The binomial distribution

INTRODUCTION TO STATISTICS

George Boorman
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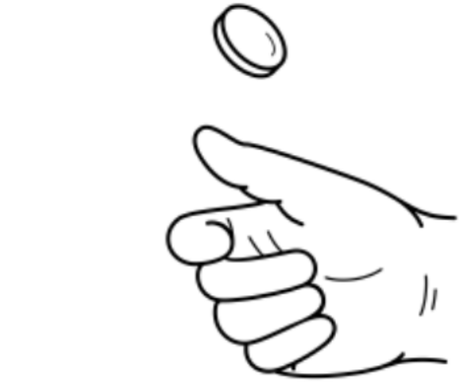
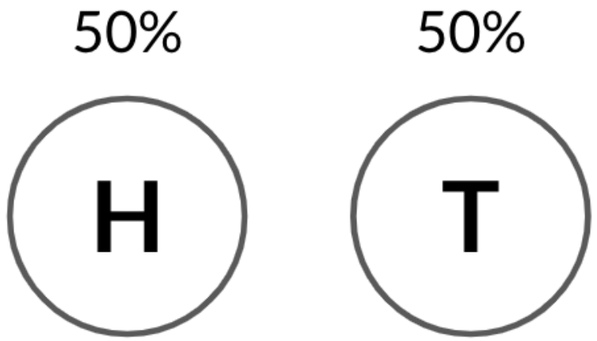
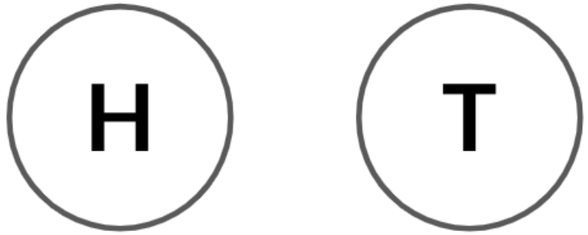
Coin flipping





Binary outcomes



1	0
Success	Failure
Win	Loss

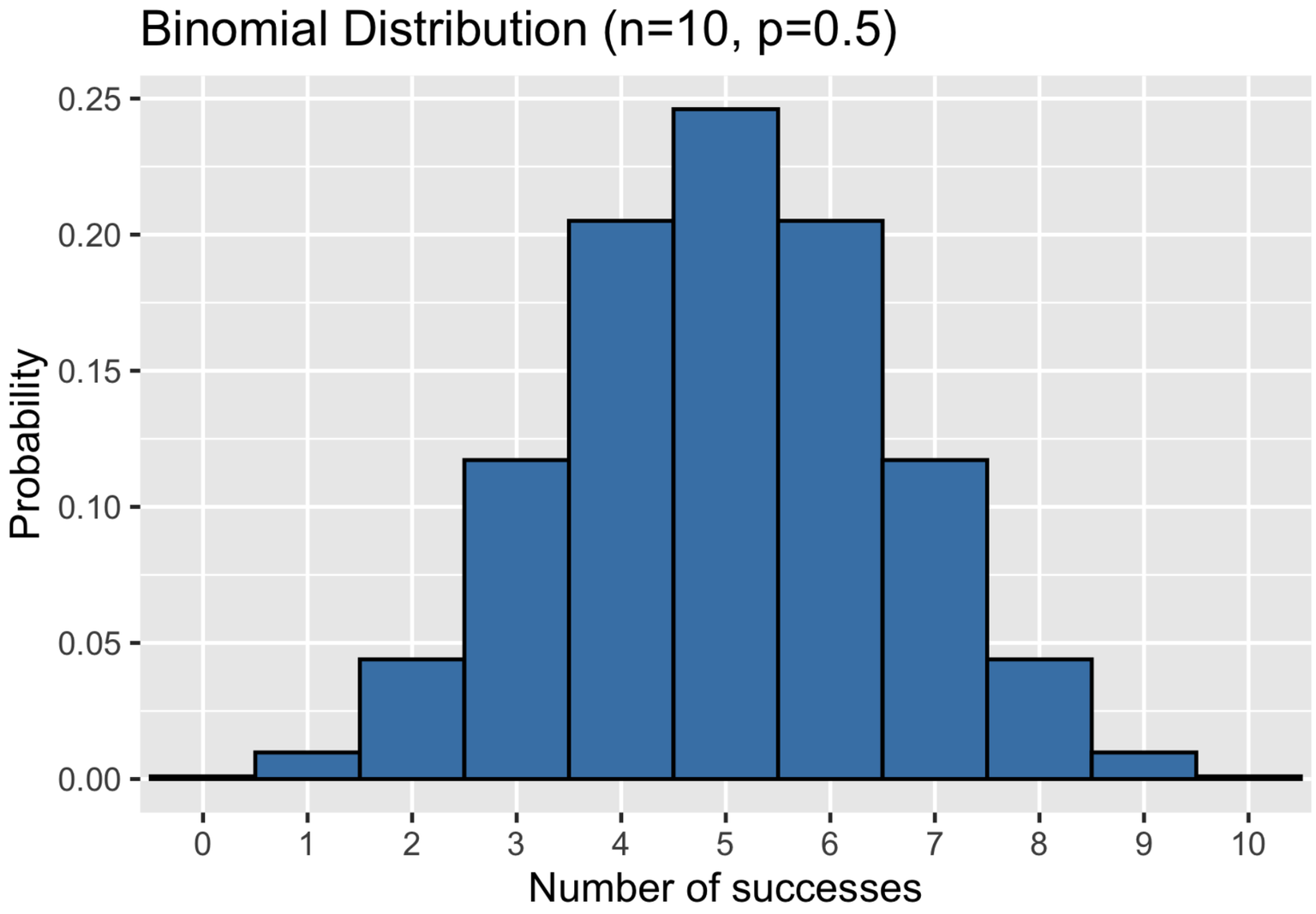
One coin flip many times

Coin Flip	Result
1	0
2	0
3	0
4	1
5	0
6	0
7	1
8	0
9	1
10	1

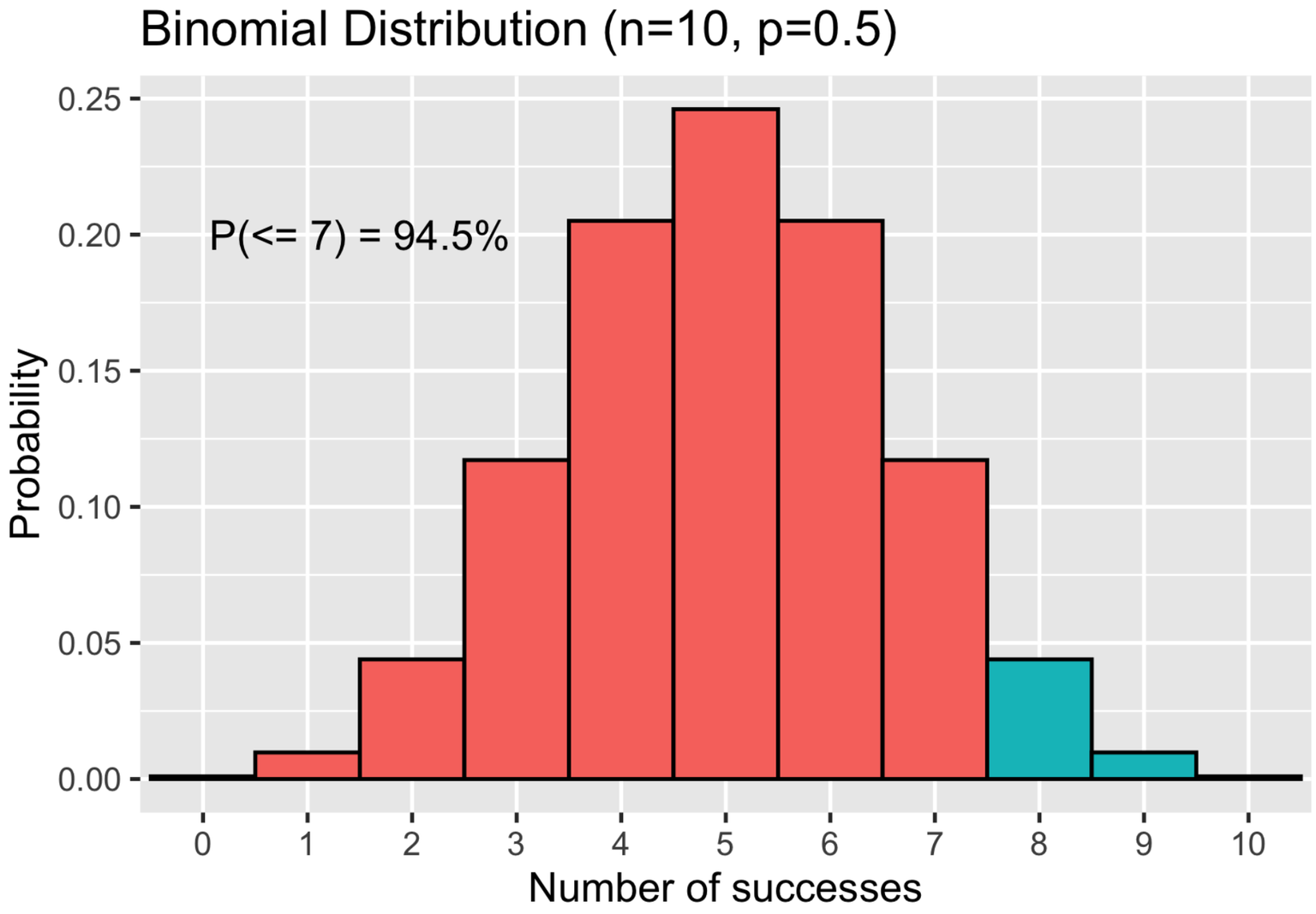
Binomial distribution

- Probability distribution of the **number of successes** in a *sequence* of **independent events**
- For example, the number of heads in a sequence of coin flips
- Described by n and p
  - n: total number of events
  - p: probability of success

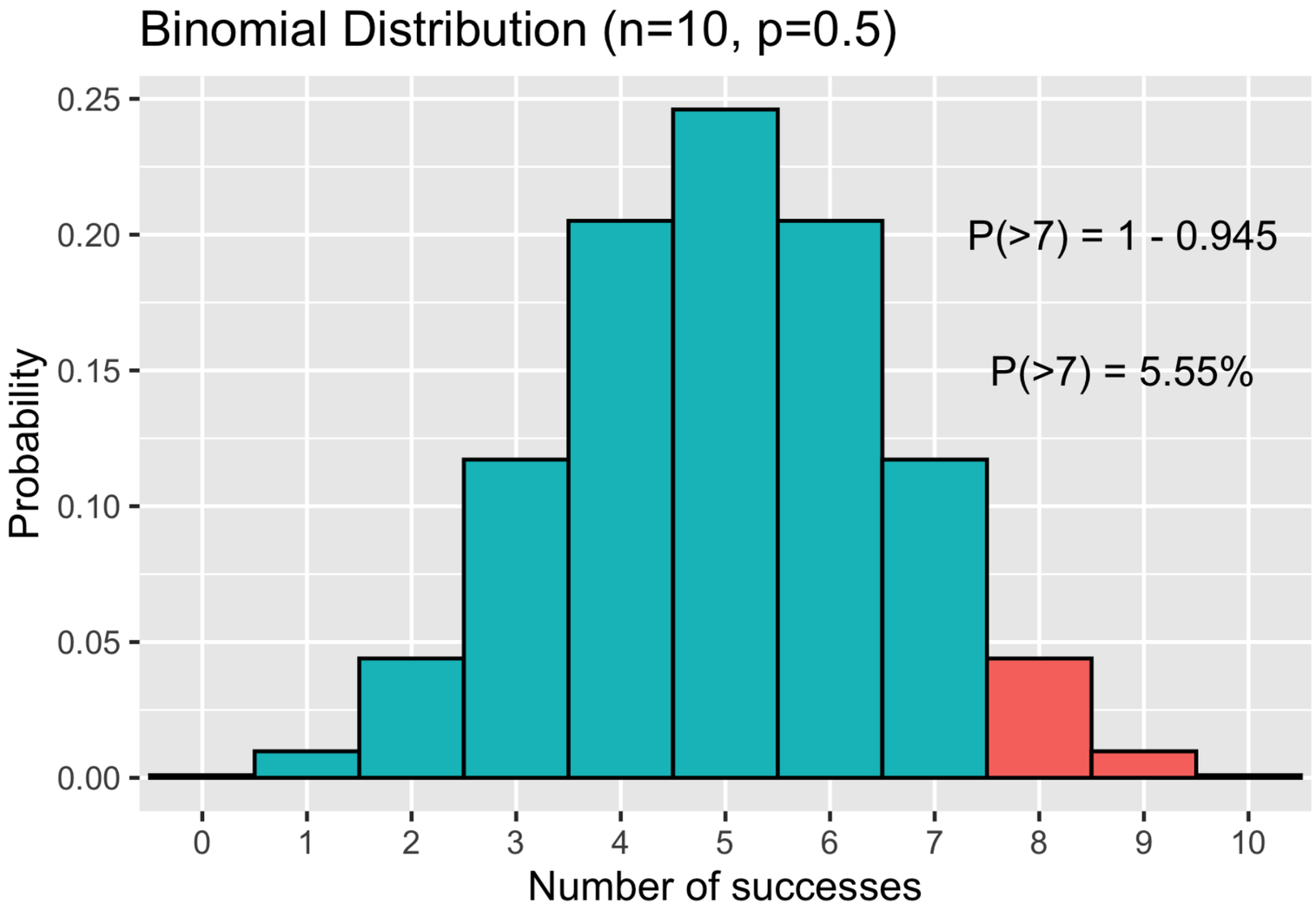
Binomial distribution



Probability of 7 or fewer heads



Probability of 8 or more heads



Expected value

$$Expected\ value = n \times p$$

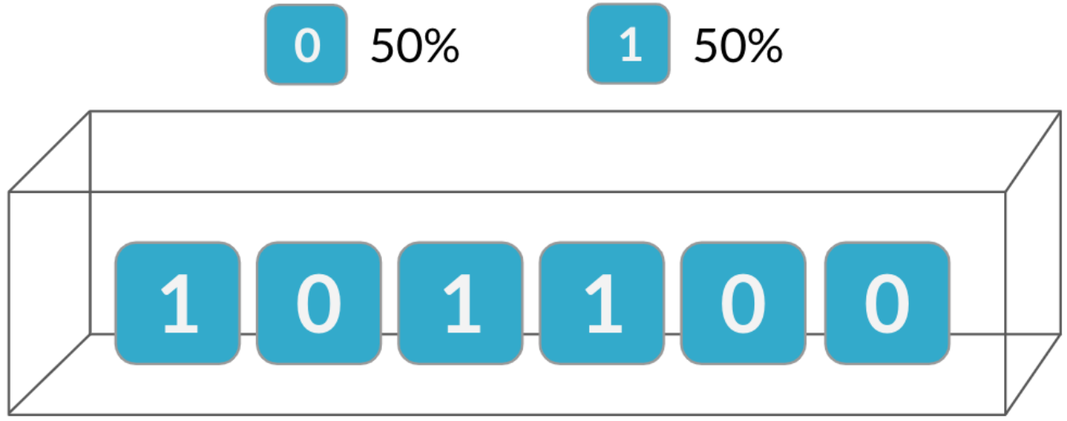
Expected number of heads out of 10 flips $= 10 \times 0.5 = 5$

