

UNIT 1 · PART 2 OF 2

AP® STATISTICS
ALIGNED TO THE 2026 CED

PROBLEM PACKET

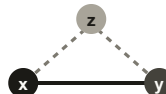
Unit 1B

Collecting Data

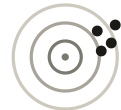
SAMPLE



EXPERIMENT



CONFOUNDING



BIAS

READ THIS FIRST

How this packet works

This is a **problems-only** packet — your notes and worked examples live in the Guided Notes. Part 1 was about *picturing* data; Part 2 is about **where data come from**. Work runs in five short modules (A–E) that follow the life of a study: **decide how to produce the data, judge what the data can prove, choose a sample, avoid bias**, and finally **design an experiment that earns a cause-and-effect claim**. Inside each module, problems climb from warm-up to exam-level and mix short answer, multiple choice, and free response. Answer in context and use the right vocabulary. Difficulty is tagged with stars:

★ ★ ★ ★ WARM-UP — recall & one step

★ ★ ★ ★ PROFICIENT — standard multi-step skill

★ ★ ★ ★ ADVANCED — true exam level: explain & justify

★ ★ ★ ★ CHALLENGE — hardest exam reasoning

How Data Are Produced

Statistical questions · explanatory & response variables · surveys, observational studies & experiments · components of an investigative question

1 **True or False.** For any you mark false, give a one-line reason.

★★★★

- a) An *experiment* deliberately imposes treatments on experimental units in order to measure a response.
- b) In an *observational study*, the researcher decides which treatment each individual receives.
- c) A survey is one kind of observational study.

2 In a statistical study, the variable that measures the *outcome* of interest is called the

★★★★



- A) response variable.
- B) explanatory variable.
- C) confounding variable.
- D) experimental unit.
- E) treatment.

3 A trainer wonders whether the amount of sleep a player gets the night before affects how fast they react in a game. For 40 players she records hours slept and their average reaction time (milliseconds) in a match the next day.

★★★★

- a) Identify the explanatory variable and the response variable.
- b) Classify each variable as categorical or quantitative.

4 For each study, state whether it is a **survey**, an **observational study that is not a survey**, or an **experiment**.
Give a one-line reason.

★★★★

- a) A school counselor asks a random sample of 200 students a fixed list of questions about stress.
- b) A coach randomly assigns half of the team to a new warm-up routine and the other half to the usual one, then compares sprint times.
- c) Researchers follow a group of teen drivers for two years, recording phone use and accidents, without telling anyone how to drive.

5

★★★★



Which of the following is an **experiment**?

- A) A magazine asks readers to log on and rate their favorite sneaker brand.
- B) A streaming service records which shows 10,000 randomly chosen subscribers watched last month.
- C) A nutritionist randomly assigns volunteers to drink either a sports drink or water during a workout and compares their finishing times.
- D) A researcher reviews medical records to see whether teens who play sports have fewer injuries than those who don't.
- E) A pollster phones 1500 adults and asks who they plan to vote for.

6

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Researchers tracked 1200 randomly selected teenagers for one year. They found that teens who reported spending more hours per day on social media also tended to report more trouble falling asleep.

- a) Identify the explanatory and response variables, and classify each as categorical or quantitative.
 - b) Explain how you know this was an observational study and not an experiment.
 - c) Write a valid investigative question this study could address, phrased so it does *not* claim that social media *causes* sleep trouble.
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7

★★★★

Matching. Write the letter of the example that best fits each term. Each is used once. (Context: a study testing whether a new grip tape lowers the number of dropped passes for football receivers.)

- | | |
|----------------------|--|
| 1. experimental unit | A. the kind of grip tape applied (new or standard) |
| 2. treatment | B. one receiver in the study |
| 3. factor | C. "new grip tape" |
| 4. level | D. number of dropped passes |
| 5. response variable | E. a human experimental unit |
| 6. subject | F. "new grip tape" assigned to a receiver |

8

★★★★

A boba shop wants to find the recipe that customers rate highest. They prepare drinks using every combination of three sweetness levels (25%, 50%, 100%) and three ice levels (regular, light, none), then have tasters rate each drink from 1 to 10.

- a) Identify the experimental units and the response variable.
 - b) List the factors and the number of levels of each.
 - c) If every possible combination of levels is used as a treatment, how many treatments are there?
 - d) List two of the treatments.
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A coach tests how warm-up length (5, 10, or 15 minutes) and music tempo (slow or fast) affect vertical jump height. If every combination is used, the number of **treatments** in this experiment is

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- A) 2
- B) 3
- C) 5
- D) 6
- E) 9

10

★★★★

Classify each observational study as **retrospective** or **prospective**, and give a one-line reason.

- a) A researcher selects 300 current college athletes and follows them for four years, recording training habits and injuries as they happen.
- b) A researcher selects 300 adults today and looks back through their old fitness-app records to study teenage exercise habits.

11

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A **survey** is best described as

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- A) an observational study in which data are collected by asking people a common set of questions.
- B) any study in which treatments are assigned to subjects.
- C) a study that always uses a simple random sample.
- D) a study that can establish cause and effect.
- E) a census of an entire population.

