¶ 3.1

We almost never measure everyone we care about. We study a sample to learn about the population.

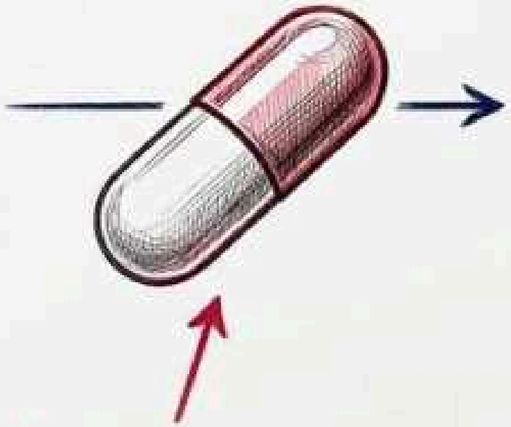


The Population

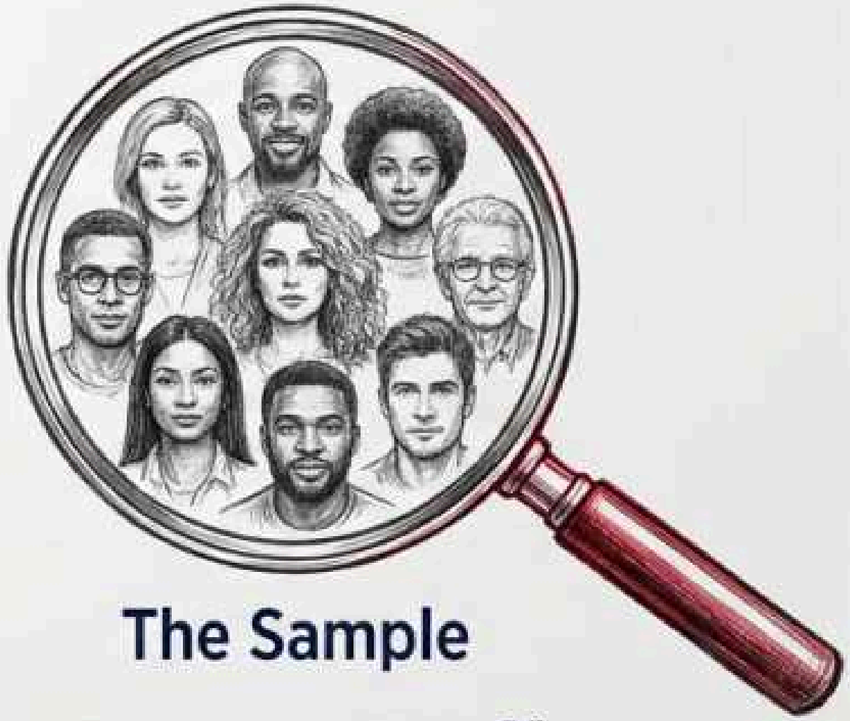
N = Total Population Size

μ = Population Mean (True Average)

σ^2 = Population Variance



500 trial patients → Millions of future patients.



The Sample

n = Sample Size ($n \ll N$)

$\bar{x}$ = Sample Mean (Estimate of μ)

s^2 = Sample Variance (Estimate of σ^2)

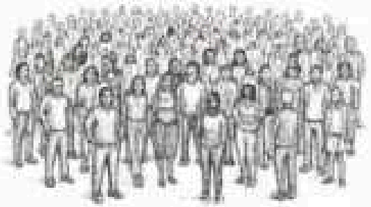
Standard Error = $\frac{s}{\sqrt{n}}$

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¶ 3.2

Different samples from the same population give different results, simply by chance.

The Population





Group A

118 mmHg



Group B

121 mmHg



Group C

119 mmHg

This sampling variation is unavoidable. Statistics exists largely to measure it.