If we don't know p, but know n and the expected value:

$$p = \frac{expected\ value}{n}$$

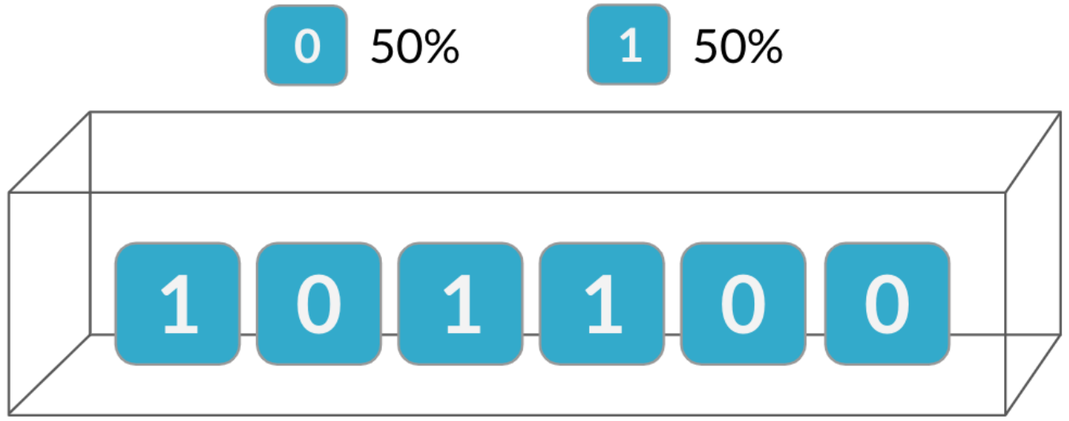
Independence

*The binomial distribution is a probability distribution of the number of successes in a sequence of **independent** events*

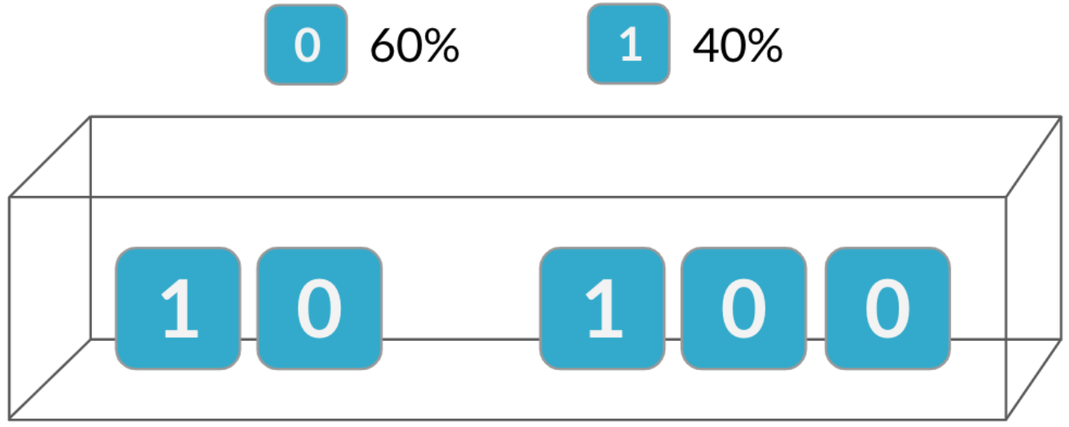


Independence

*The binomial distribution is a probability distribution of the number of successes in a sequence of **independent** events*



Probabilities of second event are altered due to outcome of the first



If events are not independent, the binomial distribution does not apply!

General applications

The binomial distribution can be used for ***independent*** *events producing* ***binary outcomes***

- Clinical trial measuring drug effectiveness
  - Effective or not

- Betting on the result of a sports match
  - Bettor can win or lose

[1] Image credit: https://unsplash.com/@towfiqu999999

Let's practice!

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The normal distribution

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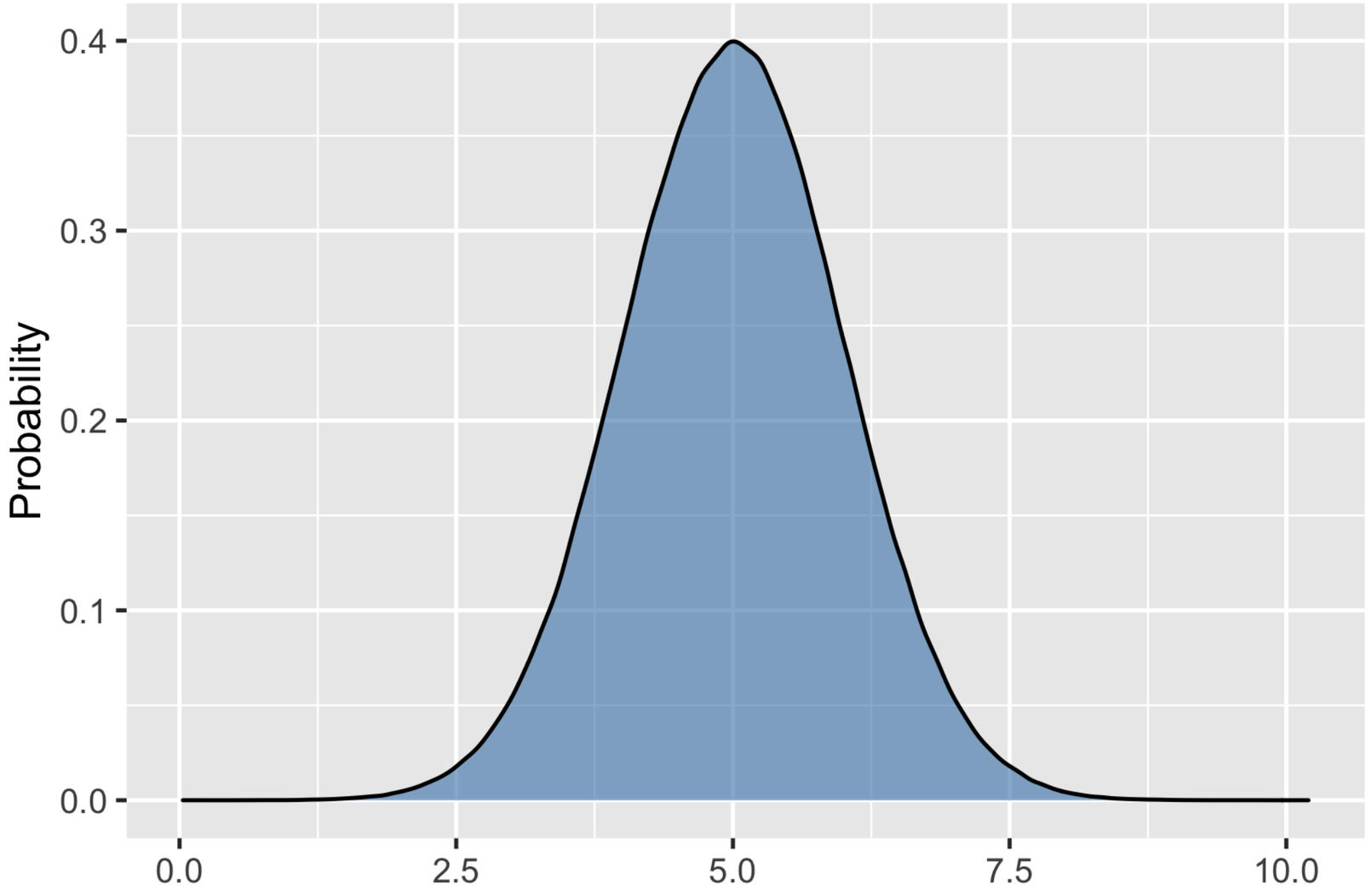
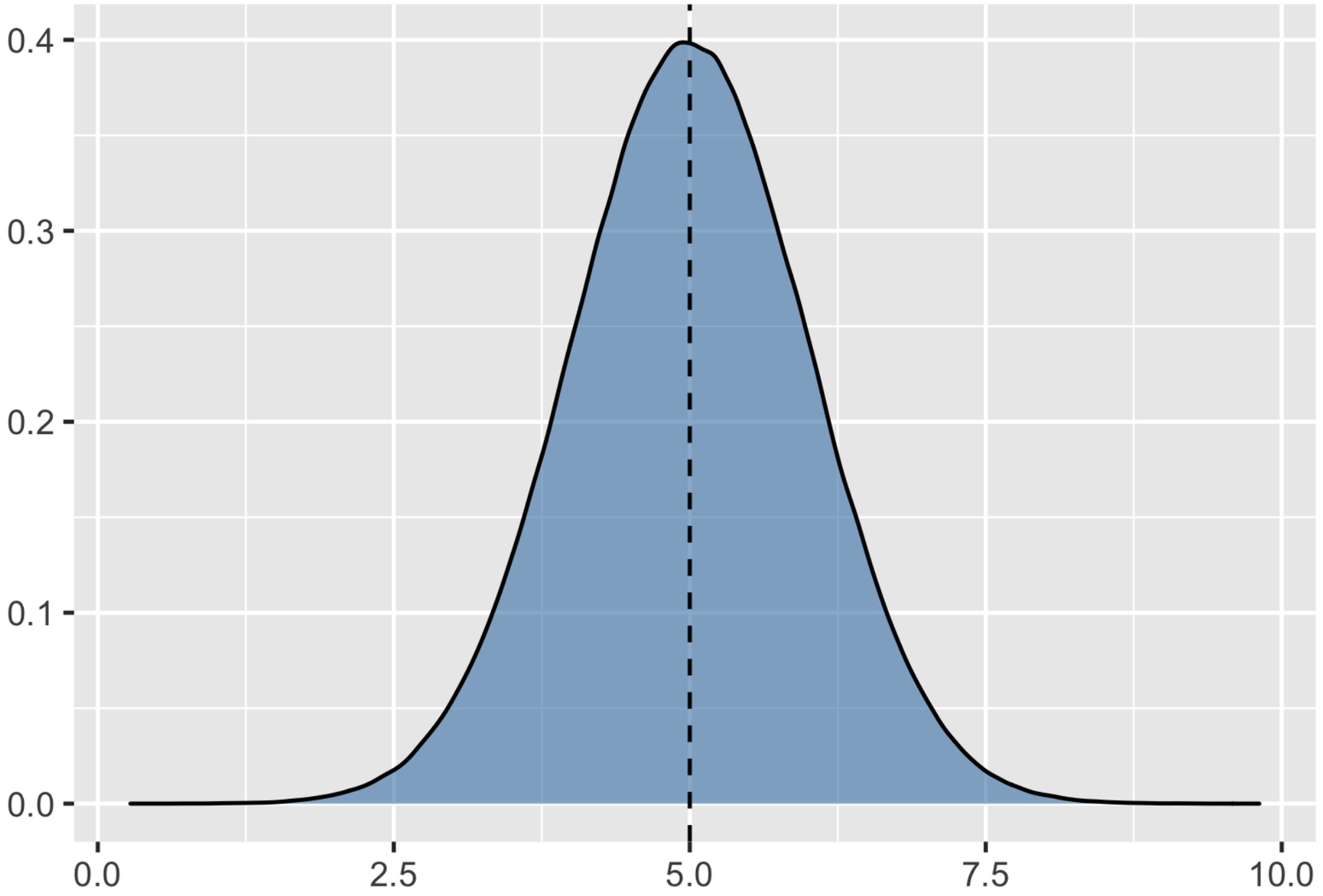
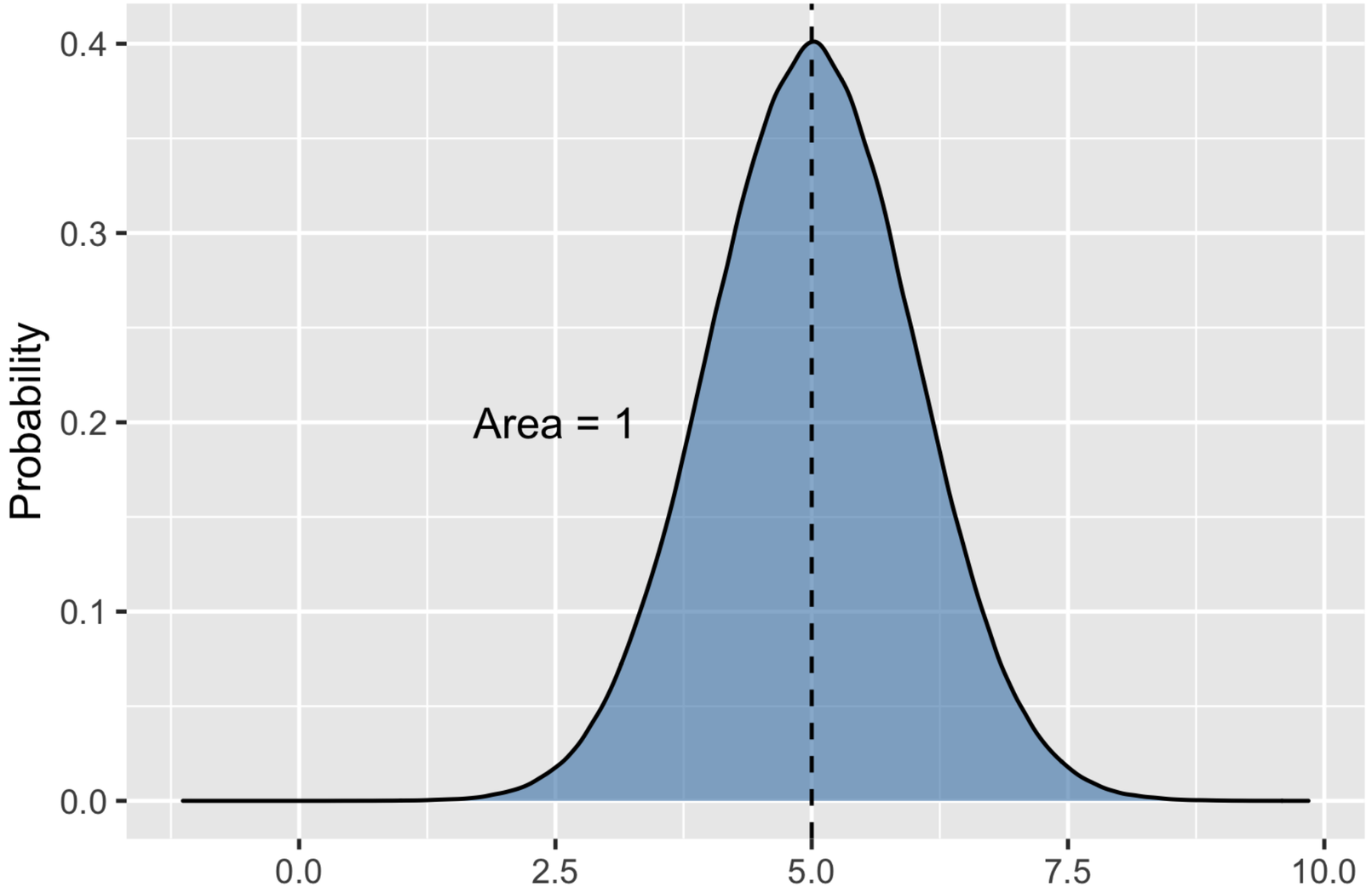
What is the normal distribution?



