

What are the chances?

INTRODUCTION TO STATISTICS



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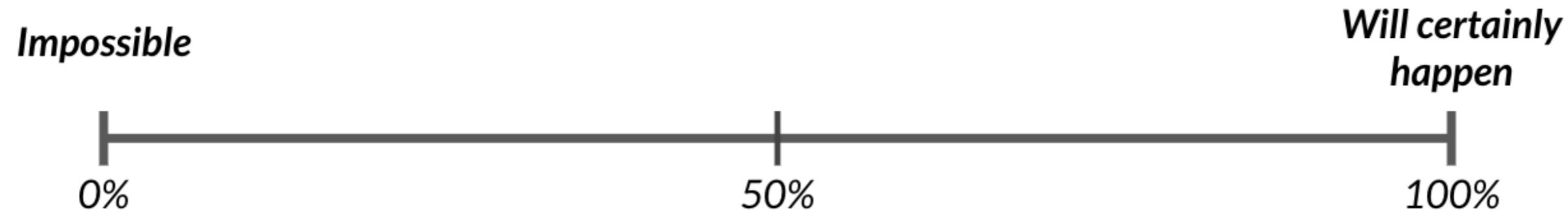
Measuring chance

What's the probability of an event?

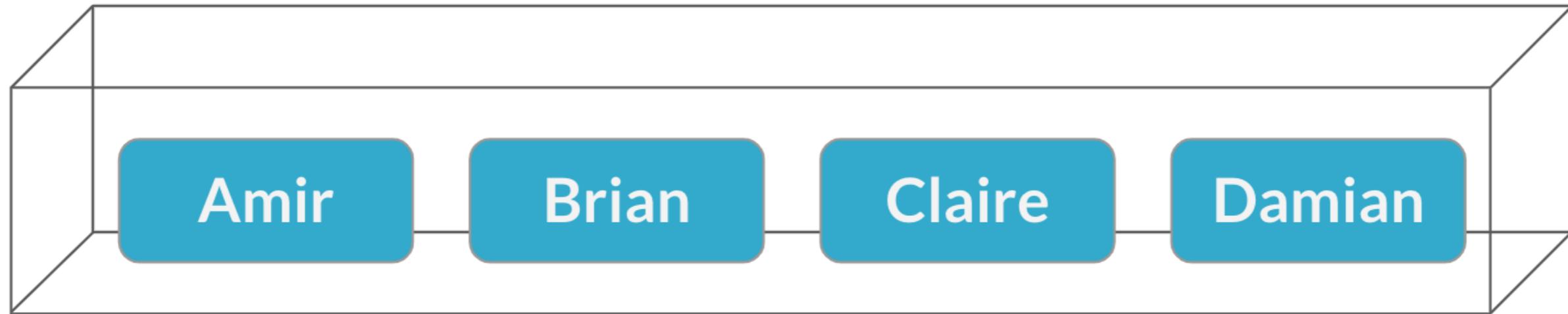
$$P(\text{event}) = \frac{\# \text{ ways event can happen}}{\text{total } \# \text{ of possible outcomes}}$$

Example: a coin flip

$$P(\text{heads}) = \frac{1 \text{ way to get heads}}{2 \text{ possible outcomes}} = \frac{1}{2} = 50\%$$

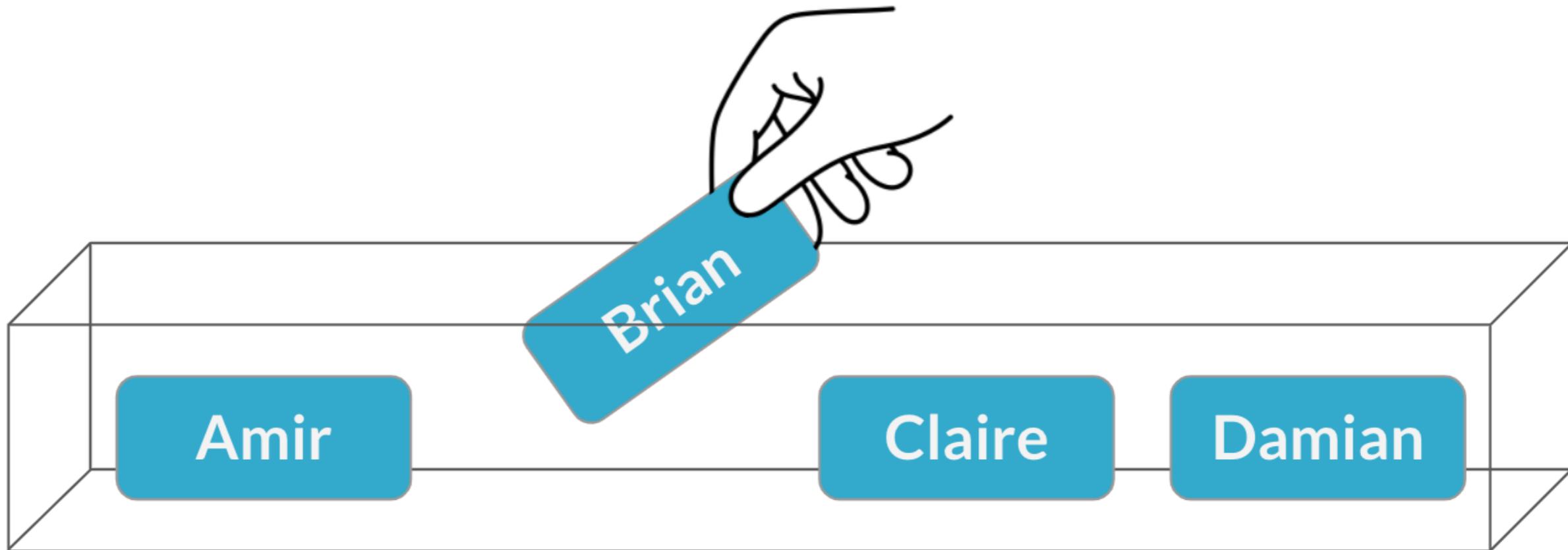


Assigning salespeople



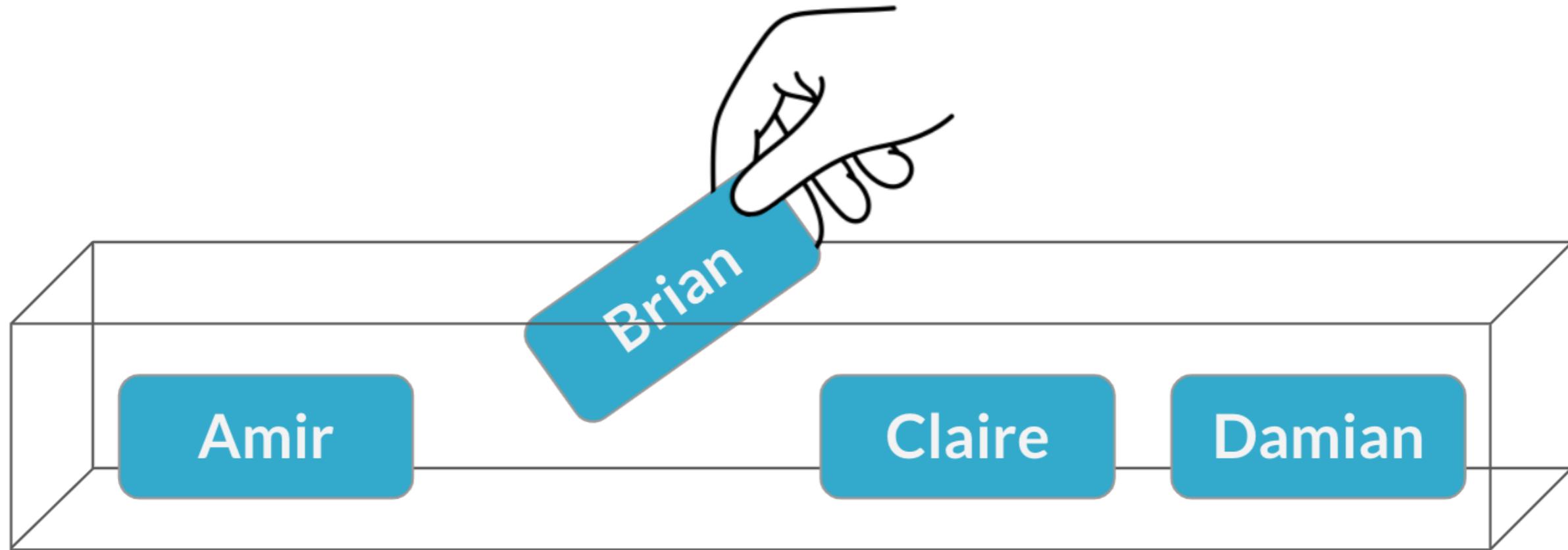
- Sampling

Assigning salespeople

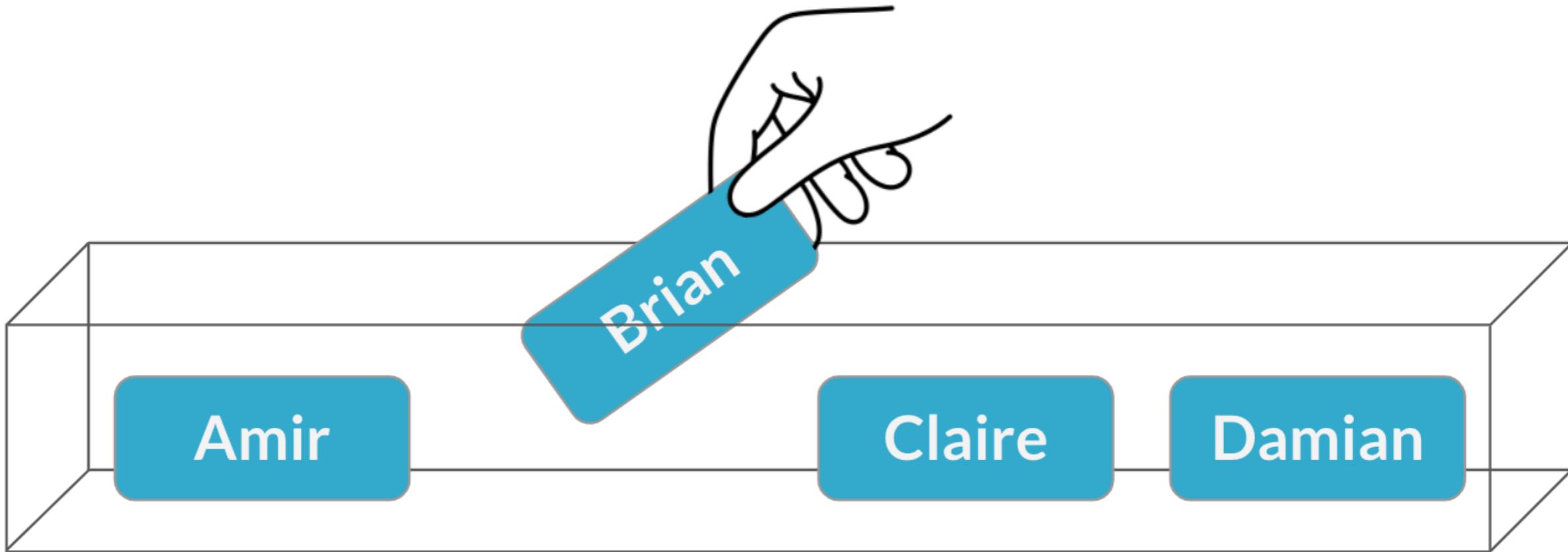


$$P(\text{Brian}) = \frac{1}{4} = 25\%$$

Morning meeting



Afternoon meeting



$$P(\text{Brian}) = \frac{1}{4} = 25\%$$

- Sampling with replacement

Independent probability

*Two events are **independent** if the probability of the second event **does not** change based on the outcome of the first event.*

Online retail sales

Order Number	Product Type	Net Quantity	Gross Sales	Discounts	Returns	Net Sales
200	Basket	13	3744.0	-316.80	0.00	3427.20
201	Basket	12	3825.0	-201.60	-288.0	3335.40
202	Basket	17	3035.0	-63.25	0.00	2971.75
203	Art & Sculpture	47	2696.8	-44.16	0.00	2652.64
204	Basket	17	2695.0	-52.50	-110.00	2532.50



¹ Image credit: <https://unsplash.com/@rodriguezedm>

Probability of an order for a jewelry product

Product Type	Order Count
Basket	551
Art & Sculpture	337
Jewelry	210
Kitchen	161
Home Decor	131
...	...
Total	1767

Probability of an order for a jewelry product

$$P(\text{Jewelry}) = \frac{\text{Order Count}(\text{Jewelry})}{\text{Sum}(\text{Total Order Count})}$$

$$P(\text{Jewelry}) = \frac{210}{1767}$$

$$P(\text{Jewelry}) = 11.88\%$$

Probabilities for all product types

Product Type	Order Count	Probability
Basket	551	31.18%
Art & Sculpture	337	19.07%
Jewelry	210	11.88%
Kitchen	161	9.11%
Home Decor	131	7.41%
...
Total	1767	100%

Let's practice!

