

There are 4 types you need to know

- Completely Randomised Design (CRD)** – each person receives one treatment out of any possible number of treatments
- Randomized Complete Block Design (RCBD)** aka block design- block into strata and then do a CRD on each strata. Each person receives one treatment, but we put into blocks first based on similarities
- Matched pairs** – This is a special case of RBC and involves 2 treatments only. Each person receives both treatments OR they get paired up based on being similar and each receives one treatment meaning they are so similar that it is essentially the same as each subject getting both treatments.
- Multifactor** – CRD set-up whereby we choose and set the levels of each factor and assign all the combinations of treatments

Definition	Template	Example
<p>Completely Randomized (CRD)</p> <p>This is the simplest experimental design. Each subject receives only one treatment</p>		<p>Example</p> <p>160 patients suffering from stomach ulcers are told the possibilities of gastric freezing, a process in which the pain is reduced by a deflated balloon into the stomach which is then filled (via tubes) with a refrigerated liquid to reduce stomach acid and reduce the cause of stomach ulcers. 78 patients receive the treatment and 34% of these patients improve. 38% of the 82 patients in the placebo group improved as well. Design this experiment and discuss whether or not gastric freezing is an effective method of treating stomach ulcers</p> <p>Not effective as similar percentage to placebo</p>
<p>Randomized (complete) Block Design (RCBD)</p> <p>Block (stratify) first by some similarity expected to affect the result and then perform a CRD on each block. We block to reduce variation Each subject receives only one treatment</p>	<p>Note: in each block copy and paste a completely randomized design</p>	<p>As a researcher for a pharmaceutical company, you are designing a study to test the effectiveness of a new treatment for migraine headaches. You have been given a list of 126 people willing to participate in the trial. The first 70 people are female, the remaining 56 are male. Design this experiment in diagram form and be specific about how the response variable will be measured.</p>
<p>Matched Pairs Type 1</p> <p>Experimental units are the same for each treatment</p> <p>ONLY TWO treatment conditions now. Each subject gets both treatments (in any order, order must be random)</p> <p>This is a special case of RCBD (subset of RCBD). For RCBD you put into blocks based on similarity first and for matched pairs everyone receives one treatment or you have "twins" each receiving one treatment which is also based on similarity.</p>	<p>This can be simplified to</p>	<p>You want to see if the right hand is stronger than the left hand in right handed people. You've got 30 volunteers who are willing to be subjects in an experiment to investigate this question. You can get a somewhat accurate measure of hand strength by placing a bathroom scale on a shelf and protruding one side of it so that each subject can squeeze the scale with their thumb on the underside and the other four fingers above</p> <p>Design the experiment in diagram form. Be specific about how the response variable will be measured.</p>
<p>Matched Pairs Type 2</p> <p>Experimental units are similar for each treatment</p> <p>ONLY TWO treatment conditions now.</p> <p>"Twin pairs" where each subject gets 1 of the 2 treatments. We put subjects into pairs by some similar characteristic and each subjects gets one treatment. This is almost identical to type 1 except since between them they get both treatments and they are so similar that its essentially the same as each subject getting both treatments i.e. Type 1</p>	<p>Some intuition: We pair into twins based on similar GPA and each receives one of the 2 treatments in any random order.</p> <p>As a diagram this looks like</p> <p>This can be simplified to</p>	<p>A researcher is trying to determine whether or not sleep deprivation has an effect on test scores. Describe how a matched-pairs design would be used.</p> <p>We could try giving both treatments to the same experimental units like in above. In other words we could have the same person write the test on 2 different days, one being sleep deprived and the other with sufficient sleep. Design an experiment</p> <p>The problem with this is that we can't have the same subject write the same test because they would know what is on the exam when they write it the 2nd time, so this would be unfair. Instead, we can pair off students with similar GPAs. Students with higher GPAs paired together and 2 students with lowest GPAs paired together. This is not like type i. since it is not 1 person receiving both treatments but two similar people (think of as twins) receiving one treatment each. They are so similar though that it is like 1 person receiving both treatments.</p>

Multifactor

CRD set-up whereby we choose and set the levels of each factor and assign all the combinations of treatments

For example:
 Choosing dosage levels of a drug (10ml, 20ml, 30ml,...)
 Choosing the temperature at which to run a process (250, 300,...)
 Choosing day length exposure (short, long)

25 people administered a drug for 45 seconds and 90 seconds. Repeated once, three times or five times.