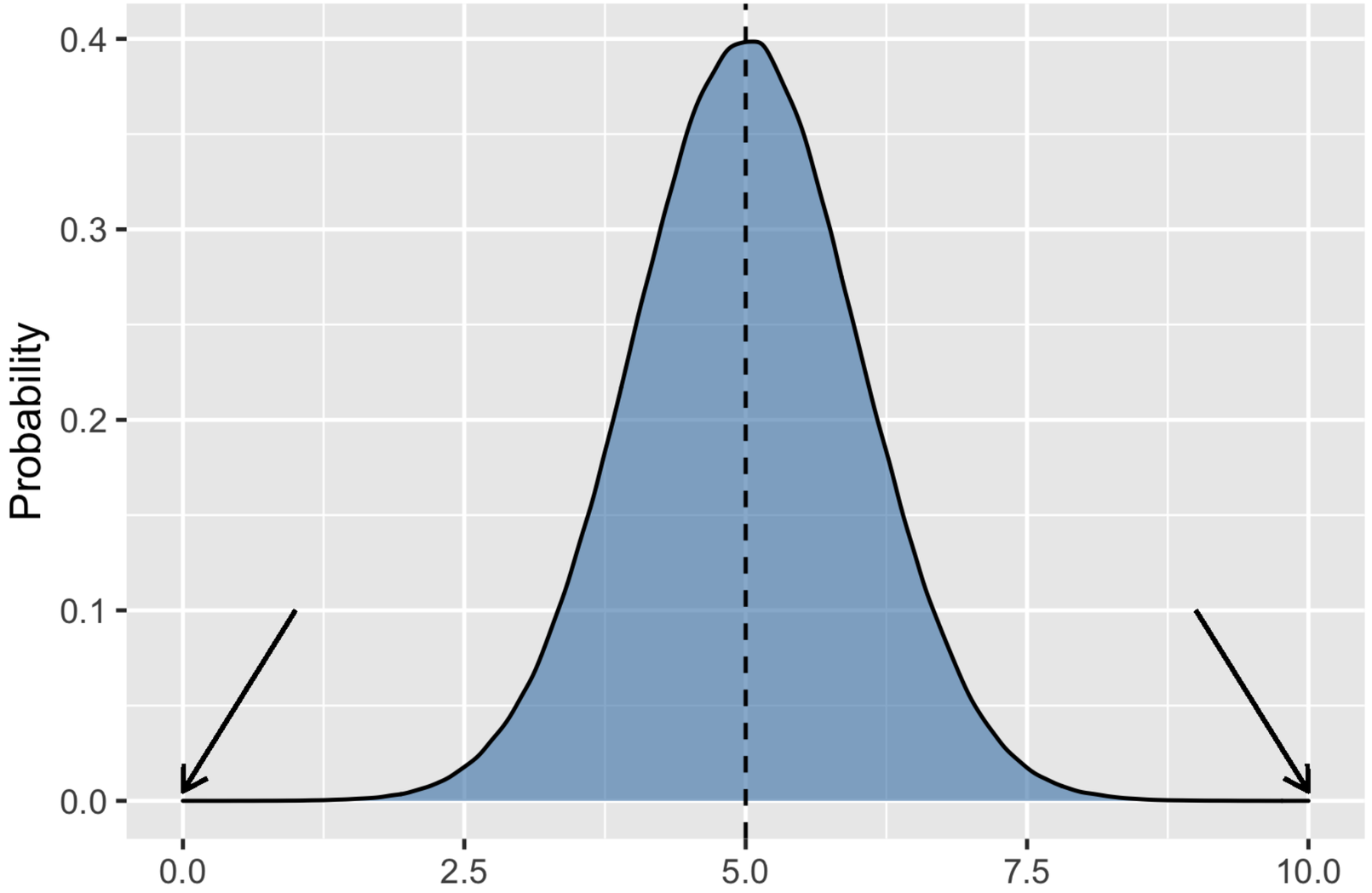
Symmetrical



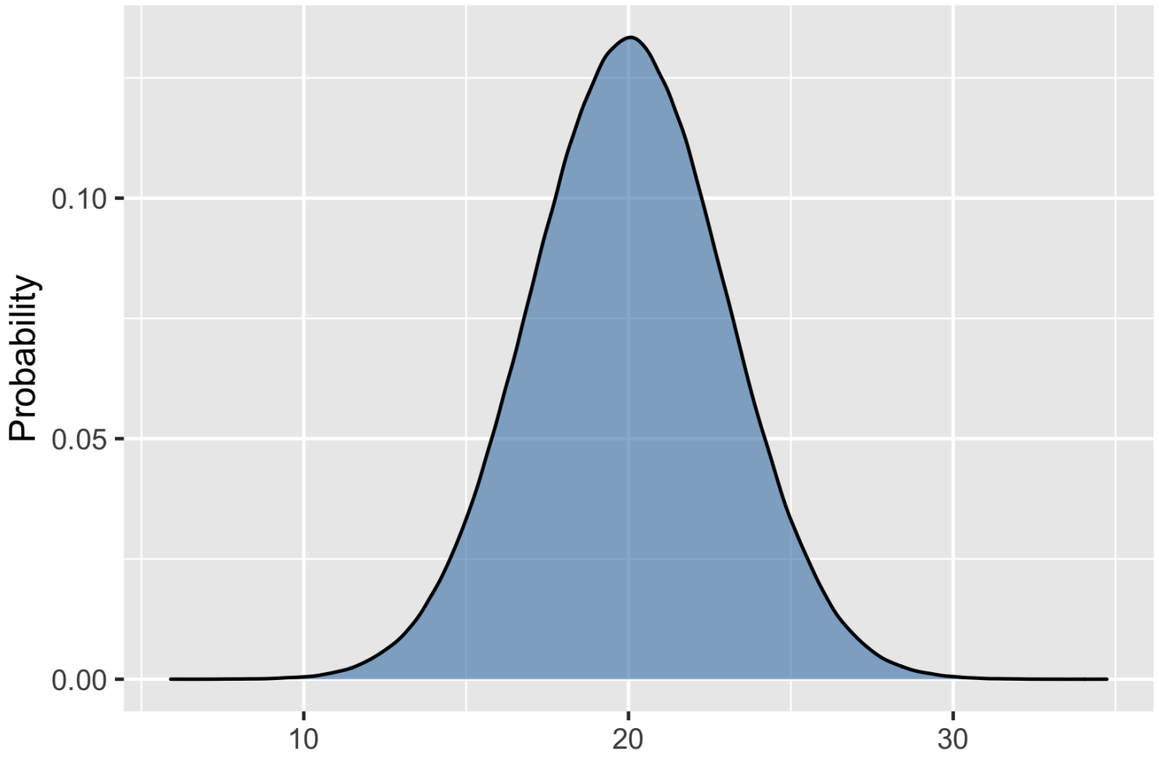
Area = 1



Curve never hits 0

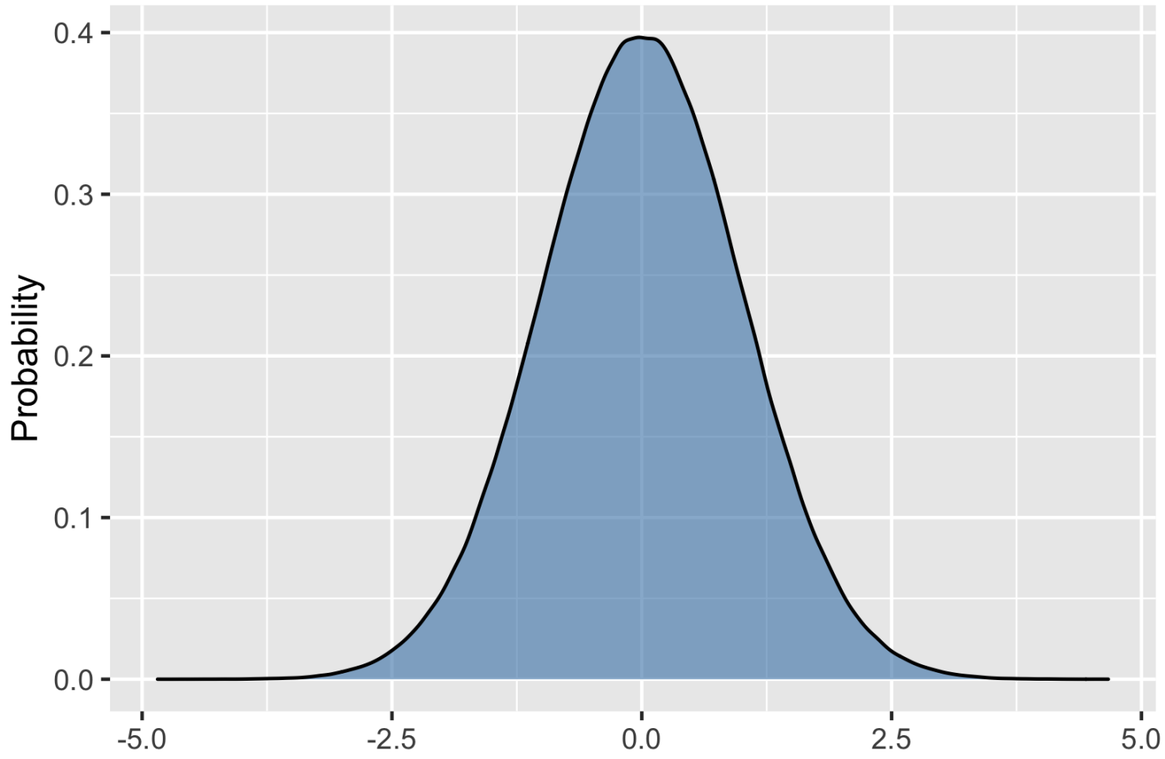


Described by mean and standard deviation



$$Mean = 20$$

$$Standard\ Deviation = 3$$

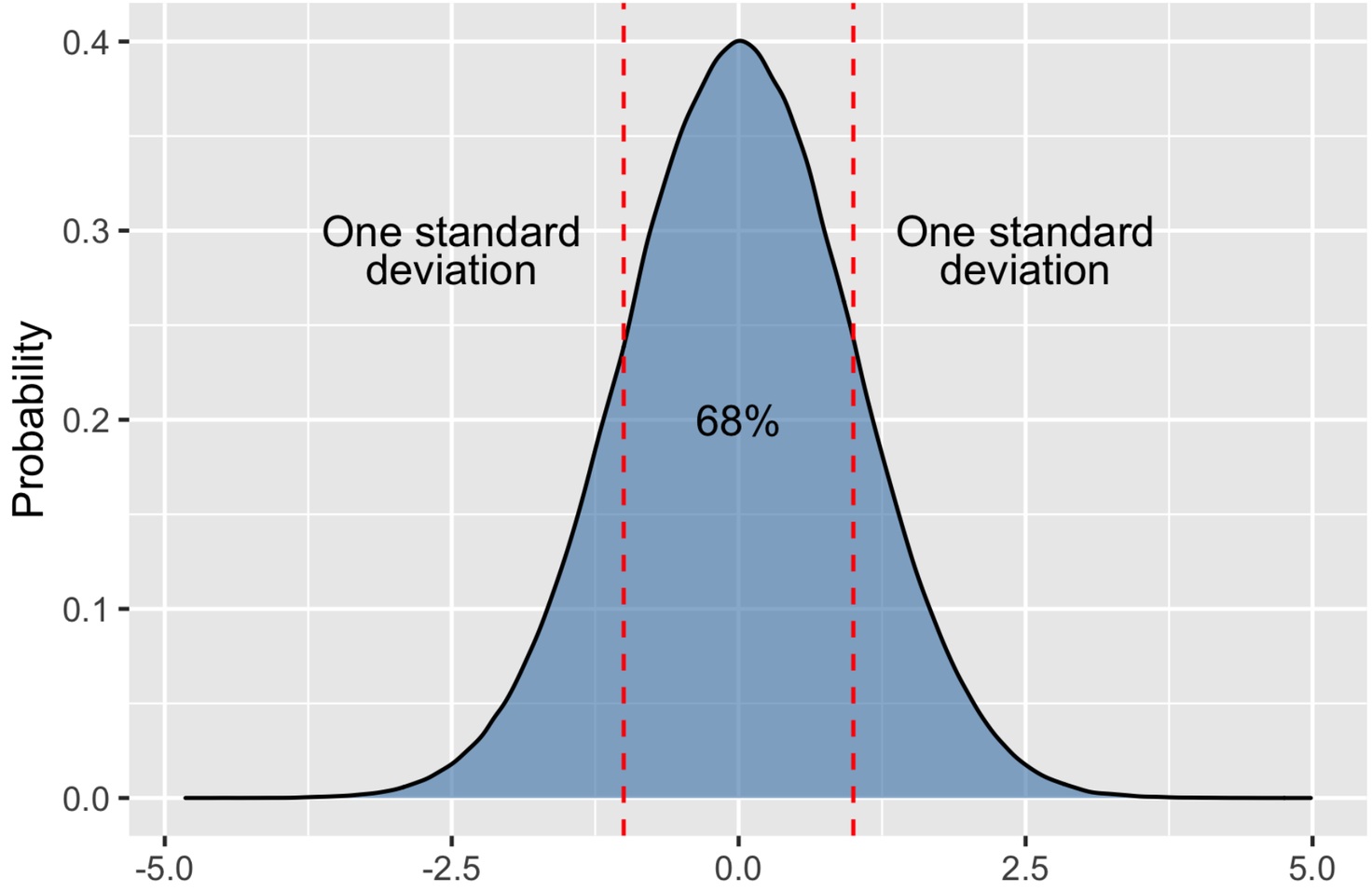


$$Mean = 0$$

$$Standard\ Deviation = 1$$

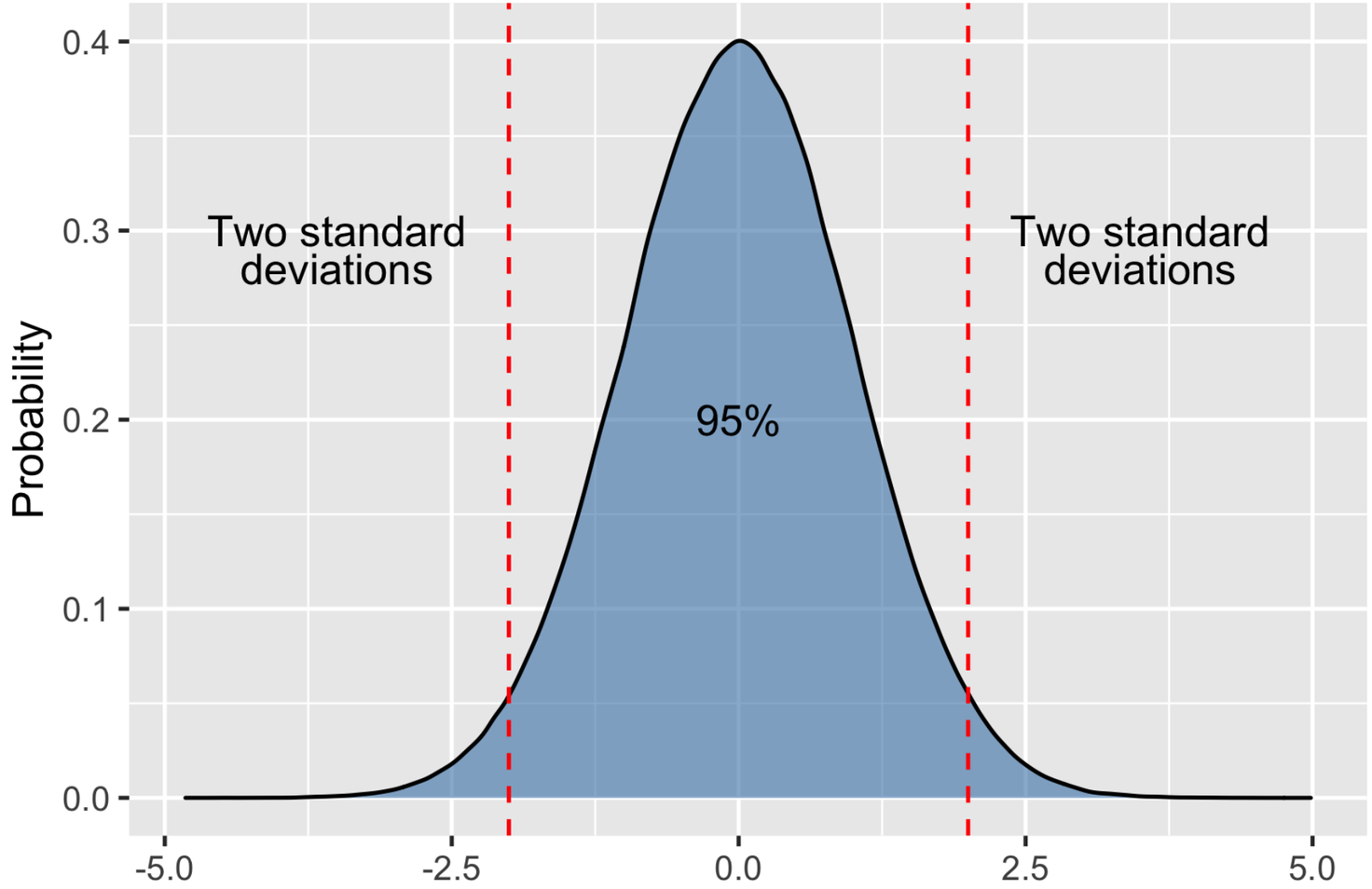
Areas under the normal distribution

68% falls within one standard deviation



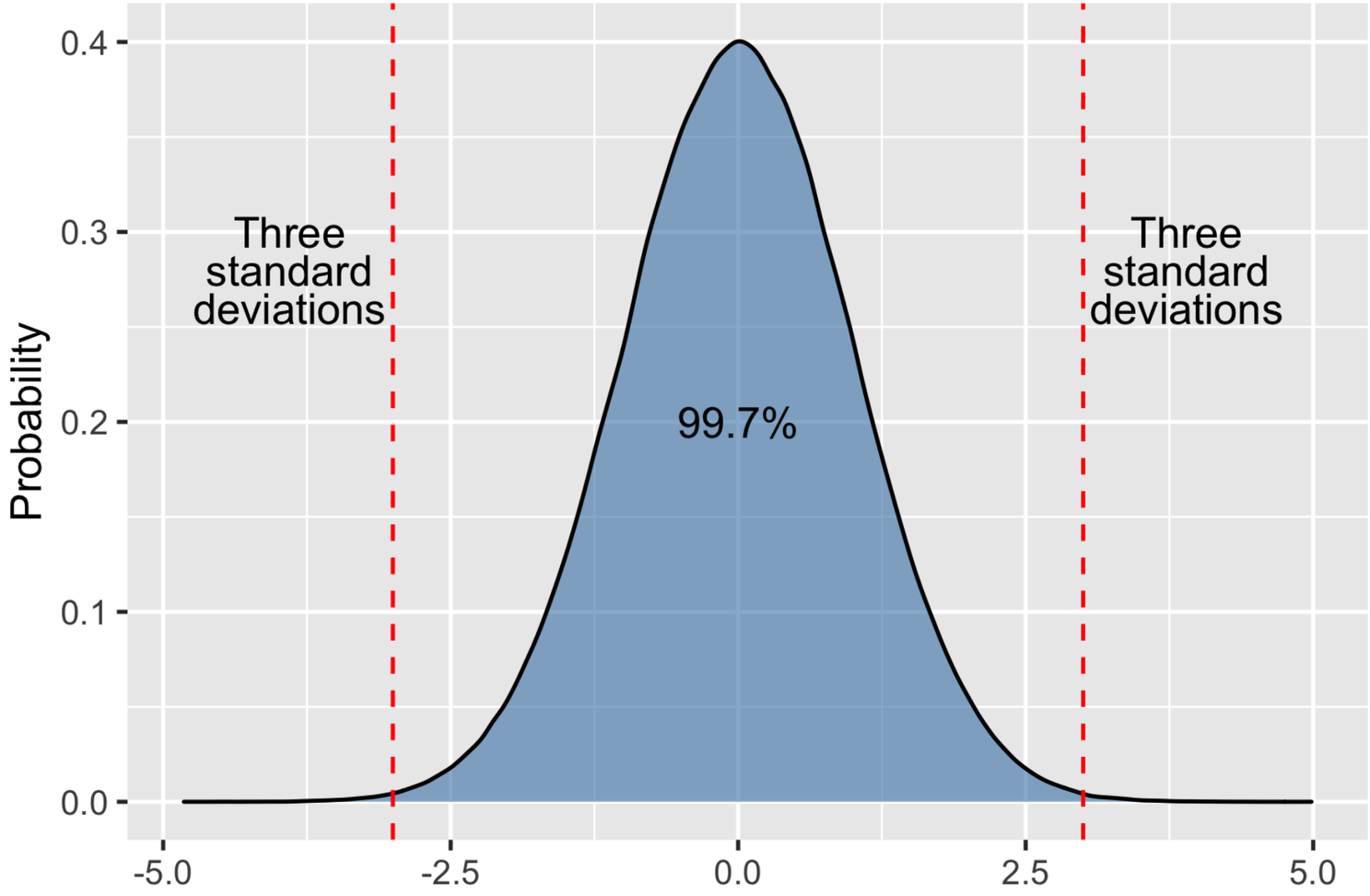