12

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Error Analysis. A student writes: “A study compared the typing speed of students who use a phone a lot versus students who use it a little. The researchers measured each group, so this is an experiment.” Identify the mistake and write a corrected sentence that names the correct type of study and why.

13

★★★★

Always / Sometimes / Never. Write **A**, **S**, or **N** with a one-line reason.

- a) An experiment imposes a treatment on the experimental units.
- b) The explanatory and response variables in a study are quantitative.
- c) An observational study can be used to estimate a population parameter.
- d) A study that simply records what people already do is an experiment.

14 ★★★ A phone-game studio tests whether a new in-game tutorial changes how long new players keep playing. They randomly give half of 600 new players the new tutorial and the other half the old tutorial, then record each player's total minutes played in the first week.

- a) Is this an experiment or an observational study? Justify.
- b) Identify the experimental units, the factor, its levels, and the treatments.
- c) Identify the response variable and classify it as categorical or quantitative.

15 ★★★ A bakery tests two oven temperatures (325°F, 350°F) and four bake times (10, 12, 14, 16 min) to see which cookie recipe gets the highest taste rating. (a) How many treatments are there if every combination is used? (b) Write out two different treatments using the form “temperature / time.”

16 ★★★ Determine the three components of this investigative question: “What are the plausible values for the mean number of hours per week that students at our school spend on homework?”

- a) Identify the variable(s) of interest.
- b) Identify the type of inference, including any parameter. (Is the goal to *estimate* a parameter or to *test* a claim?)
- c) Indicate the type of conclusion: to what population can the results be generalized, and is a cause-and-effect conclusion appropriate?

17 ★★★ Determine the three components (variables, type of inference, type of conclusion) of this investigative question: “Is the proportion of all students at North High who skip breakfast greater than the proportion of all students at South High who skip breakfast?”

18 ★★★ A consumer group randomly selected 12 Brand A and 12 Brand B portable chargers and measured how many full phone charges each delivered, to see if the two brands differ. State the investigative question for this study.

19 ★★★ An investigative question asks for “the plausible values for the proportion of all teens in the district who own a smartwatch.” The type of inference is best described as

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- A) testing a claim about a single proportion.
- B) estimating a single population proportion.
- C) testing a claim about a difference between two proportions.
- D) estimating a population mean.
- E) making a cause-and-effect conclusion.

20 ★★★ A student council asks, “Is there convincing evidence of an **association** between a student’s grade level and whether they buy lunch at school?” The type of inference this question calls for is best described as

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- A) estimating a single population proportion.
- B) testing a claim about a difference between two means.
- C) testing a claim about an association between two categorical variables.
- D) estimating a difference between two proportions.
- E) making a cause-and-effect conclusion, because two variables are compared.

21 ★★★ In each setting, identify the largest population to which the results can be generalized, and explain your answer.

- a) A national study randomly selected 2500 U.S. high-school students and found that those who reported eating breakfast at least 5 days a week had higher self-reported energy levels.
- b) Researchers recruited 60 volunteers from a gym and randomly assigned each to a new stretching routine or the usual one, then measured flexibility gains.

22 ★★★ For each study, name which variable is *explanatory* and which is *response*.

- a) Does the brightness setting on a laptop screen affect its battery life?
- b) Do students who drink more water during the day report fewer headaches?

- 23**
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- A student council has a vague question: “Are students happy with the new lunch schedule?” Turn this into a complete investigative question. Your answer must:
- a) state a precise, valid investigative question that names a population and references a parameter idea;
 - b) identify the variable(s) of interest and classify each;
 - c) state the type of inference (estimate or test) and the type of conclusion (population to generalize to; whether cause-and-effect is possible) for your question.
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- 24**
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- A principal collects responses from *every* student in the school about the new bell schedule, rather than from a sample. Recording information from all individuals in the entire population like this is called a



- A) stratified random sample.
- B) simple random sample.
- C) census.
- D) convenience sample.
- E) voluntary response sample.

What the Data Can (and Can't) Prove

Confounding & extraneous variables · observation vs. causation · random sampling & generalizing · the two big ideas of data collection

25 A **confounding variable** is best described as a variable that

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- A) is measured as the outcome of a study.
- B) is deliberately manipulated by the researcher.
- C) is always controlled in an observational study.
- D) has no effect on the response variable.
- E) is associated with both the explanatory variable and the response variable, so its effect can't be separated from the explanatory variable's.

26 In a study of whether teens who use a study-planner app have higher GPAs, name one *extraneous* variable (a variable other than app use that could affect GPA). Then explain what would have to be true for that variable to be *confounded* with app use.

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27 An observational study found that teens who play a musical instrument tend to have higher math grades than teens who don't.

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- a) Identify a possible confounding variable in this study.
- b) Explain how your variable is associated with *both* playing an instrument *and* math grades, and why this makes a cause-and-effect conclusion impossible.

28 A fitness app reports that users who close their “move ring” every day have lower resting heart rates than users who don't. The app concludes that closing your move ring lowers your heart rate.

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- a) Explain why this observational study cannot support a cause-and-effect claim.
- b) Identify a confounding variable and describe both of its associations.

29

True or False. For any you mark false, give a one-line reason.