- What is the response variable
- What are the explanatory variables?
- Who are the subjects/experimental units?
- What are the factors?
- What are the levels?
- What are the treatments?

Ans. Drawing a two-way table will help you visually see what is going on

		Repetition (Factor)		
		once	3 times	5 times
Length (Factor)	45 secs	Treatment 1: Once for 45 secs	Treatment 2: 3 times for 45 secs	Treatment 3: 5 times for 45 secs
	90 secs	Treatment 4: Once for 90 secs	Treatment 5: 3 times for 90 secs	Treatment 6: 5 times for 90 secs

= levels
 = factors
 = treatments

Concentration in bloodstream after 45 and 90 seconds, Length and repetitions, 25 people, 2 factors - Length of time AND repetition (2 factors), 2 levels for length of time (45 and 90 seconds) AND 3 levels for repetition (1,3, and 5), 2x3=6 treatments)

A consumer product agency tests miles per gallon for a sample of automobiles using each of four different octanes of gasoline. Which of the following is true?

- There are 4 explanatory variables and one response variable
- There is one explanatory variable with four levels of response
- Miles per gallon is the only explanatory variable, but there are 4 response variables corresponding to the different octanes
- There are 4 levels of a single explanatory variable
- Each explanatory level has an associated level of response

Ans. d

A chemical engineer is designing the production process for a new product. The chemical reaction that produces the product may have a higher or lower yield depending on the temperature and stirring rate in the vessel in which the reaction takes place. The engineer decides to investigate the effects of combinations of two temperatures (50°C and 60°C) and three stirring rate in this (60 rpm, 90 rpm and 120 rpm) on the yield of the process. Ten batches of feedstock will be processed at each combination of temperature and stirring rate.

- Identify the experimental units
- Identify the factors
- Identify the levels
- What is the response variable?
- How many treatments are there in total? What are they?
- How many experimental units are needed?

(The batches of feedstock, the temperatures and stirring rates, Temps: 50°C, 60°C and stirring rates: 60 rpm, 90 rpm and 120 rpm, The yield, 6, 60)

A teacher at a culinary arts school will conduct an experiment to investigate which of three methods of instruction works best in teaching students how to make a good pie crust. Each student in a group of 60 students will be randomly assigned to one of three methods: in-person demonstration by the instructor, watching a video, and reading a recipe. The students will be assigned so that each method will have 20 students. Each pie crust made will be judged on its taste and texture. What are the treatments of the experiment?

- The 60 students
- The three methods of instruction
- The 20 students within each group
- The scores on taste and texture
- The 60 pie crusts made

(ans b)

Harder: An experiment compared the adhesion of 2 types of paint, A and B, to 3 types of metal, 1, 2, and 3, used in automobiles. Thirty sheets of metal were used in the experiment: 10 of Metal 1, 10 of Metal 2, and 10 of Metal 3. Half of each metal type will receive paint A and the other half will receive paint B. The adhesion of the paints was measured, and the measures were compared. How many experimental units are in the experiment?

- 2
- 3
- 10
- 30
- 60

Hint: We have 6 treatments: 1A, 1B, 2A, 2B, 3A, 3C. This like saying there are 10 of 1A & 1B, 10 of 2A & 2B, 10 of 3A & 3B so each single treatment is 5. 6(5)=30
(ans d)

Multi Factor CRD: A biologist is interested in studying the effect of growth-enhancing nutrients and different salinity (salt) levels in water on the growth of shrimp. The biologist has ordered a large shipment of young tiger shrimps from a supply house to use for the study. The experiment is to be conducted in a lab where there are 12 tanks (with equal amount of shrimp in each) in a controlled environment. The biologist is planning to use 3 different growth enhancing nutrients (A, B and C) and two different salinity levels (high and low).