Areas under the normal distribution

95% falls within two standard deviations



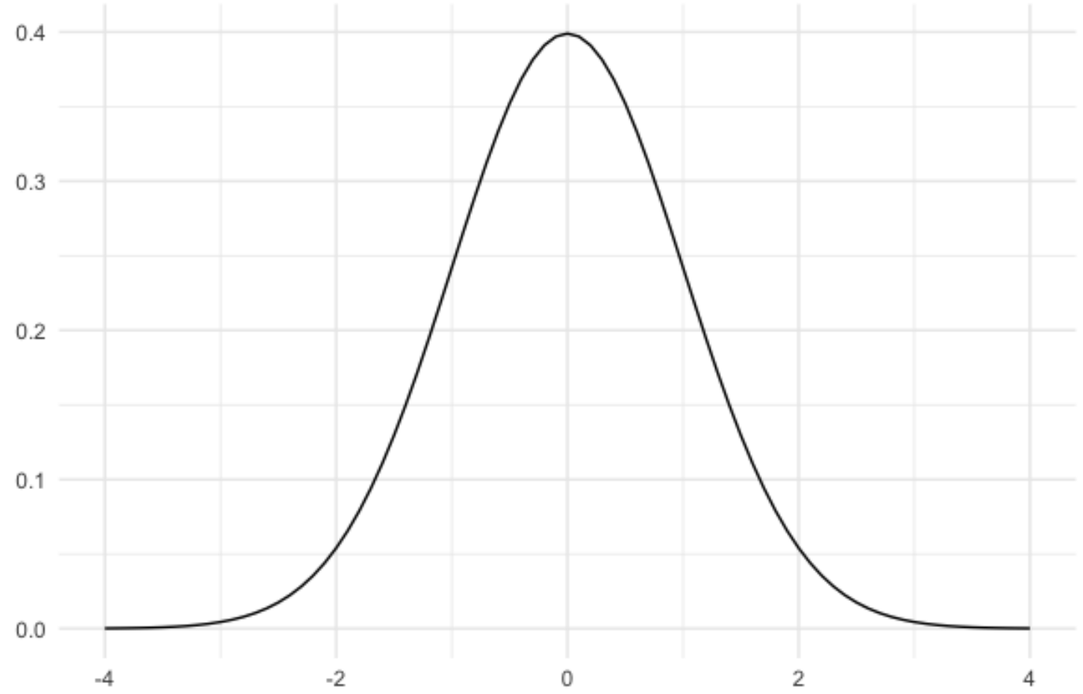
Areas under the normal distribution

99.7% falls within three standard deviations

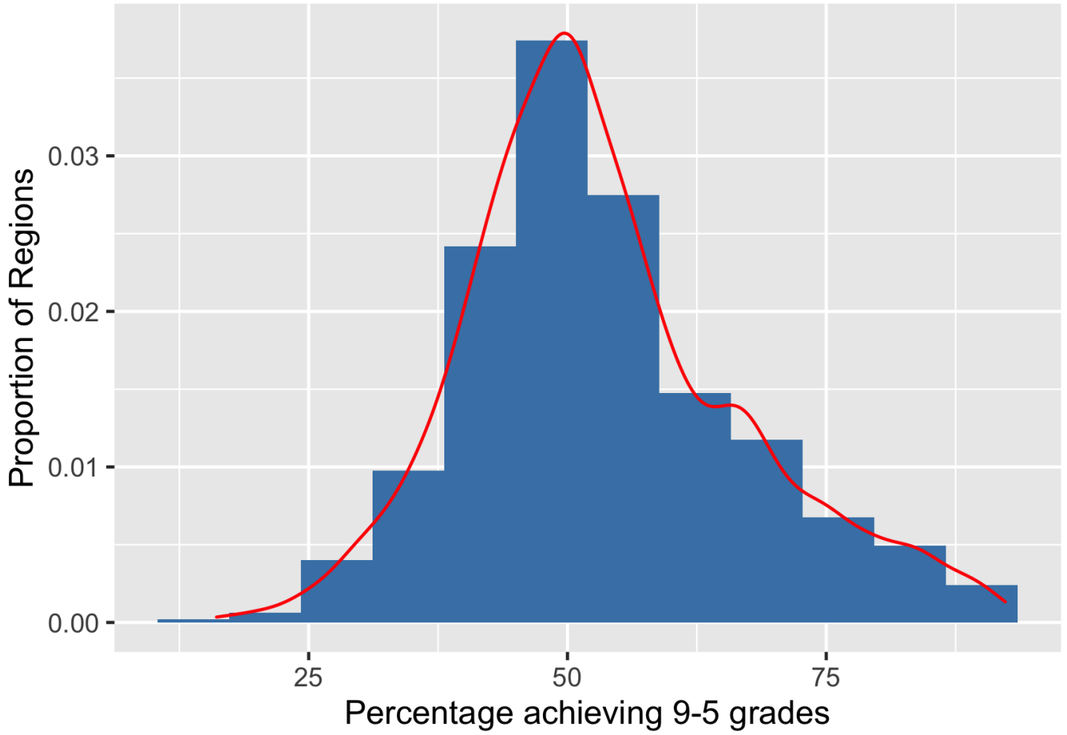


Why is the normal distribution important?

- Lots of real-world data resembles a normal distribution.

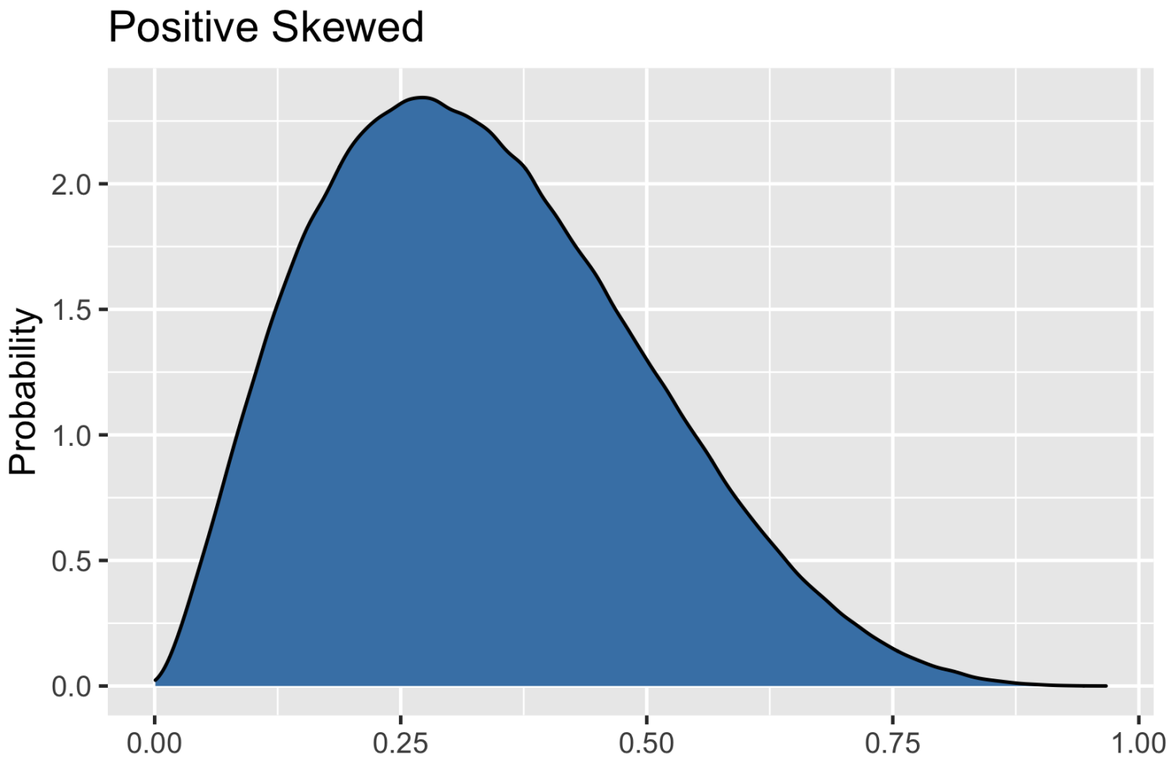


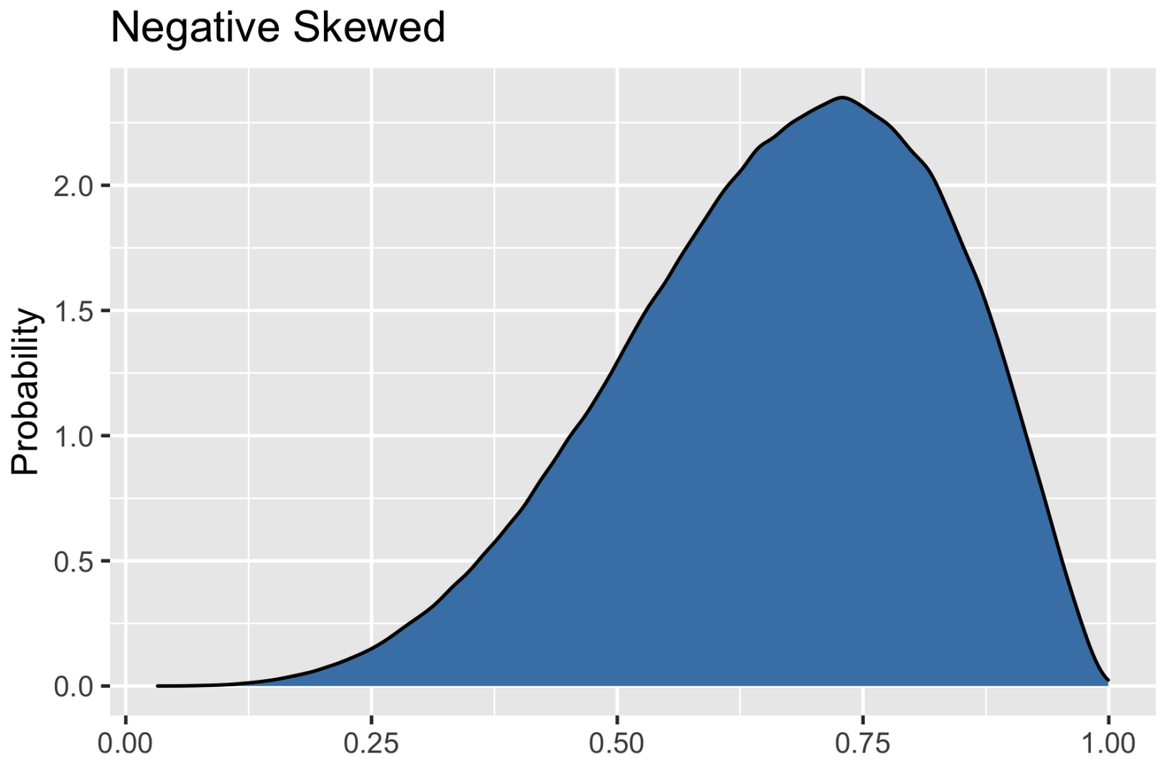
- A normal distribution is required for many statistical tests.