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- a) Random *sampling* from a population is what lets us generalize a study's results to that population.
 - b) Random *assignment* of treatments is what lets us draw a cause-and-effect conclusion.
 - c) A well-designed observational study can establish cause and effect just as well as an experiment.
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Which study design gives the strongest evidence that a change in the explanatory variable *causes* a change in the response variable?

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- A) A survey of a simple random sample.
- B) A retrospective observational study.
- C) A prospective observational study with a large sample.
- D) An experiment that randomly assigns treatments to experimental units.
- E) A census of the entire population.

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A researcher selects a simple random sample of 800 students from a university of 20,000 and surveys them about study habits. Explain why the researcher can generalize the results to *all* 20,000 students, and state what would limit generalizing if the sample had *not* been chosen at random.

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For each study, state (i) whether the results can be **generalized to a larger population** and (ii) whether a **cause-and-effect** conclusion is appropriate. Briefly justify each answer using the ideas of random sampling and random assignment.

- a) Researchers take a random sample of 500 teens nationwide and randomly assign each to watch a 10-minute funny video or a neutral video, then measure mood.
 - b) Researchers take a random sample of 500 teens nationwide and simply record their daily screen time and mood.
 - c) A teacher's 30 volunteer students are randomly assigned to study with music or in silence, then take the same quiz.
 - d) A teacher records, for her 30 students, whether they study with music and their quiz scores.
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- 33** **Error Analysis.** A headline reads: “Study shows part-time jobs lower teen grades.” The study simply compared the GPAs of teens who had jobs with those who didn’t—no treatments were assigned. Explain the error in the headline’s wording and rewrite it so the claim matches what an observational study can show.
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- 34** **Always / Sometimes / Never.** Write **A**, **S**, or **N** with a one-line reason.

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- a) An observational study can show an association between two variables.
 - b) If two variables are associated, one of them causes the other.
 - c) Random assignment tends to balance extraneous variables across the treatment groups, which guards against confounding.
 - d) The results of an experiment on volunteers can be generalized to a large population the volunteers were not randomly selected from.
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- 35** A news story reports: “Teens who drink energy drinks score lower on memory tests.” The data come from a survey in which teens reported their energy-drink habits and took a memory test.
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- a) Explain why these data cannot show that energy drinks *cause* lower memory scores.
 - b) Identify a confounding variable and explain its association with both the explanatory and response variables.
 - c) Describe an experiment that *could* provide evidence about whether energy drinks affect memory. Explain what feature of your design makes a cause-and-effect conclusion possible.
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- 36** A nutrition company recruits 80 volunteers who answer an online ad and randomly assigns each to a new protein bar or a standard bar, then measures muscle gain over 8 weeks. The largest population to which the results can be generalized is

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- A) people like the 80 volunteers in the experiment.
- B) all people who eat protein bars.
- C) all adults in the country.
- D) all people who saw the online ad.
- E) no one, because the study used volunteers.

- 37** Even a well-designed experiment often uses volunteers rather than a random sample from a population.
★★★★ Explain why this means we can usually apply the experiment's cause-and-effect conclusion only to “individuals like the subjects” rather than to a larger population.

- 38** A study randomly selected 1500 U.S. teens and recorded how many hours per week they game and their self-reported stress levels. Teens who gamed more reported more stress.

- a) Was this an observational study or an experiment? Justify.
b) What is the largest population to which we can generalize the results? Explain.
c) Is a cause-and-effect conclusion appropriate? Explain.
d) State the investigative question for this study.

- 39** A study finds that students who carry reusable water bottles get better grades. A reporter says the bottles must cause better grades. The most reasonable statistical objection is that



- A) the sample was too large.
B) an observational study can never show association.
C) grades are a categorical variable.
D) the response variable was not measured.
E) a confounding variable (such as overall conscientiousness) could be associated with both carrying a bottle and getting good grades.

- 40** Two students disagree. One says, “Random *sampling* is what lets you prove cause and effect.” The other says, “No—random *assignment* is.” Explain who is correct and clearly state what each kind of randomness lets you do.

- 41** A sports-drink ad claims: “*Athletes who use our drink recover faster—so our drink speeds recovery!*” The claim is based on a survey of athletes who chose on their own whether to use the drink.

- a) Explain, using the idea of confounding, why the ad's cause-and-effect claim is not justified.
b) Describe the key features a study would need in order to justify the claim that the drink *causes* faster recovery, and explain what each feature accomplishes.

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Construct & Explain. Invent your own teen-life example of two variables that would be *associated* even though neither causes the other, because a third variable is driving both.

- a) Name the explanatory variable, the response variable, and the third (confounding) variable.
- b) Explain how the third variable is linked to each of the other two.
- c) Explain in one sentence why this shows “association does not imply causation.”

Choosing a Sample

Simple random samples · stratified, cluster & systematic random sampling · choosing a method and explaining its advantage

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- ★★★★
- MC
- A simple random sample (SRS) of size n is a sample chosen so that
- A) every individual has *some* chance of being selected.
- B) every group of n individuals has an equal chance of being the sample selected.
- C) the sample is selected from easy-to-reach members of the population.
- D) individuals volunteer to take part.
- E) every k th individual on a list is chosen.

USE THIS ROSTER FOR PROBLEMS 43–44

An esports club has 18 members, listed alphabetically below. The coach wants a simple random sample of 4 members to test new headsets.