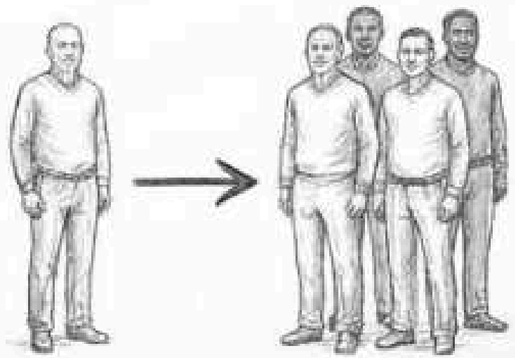
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The standard error measures how much a sample **estimate** would vary from sample to sample.

$$SE = \frac{SD}{\sqrt{n}}$$

Standard Deviation

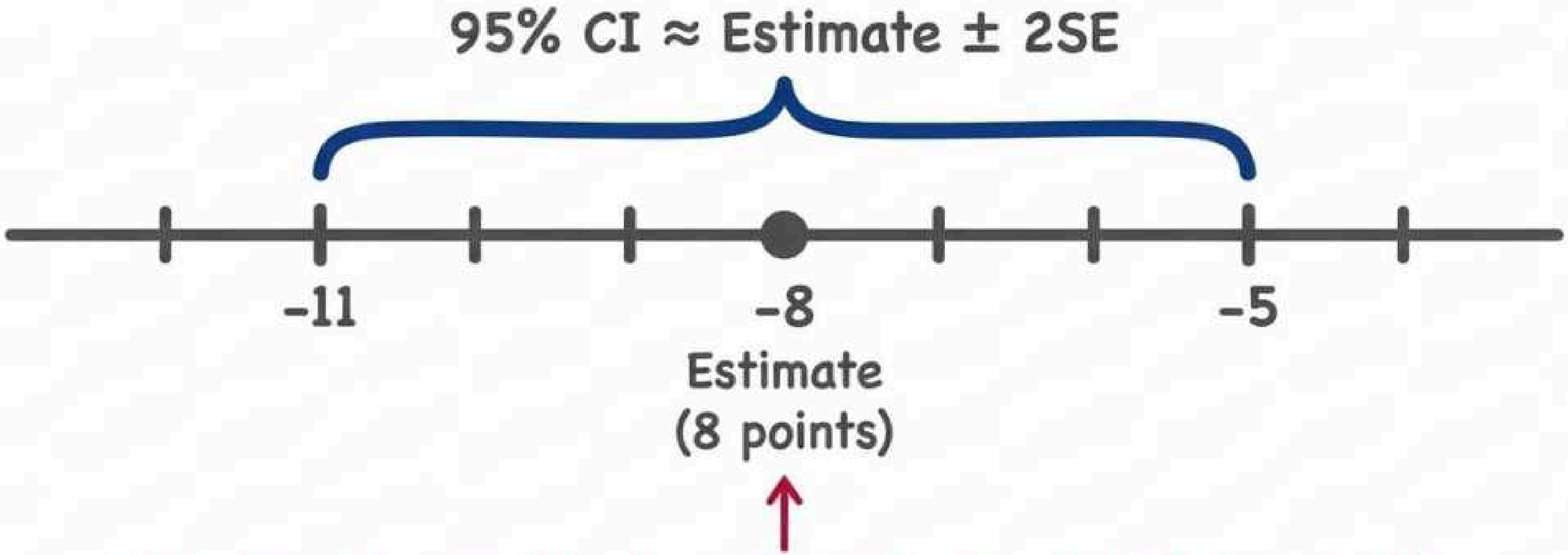
Sample Size



Because of the square root, halving the standard error requires four times as many people.

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A confidence interval turns the standard error into a range of plausible values for the true population figure.