INTRODUCTION TO STATISTICS

Conditional probability

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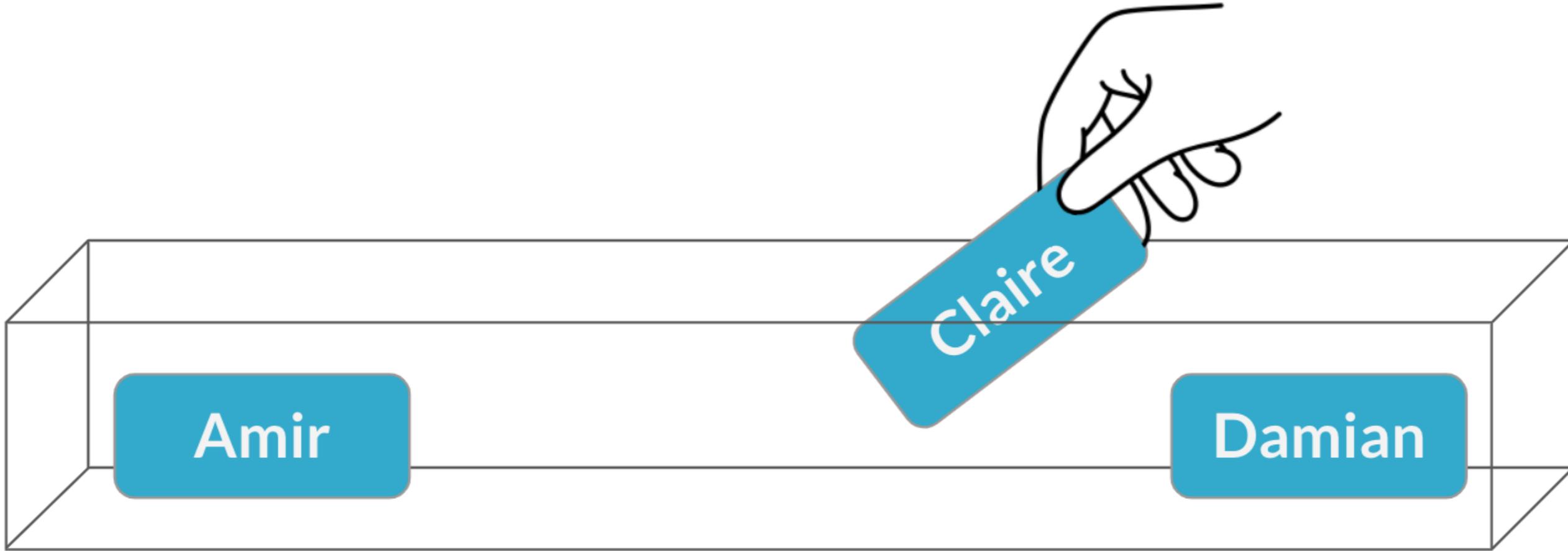
Multiple meetings

Sampling without replacement



Multiple meetings

Sampling without replacement



$$P(\text{Claire}) = \frac{1}{3} = 33\%$$

Dependent events

Probability of the second event is affected by the outcome of the first event

Sampling without Replacement

First pick

Second pick

Amir

Brian

Damian

Claire

Dependent events

Probability of the second event is affected by the outcome of the first event

Sampling without Replacement

First pick

Amir

Second pick

Brian

Damian

Claire

Claire

0%

Dependent events

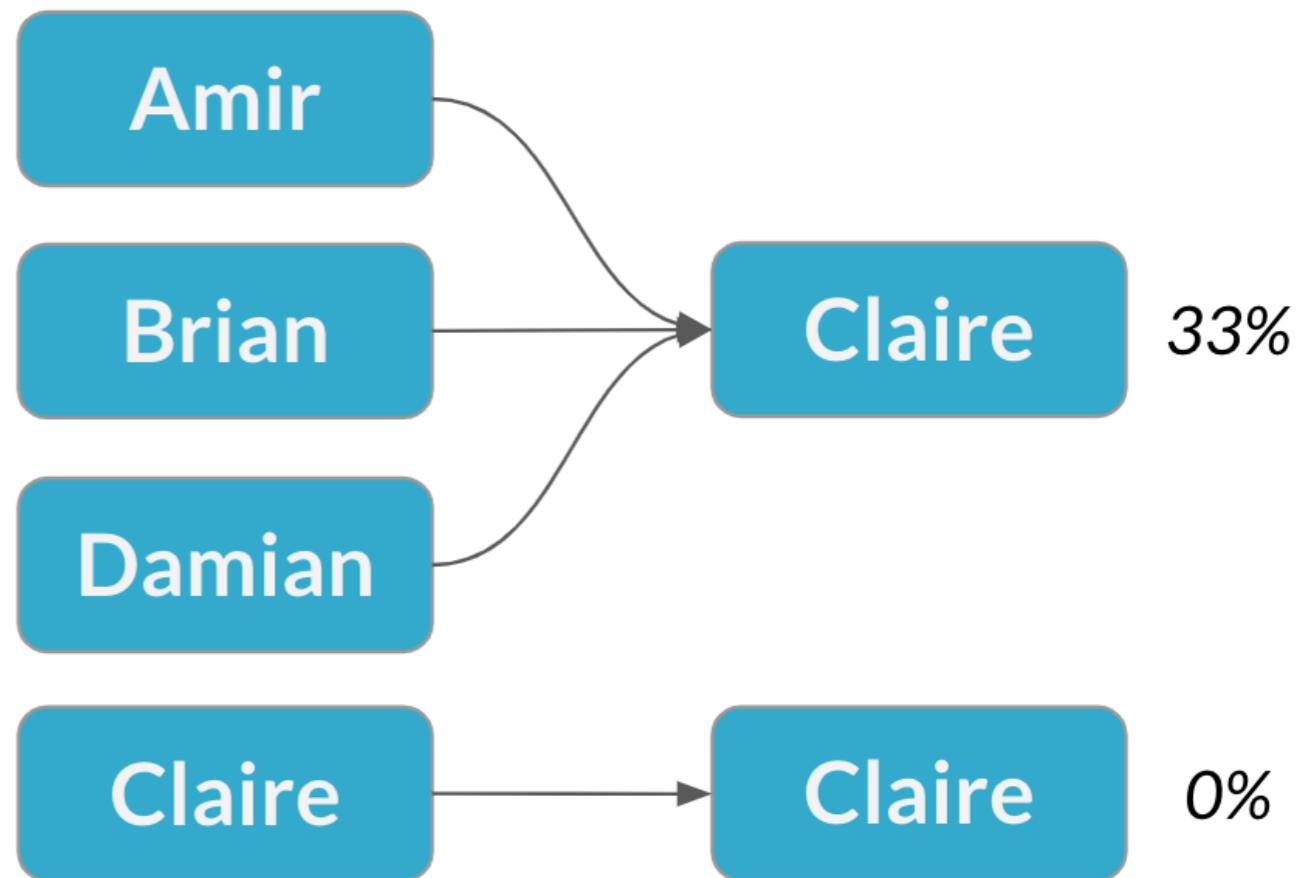
Probability of the second event is affected by the outcome of the first event

Sampling without replacement = each pick is dependent

Sampling without Replacement

First pick

Second pick



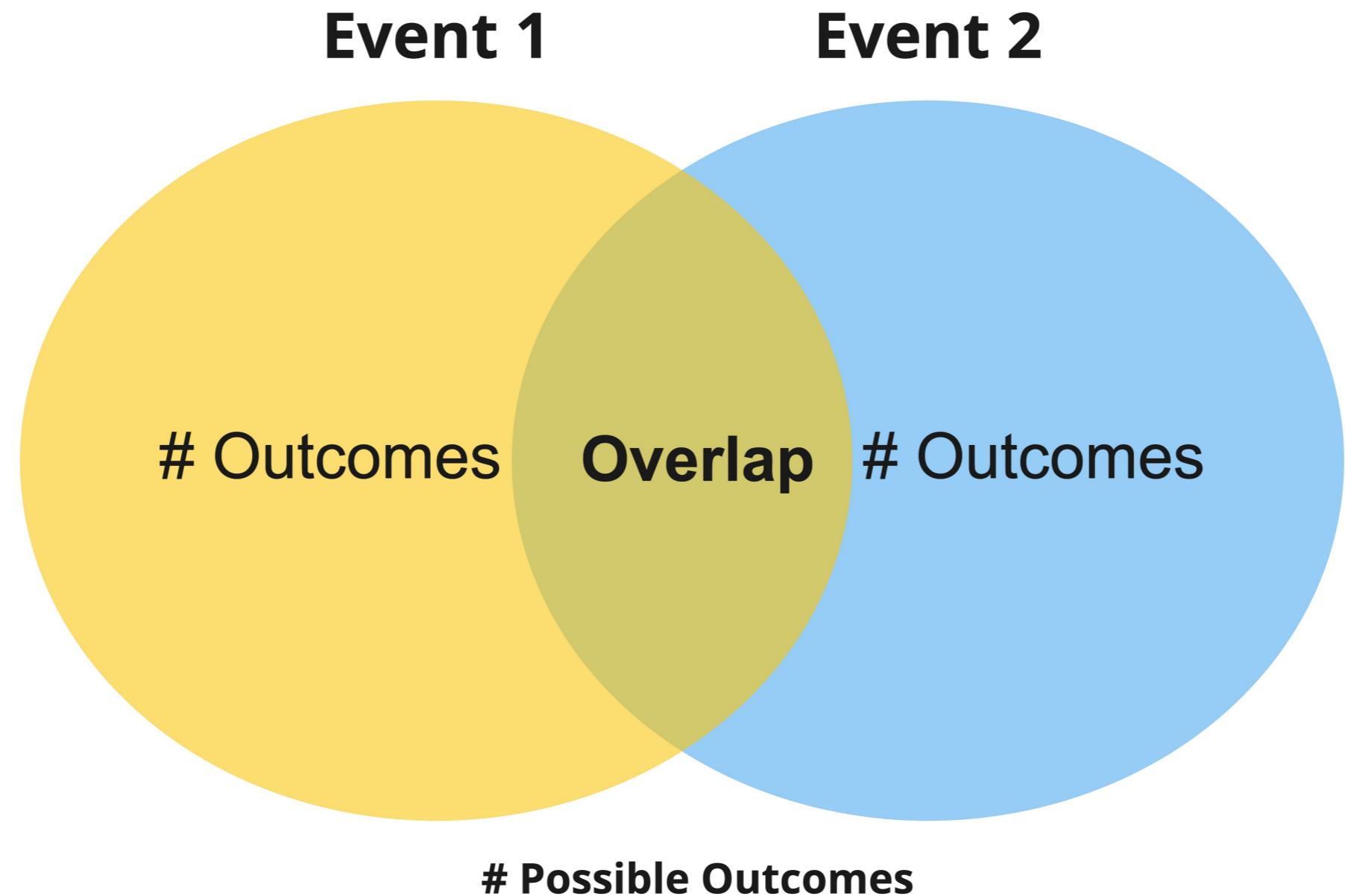
Conditional probability

- **Conditional probability** is used to calculate the probability of dependent events
 - The probability of one event is **conditional** on the outcome of another