[1] Data source: https://data.gov.uk/dataset/ec1efd76-d6ad-4594-9b4d-944aa4170e63/gcse-english-and-maths-results-by-ethnicity

Skewness

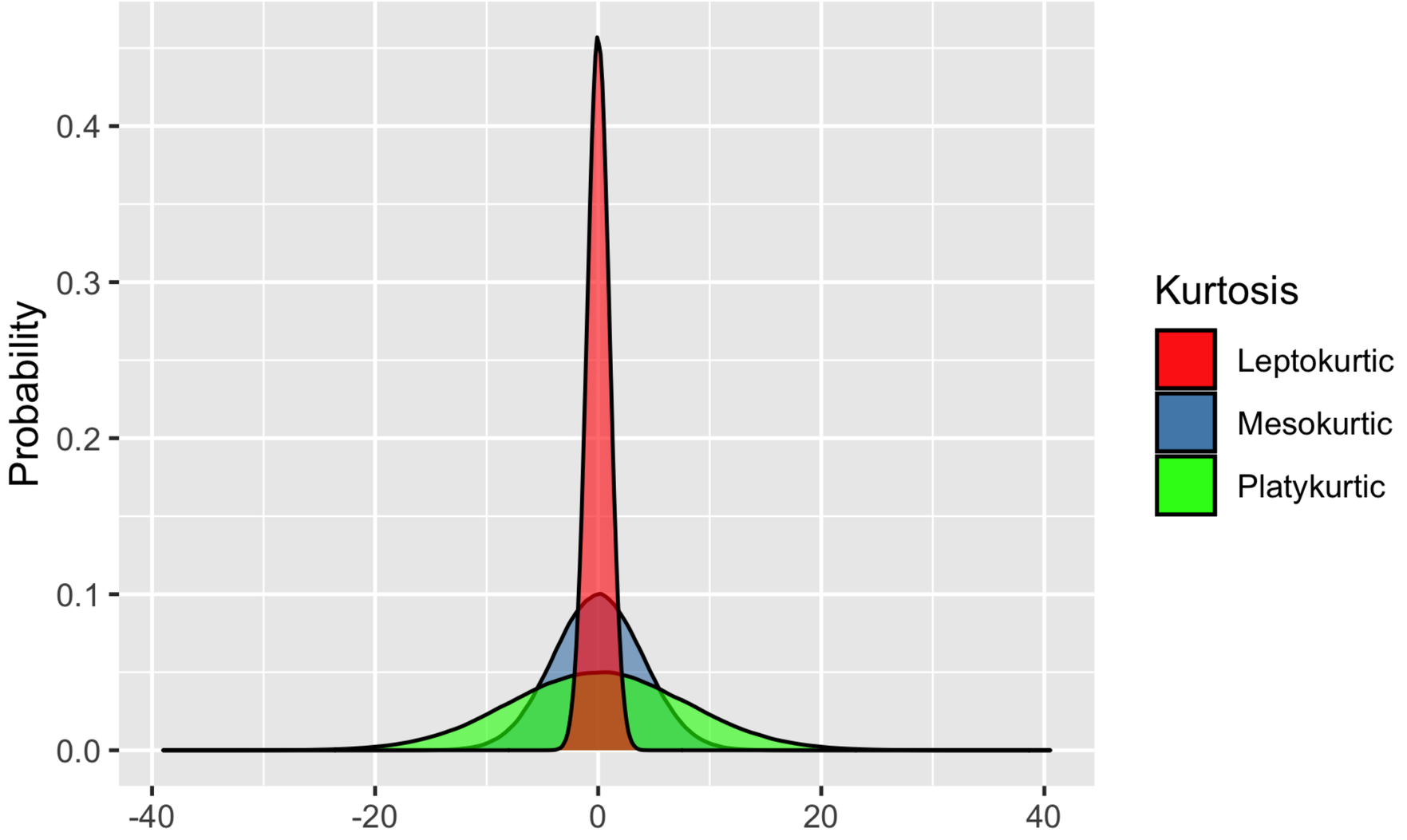

Positive Skewed
Probability
2.0
1.5
1.0
0.5
0.0
0.00
0.25
0.50
0.75
1.00


Negative Skewed
Probability
2.0
1.5
1.0
0.5
0.0
0.00
0.25
0.50
0.75
1.00

Kurtosis

- Kurtosis - a way of describing the occurrence of extreme values in a distribution.
- Three types of kurtosis

Kurtosis


Probability
0.4
0.3
0.2
0.1
0.0
-40
-20
0
20
40
Kurtosis
Leptokurtic
Mesokurtic
Platykurtic

Let's practice!

INTRODUCTION TO STATISTICS

The central limit theorem

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Rolling a die five times

Roll	Result
1	1
2	3
3	4
4	1
5	1

$$Mean(Results) = 2$$

Rolling a die five times

Roll	Result
1	4
2	4
3	5
4	3
5	6

$$Mean(Results) = 4.4$$

Roll	Result
1	1
2	3
3	1
4	5
5	6

$$Mean(Results) = 3.2$$

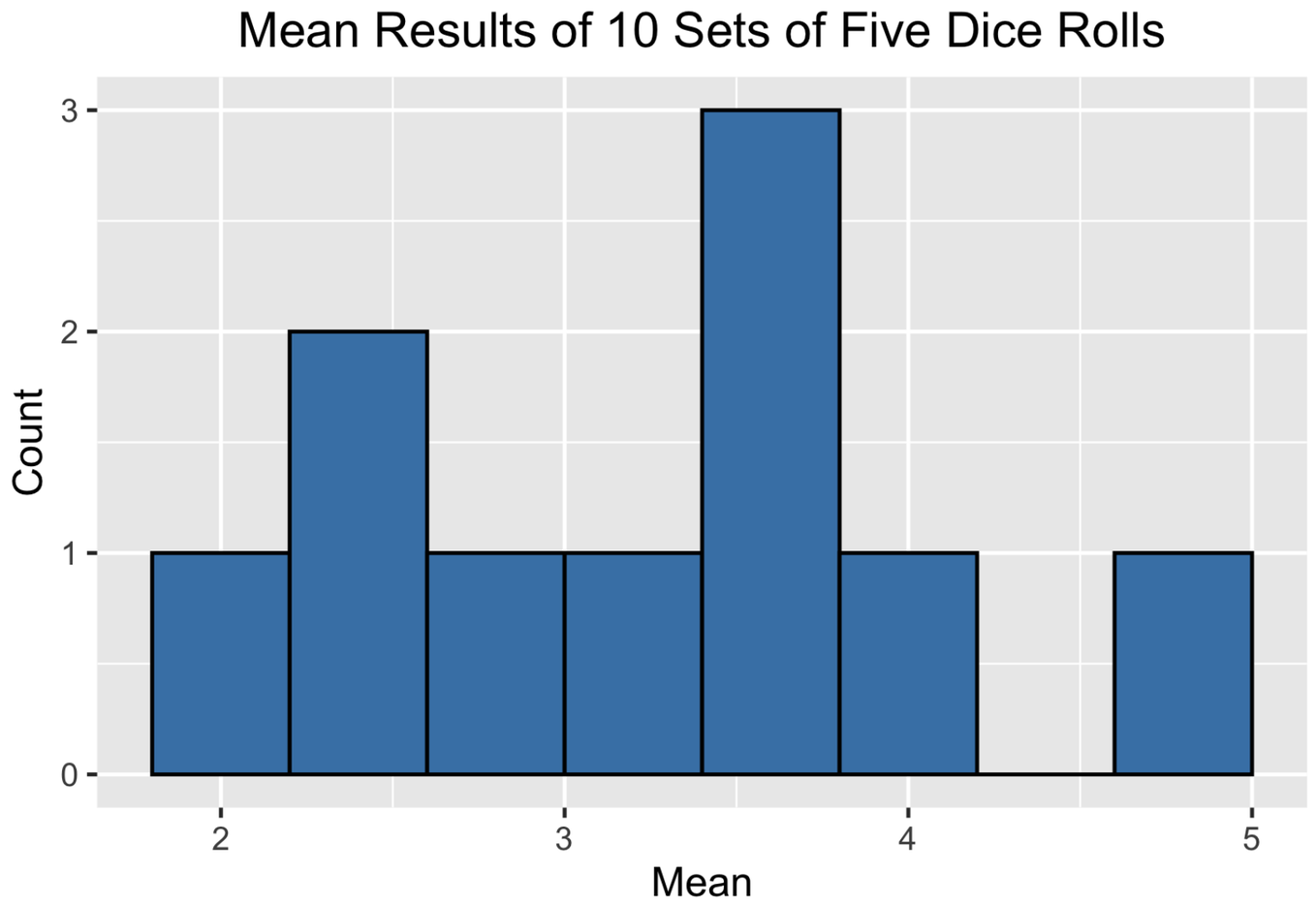
10 sets of five die rolls

- Roll a die five times
- Record the mean
- Repeat 10 times

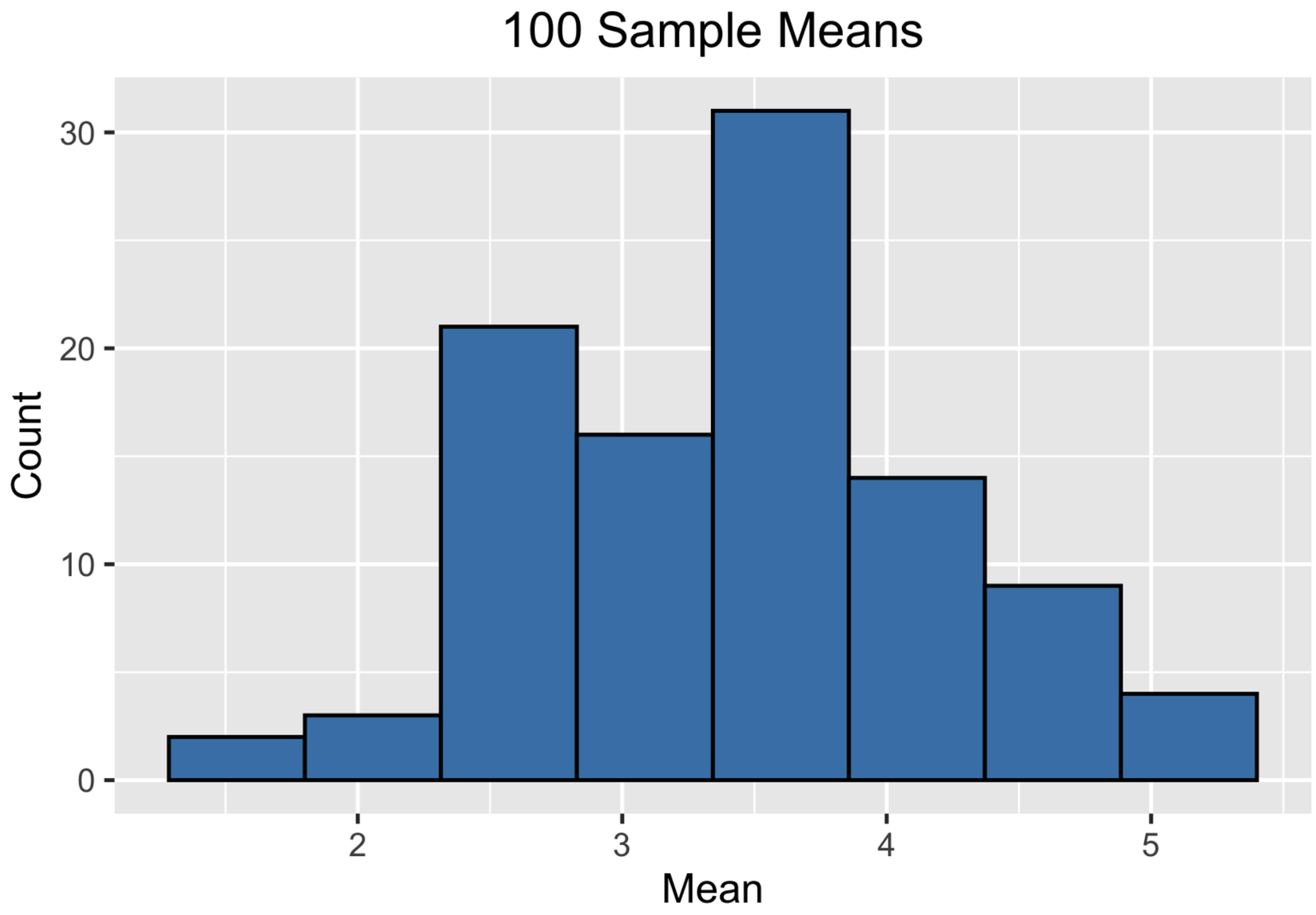
Set	Mean
1	3.8
2	4.0
3	3.8
4	3.6
5	3.2
6	4.8
7	2.6
8	3.0
9	2.6
10	2.0

Sampling distributions

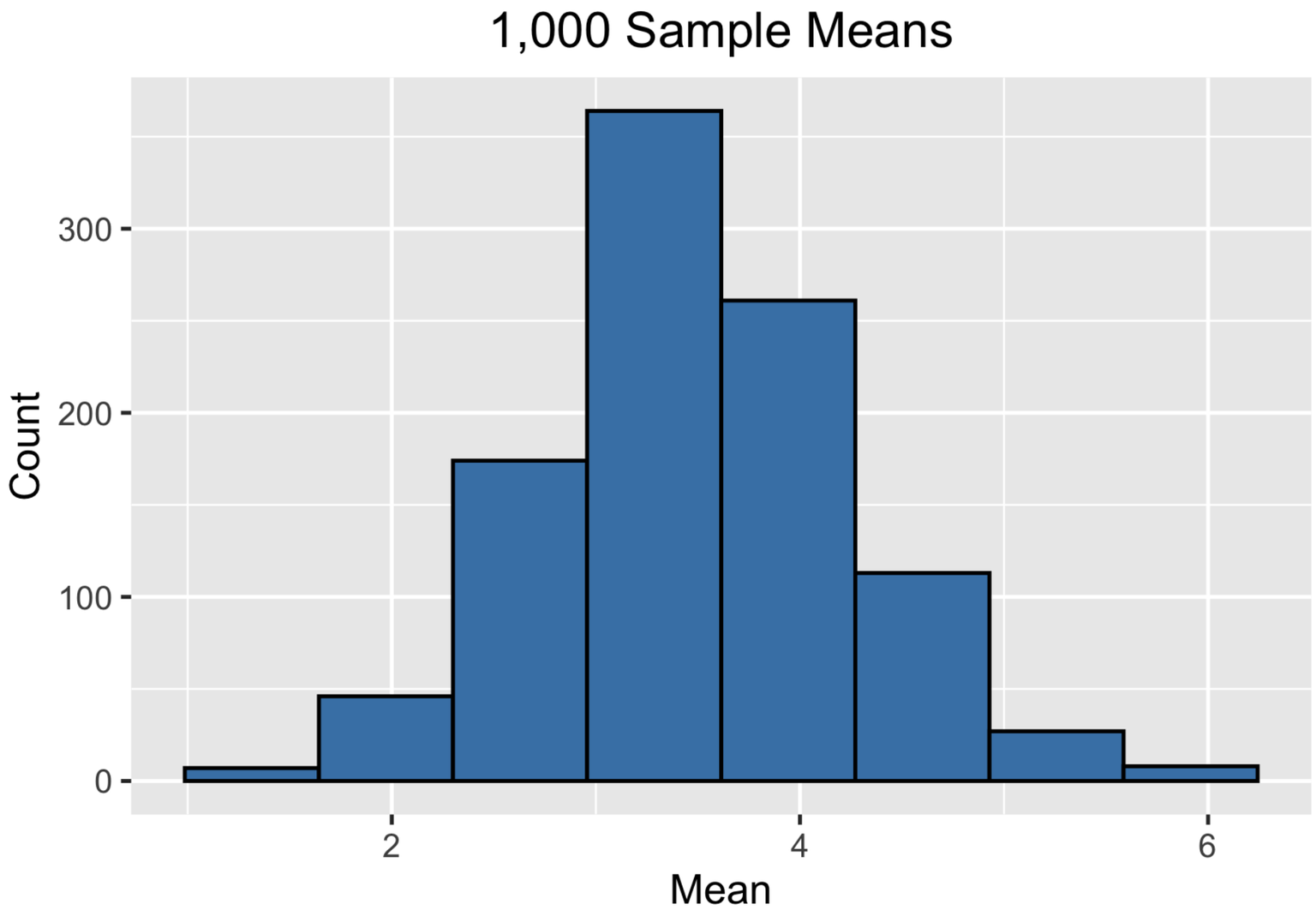
Sampling distribution of the sample mean