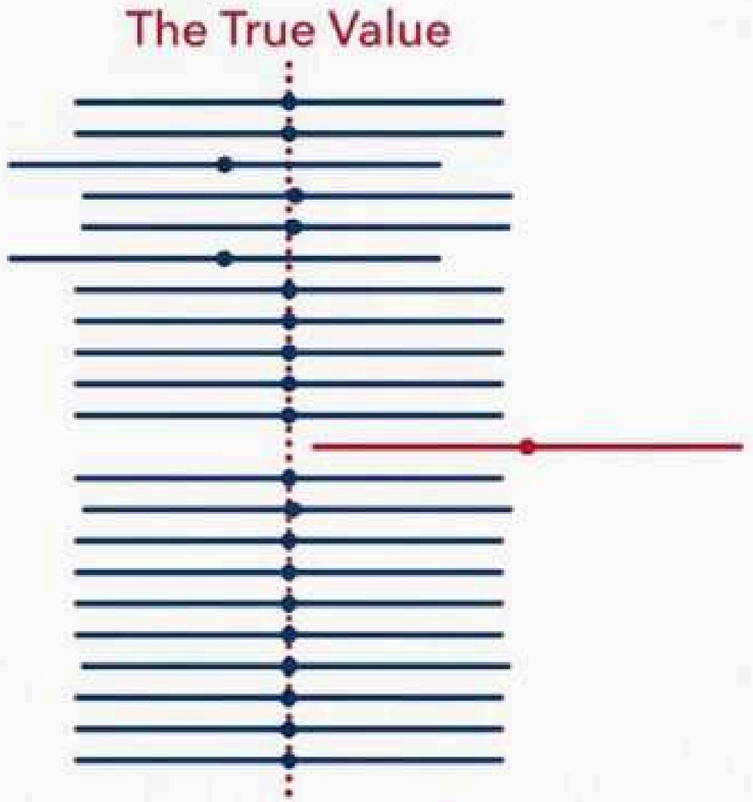
If a drug lowers blood pressure by 8 points (CI: 5 to 11), the true effect is plausibly anywhere in that range.

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The precise meaning is subtle. Any single interval either contains the true value or it does not.

¶ 3.5

Long-Run Reliability cascade chart

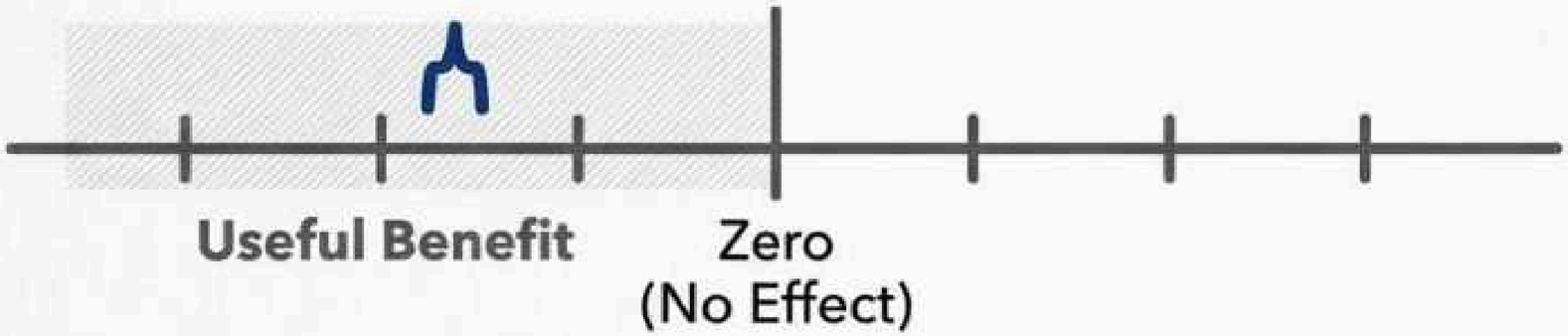


The method is reliable in the long run. If repeated many times, about 95% of intervals will contain the true value.