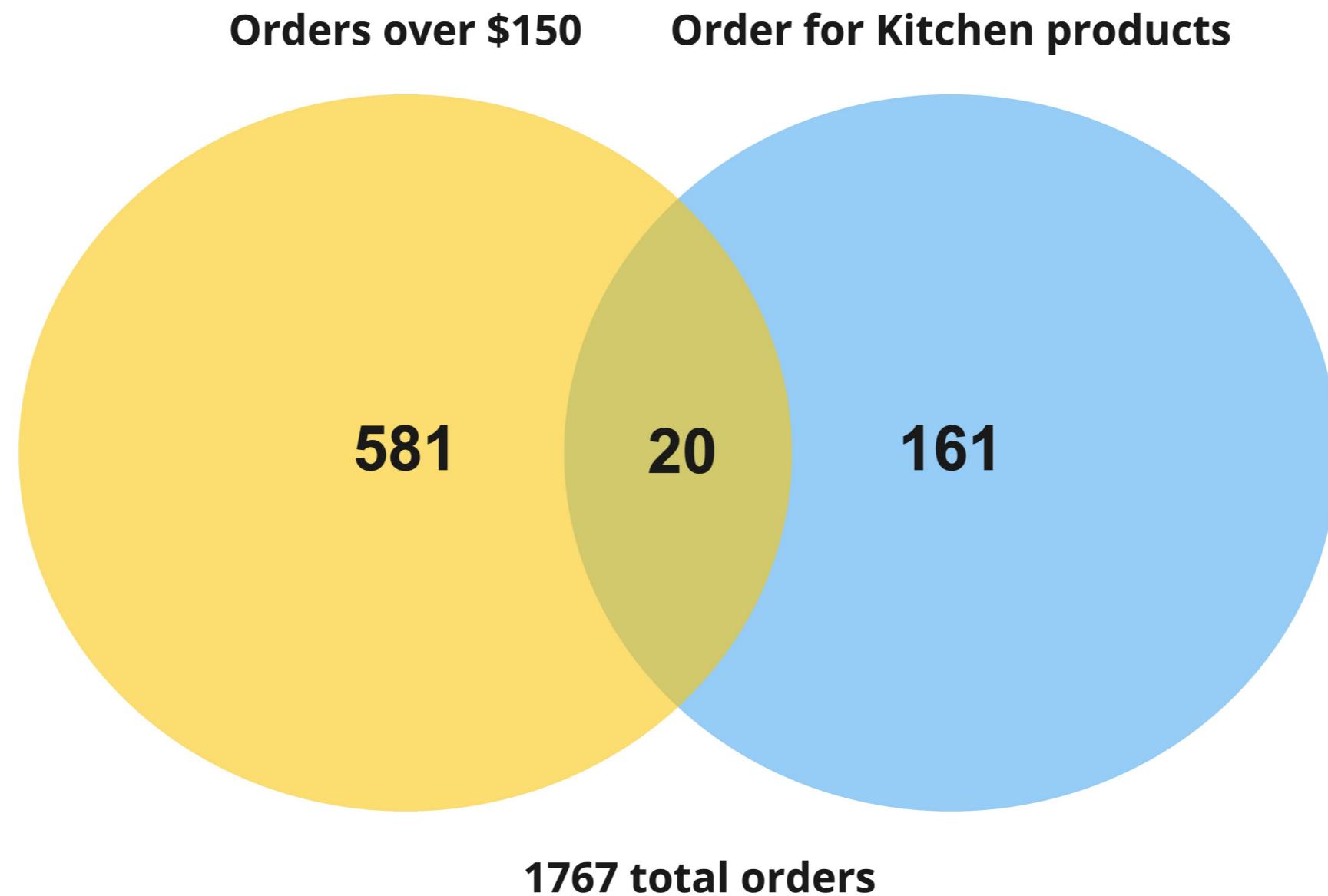


¹ Image credit: <https://unsplash.com/@pixeldan>

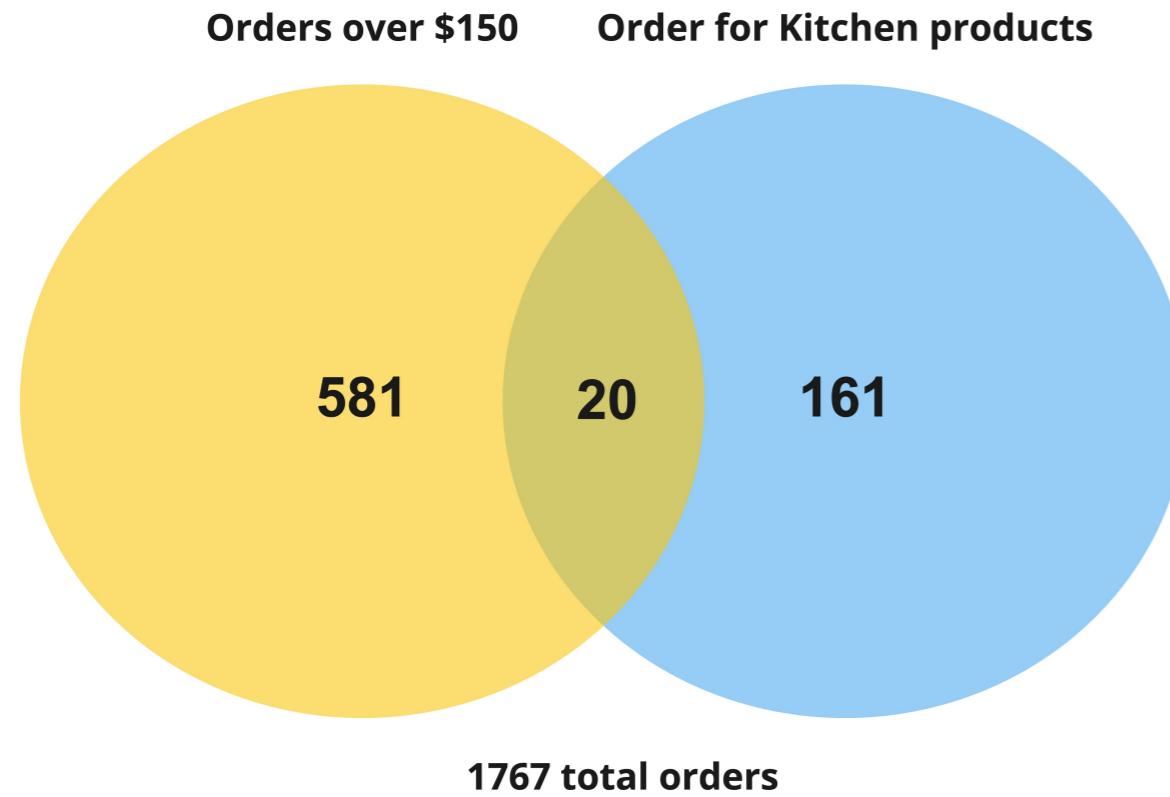
Venn diagrams



Kitchen sales over \$150



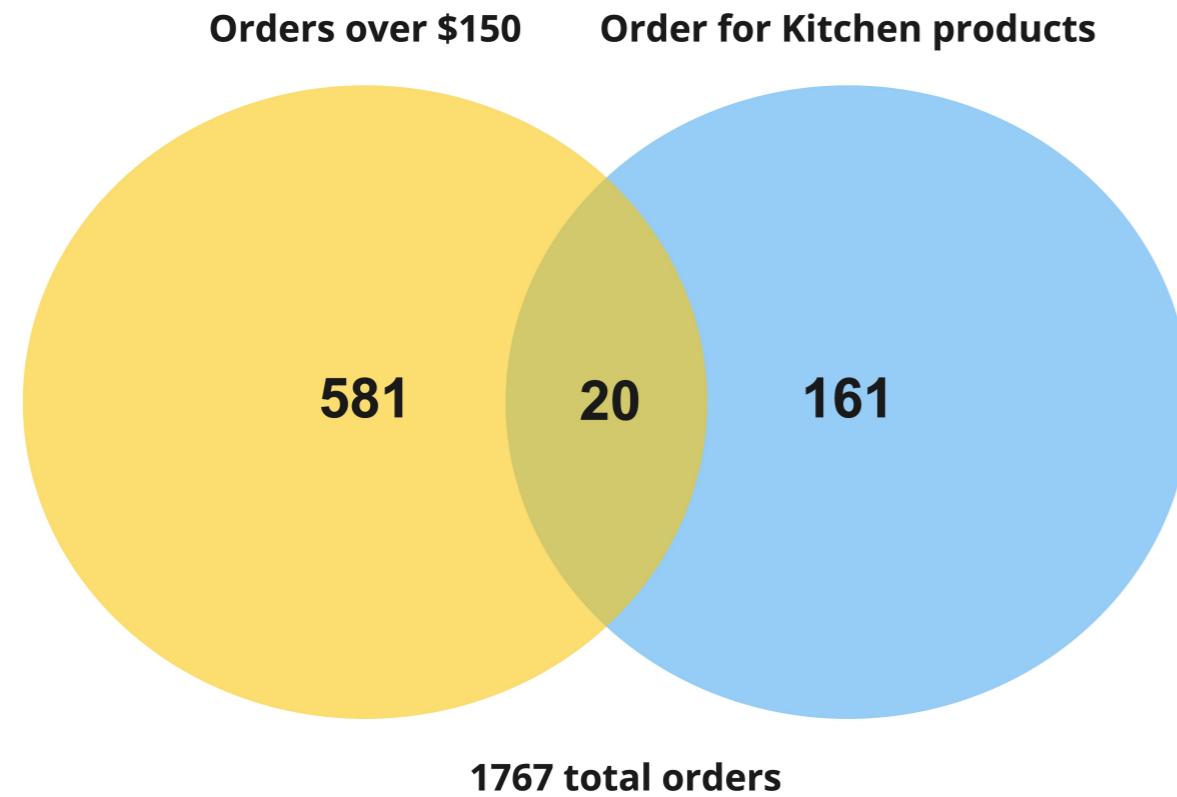
Kitchen sales over \$150



$$P(\text{Order} > 150 | \text{Kitchen}) = \frac{20}{\frac{1767}{181}}$$

$$P(\text{Order} > 150 | \text{Kitchen}) = \frac{20}{181}$$

The order of events matters



$$P(Kitchen | Order > 150) = \frac{20}{\frac{1767}{601}}$$

$$P(Kitchen | Order > 150) = \frac{20}{601}$$

Conditional probability formula

$$P(A|B) = \frac{P(A \cap B)}{P(B)}$$

- $P(A|B)$ → Probability of event A, given event B
- $P(A \cap B)$ → Probability of event A **and** event B
 - Divided by the probability of event B → $P(B)$

Let's practice!

