were stored in:

- `gender`: What is your gender?
- `intro_extra`: What is your gender?
- `sleep`: How many hours do you sleep at night, on average?
- `bedtime`: What time do you usually go to bed?
- `countries`: How many countries have you visited?
- `dread`: On a scale of 1-5, how much do you dread being here?

# Data matrix

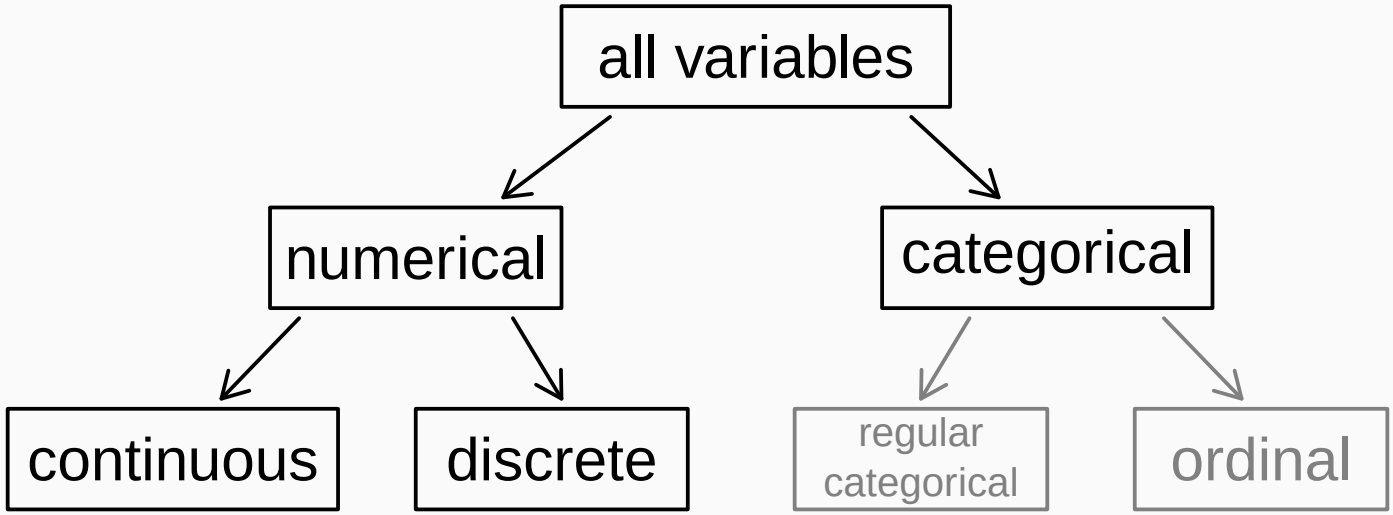
Data collected on students in a statistics class on a variety of variables:

*variable* ↓

| Stu. | `gender` | `intro_extra` | $\cdots$ | `dread` |
|---|---|---|---|---|
| 1 | male | extravert | $\cdots$ | 3 |
| 2 | female | extravert | $\cdots$ | 2 |
| 3 | female | introvert | $\cdots$ | 4 |
| 4 | female | extravert | $\cdots$ | 2 |
| $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ | $\vdots$ |
| 86 | male | extravert | $\cdots$ | 3 |