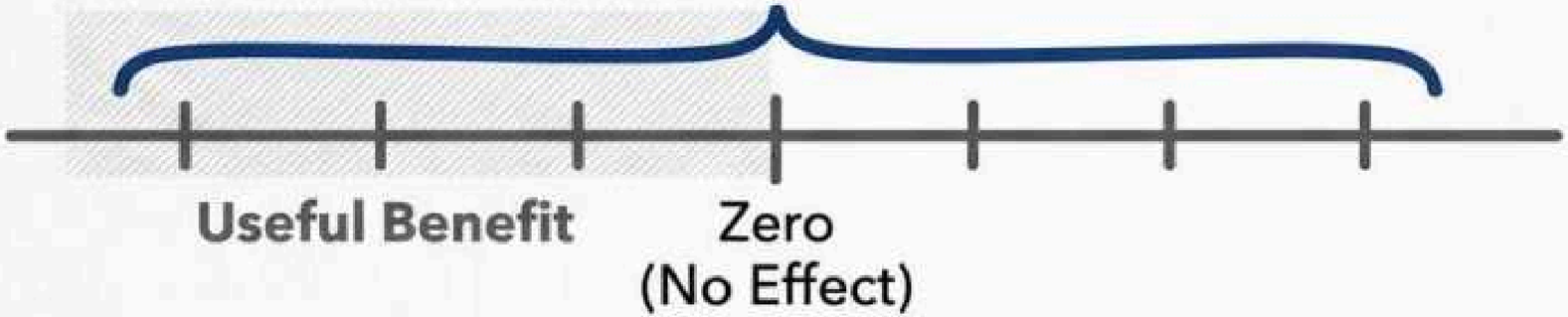
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Confidence intervals are vastly more informative than a bare yes-or-no verdict.

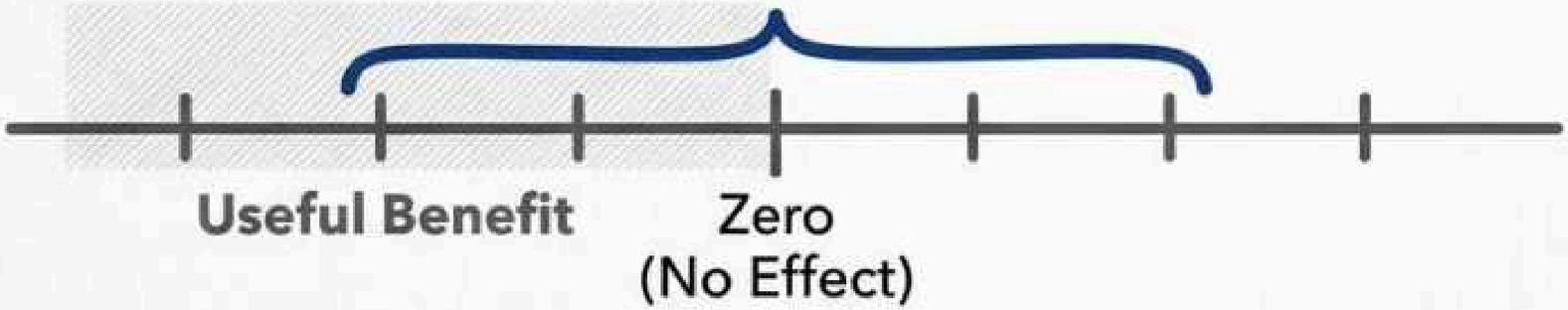
¶ 3.6



Narrow: The effect has been measured precisely.



Wide: The study was too small to pin it down.



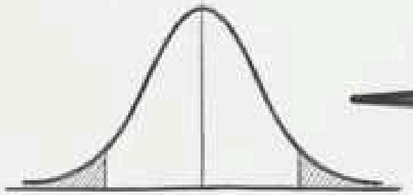
Crossing Zero & Benefit: The question remains open.

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Sample size must be planned before a study begins based on these three variables.