INTRODUCTION TO STATISTICS

Discrete distributions

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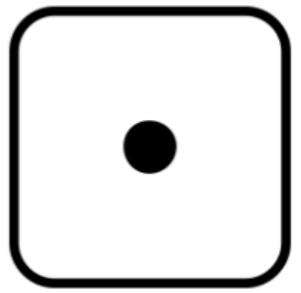


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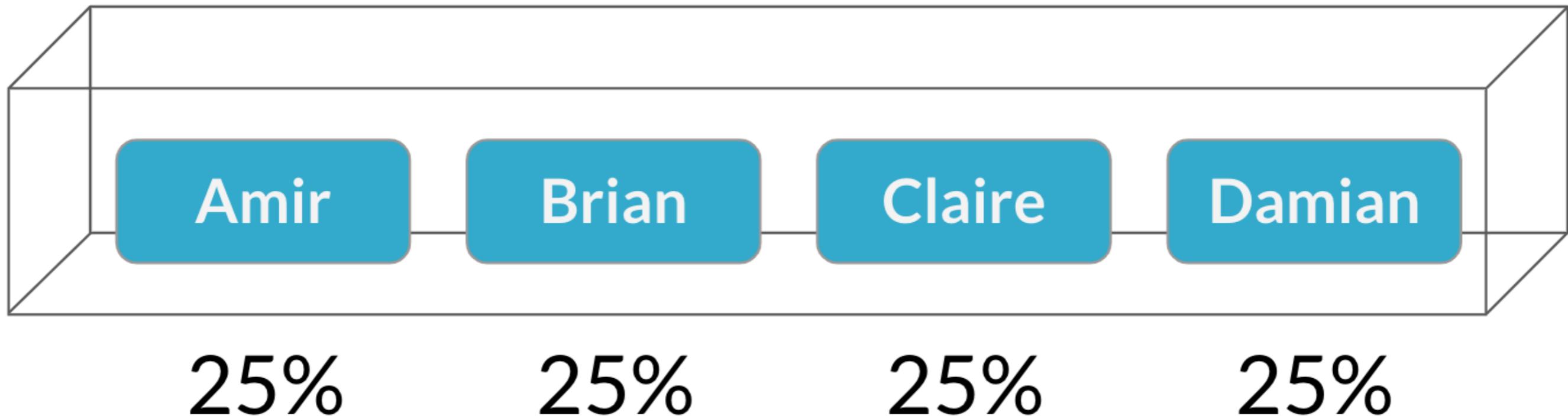
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Rolling the dice

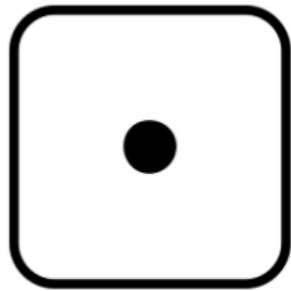
 $\frac{1}{6}$  $\frac{1}{6}$  $\frac{1}{6}$  $\frac{1}{6}$  $\frac{1}{6}$  $\frac{1}{6}$

Choosing salespeople



Probability distribution

Describes the probability of each possible outcome in a scenario



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$

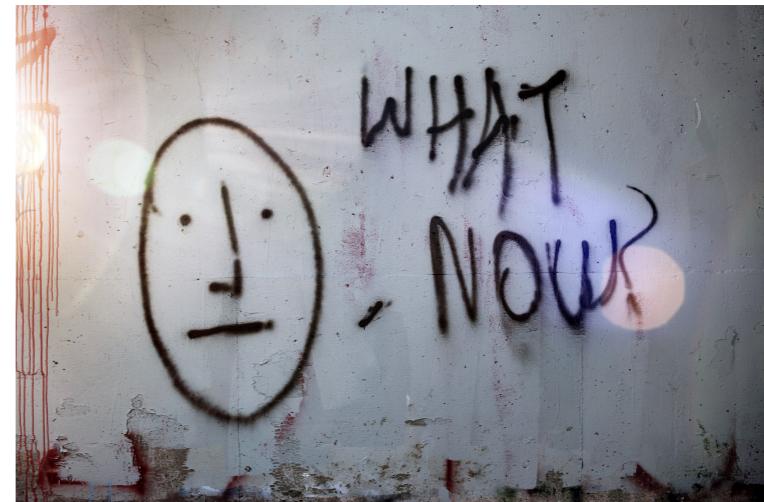
Expected value: The *mean* of a probability distribution

Expected value of a fair die roll =

$$(1 \times \frac{1}{6}) + (2 \times \frac{1}{6}) + (3 \times \frac{1}{6}) + (4 \times \frac{1}{6}) + (5 \times \frac{1}{6}) + (6 \times \frac{1}{6}) = 3.5$$

Why are probability distributions important?

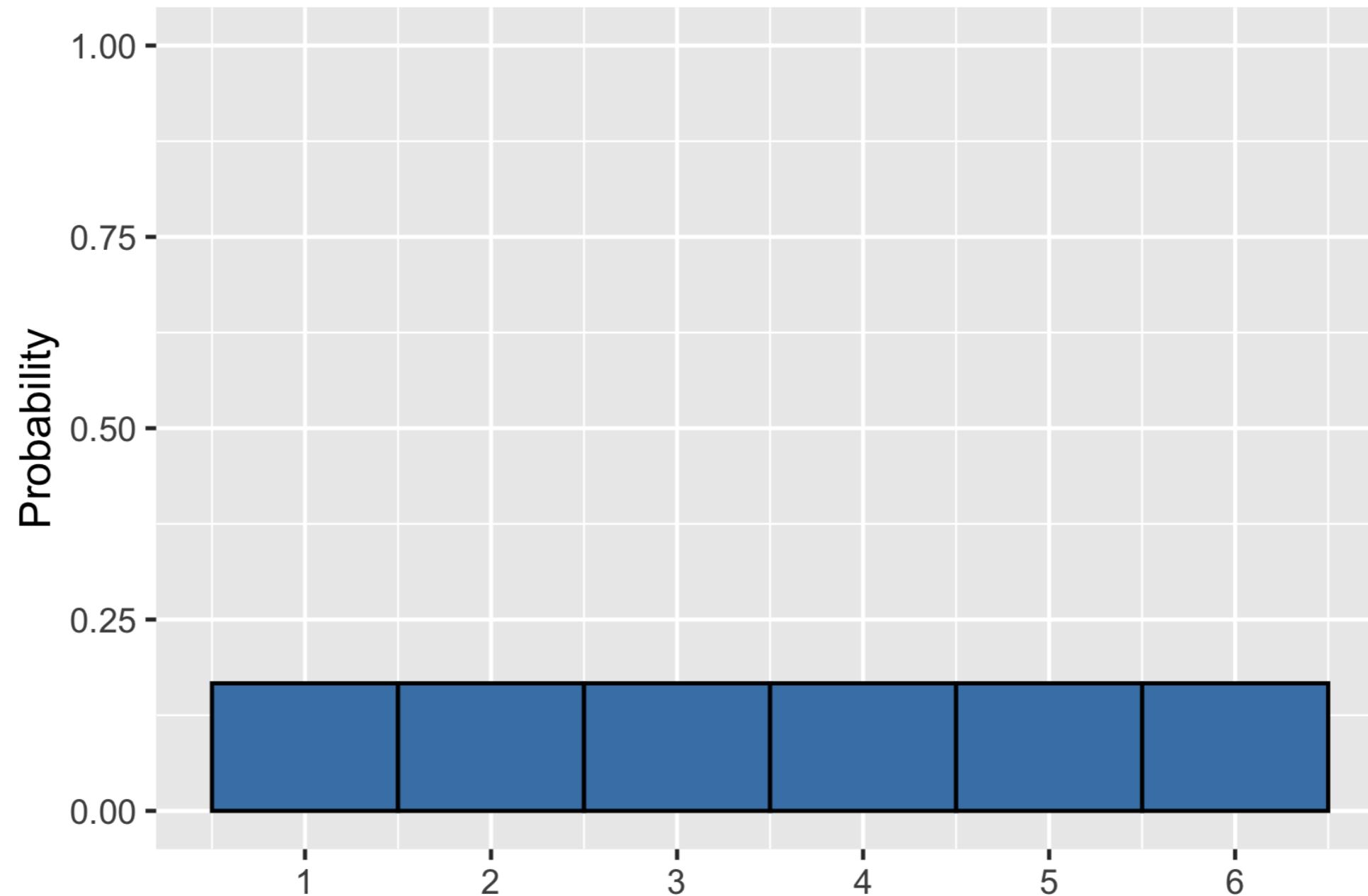
- Help us to quantify risk and inform decision making



- Used extensively in hypothesis testing
 - Probability that the results occurred by chance

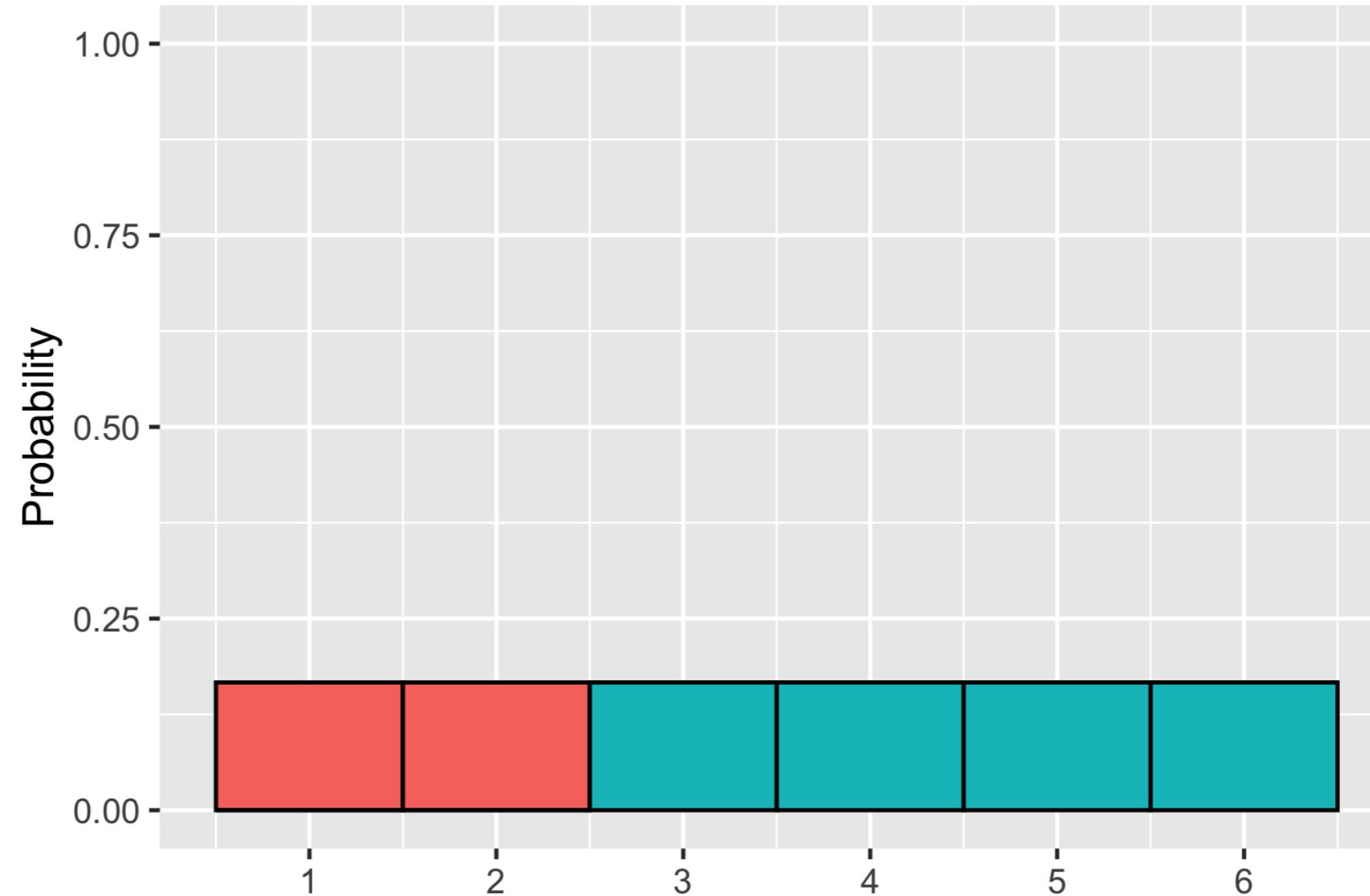
¹ Image credit: <https://unsplash.com/@timmosholder>