← *observation*

# Types of variables



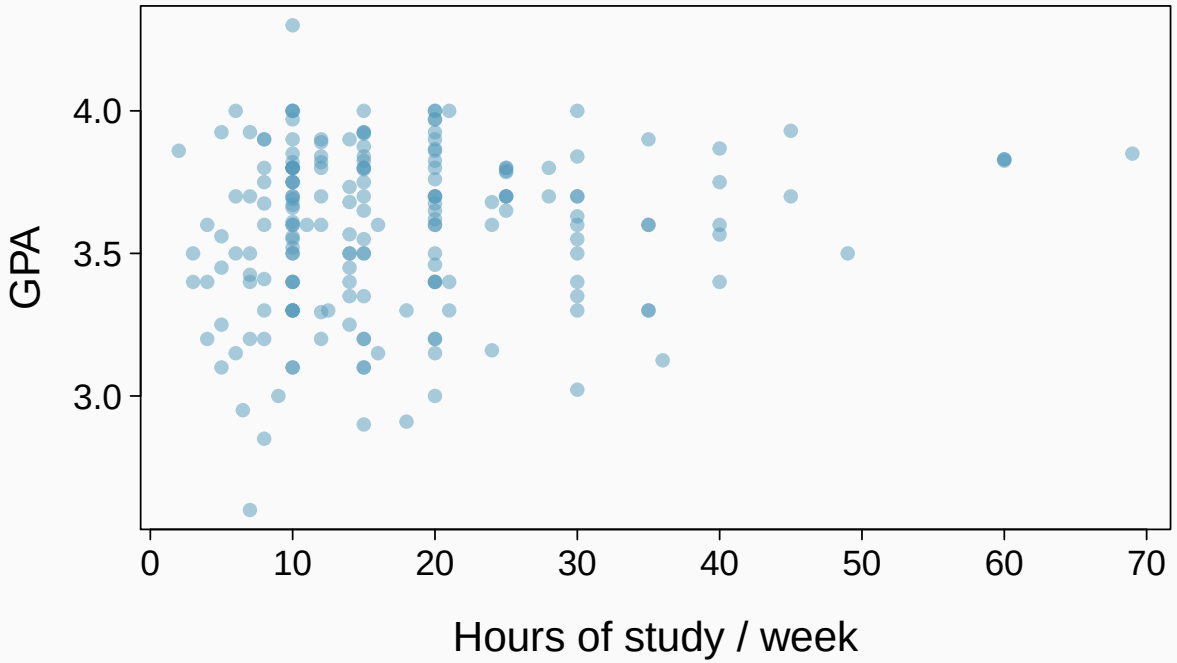
# Types of variables (cont.)

| | gender | sleep | bedtime | countries | dread |
|---|---|---|---|---|---|
| 1 | male | 5 | 12-2 | 13 | 3 |
| 2 | female | 7 | 10-12 | 7 | 2 |
| 3 | female | 5.5 | 12-2 | 1 | 4 |
| 4 | female | 7 | 12-2 | | 2 |
| 5 | female | 3 | 12-2 | 1 | 3 |
| 6 | female | 3 | 12-2 | 9 | 4 |

- `gender`: *categorical*
- `sleep`: *numerical, continuous*
- `bedtime`: *categorical, ordinal*
- `countries`: *numerical, discrete*
- `dread`: *categorical, ordinal - could also be used as numerical*

# Relationships among variables

Does there appear to be a relationship between GPA and number of hours students study per week?




Can you spot anything unusual about any of the data points?

*There is one student with GPA > 4.0, this is likely a data error.*

# Explanatory and response variables

- To identify the explanatory variable in a pair of variables, identify which of the two is suspected of affecting the other:

$$\text{explanatory variable} \xrightarrow{might\ affect} \text{response variable}$$

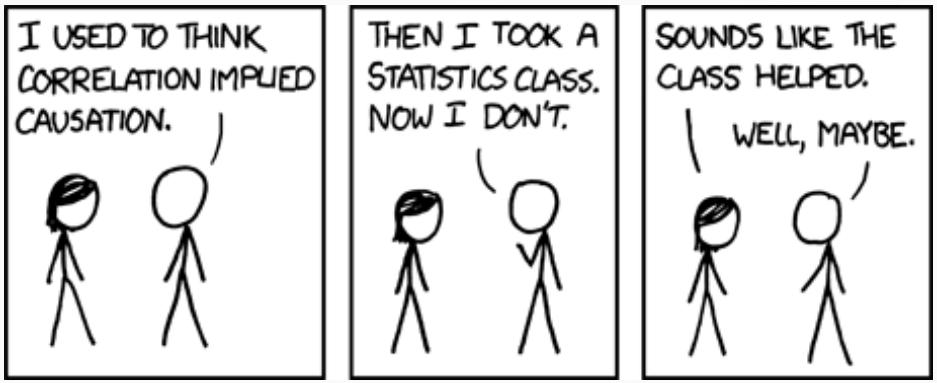
- Labeling variables as explanatory and response does not guarantee the relationship between the two is actually causal, even if there is an association identified between the two variables. We use these labels only to keep track of which variable we suspect affects the other.