How small an effect matters



Expected variation



Desired confidence

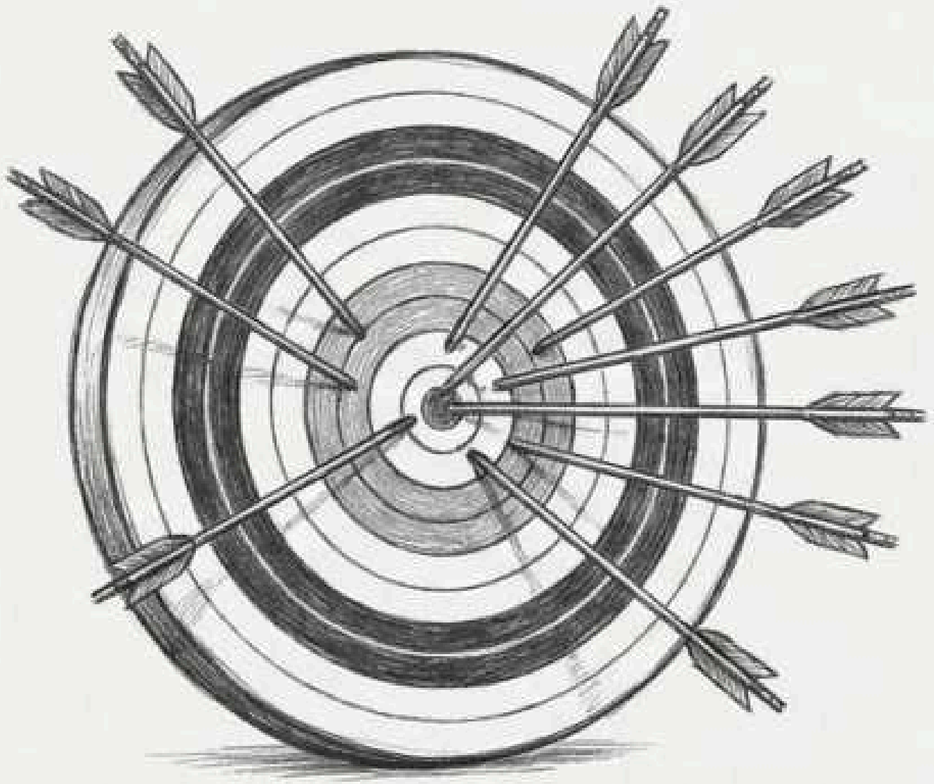
$$N\left(\begin{matrix}\text{Participants}\\ \text{Needed}\end{matrix}\right)$$



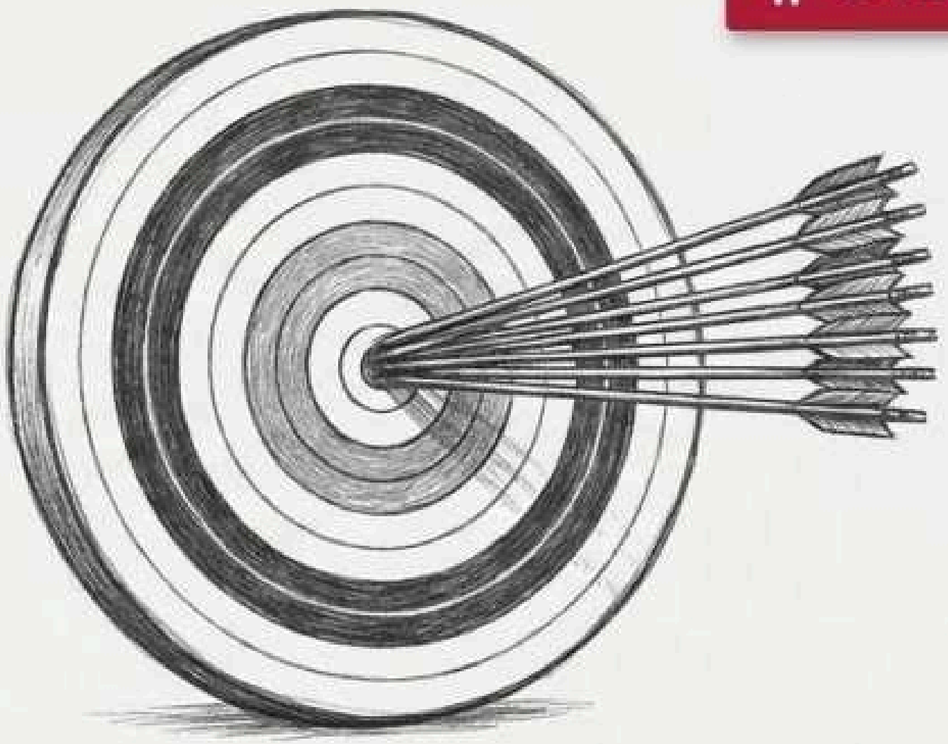
A study that is too small may miss a real benefit—wasting effort and exposing participants to risk without answering the question.