Ali	Bao	Cruz	Diaz	Ek	Fox
Gho	Han	Ito	Jain	Kim	Lee
Mora	Ng	Oh	Pal	Ruiz	Sato

- 44
- ★★★★
- Describe how to use a random number generator to choose the SRS of 4 members. Be sure to include all three steps: **label**, **randomize**, and **select**, and address what to do about repeated numbers.

- 45
- ★★★★
- Using your method, you run a generator that produces the integers 11, 4, 11, 17, 2 (in that order). (a) Which members are in the sample? (b) Explain why one of the numbers was skipped, using the idea of sampling *without replacement*.

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Which sampling method produces a **simple random sample** of 50 students from a school of 1000?

- A) Survey the first 50 students who arrive at school.
- B) Randomly pick 5 of the 20 homerooms and survey everyone in them.
- C) Number all 1000 students and use a random number generator to select 50 different numbers.
- D) Randomly select 10 students from each grade.
- E) Survey every 20th student on an alphabetical list.

47

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A district wants to estimate the proportion of its 4000 high-school students who support a later start time. Sleep needs may differ a lot by grade level, but be similar within a grade. The district wants a sample of 200 students.

- a) Describe how to select a **stratified random sample** using grade level as the strata.
- b) Explain why this method might give a more precise estimate than a simple random sample of the same size.

48

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A weekend music festival houses its 3,000 campers in 50 lettered camping zones of about 60 people each. The organizers want to survey about 120 campers about the food vendors but don't want to wander the campground tracking down scattered people.

- a) Describe how to select a **cluster random sample** using camping zones as clusters.
- b) Explain why this method might be preferred to a simple random sample here.

49

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A theme park wants to survey 80 of the 800 guests entering through one gate during an hour. They decide to use a **systematic random sample**. (a) What interval k should they use? (b) Describe how to pick the random starting guest. (c) If the random start is the 7th guest, list the first three guests who are surveyed.

- 50** **Matching.** Write the letter of the sampling method that best matches each description. Each is used once.
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|-----------------------------|---|
| 1. Simple random sample | A. Split the population into nearby groups; take an SRS of whole groups and survey everyone in them. |
| 2. Stratified random sample | B. Number everyone; use a generator to pick the sample so every group of that size is equally likely. |
| 3. Cluster random sample | C. Choose a random start among the first k , then take every k th individual. |
| 4. Systematic random sample | D. Split the population into similar groups; take an SRS from each and combine. |

51 A music-streaming company divides its users into “free” and “paid” accounts, then takes a separate SRS from each group and combines them. This is a
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MC

- A) simple random sample.
- B) systematic random sample.
- C) cluster random sample.
- D) stratified random sample.
- E) convenience sample.

52 Both stratified random sampling and cluster random sampling divide the population into groups, but the goal of the grouping is different. Explain the key difference in what we *want* each kind of group to look like (use the phrases “similar within, different between” and “looks like the population”).
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53 A school store manager wants a stratified random sample of students to estimate the proportion who would buy a new hoodie.
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- a) Give a variable that would make a *good* choice for forming strata, and explain why.
- b) Give a variable that would make a *poor* choice for forming strata, and explain why.

USE THIS SETTING FOR PROBLEM 54

A charity 5K has 900 registered runners, each wearing a numbered bib (1–900). Bibs were issued by age group: runners under 20 got bibs 1–300, ages 20–39 got 301–600, and 40-and-over got 601–900. The organizers want to survey 60 runners about the course.

- 54** ★★★★★ Describe how the organizers could obtain a sample of 60 runners using each method below, and give one reason it might be preferred to a simple random sample.
- a) a **stratified** random sample (explain your choice of strata);
- b) a **systematic** random sample (state the interval and the random start).
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- 55** ★★★★★ A city parks department randomly selects 6 of the city's 40 neighborhood parks and interviews every visitor at those 6 parks on one day. This sampling method is best described as
- MC**
- A) a simple random sample of visitors.
- B) a stratified random sample, with parks as strata.
- C) a voluntary response sample.
- D) a systematic random sample.
- E) a cluster random sample, with parks as clusters.
- 56** ★★★★★ Explain why stratified random sampling tends to produce *more precise* estimates than a simple random sample of the same size when the strata are chosen well. Refer to variability within and between the strata.
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- 57** ★★★★★ **Error Analysis.** A student writes: “To get a cluster sample of students, divide them into groups that are each as different from one another as possible, then take an SRS from every group.” Two ideas are mixed up here. Identify what the student is actually describing, and write a correct description of a cluster random sample.
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- 58** ★★★★★ **Always / Sometimes / Never.** Write **A**, **S**, or **N** with a one-line reason.
- a) In a simple random sample, every individual has an equal chance of being selected.
- b) If every individual has an equal chance of being selected, the sample is a simple random sample.
- c) A systematic random sample uses a chance process to choose the starting point.
- d) A cluster random sample gives more precise estimates than a stratified random sample of the same size.
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59 ★★★ A factory produces 6000 phone cases in a day. A quality inspector will check a systematic random sample of 120 cases as they come off the line.

- a) Find the interval k and describe how to choose the random starting case.
- b) Explain one advantage of this method over a simple random sample in this setting.
- c) Describe a pattern in the production line that could make this systematic sample *unrepresentative*.