- List the treatments that the biologist plans to use in this experiment
- Using the treatments listed in part a) describe a completely randomized design that will allow the biologist to compare the shrimps growth after 3 weeks
- Give one statistical advantage of having only tiger shrimp in the experiment. Explain why this is an advantage.
- Give one statistical disadvantage of having only tiger shrimp in the experiment. Explain why this is a disadvantage.

Same and different treatment groups when using CRD AND RCBD

CRD AND RBD: Assigning subjects to treatment groups:

We can either have the same number of subjects in each treatment group or a different number. If question doesn't specify, just put the same number in each.

- If want the SAME number in each (treatment) group

We label subjects to randomly assign people to set treatment groups

Use random number generator to select the same number of students for each treatment

e.g. 4 treatments and 20 subjects

Way 1:

Label subjects 01-20

Use RandintNoRepeat(01,20,20) to select 20 students

Treatment 1: Assign this to the first 5 students on the random list

Treatment 2: Assign this to the next 5 students on the random list

Treatment 3: Assign this to the penultimate 5 students on the random list

Treatment 4: Assign this to the remaining 5 students

Way 2:

- Treatment 1: Label subjects 01-20: Randint(01,20,5). Select 5 students for this treatment 1. This is group 1
- Treatment 2: Label remaining 15 subjects 01-15: Randint(01,15,5). Select 5 students for this treatment 2. This is group 2
- Treatment 3: Label remaining 10 subjects 01-10: Randint(01,10,5). Select 5 students for this treatment 3. This is group 3
- Treatment 4: Remaining 5 go into this group

Note: If only two treatments don't need to use Randint for second treatment group
Treatment 1: Randint(01,20,10). Select 10 students randomly for this treatment 1. This is group 1
Then just put the remainder that haven't been selected out of the 20 into the next treatment group

- ii. If want DIFFERENT number in each (treatment) group
 We **label treatments** to randomly assign the people to their respective treatment groups
 Use random number generator and select treatments until you reach the desired total number. Allocate the subjects to their respective treatments which are already labelled
 e.g. 4 treatments 20 subjects
 Label treatments 01-04
 Randint (01,04,20)
 Select 20 treatments
 Sort out which are treatment 1, treatment 2, treatment 3, etc. This will then tell you how many for each treatment

300 adults who have experienced episodes of pain from sickle cell anemia in the past year are brought in to study the effects of hydroxyurea. A simple random sample of 152 of these people are treated with the hydroxyurea, which the other 148 are given a placebo which looks and tastes the same.

- i. Identify explanatory and response variables
- ii. In diagram form, design an experiment to test the effects of the hydroxyurea.
- iii. Explain how proper randomization of the subjects could occur in which an equal amount doesn't necessarily get placed into both the treatment and placebo groups.
- iv. Explain how proper randomization of the subjects could occur in which 150 would be placed in each treatment group.

Multiple Choice Questions

Madelief has heard that if you look at the other persons elbow when delivering a high five, it will result in a great high-five everytime. She's skeptical and wants to test this out. She sets up an experiment in which each of her subjects high-fives her while they look at each other's elbow and then they high-five again without looking at each other's elbow's. The order of the high-fives (looking at the elbow and now looking at the elbow) is randomly chosen for each subject and then the subject will give a 1 out of 10 rating on how solid each high five was. What is this type of experiment design called?

- a) Matched pairs
- b) Multifactor experiment
- c) Stratified random sample
- d) Block design
- e) A badly designed experiment

To investigate the effectiveness of an herbal medication for pain relief, a researcher randomly selected 80 patients who were undergoing physical therapy while recovering from an injury. Of the patients, 40 had knee injuries, 16 had arm injuries, and 24 had foot injuries. The researcher will use two treatments for the investigation: the herbal medication and a standard medication. After the patients are on the medication for two weeks, the amount of pain reduction will be measured for each patient. Which of the following best describes why a randomized block design is appropriate for the investigation?