# Two primary types of data collection

- *Observational studies:* Collect data in a way that does not directly interfere with how the data arise (e.g. surveys).
  - Can provide evidence of a naturally occurring association between variables, but they cannot by themselves show a causal connection.
- *Experiment:* Researchers randomly assign subjects to various treatments in order to establish causal connections between the explanatory and response variables.

# Association vs. causation

- When two variables show some connection with one another, they are called *associated* variables.
  - Associated variables can also be called *dependent* variables and vice-versa.
- If two variables are not associated, i.e. there is no evident connection between the two, then they are said to be *independent*.
- In general, association does not imply causation, and causation can only be inferred from a randomized experiment.




http://xkcd.com/552/

# Sampling principles and strategies

# Populations and samples


PHYS ED | AUGUST 29, 2012, 12:01 AM | 21 Comments

Finding Your Ideal Running Form

By GRETCHEN REYNOLDS

David De Lossy/Getty Images

*http://well.blogs.nytimes.com/2012/08/29/finding-your-ideal-running-form*

*Research question:* Can people become better, more efficient runners on their own, merely by running?

*Population of interest:* *All people*

*Sample:* Group of adult women who recently joined a running group

*Population to which results can be generalized:* *Adult women, if the data are randomly sampled*

# Anecdotal evidence and early smoking research

- Anti-smoking research started in the 1930s and 1940s when cigarette smoking became increasingly popular. While some smokers seemed to be sensitive to cigarette smoke, others were completely unaffected.
- Anti-smoking research was faced with resistance based on *anecdotal evidence* such as “My uncle smokes three packs a day and he’s in perfectly good health”, evidence based on a limited sample size that might not be representative of the population.
- It was concluded that “smoking is a complex human behavior, by its nature difficult to study, confounded by human variability.”
- In time researchers were able to examine larger samples of cases (smokers), and trends showing that smoking has negative health impacts became much clearer.

# Census

- Wouldn't it bes better to just include everyone and "sample" the entire population?
  - This is called a *census*.
- There are problems with taking a census:
  - It can be difficult to complete a census: there always seem to be some individuals who are hard to locate or hard to measure. *And these difficult-to-find people may have certain characteristics that distinguish them from the rest of the population.*
  - Populations rarely stand still. Even if you could take a census, the population changes constantly, so it's never possible to get a perfect measure.
  - Taking a census may be more complex than sampling.

# Illegal Immigrants Reluctant To Fill Out Census Form

by PETER O'DOWD

March 31, 2010 4:00 AM

from KJZZ

Listen to the Story

Morning Edition

3 min 48 sec

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There is an effort underway to make sure Hispanics are accurately counted in the 2010 Census. Phoenix has some of the country's "hardest-to-count" districts. Some Latinos, especially illegal residents, fear that participating in the count will expose them to immigration raids or government harassment.

*http://www.npr.org/templates/story/story.php?storyId=125380052*

# Exploratory analysis to inference

- Sampling is natural.
- Think about sampling something you are cooking - you taste (examine) a small part of what you're cooking to get an idea about the dish as a whole.
- When you taste a spoonful of soup and decide the spoonful you tasted isn't salty enough, that's *exploratory analysis*.
- If you generalize and conclude that your entire soup needs salt, that's an *inference*.
- For your inference to be valid, the spoonful you tasted (the sample) needs to be *representative* of the entire pot (the population).
    - If your spoonful comes only from the surface and the salt is collected at the bottom of the pot, what you tasted is probably not representative of the whole pot.
    - If you first stir the soup thoroughly before you taste, your

# Sampling bias

- *Non-response:* If only a small fraction of the randomly sampled people choose to respond to a survey, the sample may no longer be representative of the population.
- *Voluntary response:* Occurs when the sample consists of people who volunteer to respond because they have strong opinions on the issue. Such a sample will also not be representative of the population.