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¶ 3.8



Random Error: The scatter caused by chance. (What Confidence Intervals measure).



Bias: Systematic error that pushes results in one direction.

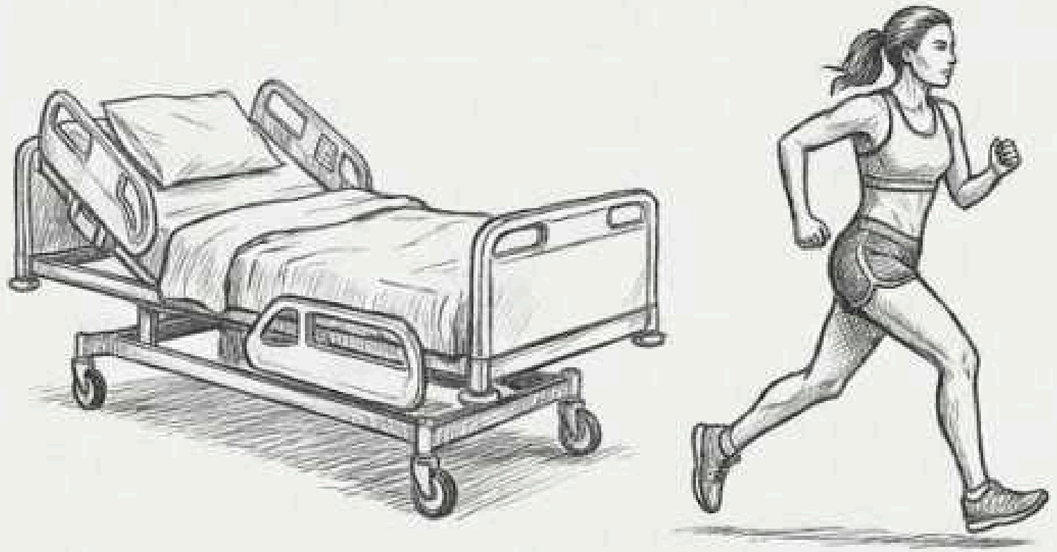
A very large study can produce a perfectly narrow interval around the exact wrong answer if the sample does not represent the population.

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¶ 3.9

Selection Bias

(When people studied differ systematically from the population).



- Hospital patients overstate average disease severity.
- Volunteers are often healthier than average.

Measurement Bias

(When the way data are collected collected distorts them).