- a) The 80 patients were selected at random from all patients undergoing physical therapy while recovering from an injury.
- b) The sample size was greater than 30.
- c) Each patient will be randomly assigned to either the herbal medication or the standard medication.
- d) Blocking on injury type will help to separate natural variability from differences due to injury type.
- e) Each patient assigned to the herbal medication will be paired with a patient assigned to the standard medication.

A researcher randomly selected 30 people to participate in a study to investigate which of two materials, A or B, used in the heels of sneakers will last longer. The researcher is considering two design types for the study.
 Design 1: Randomly assign 15 participants to wear sneakers with material A on their left feet and material B on their right feet. The remaining participants will wear sneakers with material B on their left feet and material A on their right feet.
 Design 2: Randomly assign 15 participants to wear sneakers with material A on both feet and the remaining participants to wear sneakers with material B on both feet.

Which of the following best describes each design?

- a) Design 1 is a completely randomized design, and design 2 is a matched pairs design.
- b) Design 1 is a matched pairs design, and design 2 is a completely randomized design.
- c) Design 1 is a matched pairs design, and design 2 is a matched pairs design.
- d) Design 1 is a completely randomized design, and design 2 is a completely randomized design.
- e) Design 1 is a completely randomized design, and design 2 is a randomized block with materials as blocks.

An agricultural researcher wants to compare the yield of five corn varieties: A,B,C,D and E. The field in which the experiment will be carried out increases in fertility from North to South. The researcher therefore divides the field into 25 plots of equal size, as shown. What type of design should the researcher use?

- a) Block design in which each block is a row of the field
- b) Block design in which each block is a column of the field
- c) Multifactor design experiment
- d) Completely randomized experiment

Hard: The two graduates with the greatest from each of 14 randomly selected law schools were recruited to investigate a new method of preparation for a law exam. For each school, one student was randomly assigned to prepare using the standard method and the other student was assigned to prepare using the new method. At the end of the preparation, all 28 students were given the same exam, and their scores were recorded.

Which of the following best describes why a matched-pairs design is an appropriate design for the investigation?

- a) Each graduate was randomly assigned to one method
- b) The law schools were randomly selected
- c) Each method served as a block
- d) The sample size was less than 30
- e) Each law school served as a block, and the graduates were paired within each law school and randomly assigned to one of the two methods

A pottery school wants to study whether the glaze of stoneware bowls is affected by the temperature used to harden the bowls. The study will use 3 different types of clay because glaze can affect different clay in different ways. Eight bowls will be made with each clay type for a total of 24 bowls, and 4 different temperatures will be used. What is the best design to use for the study?

- a) A completely randomized design. Randomly assign temperatures so that 6 bowls are glazed at each temperature.
- b) A completely randomized design. Randomly assign temperatures so that 2 bowls of each clay type are glazed at each temperature.
- c) A randomized block design. Randomly assign temperatures so that 6 bowls are glazed at each temperature.
- d) A randomized block design. Randomly assign temperatures so that 2 bowls of each clay type are glazed at each temperature.
- e) A matched pairs design. Randomly assign temperatures so that 2 bowls of each clay type are glazed at each temperature.

3 blocks of clay: clay type 1, clay type 2, and clay type 3 with n=8 in each block hence 24 bowls. Each block will have 4 treatments (different temperatures)
 Response variable is to check the glaze, explanatory is the temp

Which of the following are true about the design of matched-pair experiments

- I. Each subject might receive both treatments
 - II. Each pair of subjects receives the identical treatment, and differences in the responses are noted
 - III. Blocking is one form of matched pair design
- a) I only
 - b) II only
 - c) III only
 - d) I and III
 - e) II and III

A new medication for lowering cholesterol in people with high cholesterol is currently being tested, however the experimenters think that men and women will respond differently to the medication. Because of this, the experimenters should use what type of experimental design which would allow us to run the experiment with men and women separately?