Visualizing a probability distribution



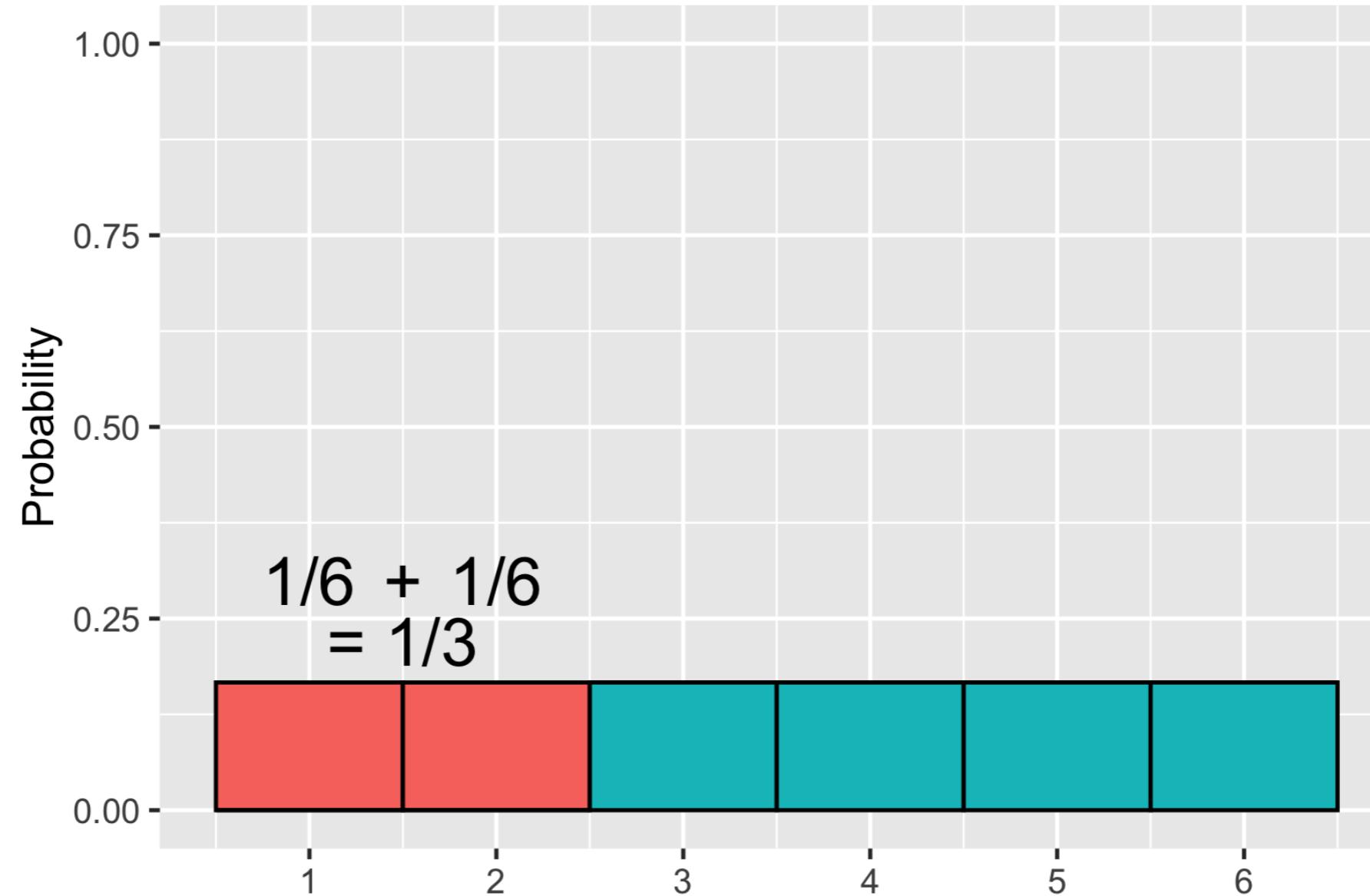
Probability = area

$$P(\text{die roll}) \leq 2 = ?$$

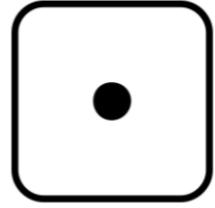


Probability = area

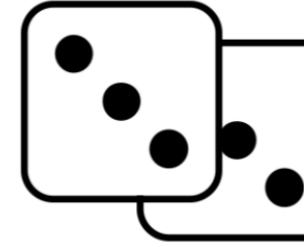
$$P(\text{die roll}) \leq 2 = 1/3$$



Uneven die



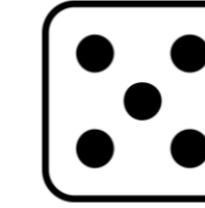
$\frac{1}{6}$



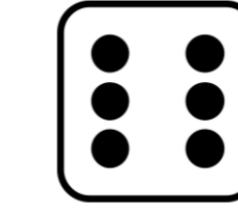
$\frac{1}{3}$



$\frac{1}{6}$



$\frac{1}{6}$

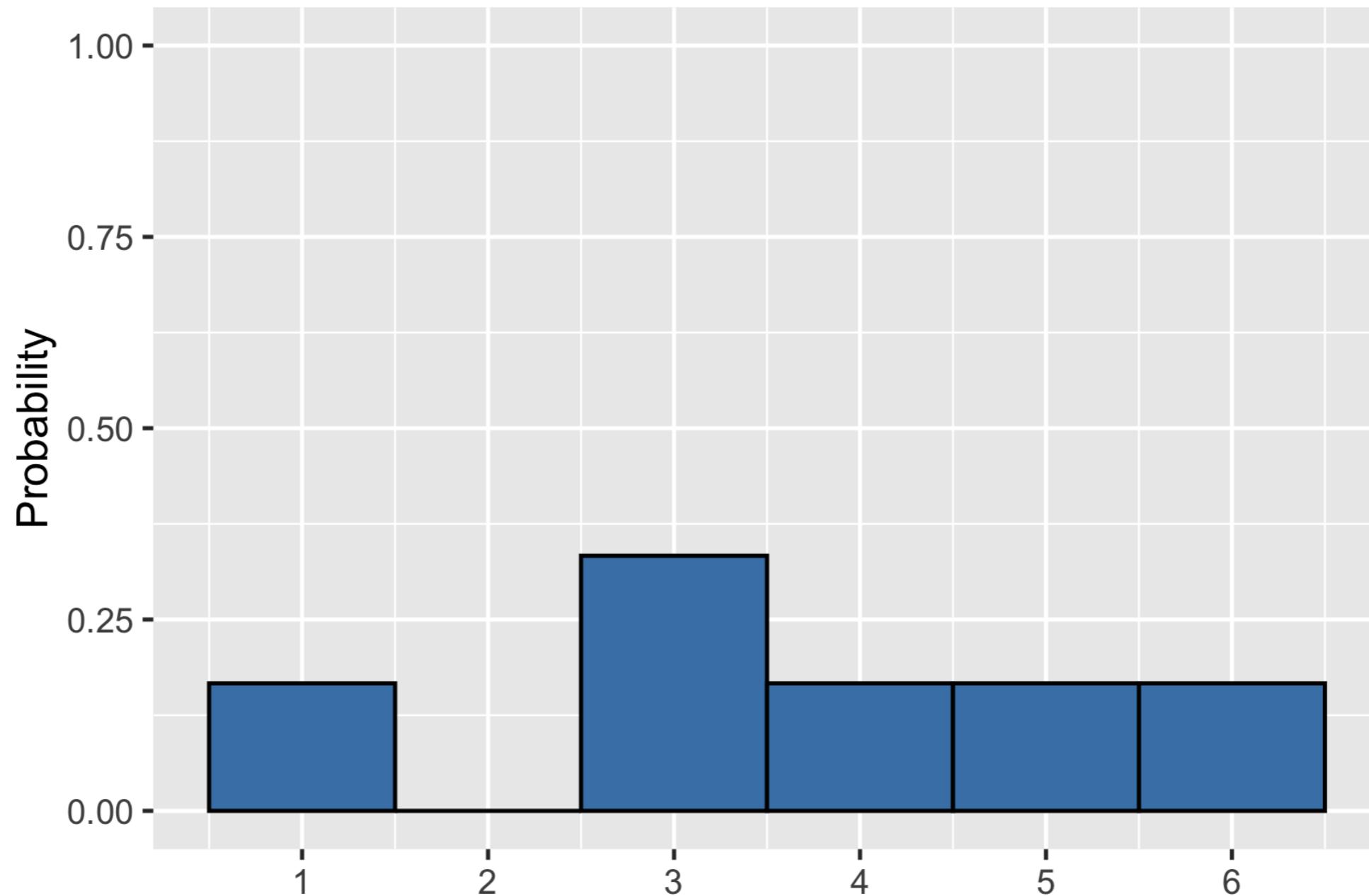