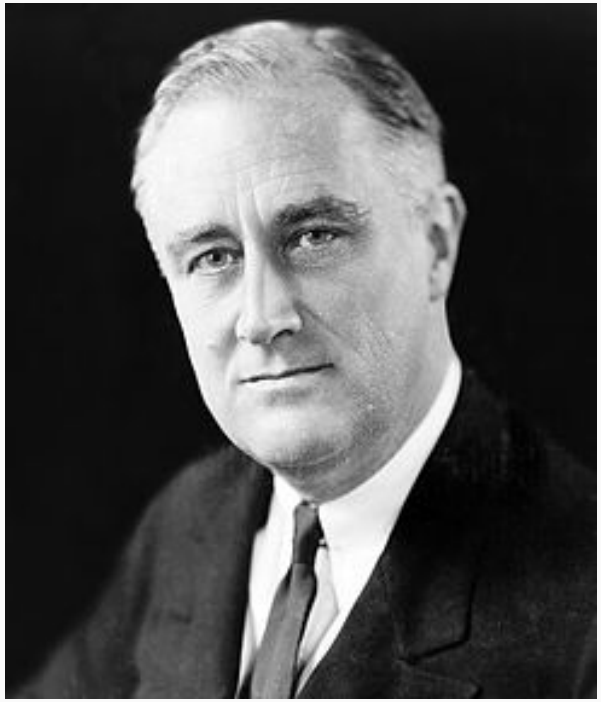

cnn.com, Jan 14, 2012

- *Convenience sample:* Individuals who are easily accessible are more likely to be included in the sample.

# Sampling bias example: Landon vs. FDR

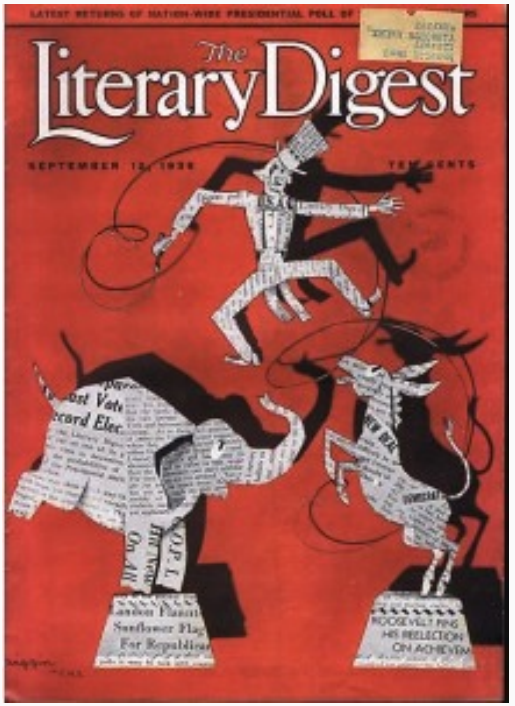
A historical example of a biased sample yielding misleading results:

In 1936, Landon sought the Republican presidential nomination opposing the re-election of FDR.



# The Literary Digest Poll

- The Literary Digest polled about 10 million Americans, and got responses from about 2.4 million.
- The poll showed that Landon would likely be the overwhelming winner and FDR would get only 43% of the votes.
- Election result: FDR won, with 62% of the votes.
  - The magazine was completely discredited because of the poll, and was soon discontinued.



# The Literary Digest Poll – what went wrong?

- The magazine had surveyed
  - its own readers,
  - registered automobile owners, and
  - registered telephone users.
- These groups had incomes well above the national average of the day (remember, this is Great Depression era) which resulted in lists of voters far more likely to support Republicans than a truly *typical* voter of the time, i.e. the sample was not representative of the American population at the time.

# Large samples are preferable, but...

- The Literary Digest election poll was based on a sample size of 2.4 million, which is huge, but since the sample was *biased*, the sample did not yield an accurate prediction.
- Back to the soup analogy: If the soup is not well stirred, it doesn't matter how large a spoon you have, it will still not taste right. If the soup is well stirred, a small spoon will suffice to test the soup.