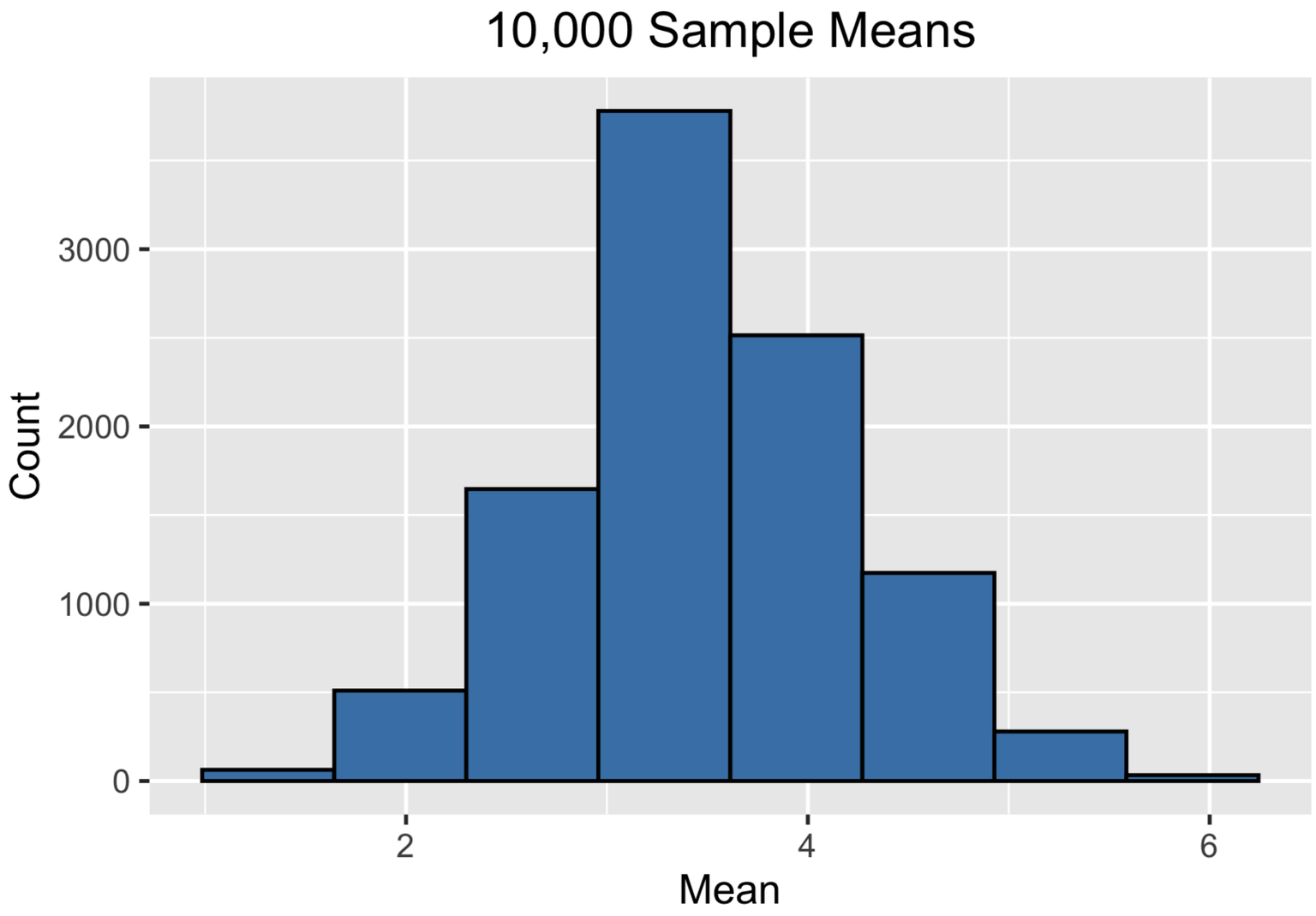
100 sample means



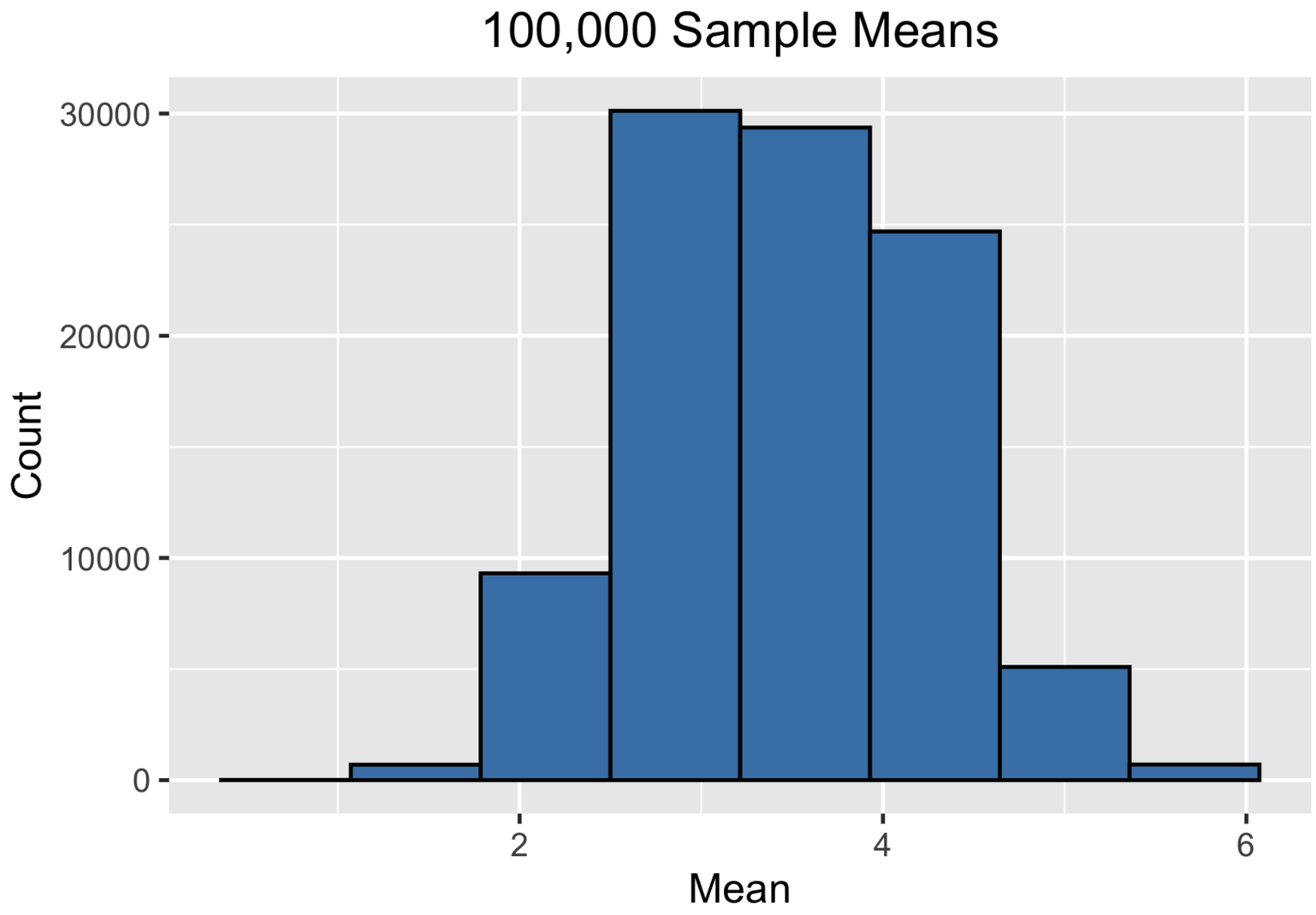
1000 sample means



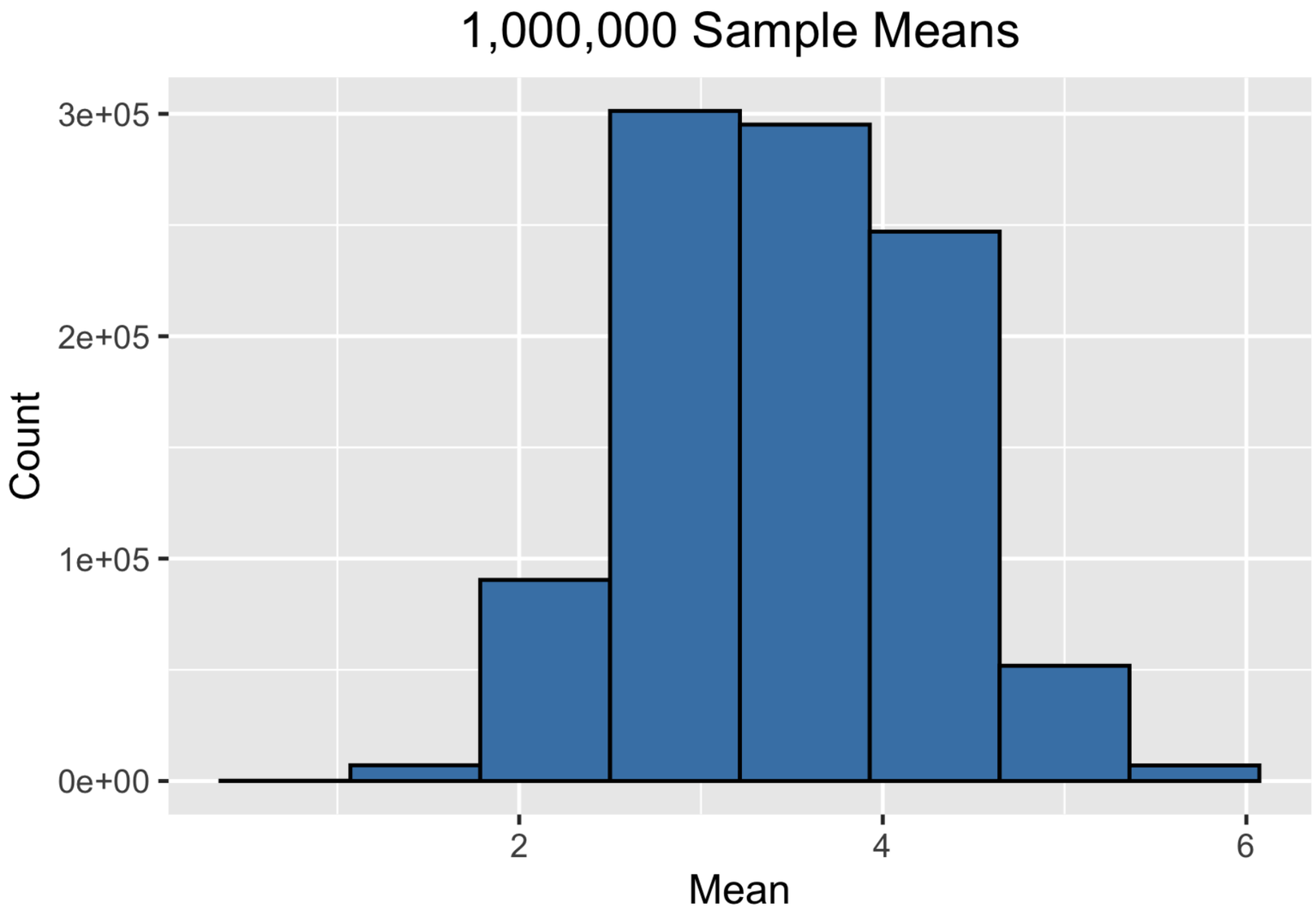
10000 sample means



100000 sample means

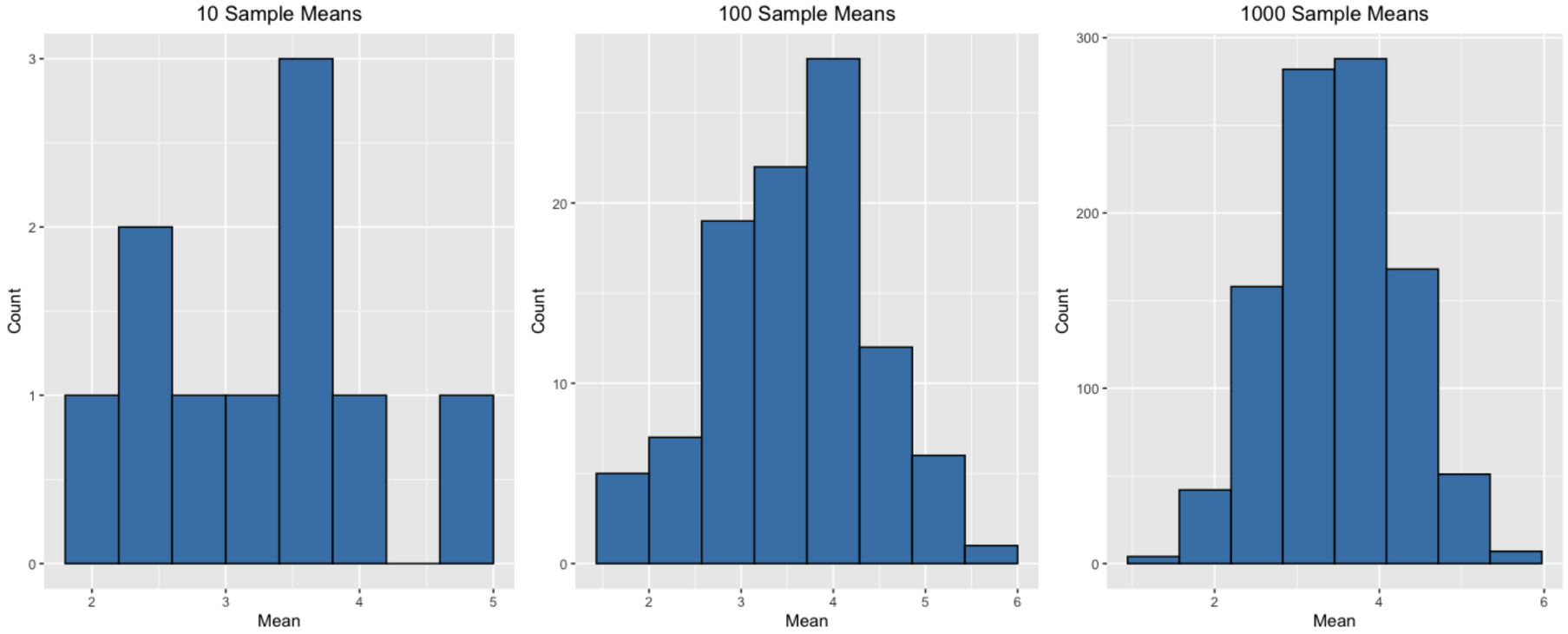


One million sample means



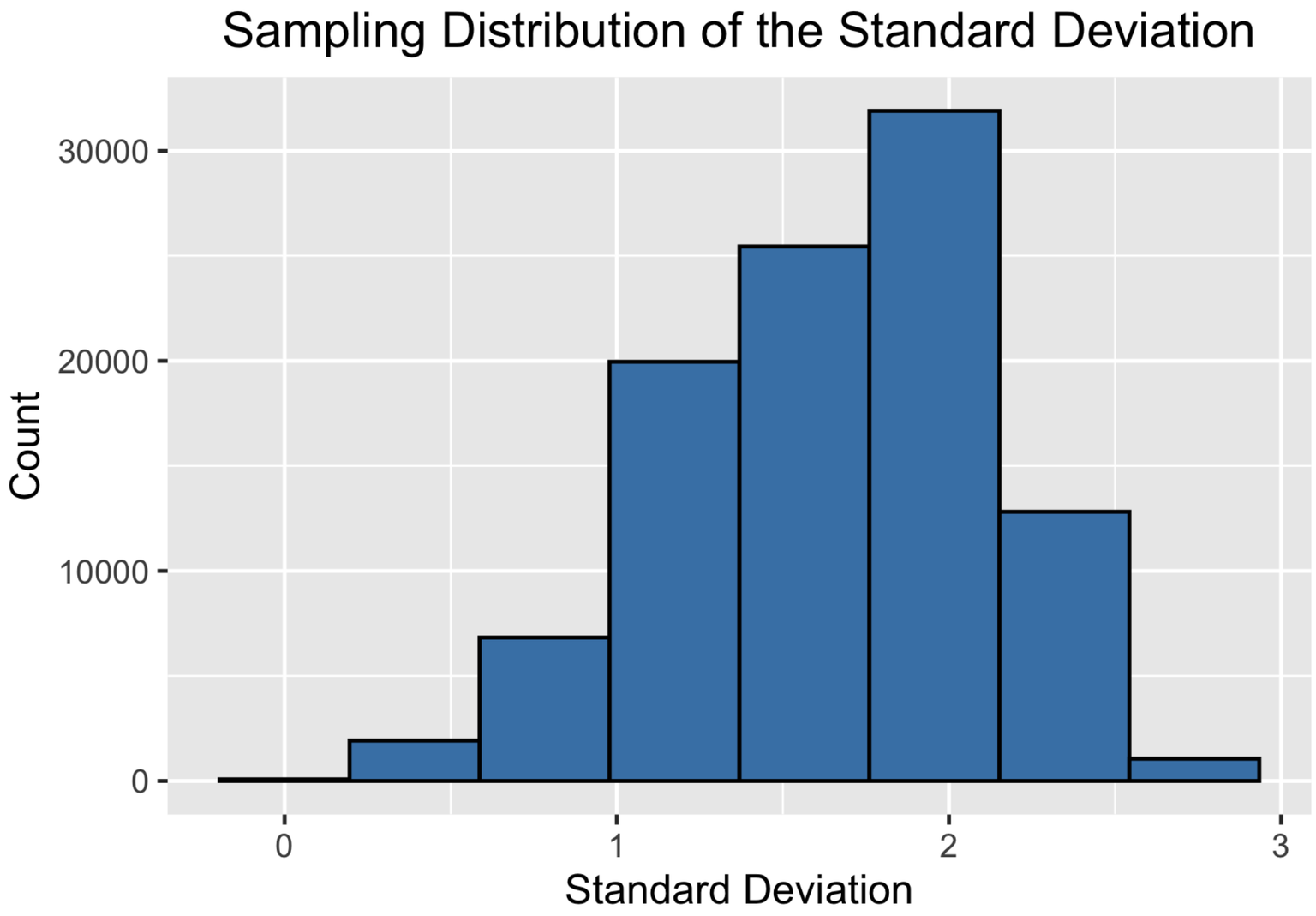
Central limit theorem

The sampling distribution of a statistic becomes closer to the normal distribution as the size of the sample increases.