60 Which of the following is **NOT** a random sampling method?

★★★★



- A) Voluntary response sample
- B) Cluster random sample
- C) Systematic random sample
- D) Simple random sample
- E) Stratified random sample

61 ★★★ A college wants to estimate the proportion of students who commute by car. Commuting habits are very different for students who live on campus versus off campus, but fairly similar within each group.

- a) What variable would be a good choice for forming strata? Explain.
- b) Describe how to select a stratified random sample of about 150 students using this variable.

62 ★★★ **Design a sampling plan.** A streaming app with 500,000 subscribers (spread across many cities) wants to estimate the mean number of hours subscribers watch per week.

- a) Choose one random sampling method (stratified, cluster, or systematic) and justify why it fits this situation.
- b) Describe the steps to carry out your plan (label, randomize, select).
- c) State one disadvantage of your chosen method compared with a simple random sample.

63

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To estimate the proportion of blue gumballs in a large machine, Mia draws a gumball, records its color, *puts it back*, mixes, and repeats many times. Because a gumball can be selected more than once, Mia is using

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- A) sampling without replacement.
- B) stratified random sampling.
- C) sampling with replacement.
- D) cluster sampling.
- E) systematic random sampling.

When Samples Go Wrong

Convenience & voluntary-response sampling · bias & its direction · undercoverage, nonresponse, response bias & question wording

64

★★★★



A **voluntary response sample** consists of

- A) the members of the population that are easiest to reach.
- B) people who choose to take part by responding to a general invitation.
- C) every k th individual on a list.
- D) individuals selected by a random number generator.
- E) one randomly chosen group of nearby individuals.

65

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For each, name the (poor) sampling method—**convenience** or **voluntary response**—and state whether the resulting estimate is likely to be too high or too low.

- a) To estimate the average daily screen time of all students, a blogger posts a poll and lets anyone who feels strongly reply.
- b) To estimate how much homework students do, a reporter asks the first 25 students leaving the library.

66

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To estimate the proportion of all students at a school who exercise daily, a coach surveys the students in the weight room after practice.

- a) Name the sampling method.
- b) Describe how the members of this sample are likely to differ from the rest of the population, and explain whether this leads to an overestimate or an *underestimate* of the true proportion.

67

★★★★



The design of a statistical study shows **bias** if

- A) one particular sample happens to give an unusual result by chance.
- B) the sample size is too small.
- C) the population is very large.
- D) the response variable is categorical.
- E) the resulting sample statistic is very likely to consistently overestimate or underestimate the parameter due to a flaw in the data-collection process.

68

★★★★

A video game's official account posts: "Tap YES if you want the old map back!" Over 50,000 fans reply and 92% tap YES. Explain why 92% is likely a poor estimate of the proportion of *all* players who want the old map back, and state the likely direction of the bias.

69 ★★★★★ A polling group estimates the proportion of adults who support a ballot measure by randomly dialing *landline* phone numbers only.

- a) Name the source of bias (convenience, voluntary response, undercoverage, nonresponse, or response bias).
 - b) Explain who is left out and how this could push the estimate too high or too low.
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70 ★★★★★ A school mails a survey to a random sample of 400 families asking how many hours per week parents help with homework. Only 90 families mail it back. Parents who are very busy are less likely to respond.

- a) Name the source of bias.
 - b) Explain the likely direction of the bias in the estimated mean number of hours.
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71 ★★★★★ Explain the difference between **nonresponse** and a **voluntary response sample**. In particular, explain why nonresponse can occur only *after* a sample has been selected, while a voluntary response sample has no nonresponse.

72 ★★★★★ A health teacher asks students face-to-face, “How many hours of sleep do you get on a school night?” Some students may lie. Name the source of bias and state whether the estimated mean sleep is likely too high or too low.

73 ★★★★★ A club wants to know whether students support a longer lunch period. They consider two versions of the question:

Version 1: “Do you support a longer lunch period?”

Version 2: “Do you support wasting valuable class time on an even longer lunch period?”

Identify the source of bias and explain which version would produce a higher level of support and why.

74 ★★★★★ **Error Analysis.** A student writes: “The principal emailed a survey to a random sample of 300 students, but only 120 replied. This is a voluntary response sample.” Explain why this is the wrong term, and state the correct term for what happened.

75 Always / Sometimes / Never. Write A, S, or N with a one-line reason.

★★★★

- a) A convenience sample produces a biased estimate.
 - b) Increasing the sample size removes the bias from a voluntary response sample.
 - c) The wording of a question can affect the answers people give.
 - d) A simple random sample completely eliminates nonresponse.
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76 A fitness influencer asks followers to log on and vote on whether they prefer morning or evening workouts; 40,000 respond and 78% say morning. Which statement is best?

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- A) This is a simple random sample, so 78% is a good estimate.
- B) The large sample size guarantees the estimate is accurate.
- C) This is a stratified sample, so the estimate is unbiased.
- D) This is a voluntary response sample, and 78% may differ from the true proportion because people with strong opinions are overrepresented.
- E) This is a systematic sample.

77 A school newspaper's website posts the question "Should the school add a senior parking lot?" next to an article. Readers click to vote; 1,800 respond and 71% say "Yes."