# Observational studies

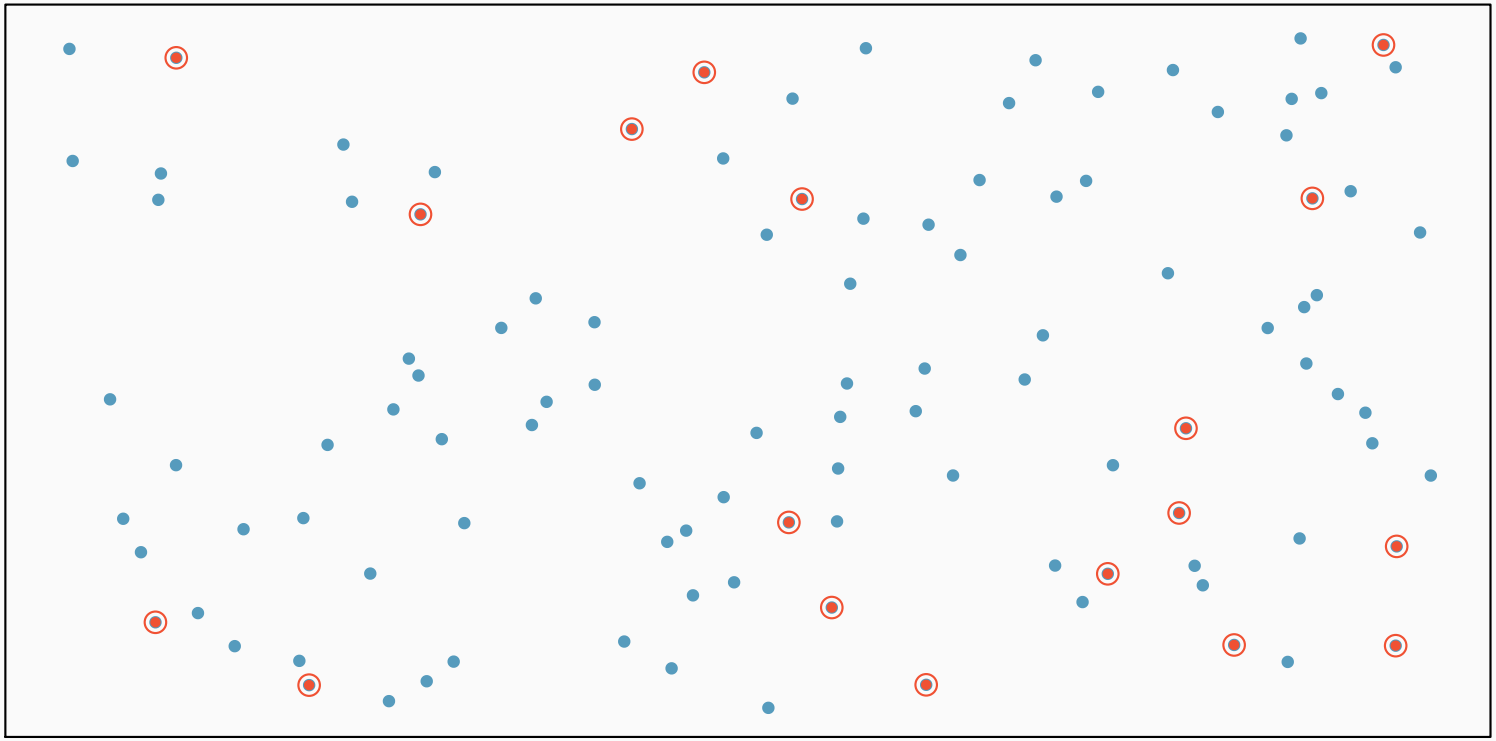
- Researchers collect data in a way that does not directly interfere with how the data arise.
- Results of an observational study can generally be used to establish an association between the explanatory and response variables.

# Obtaining good samples

- Almost all statistical methods are based on the notion of implied randomness.
- If observational data are not collected in a random framework from a population, these statistical methods – the estimates and errors associated with the estimates – are not reliable.
- Most commonly used random sampling techniques are *simple*, *stratified*, and *cluster* sampling.