$\frac{1}{6}$

Expected value of uneven die roll =

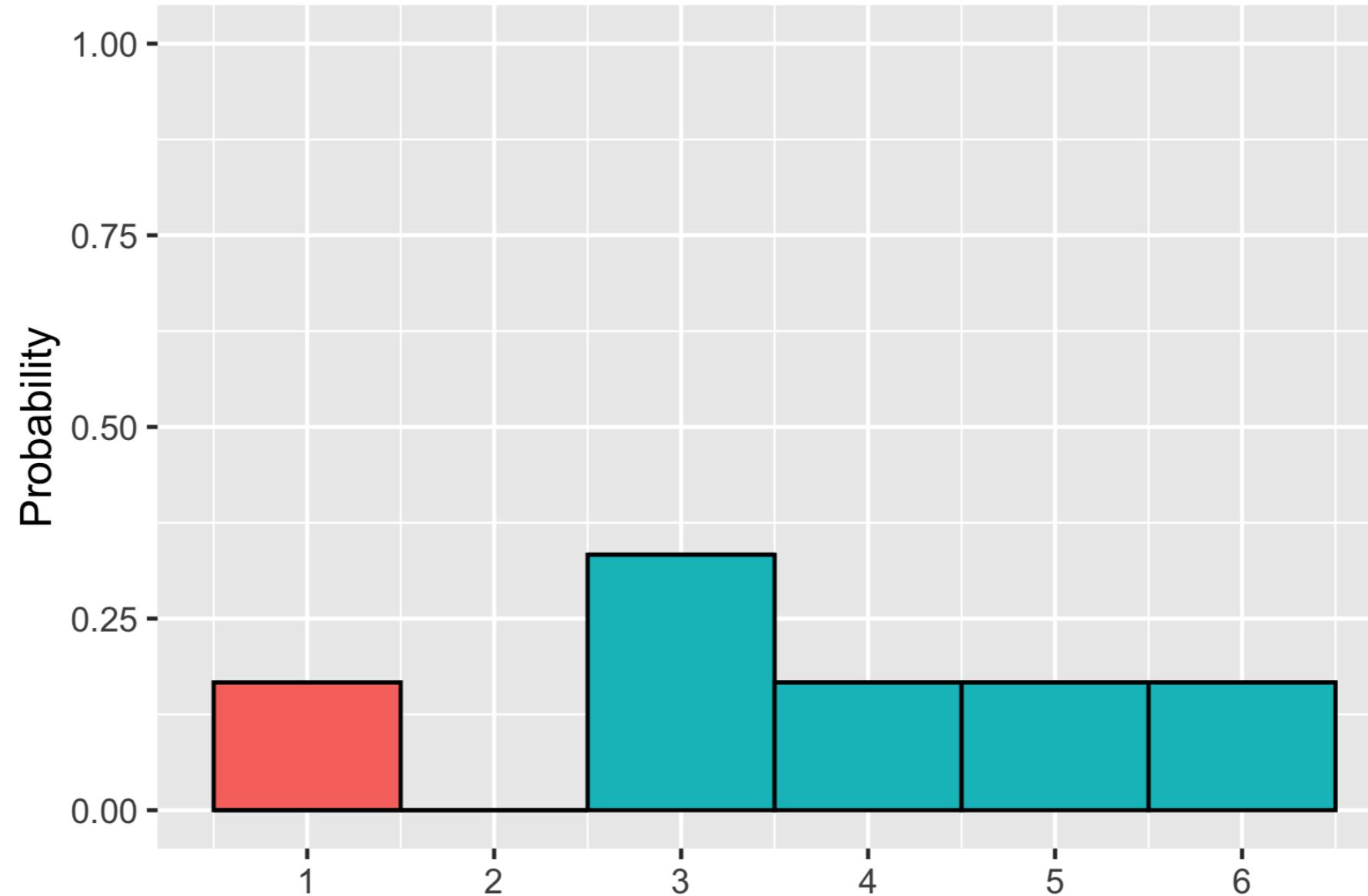
$$(1 \times \frac{1}{6}) + (2 \times 0) + (3 \times \frac{1}{3}) + (4 \times \frac{1}{6}) + (5 \times \frac{1}{6}) + (6 \times \frac{1}{6}) = 3.67$$

Visualizing uneven probabilities



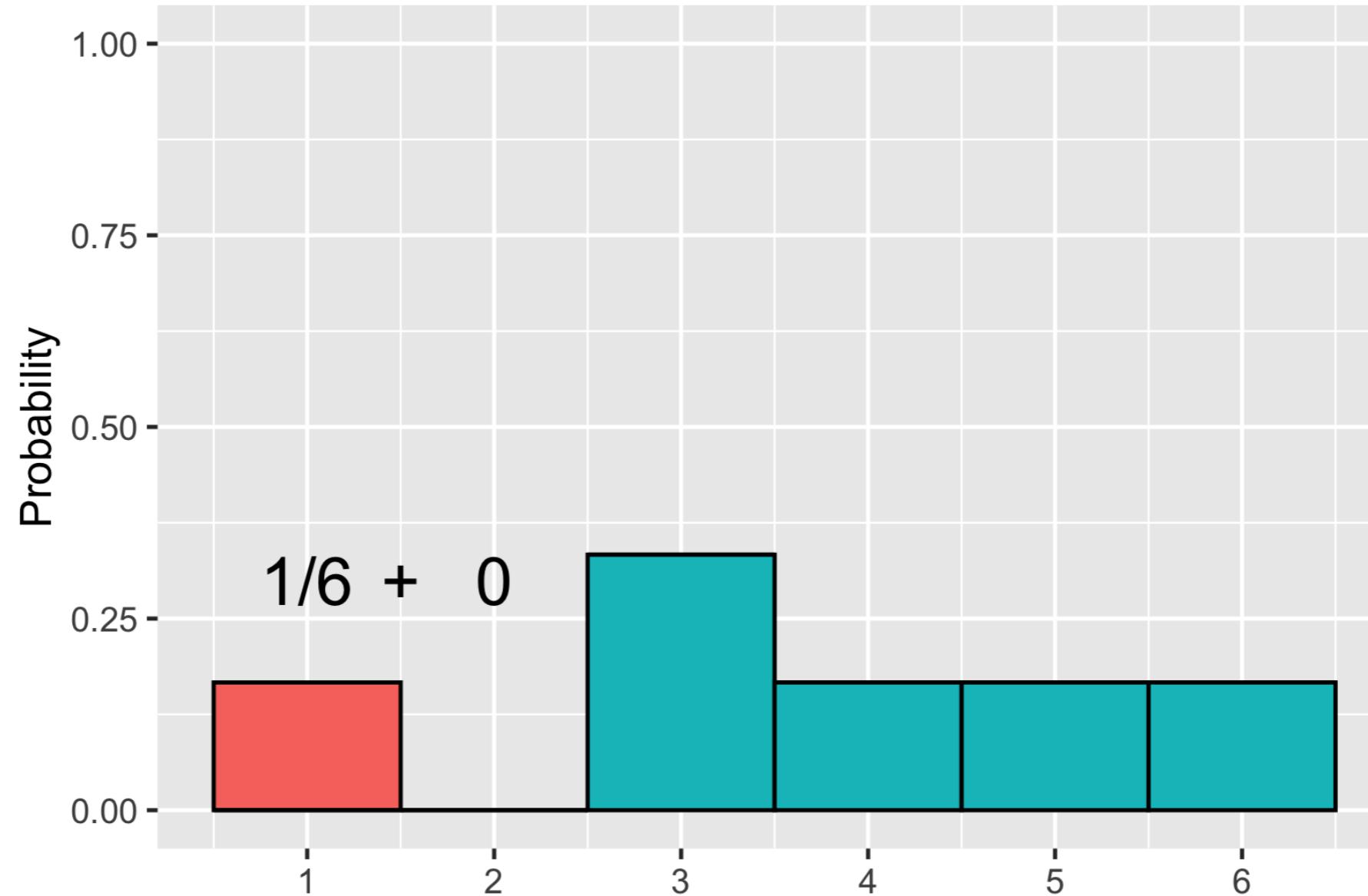
Adding areas

$P(\text{uneven die roll}) \leq 2 = ?$



Adding areas

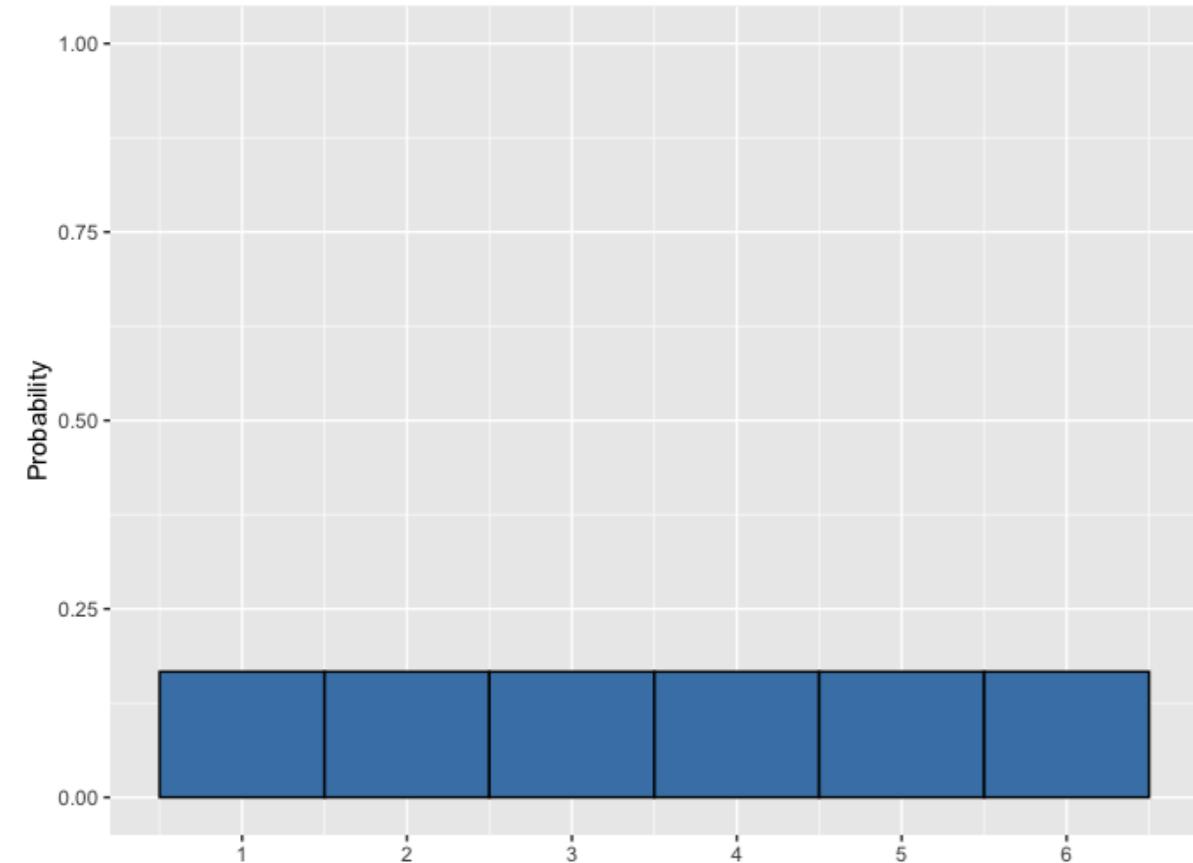
$$P(\text{uneven die roll}) \leq 2 = 1/6$$