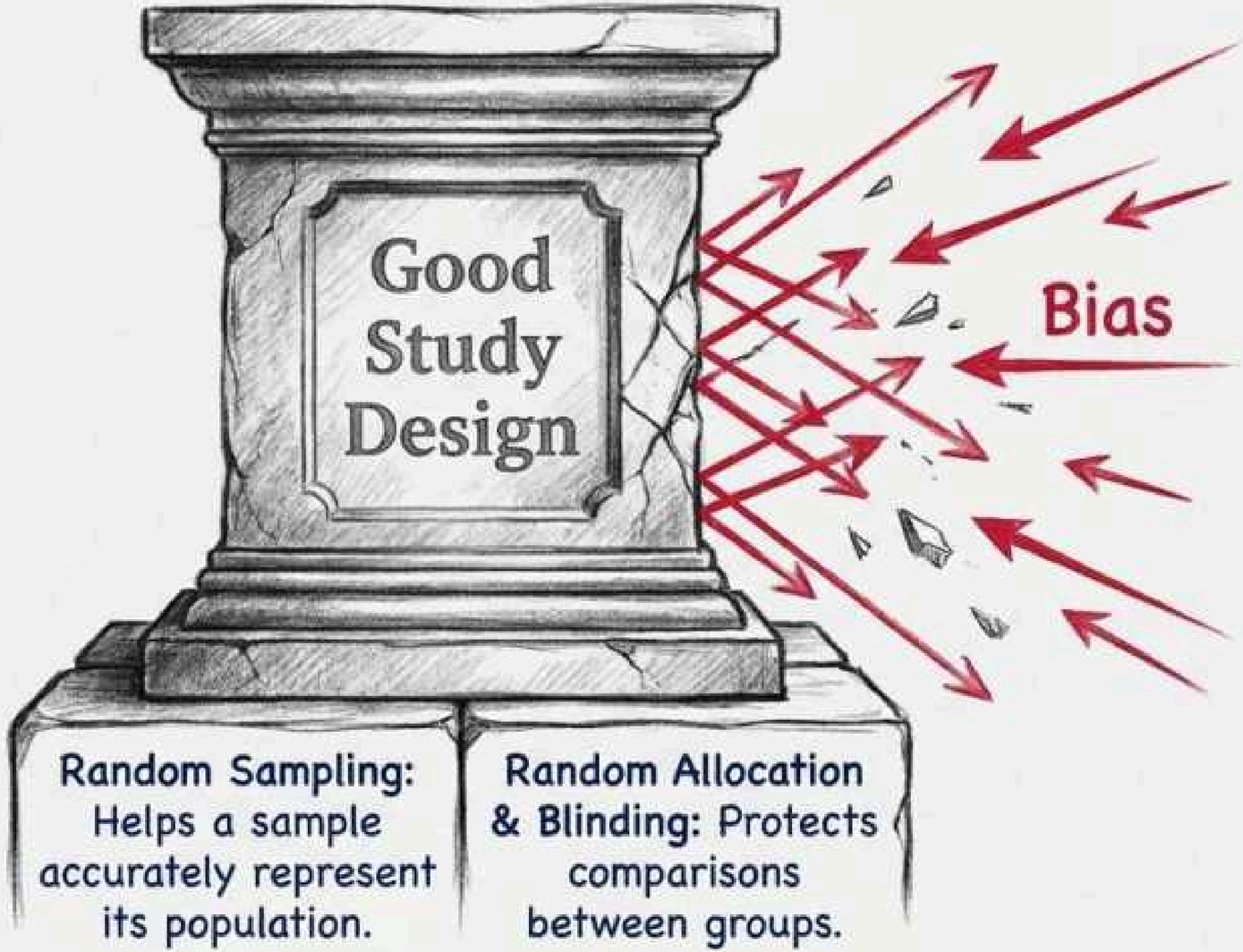


- e.g., People systematically under-reporting how much alcohol they drink.

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Good study design reduces bias in ways no statistical method can fix afterwards.