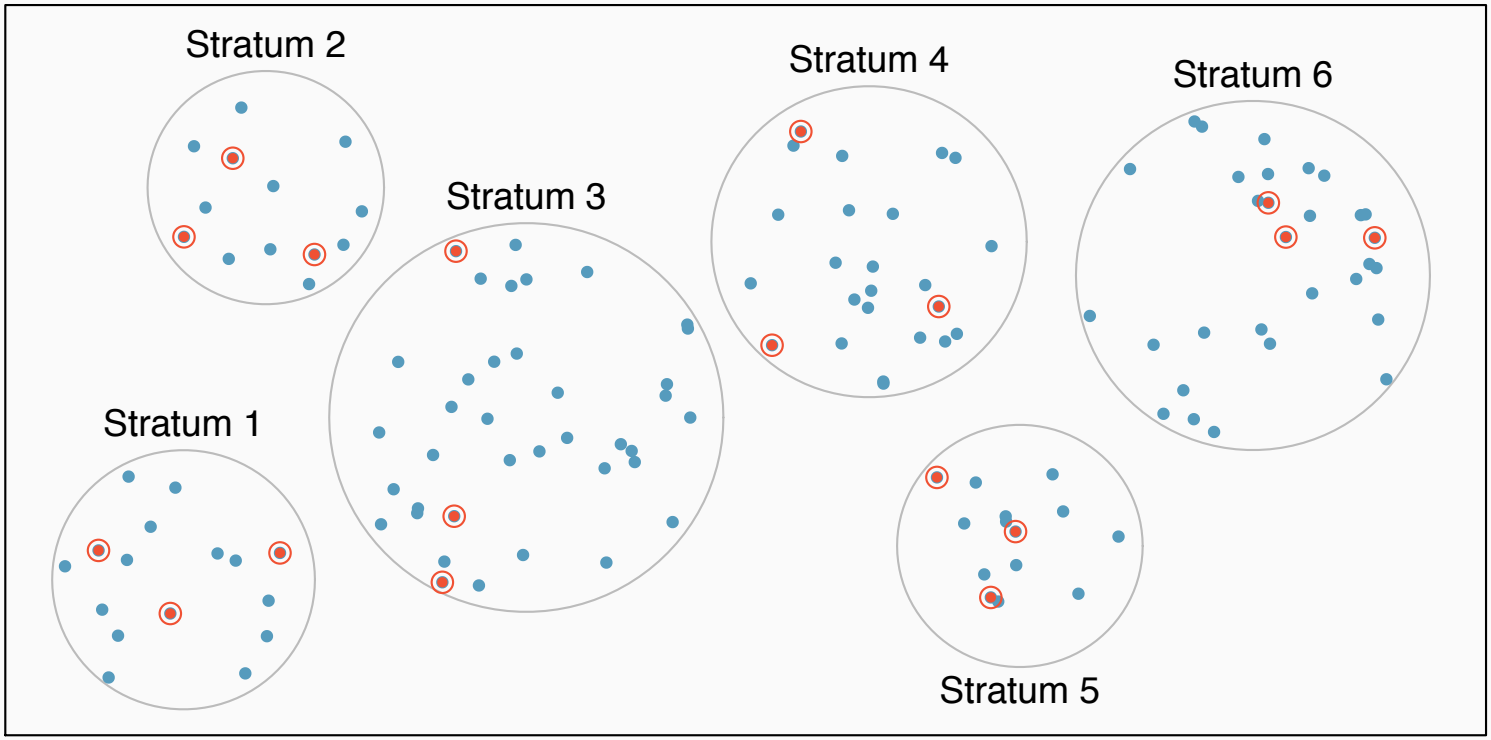
# Simple random sample

Randomly select cases from the population, where there is no implied connection between the points that are selected.