- a) Multifactor Experiment
- b) Block design
- c) Matched pairs design
- d) Stratified random sample
- e) A badly designed experiment

To test the effects of a new fertilizer, 100 plots were selected and each plot was divided in half. The fertilizer currently on the market was applied to one half of each plot and the new fertilizer was applied to the other half. Which half each was applied to was selected randomly. This is an example of a(n)

- a) Matched Pairs Design
- b) Multifactor Experiment
- c) Stratified Random Sample
- d) Block Design
- e) A Badly Designed Experiment

(ans a,d,b,a,e,d,a,b,a)

Longer Questions

Multifactor:
 Two teachers want to compare the effectiveness of a standard AP Statistics curriculum and a new technology driven AP statistics curriculum. Both teachers each teach one class with the standard curriculum and one with the new approach. They will randomly select which of their classes will receive each approach. At the end of the year, all students will take the AP Statistics exam.

- a) What type of experimental design should you employ?
- b) What the experimental units

- c) List the factors in this experiment.
 d) What is the response variable
 e) List the treatments in this experiment

Ans.

- a) Multifactor experiment
 b) The classes
 c) Teachers (2 levels) and curricula (2 levels)
 d) The difference in average scores on AP Stats exam
 e) 4 treatments:
 Teacher 1 teaching standard curriculum
 Teacher 1 teaching new curriculum
 Teacher 2 teaching standard curriculum
 Teacher 2 teaching new curriculum

A farmer wants to optimise growth of his tomatoes so he wishes to determine whether or not fertiliser is necessary, as well as how much water to use. He plants 24 similar tomato plants in similar pots and places them in a greenhouse. Half of the plants will get fertilizer and the other half will not. Eight of the plants will each get 0.5 gallons of water each day, eight will get 1 gallon per day, and the last eight will get 1.5 gallons per day.

- a) Identify the factors and the levels at which each is given
 b) How many treatments are there in total? Identify them.

Ans.

- a) 2 factors (fertilizer and water)
 2 levels of fertilizer (fertilizer or no fertilizer)
 3 levels of water (0.5, 1, 1.5)
 b) 6 treatments (Fertilizer 0.5 gallon, Fertilizer 1 gallon, Fertilizer 1.5 gallon, No fertilizer 0.5 gallon, No fertilizer 1 gallon, No fertilizer 1.5 gallon)

A nutritionalist wants to study the effect of storage time (6,12 and 18 months) on the amount of Vitamin C present in freeze dried fruit when stored for these lengths of time. Vitamin C is measured in milligrams per 100 milligrams of fruit. Six fruit packs were randomly assigned to each of the three storage times

- a) Identify the treatment
 b) Identify the experimental units
 c) Identify the response variable

Ans.

- a) Length of storage time
 b) Dried fruit
 c) Amount of vitamin C present

CRD:

A researcher wants to conduct an experiment to determine which environment is best suited to studying – a library, in one’s own home or outside. A total of 30 students volunteer to participate in the experiment. Show how you would design this experiment.

A medical study of heart surgery investigates the effect of a drug called a beta-blocker on the pulse rate of the patient during surgery. The pulse rate will be measured at a specific point during the operation. The investigators will use 20 patients facing heart surgery as subjects. You have a list of these patients.

- a) Describe the subjects, explanatory variables and response variables
 b) Describe the design of a completely randomised experiment to test the effect of beta-blockers on pulse rate during surgery. Write a few sentences about how you would implement your design
 c) Use the section from the random digits table below to carry out the randomization required by your design and report on the result

Hint: For T2, just pick the subjects out of the 20 not already picked for T1

96746 12149 37823 71868 18442 35119 62103 39244
 96927 19931 36809 74192 77567 88741 48409 41903
 43909 99477 25330 64359 40085 16925 85117 36071
 15689 14227 06565 14374 13352 49367 81982 87209
 36759 58984 68288 22913 18638 54303 00795 08727

RCBD:

High blood pressure adds to the workload of the heart and arteries and may increase the risk of heart attacks. If not treated, this condition can also lead to heart failure, kidney failure or stroke. We wish to test the effectiveness of Angiotensin-converting enzyme (ACE) inhibitors as a treatment for high blood pressure.