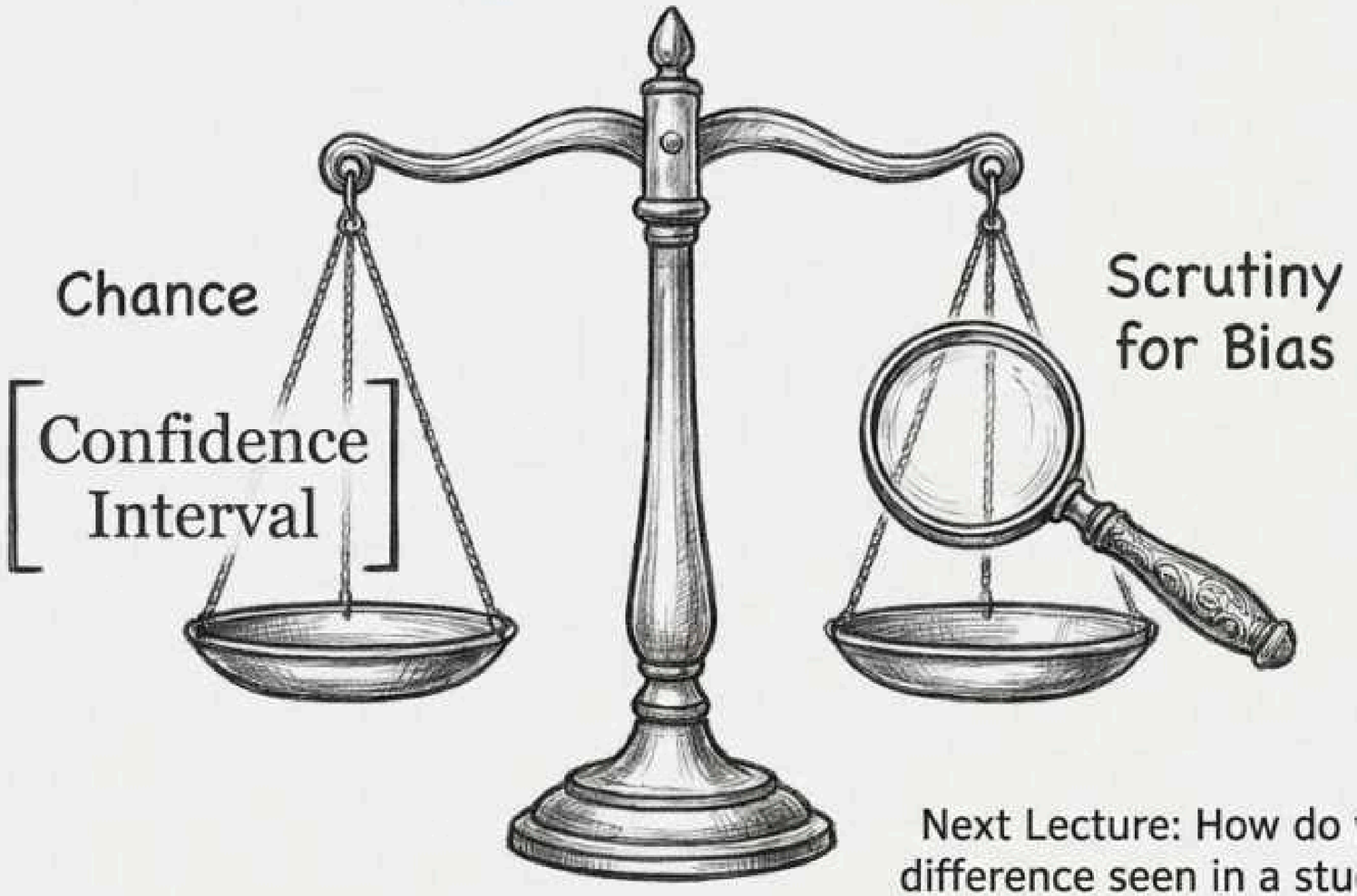
¶ 3.10



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¶ 3.11

A sample estimate must always come with a measure of its uncertainty (ideally a confidence interval) AND must always be judged for bias as well as chance.



Next Lecture: How do we decide whether a difference seen in a study is likely to be real?

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