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- a) What type of sample is this?
 - b) Explain how bias in this method could have affected the result, including the likely direction.
 - c) Describe a better method for estimating the true proportion of students who support a senior parking lot.
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78 To estimate the proportion of all students who play a school sport, a researcher surveys a random sample of 200 students *chosen only from those in PE classes*.

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- a) Describe how undercoverage could bias this estimate and state the likely direction.
 - b) Would increasing the sample size (still only from PE classes) fix this bias? Explain.
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79 A researcher asks a random sample of students how many times they have cheated on a test. Half are asked face-to-face by a teacher; the other half answer anonymously on paper. The anonymous group reports far more cheating. Explain how *response bias* accounts for the difference, and state which group's average is likely closer to the truth.

★★★★

- 80** ★★★
MC A survey selects a random sample of 500 residents from a list of *registered voters* to estimate the proportion of *all adults* in town who support a new skate park. Adults who are not registered to vote are left out entirely. This is an example of
- A) undercoverage.
 - B) voluntary response.
 - C) response bias.
 - D) nonresponse.
 - E) random sampling error only.

- 81** ★★★
a) Write a *neutral* (unbiased) version of the question.
b) Write a version whose wording would *bias* responses toward “Yes,” and explain why it would.
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- 82** ★★★
A student group wants to estimate the proportion of all students who would attend a weekend coding club. They set up a table in the senior hallway during lunch on one day and ask passing students, “You’d come to a cool new coding club, right?” Only students who stop are surveyed. Identify **three** distinct problems with this plan (name each and explain how it could bias the estimate).
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- 83** ★★★
Fix the study. A principal wants a trustworthy estimate of the proportion of all students who feel safe at school.
- a) Describe a sampling method that avoids convenience and voluntary-response bias.
 - b) Describe one step to reduce *nonresponse* once the sample is chosen.
 - c) Describe one step to reduce *response bias* when collecting the answers.
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Designing Experiments

Comparison · placebo & blinding · random assignment, replication & direct control · completely randomized, block & matched-pairs designs

84 The main purpose of a **control group** in an experiment is to

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- A) increase the number of subjects.
- B) let the results be generalized to a population.
- C) guarantee the groups are exactly equal.
- D) make the experiment double-blind.
- E) provide a baseline for comparing the effects of the other treatments.

85 A **placebo** is

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MC

- A) the group that receives the real treatment.
- B) any treatment given to the control group.
- C) a treatment with no active ingredient that is otherwise like the other treatments.
- D) the person who measures the response variable.
- E) a variable that is associated with both the explanatory and response variables.

86 A trainer wants to know if a new pre-workout stretch routine increases vertical jump. Every athlete does the new routine for two weeks, and their jumps improve. Explain why this design cannot show that the routine *caused* the improvement, and why a control group is needed.

★★★★

87 Researchers test whether a new herbal pill reduces headaches. Subjects are randomly assigned to take either the pill or an identical-looking placebo. Neither the subjects nor the staff who record the headache counts know who got which pill.

★★★★

- a) Explain what it means for this experiment to be **double-blind**.
- b) Explain why double-blinding is important here (refer to the placebo effect and to how staff might otherwise treat the groups).

88

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Classify each experiment as **double-blind**, **single-blind**, or **neither**. Give a one-line reason.

- a) Subjects don't know whether their drink contains sugar or a sugar substitute, and the staff measuring their energy levels don't know either.
 - b) Subjects know whether they were assigned to weight training or running, but the person measuring their strength does not know which group each subject is in.
 - c) Subjects know which workout playlist they got, and the coach timing their sprints also knows.
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89

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A study has 40 volunteers to test whether a standing desk improves focus compared with a sitting desk.

- a) Describe how to use a random number generator to randomly assign the 40 volunteers to the two treatments in a completely randomized design.
 - b) Explain the purpose of random assignment in this experiment.
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90

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The main purpose of **random assignment** in an experiment is to

- A) allow the results to be generalized to a population.
- B) create treatment groups that are roughly equivalent at the start, balancing out extraneous variables.
- C) make the experiment double-blind.
- D) guarantee the groups are exactly the same size.
- E) increase the number of treatments.

91

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In an experiment, **replication** means giving each treatment to multiple experimental units. Explain, in the context of testing whether a fertilizer increases tomato plant height, why an experiment with only one plant per treatment would not give convincing evidence.