- a) Assume that 600 men and 500 women suffering from high blood pressure are available for this study. In diagram form and using your answer to part a), design an experiment to test the effects of the ACE inhibitors.
 b) Explain why an experiment involving 600 men and 500 women is preferable to one involving 60 men and 50 women.
 This is due to replication! Replication improves the significance of an experiment and reduces the variability in the experimental results i.e. reduces differences based on just variability of subjects

As a researcher for a pharmaceutical company, you are designing a study to test the effectiveness of a new treatment for migraine headaches. You have been given a list of 126 people willing to participate in the trial. The first 70 people are female, the remaining 56 are male. Design this experiment in diagram form and be specific about how the response variable will be measured.

A researcher wants to conduct an experiment to determine which environment is best suited to studying – a library, in one’s own home or outside. A total of 30 students volunteer to participate in the experiment. The researcher believes that gender has an effect on the results. There are 18 females and 12 males.

Matched Pairs:

Does listening to music whilst reading a story help or hinder recall of factual details? Describe and design the type of experimental design you should answer to employ to answer this question using 30 students at your school who have agreed to participate

Is talking on a mobile phone more distracting than talking to a passenger while driving? A study which utilized 48 first-year university students was conducted to help answer this question. The researchers had half of the students drive through a course while talking on a mobile phone using a hands-free device. The students were given a list of 5 tasks to accomplish while driving through the course and the researchers recorded how many tasks they successfully completed. After a 15-minute break, the drivers then completed a similar course with similar tasks to accomplish, but this time with a passenger to talk with. The other half of the subjects did the same two courses, but in the other order.

- What type of experimental design method has been employed in this experiment? (Matched pairs)
- Identify the experimental units in this study (48 first year uni students)
- Identify the explanatory variables in this study (HFD vs person)
- Identify the response variable in this study. Be specific with regards to how this variable is measured. (average difference in number of tasks missed or accomplished)
- Describe how the experimental design concept of *control* is implemented in this experiment (each subject only control, similar course, similar tasks)

Aspirin may enhance impairment by alcohol. Aspirin, a long time antidote for the side effects of drinking, may actually enhance alcohol’s effect, researchers at the Bronx Veterans’ Affairs Medical Center say. In a report on a study published in the Journal of the American Medical Association, the researchers said they found that aspirin significantly lowered the body’s ability to break down alcohol in the stomach. As a result, five volunteers who had a standard breakfast and two extra-strength aspirin tablets an hour before drinking had blood alcohol levels 30 percent higher than each had when they drank alcohol alone. Each volunteer consumed the equivalent of a glass and a half of wine. That 30 percent could make the difference between sobriety and impairment, said Dr. Charles S. Lieber, medical director of the Alcohol Research and Treatment Center at the Bronx center, who was co-author of the report with Dr. Risto Roine.

- a) Explain why this is an experiment and not an observational study.
 b) Identify the explanatory and response variables (aspirin)
 c) Identify the experimental design used in this study. Justify your answer
 d) In the second sentence above is the phrase, “...researchers said they found that aspirin significantly lowered the body’s ability to break down alcohol...” What is the statistical meaning of the word “significantly” in the context of this study?
 e) This was a controlled experiment. Describe how it was controlled and explain the purpose of

Mix Of All Types:

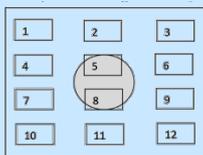
A cell phone company is considering two different keyboard designs (A and B) for its new line of cell phones. Researchers would like to conduct an experiment using subjects who are frequent texters and subjects who are not frequent texters. The subjects will be asked to text several different messages in 5 minutes. The response variable will be the number of correctly typed words. A.

- a) Explain why a randomized block design might be preferable to a completely randomized design for this experiment.
 b) Outline a randomized block experiment using 100 frequent texters and 200 novice texters. Explain how you would randomize within each block.
 c) Given an example of a confounding variable in this experiment and the explain the effect it may have on the results of the experiment

In search of a mosquito repellent that is safer than the ones that are currently on the market, scientists have developed a new compound that is rated as less toxic than the current compound thus making a repellent that contains this new compound safer for human use. Scientists also believe that a repellent containing the new compound will be more effective (at repelling mosquitoes) than the ones that contain the current compound. To test the effectiveness of the new compound versus the current compound, scientists have randomly selected 100 people from a state. Up to 100 bins, each with an equal number of mosquitoes in the bin, are available for use in this experiment. After a compound is applied to a participant's forearm, the participant will insert his or her forearm into a bin for 1 minute, and the number of mosquito bites on the arm at the end of the minute will be recorded.