** Samples should be random and independent*

Standard deviation and the CLT



Proportions and the CLT

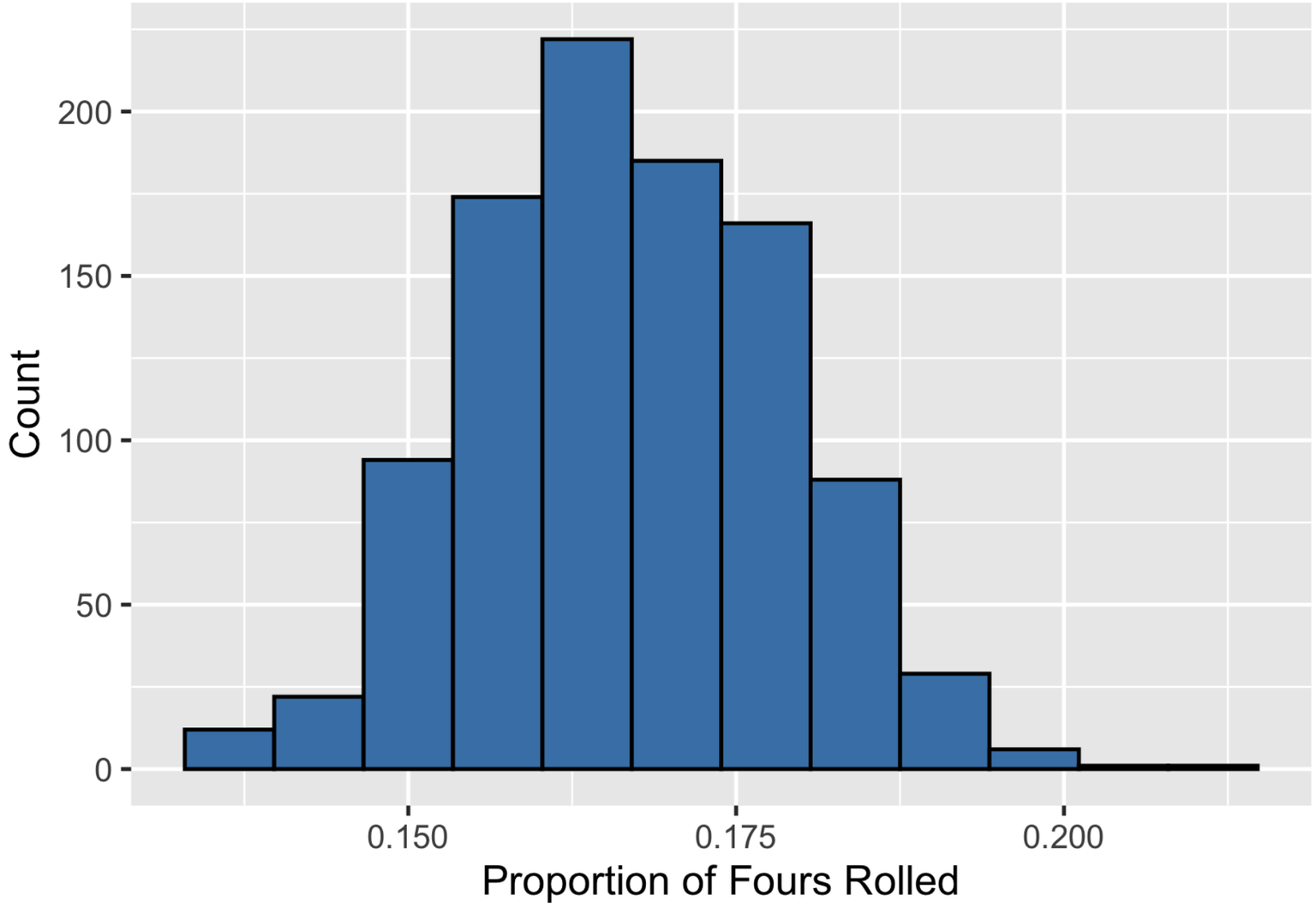
Roll	Result
1	2
2	1
3	4
4	2
5	6

- $\frac{1}{5}$ or 20% are a 4

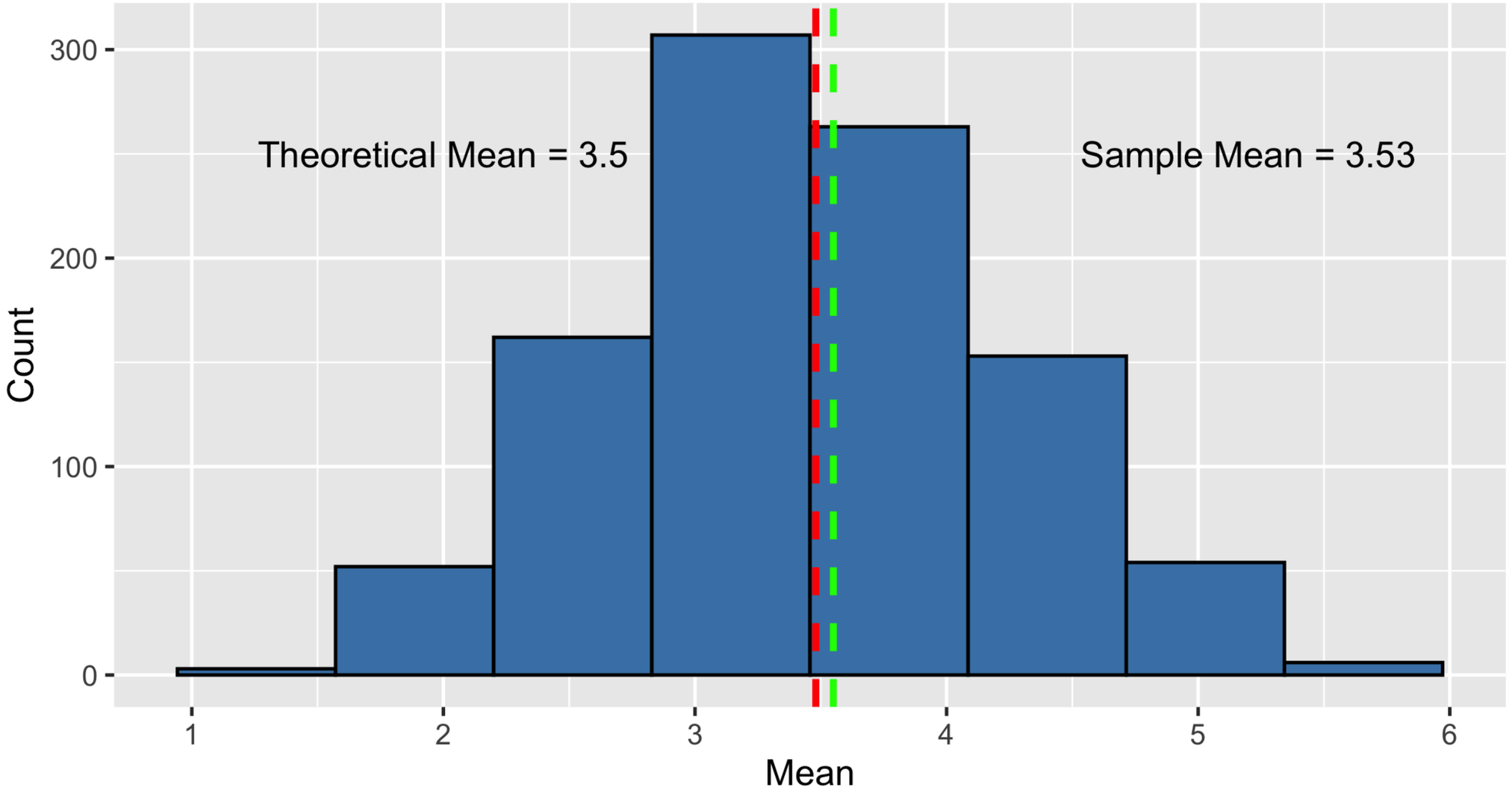
Set	Mean
1	4
2	4
3	1
4	4
5	3

- $\frac{3}{5}$ or 60% are a 4

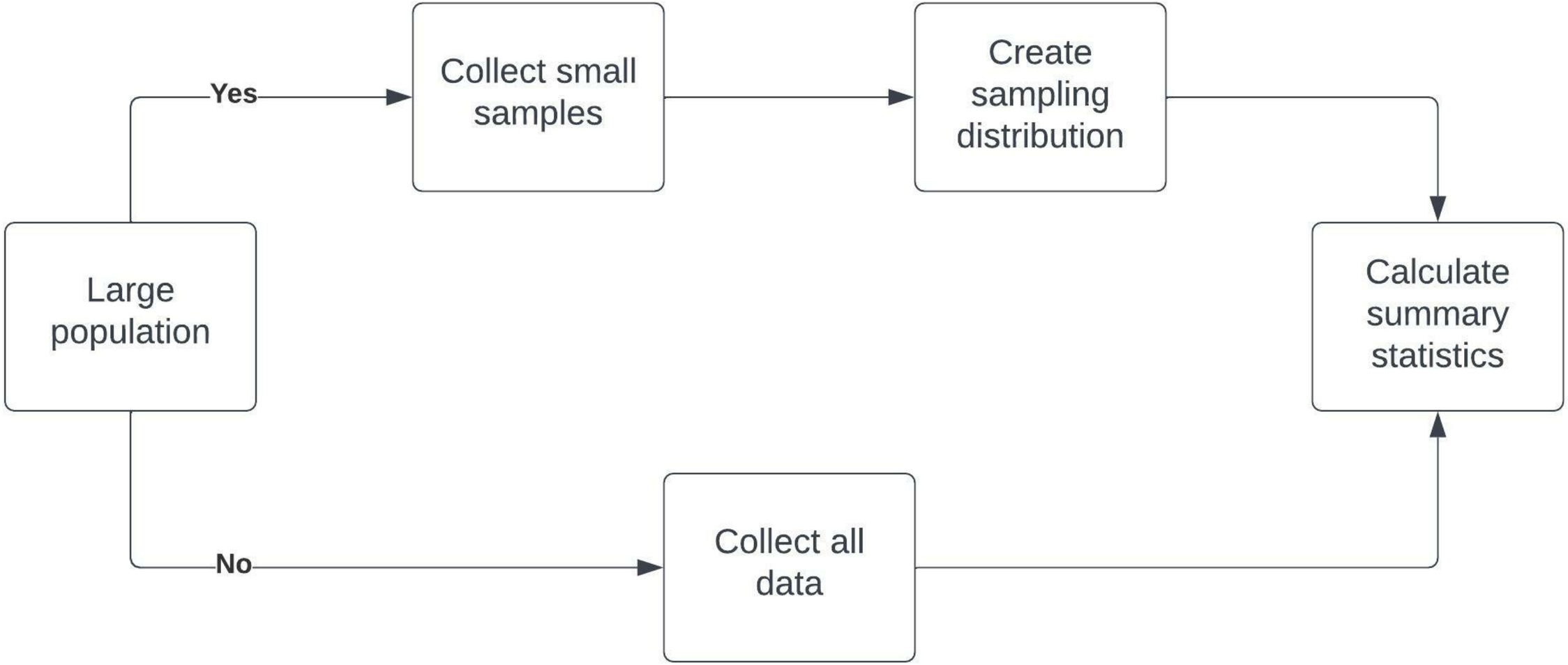
Sampling distribution of proportion



Mean of the sampling distribution



Benefits of the central limit theorem



Let's practice!