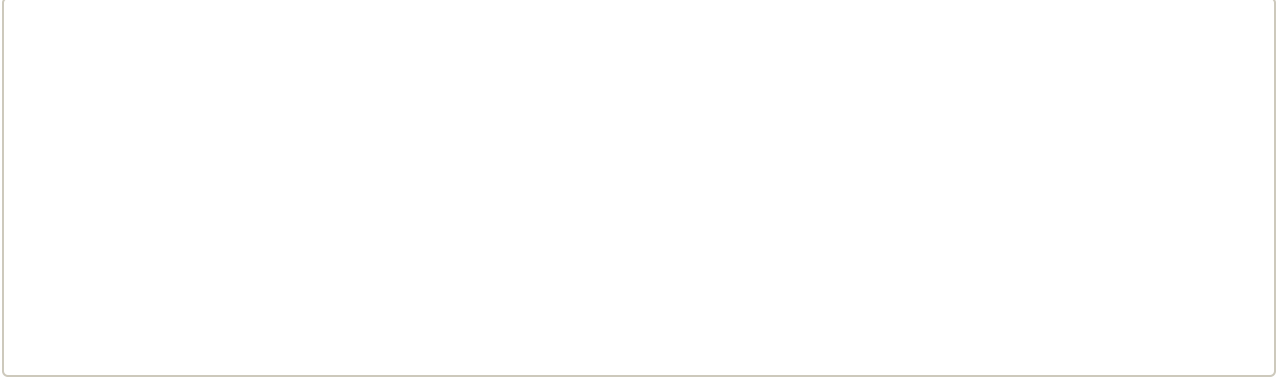
92

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In an experiment comparing two study apps, all subjects study the same material for the same 30 minutes in the same quiet room and take the same quiz.

- a) Identify two variables the researchers are directly controlling.
 - b) Describe one benefit of keeping these variables the same for all subjects.
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- 93** ★★★ A gaming company wants to know whether a new controller layout improves players' scores compared with the standard layout. They have 60 volunteer players. Describe (and draw a diagram of) a **completely randomized design** for this experiment. Your diagram should show the random assignment, the group sizes, the treatments, and the response variable to be compared.



DRAW YOUR COMPLETELY RANDOMIZED DESIGN ABOVE

- 94** ★★★ In a **completely randomized design**,
- A)** subjects choose which treatment they want.
- B)** each subject receives every treatment in order.
- C)** each treatment must be given to exactly the same number of units.
- D)** experimental units are assigned to the treatments completely at random.
- E)** treatments are assigned within blocks of similar units.



- 95** ★★★ A student tests whether plant food helps basil grow. She puts plant food on the three plants on her sunny windowsill and no plant food on the three plants in her dim closet, then compares heights after a month. For each element of a well-designed experiment, state whether her design includes it, and explain.
- a) Comparison
- b) Random assignment
- c) Direct control of other variables

- 96** ★★★ **Error Analysis.** A student writes: “To survey the school, I’ll use a randomized block design and randomly assign the treatments to three different strata.” This sentence mixes the language of experiments with the language of sampling. Explain what is wrong and rewrite it so the vocabulary is used correctly.

97 ★★★★★ A coach wants to test whether a new energy gel improves 1-mile run times. She has 12 boys and 12 girls, and run times tend to differ by sex more than by anything else.

- a) Describe a **randomized block design** for this experiment, and justify your choice of blocks.
 - b) Explain why this design might give more convincing evidence than a completely randomized design.
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98 ★★★★★ In a randomized block design, blocks should be formed from experimental units that are similar in a way that affects the response.

- a) For an experiment testing two phone-battery-saving settings on how long a charge lasts, give a good blocking variable and explain why.
 - b) Complete the saying: "Directly control what you can, ____ on what you can't, and ____ to balance out the rest."
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99 ★★★★★ A tech-review channel wants to know whether a screen protector reduces touchscreen response time. They have 16 phones of different models.

- a) Describe a **matched pairs design** in which each phone receives both treatments (protector / no protector).
 - b) Explain why testing both treatments on the *same* phone is better than splitting the 16 phones into two groups.
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100 ★★★★★ A matched pairs design is best described as

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- A) a completely randomized design with exactly two treatments.
- B) an experiment with no control group.
- C) a sampling method that pairs similar individuals.
- D) an observational study comparing two groups.
- E) a randomized block design that uses blocks of size 2 (or one unit that gets both treatments in random order).

101 ★★★★★ A trainer wants to know whether a new energy chew improves sprint times. She gives the energy chew to the 10 *fastest* runners on the team and gives nothing to the 10 *slowest* runners, then compares the two groups' sprint times. Which element(s) of a well-designed experiment is/are **missing**?



- I. Comparison of at least two treatment groups · II. Random assignment of treatments to experimental units · III. Replication
- A) I only
- B) II only
- C) III only
- D) I and II only
- E) I, II, and III

102 **True or False.** For any you mark false, give a one-line reason.

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- a) A well-designed experiment with random assignment allows a cause-and-effect conclusion.
- b) An experiment must be double-blind to be well-designed.
- c) Blocking is used to account for a source of variation the researcher can identify in advance.
- d) Random assignment guarantees that the treatment groups are exactly equal at the start of the experiment.

103 **Design an experiment.** A study app claims that doing 10 minutes of practice quizzes before bed improves test scores compared with reading notes for 10 minutes. You have 50 volunteer students and one upcoming unit test.

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- a) Describe a completely randomized design: the treatments, how you randomly assign subjects, and the response variable.
- b) Name one extraneous variable you would directly control, and how.
- c) Explain how you would decide whether practice quizzes are *more effective*, and why your random assignment lets you treat a clear difference between the groups as *caused* by the practice quizzes.

104 A runner wants to know whether wearing a new brand of socks reduces her mile time. She can run once a day for 20 days.

★★★★

- a) Describe a **matched pairs design** using herself as the experimental unit on different days. Explain how you randomly assign which sock she wears each day and why randomizing the order matters.
- b) Identify one extraneous variable this design helps account for that a two-group design on different runners would not.