- Design this experiment using a completely randomized design
- Design this experiment using a matched pairs design
- Which of the two designs (in part A or part B) is better for testing the effectiveness of the new compound versus the current compound. Justify your answer.

An experiment to determine the effect of a fertilizer on the growth of grass is to be conducted in a controlled environment. Identical soil and seeds are placed in plots in the lab. Once the grass starts growing, some plots are to be treated with the new fertilizer, while the rest receive no fertilizer. All other conditions regarding water, temperature, etc. are identical, except for the proximity of the plots to the single light source in the room. The figure below illustrates this.



Create a block design experiment. (remember, BLOCKS are groups of similar experimental units, where the similarity could have an effect on the experiment)

A researcher wants to conduct a study to test whether listening to soothing music for 20 minutes helps to reduce diastolic blood pressure in patients with high blood pressure, compared to simply sitting quietly in a noise-free environment for 20 minutes. One hundred patients with high blood pressure at a large medical clinic are available to participate in this study.

- Propose a matched pairs design for this study to compare these two treatments.
- Propose a completely randomized design for this study to compare these two treatments.

A manufacturer of boots plans to conduct an experiment to compare a new method of waterproofing to the current method. The appearance of the boots is not changed by either method. The company recruits 100 volunteers in Seattle where it rains frequently, to wear the boots as they normally would for 6 months. At the end of the 6 months, the boots will be returned to the company and evaluated for water damage.

- Describe a design for this experiment that uses the 100 volunteers. Include a few sentences on how it would be implemented (hint: the best design here is a matched pairs design)
- Could your experiment be double blind? Explain.

As dogs age, diminished joint and hip health may lead to joint pain and thus reduce a dog's activity level. Such a reduction in activity can lead to other health concerns. A study is to be conducted to see which of two dietary supplements, *glucosamine* or *chondroitin*, is more effective in promoting joint and hip health and reducing the onset of canine osteoarthritis. Researchers will randomly select a total of 300 dogs from ten different large veterinary practices around the country. All of the dogs are more than 6 years old and their owners have given consent to participate in the study. Changes in joint and hip health will be evaluated after 6 months of treatment.

- What would be an advantage of adding a control group to the design of the study?
- Assuming a control group is added, explain how you would assign the 300 dogs to the 3 treatment groups for a completely randomized design (do not draw the experiment!)
- Rather than using a completely randomized design, one group of researchers proposes blocking on clinics while another group of researchers proposes blocking on breed of dog. **How would you decide** which one of these two variables to use as a blocking variable?

When a tractor pulls a plow through an agricultural field, the energy needed to pull that plow is called the draft. The draft is affected by environmental conditions such as soil type, terrain, and moisture.

A study was conducted to determine whether a newly developed hitch would be able to reduce draft compared to the standard hitch. (A hitch is used to connect the plow to the tractor.) Two large plots of land were used in this study. It was randomly determined which plot was to be plowed using the standard hitch. As the tractor plowed that plot, a measurement device on the tractor automatically recorded the draft at 25 randomly selected points in the plot.

After the plot was plowed, the hitch was changed from the standard one to the new one, a process that takes a substantial amount of time. Then the second plot was plowed using the new hitch. Twenty-five measurements of draft were also recorded at randomly selected points in this plot.

- What was the response variable in this study? Identify the treatments
- What were the experimental units?
- Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was randomization used properly in this study? Justify your answer.
- Given that the goal of the study is to determine whether a newly developed hitch reduces draft compared to the standard hitch, was replication used properly in this study? Justify your answer.
- Plot of land is a confounding variable in this experiment. Explain why.