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The Poisson distribution

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Poisson processes

- Average # of events in a period is known
  - but the time or space between events is random
- Poisson processes
  - Number of animals adopted from an animal shelter per week
  - Number of people arriving at a restaurant per hour
  - Number of website visits in a day

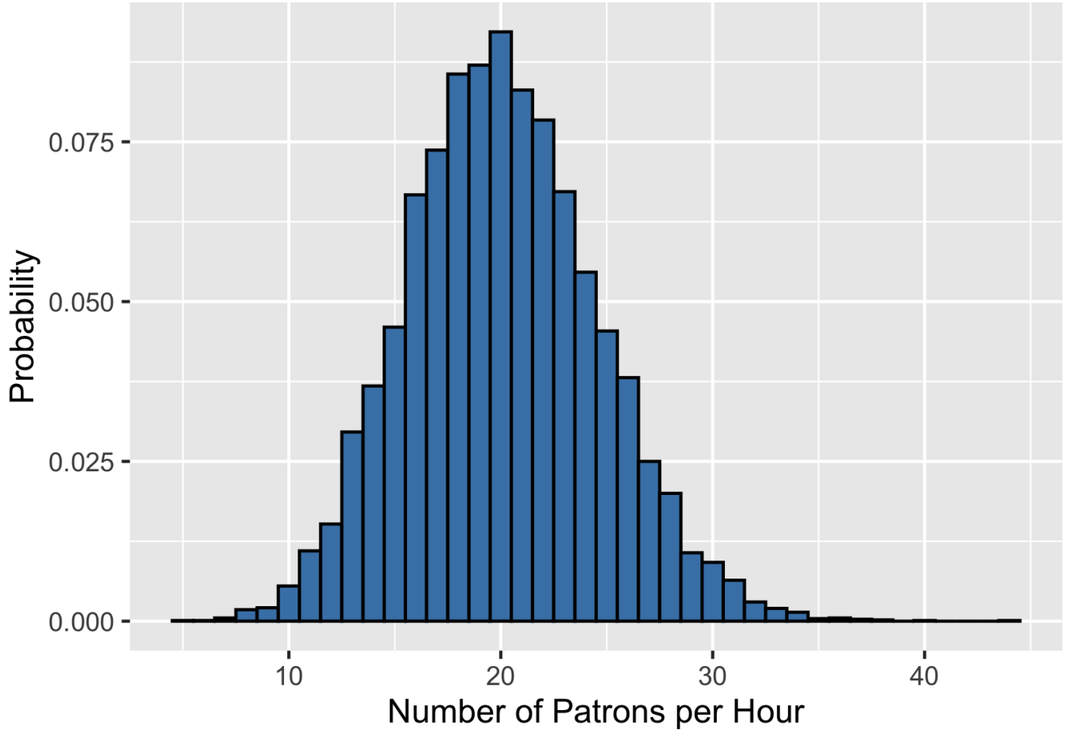
[1] Image credit: https://unsplash.com/@rodlong

Poisson distribution

- Probability of some # of events occurring over a fixed period of time
- Examples
  - Probability of at least five animals adopted from an animal shelter per week
  - Probability of 12 people arriving at a restaurant per hour
  - Probability of less than 200 visits to a website in a day

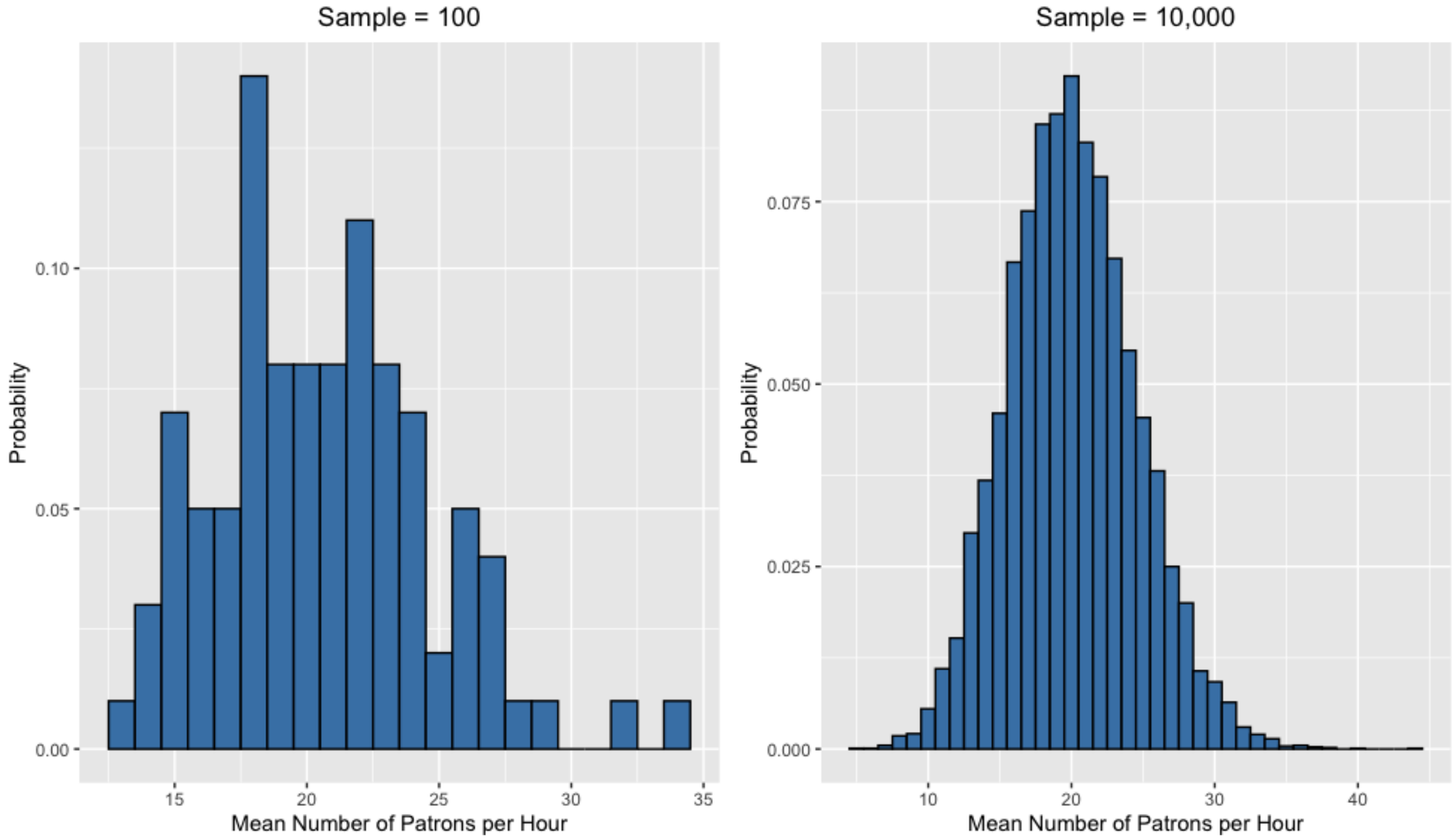
Lambda (λ)

- λ = average number of events per time interval
  - Average number of patrons per hour = 20
  - λ = the expected value of the distribution!

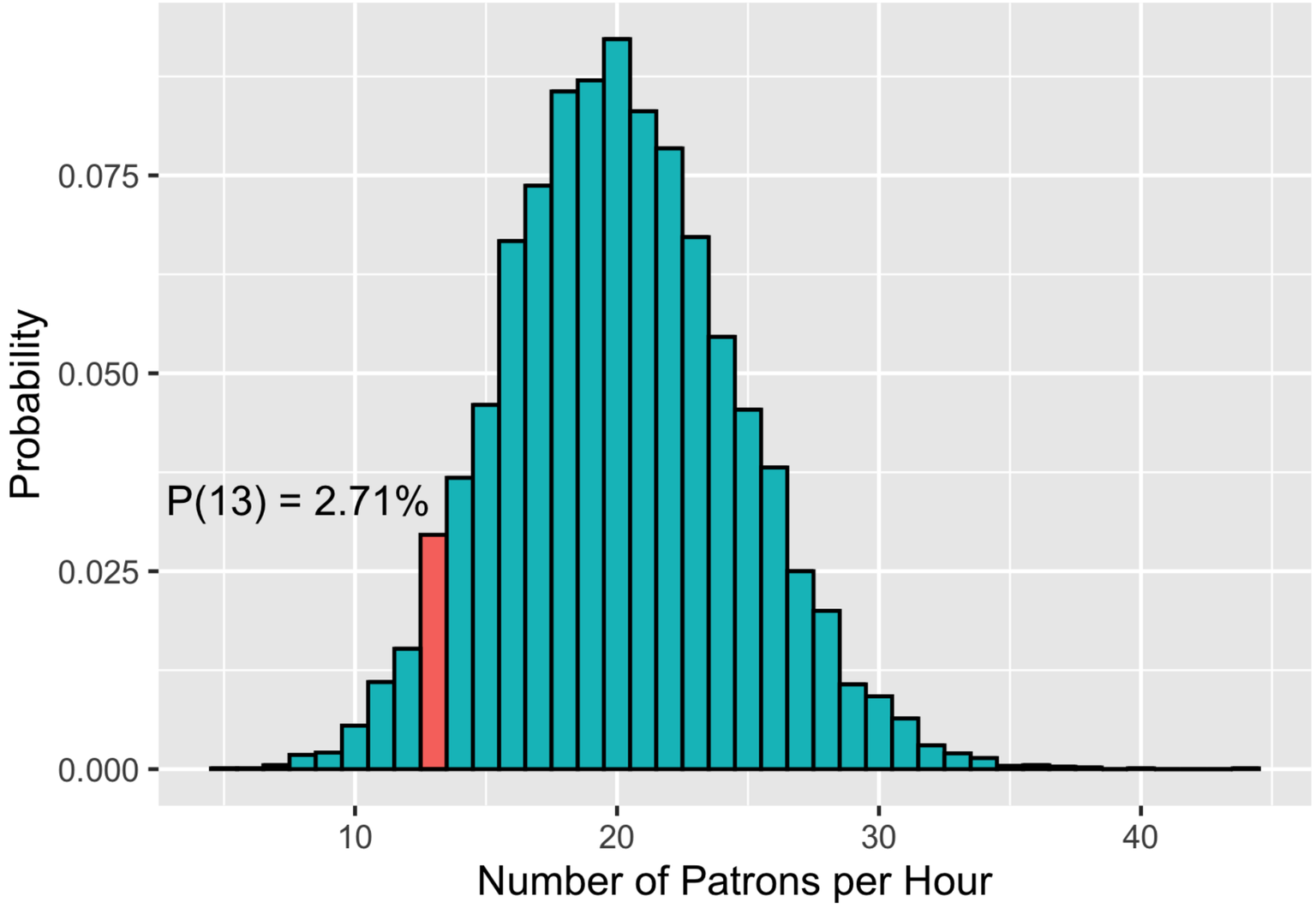


Lambda is the distribution's peak

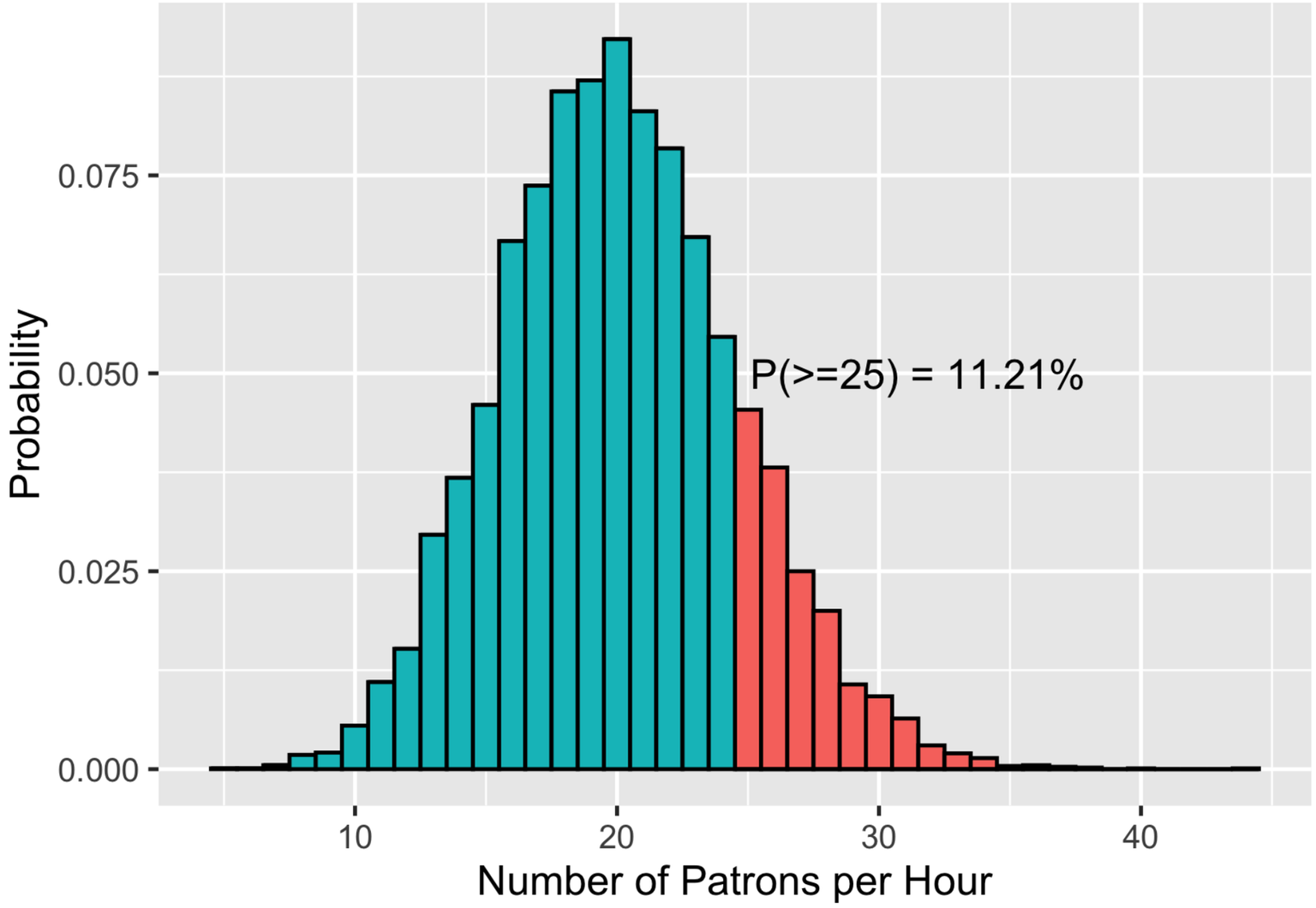
Central limit theorem still applies!



Probability of 13 patrons in an hour



Probability of 25 or more patrons



Let's practice!

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