105

★★★★

Capstone critique. An influencer posts: “I drank a green smoothie every morning for a month and my skin cleared up—these smoothies cure acne!”

- a) Identify **three** features of a well-designed experiment that this “study” is missing, and explain why each matters.
- b) Describe a well-designed experiment that could actually test whether the smoothie affects acne. Include comparison, random assignment, replication, and how you would blind it if possible.

106

★★★★★



A district tests whether a new 10-minute daily reading routine improves reading scores. It randomly assigns **24 third-grade classrooms** — 12 to use the routine and 12 to continue as usual. At the end of the year all **540 students** take the same reading test. The experimental units are

- A) the 540 students, because their scores were measured.
- B) the 24 classrooms, because the routine was assigned to whole classrooms.
- C) the 12 classrooms that used the new routine.
- D) all third graders in the district.
- E) the two treatments, since there are two groups.

Reading the Evidence

Statistical significance · randomization distributions · what the study lets you conclude, and about whom

107

★★★★



In an experiment, a result is called **statistically significant** when it is

- A) large enough to be interesting to the researcher.
- B) too unusual to be explained by chance variation in the random assignment alone.
- C) obtained from a random sample of the population.
- D) measured on more than 30 experimental units.
- E) the same in every treatment group.

108

★★★★

In an experiment, the mean response for one treatment group came out higher than for the other. There are exactly two explanations for that difference.

- a) State both explanations.
- b) Explain what has to be true about the observed difference before we are willing to rule the first explanation out.

109

★★★★

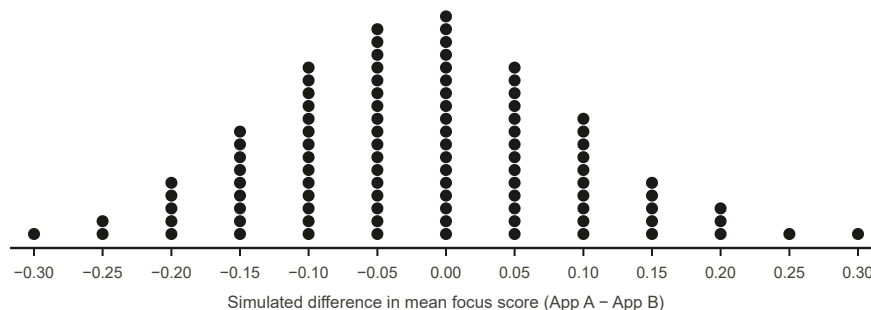
To see what differences show up *by chance alone*, researchers repeatedly shuffle the observed responses back into two groups of the same sizes and record the difference in means each time. The dotplot of all those differences is called a **randomization distribution**.

- a) What assumption is being made about the treatments while the shuffling is done?
- b) Explain, in context, what a *single dot* on a randomization distribution represents.
- c) Why is the distribution centered near 0?

110

★★★★

Fifty volunteers were randomly assigned to focus app **A** or focus app **B** (25 each) and then took the same concentration test. The observed difference in mean focus score was $A - B = 0.25$. The dotplot below shows **100 simulated random assignments** of the same responses, assuming the app makes no difference.



- a) How many of the 100 simulated differences were **0.25 or greater**?

- b) Based on that, is the observed difference statistically significant? Explain your reasoning.
- c) State the conclusion you are allowed to make, and say what feature of the study allows it.

111

★★★



Sixty students **volunteered** for a study and were **randomly assigned** to two study methods. The method-A group scored significantly higher. The most complete conclusion is that

- A) method A causes higher scores for all students at the school.
- B) method A is associated with higher scores for all students at the school.
- C) method A causes higher scores for students like the volunteers in this study.
- D) nothing can be concluded, because the students were not randomly selected.
- E) method A would cause higher scores only if the study were repeated.

112

★★★

For each study, state (i) the largest population the results generalize to and (ii) whether a cause-and-effect conclusion is justified. Give a one-line reason for each.

- a) A random sample of 500 U.S. teens is surveyed about screen time and sleep; more screen time goes with less sleep.
- b) Forty students who answered a flyer are randomly assigned to a standing desk or a sitting desk; the standing group scores higher on a focus test.
- c) A random sample of 300 Soffer students is randomly assigned to two versions of a review packet; version 1 produces higher quiz scores.
- d) A teacher compares the grades of students who happen to sit in the front row with those who sit in the back.

113

★★★

Error Analysis. A student writes: “Our experiment used a random sample of volunteers, so we can generalize to everyone AND say the treatment caused the difference.”

- a) Identify the two things wrong with that sentence.
- b) Rewrite it so both claims are stated correctly.

114

★★★★

Capstone. A sports-drink company claims its drink improves endurance. You have 60 volunteers from a running club and access to a treadmill lab.

- a) Describe a completely randomized, double-blind experiment: treatments, random assignment, response variable, and one variable you directly control.

- b) Suppose the drink group lasts 1.4 minutes longer on average. Describe how you would use a **simulation** to decide whether 1.4 minutes is more than chance variation in the random assignment could reasonably produce.
- c) Suppose only 2 of 200 simulated random assignments produced a difference of 1.4 minutes or more. Write the complete conclusion: what you conclude, about whom, and why you are (or are not) allowed to say “caused.”