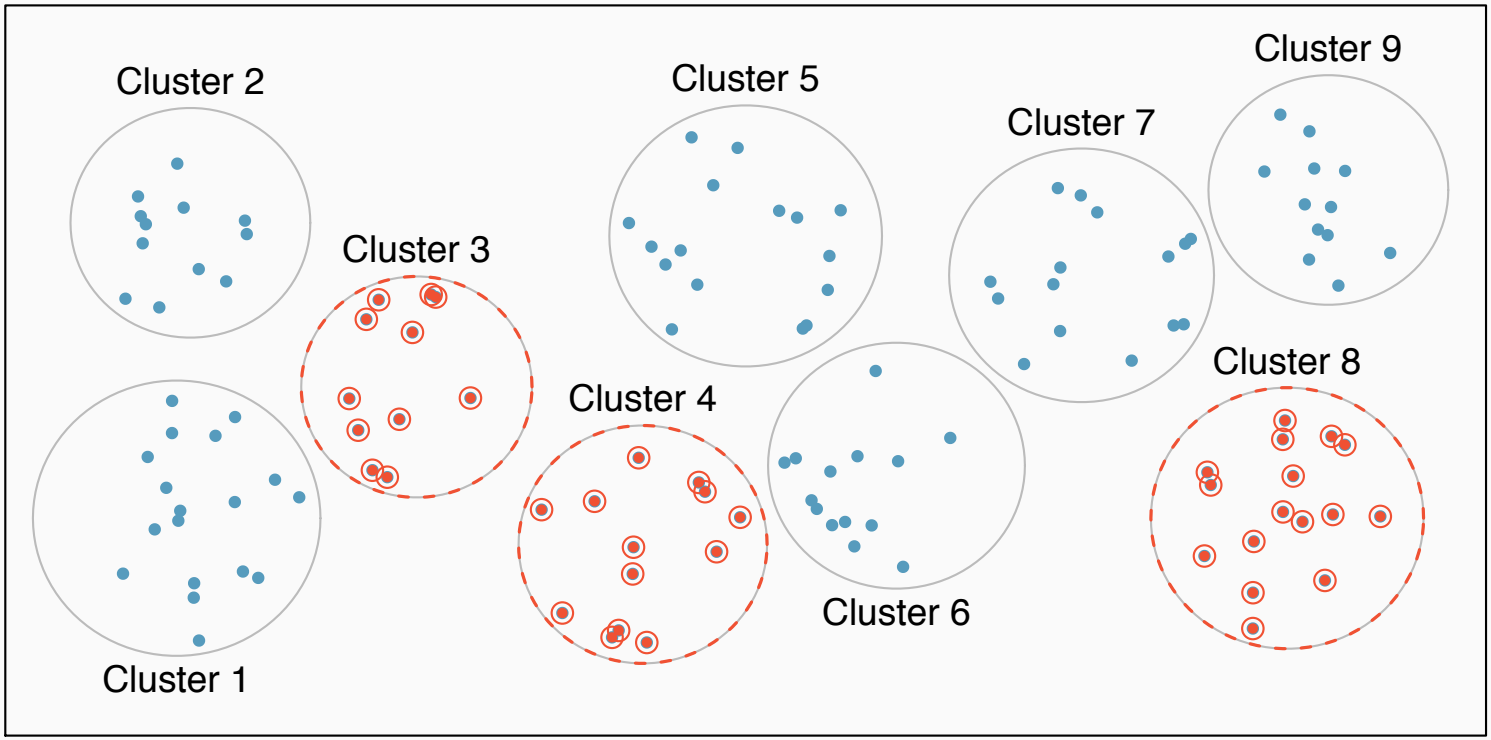
# Stratified sample

*Strata* are made up of similar observations. We take a simple random sample from each stratum.