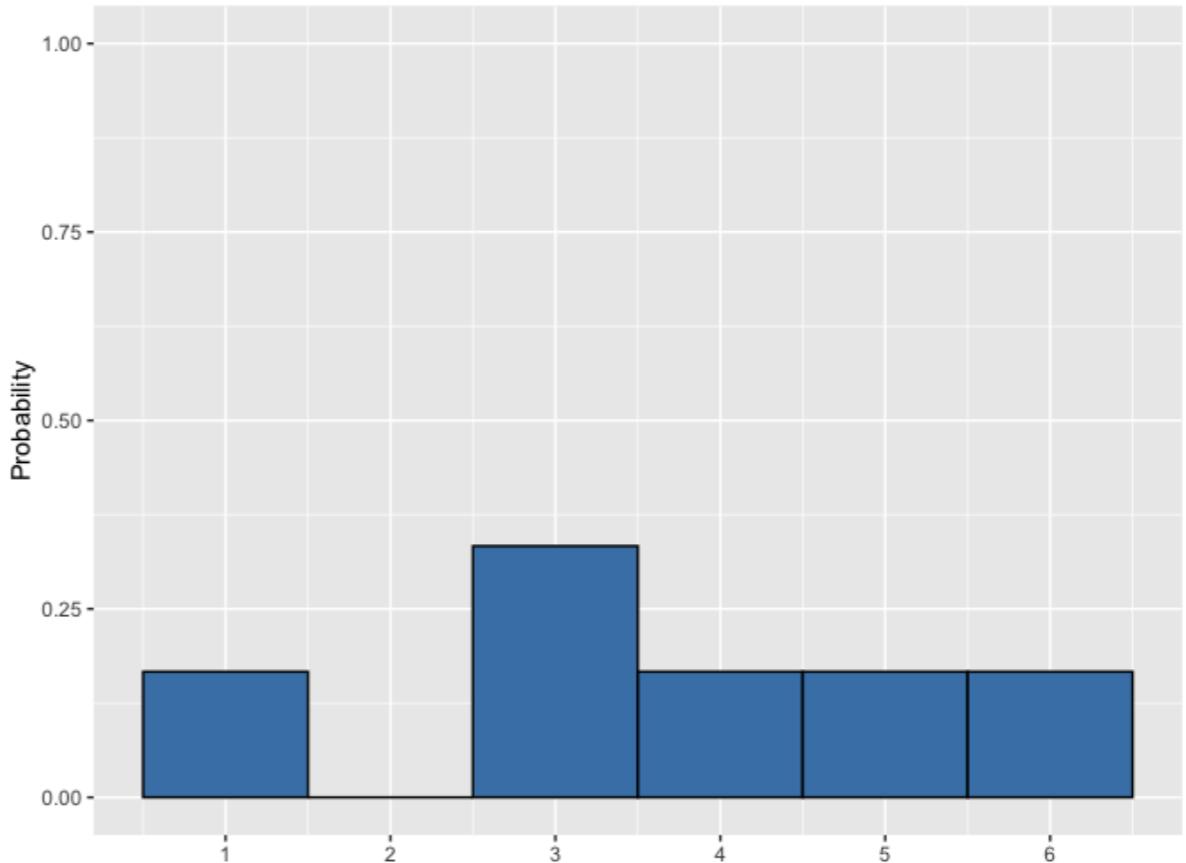
Discrete probability distributions

Describe probabilities for discrete outcomes

Fair die



Uneven die



Discrete uniform distribution

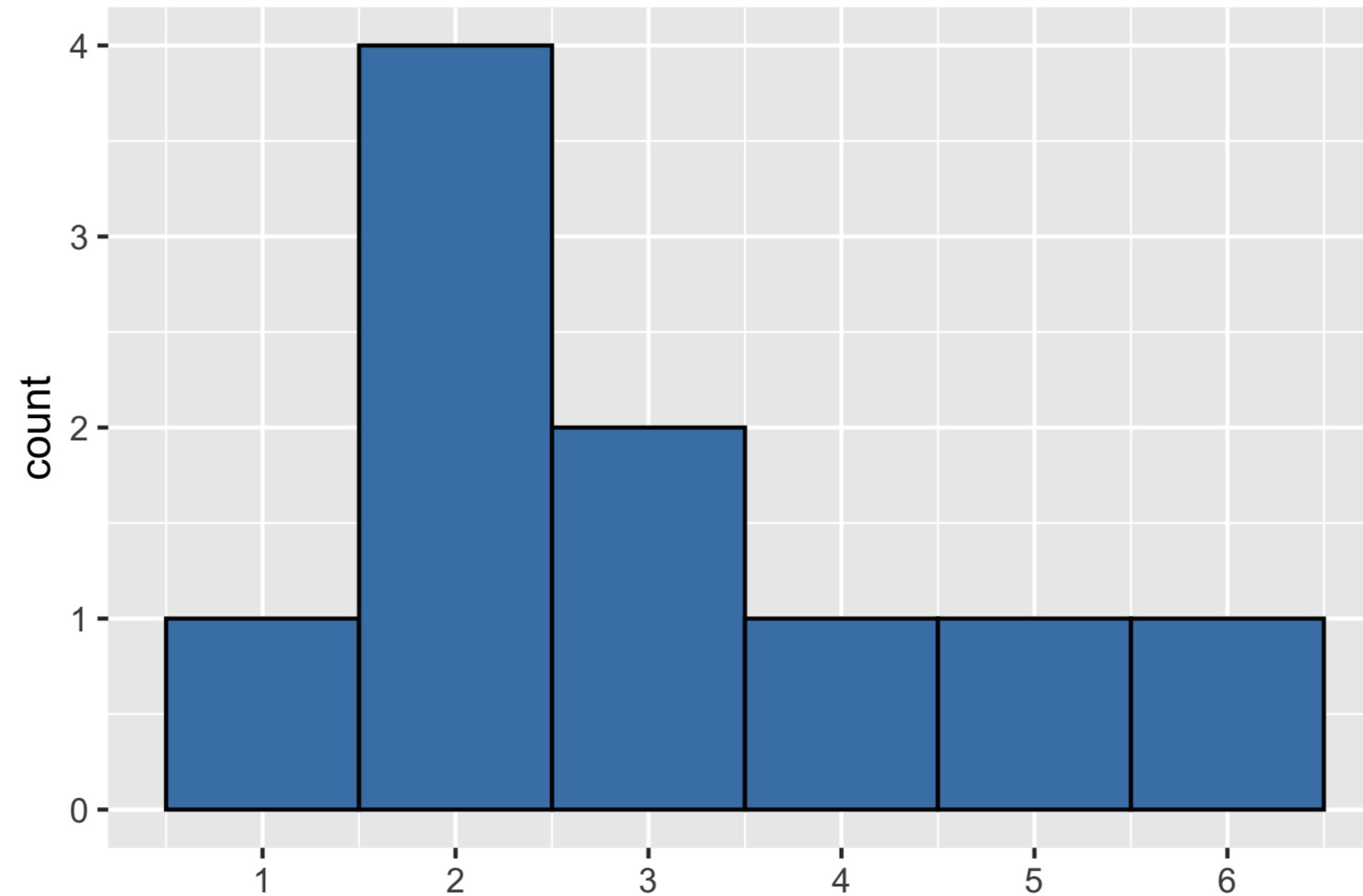
Sampling from a discrete distribution

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

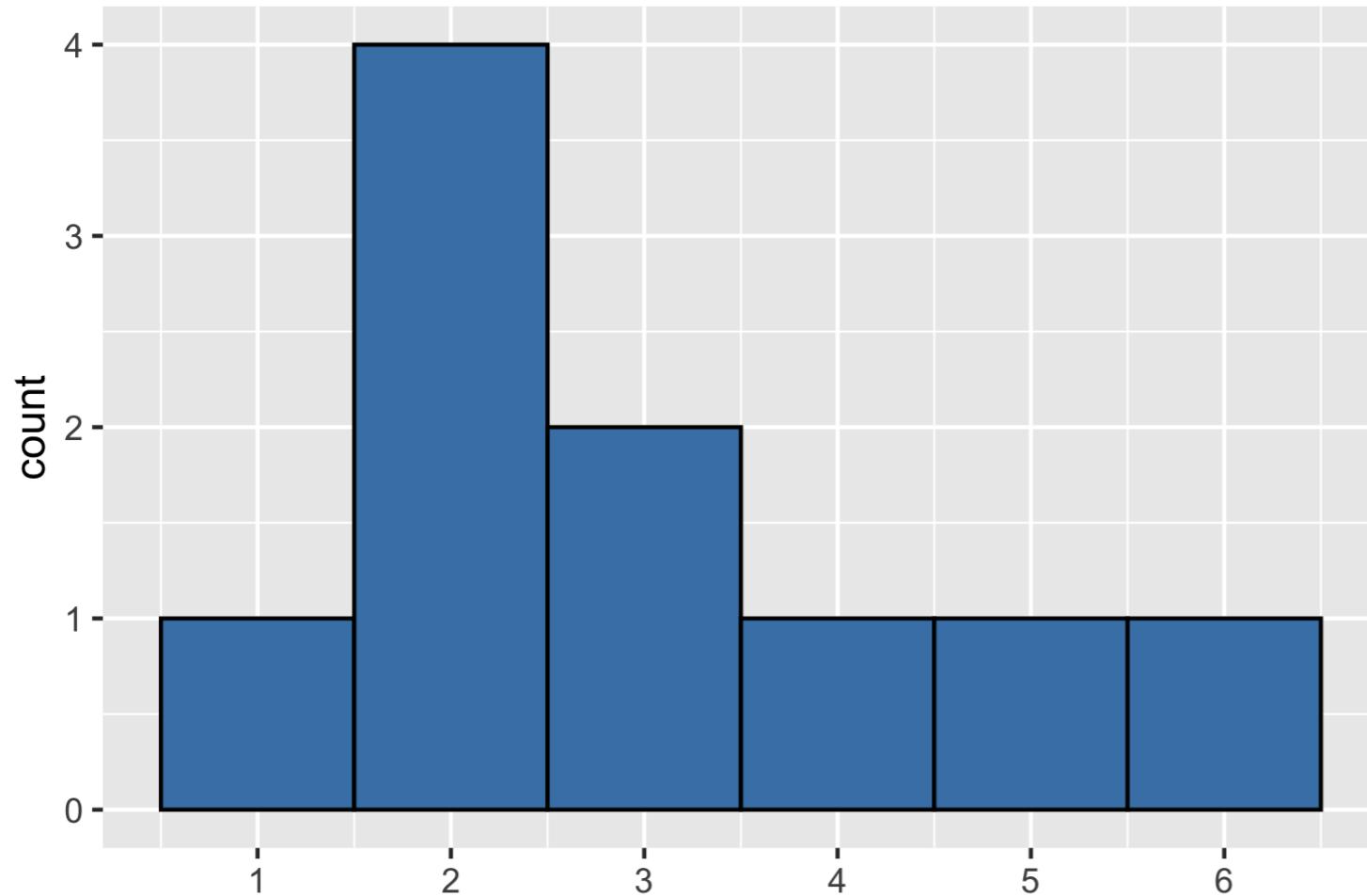
$$\text{Mean} = 3.5$$

Roll	Result
1	3
2	1
3	2
4	4
5	6
6	3
7	2
8	2
9	2
10	5

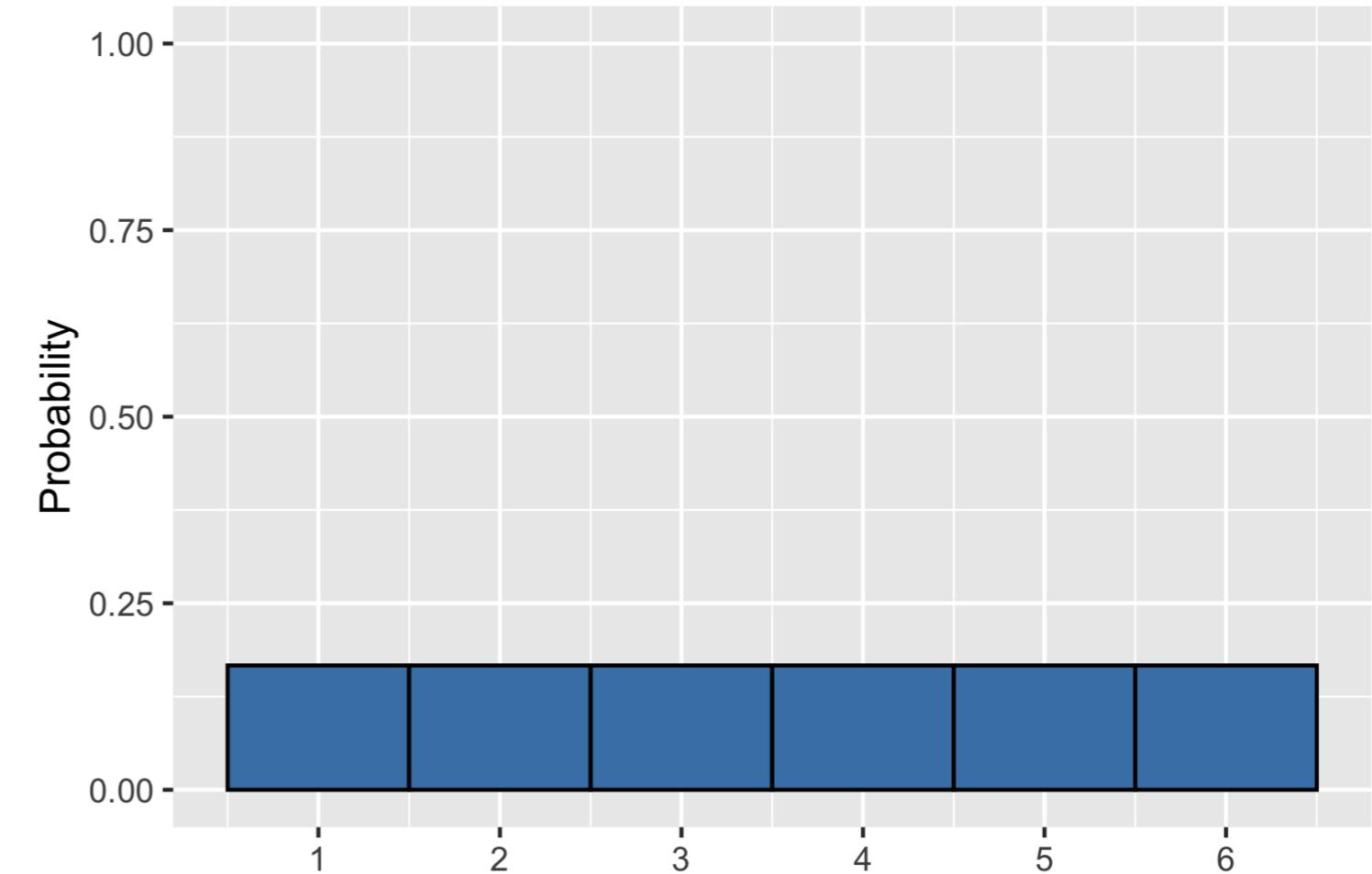
Visualizing a sample



Sample distribution vs theoretical distribution