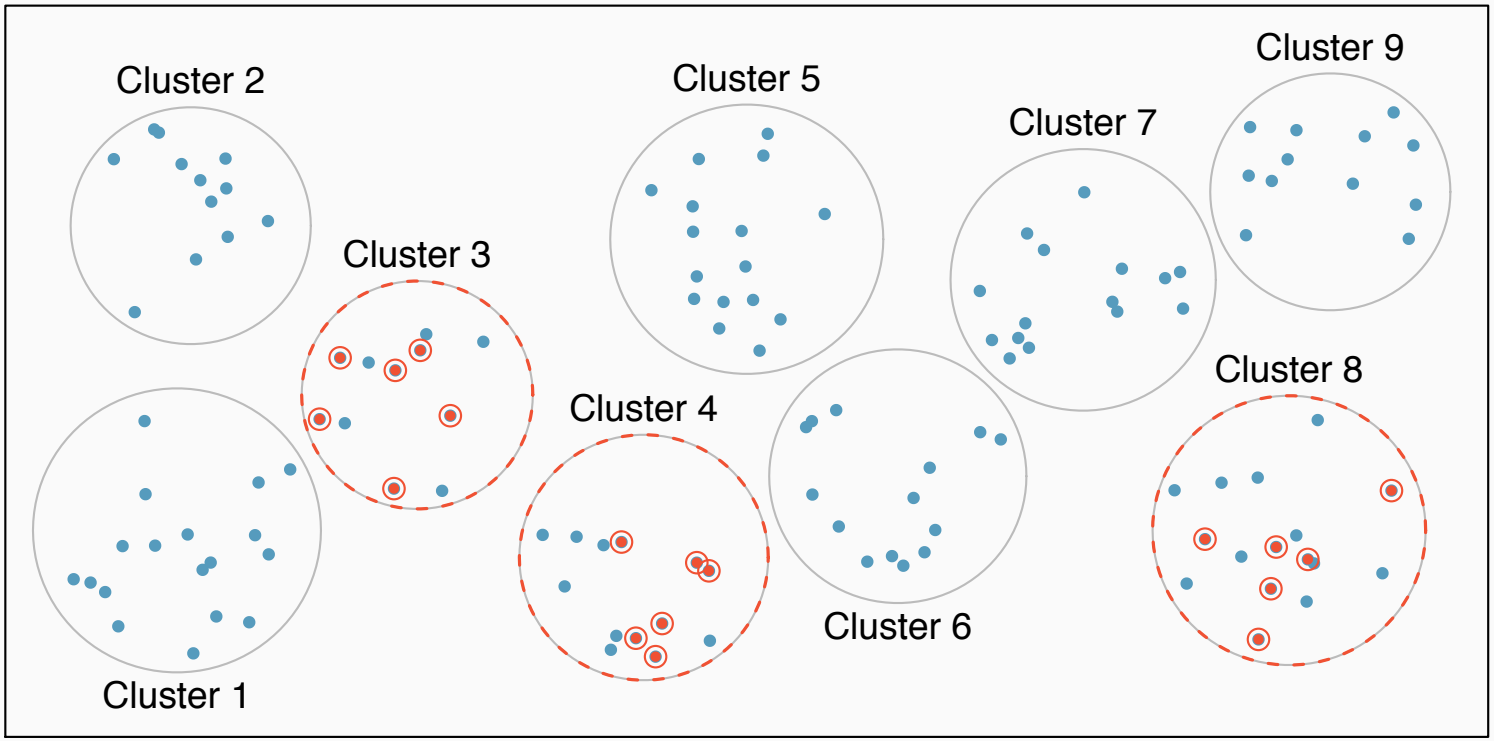
# Cluster sample

*Clusters* are usually not made up of homogeneous observations. We take a simple random sample of clusters, and then sample all observations in that cluster. Usually preferred for economical reasons.



# Multistage sample

*Clusters* are usually not made up of homogeneous observations. We take a simple random sample of clusters, and then take a simple random sample of observations from the sampled clusters.



# Experiments

# Principles of experimental design

1. *Control:* Compare treatment of interest to a control group.
2. *Randomize:* Randomly assign subjects to treatments, and randomly sample from the population whenever possible.
3. *Replicate:* Within a study, replicate by collecting a sufficiently large sample. Or replicate the entire study.
4. *Block:* If there are variables that are known or suspected to affect the response variable, first group subjects into *blocks* based on these variables, and then randomize cases within each block to treatment groups.

# More on blocking


- We would like to design an experiment to investigate if energy gels makes you run faster:
  - Treatment: energy gel
  - Control: no energy gel
- It is suspected that energy gels might affect pro and amateur athletes differently, therefore we block for pro status:
  - Divide the sample to pro and amateur
  - Randomly assign pro athletes to treatment and control groups
  - Randomly assign amateur athletes to treatment and control groups
  - Pro/amateur status is equally represented in the resulting treatment and control groups

# Difference between blocking and explanatory variables

- Factors are conditions we can impose on the experimental units.
- Blocking variables are characteristics that the experimental units come with, that we would like to control for.
- Blocking is like stratifying, except used in experimental settings when randomly assigning, as opposed to when sampling.

# More experimental design terminology...

- *Placebo:* fake treatment, often used as the control group for medical studies
- *Placebo effect:* experimental units showing improvement simply because they believe they are receiving a special treatment
- *Blinding:* when experimental units do not know whether they are in the control or treatment group
- *Double-blind:* when both the experimental units and the researchers who interact with the patients do not know who is in the control and who is in the treatment group

# Random assignment vs. random sampling