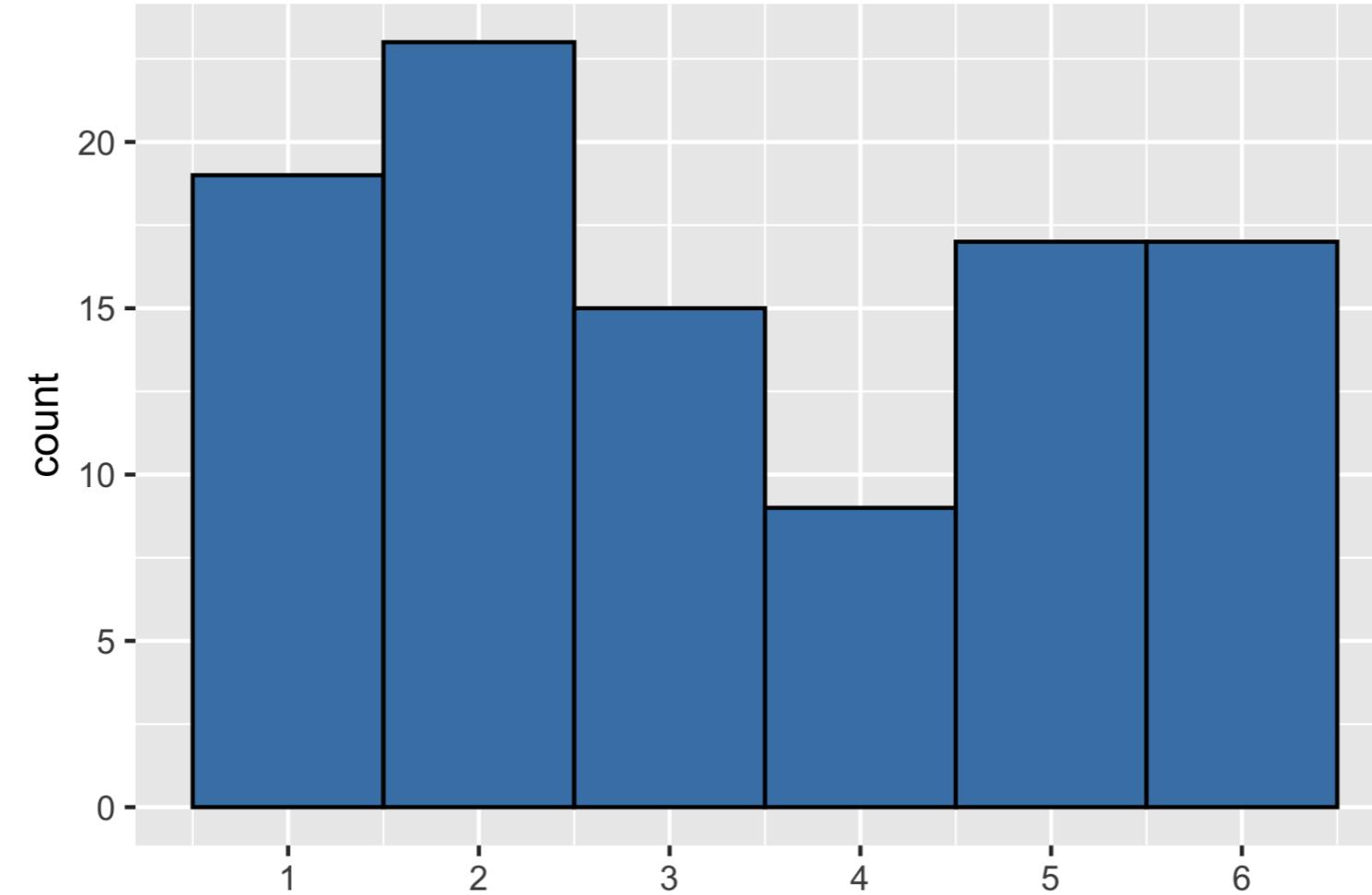
Mean = 3.0



Mean = 3.5

A bigger sample

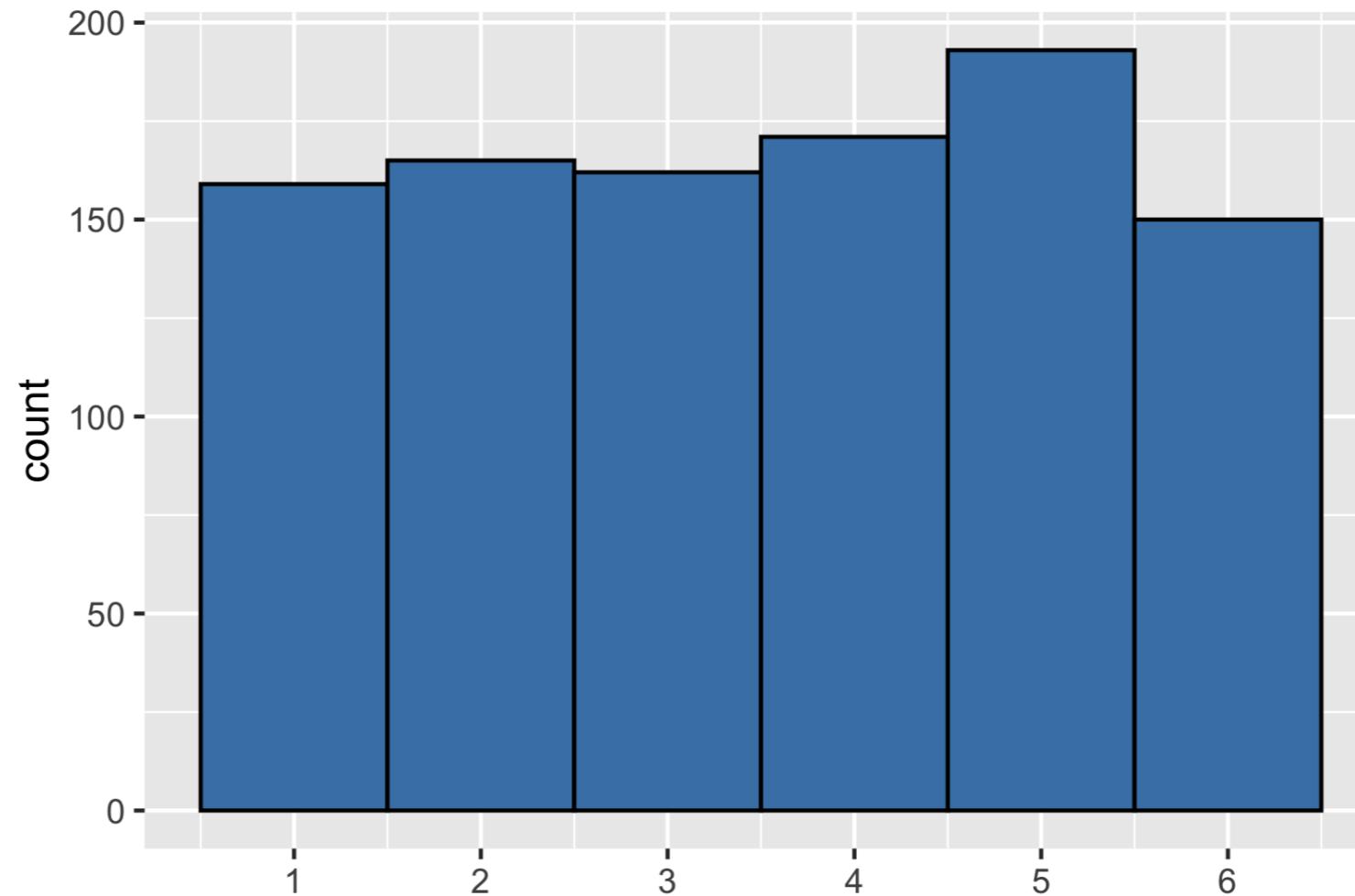
Sample of 100 rolls



$$\text{Mean} = 3.33$$

An even bigger sample

Sample of 1000 rolls



$$\text{Mean} = 3.52$$

Law of large numbers

As the size of your sample increases, the sample mean will approach the expected value.

Sample size	Mean
10	3.00
100	3.33
1000	3.52

Let's practice!

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Continuous distributions

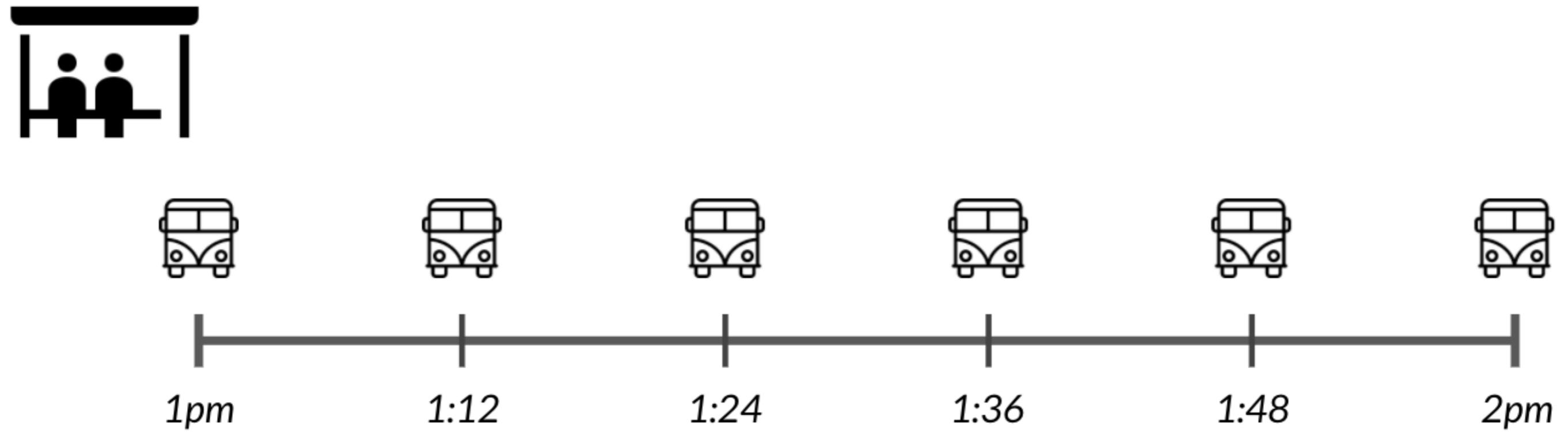
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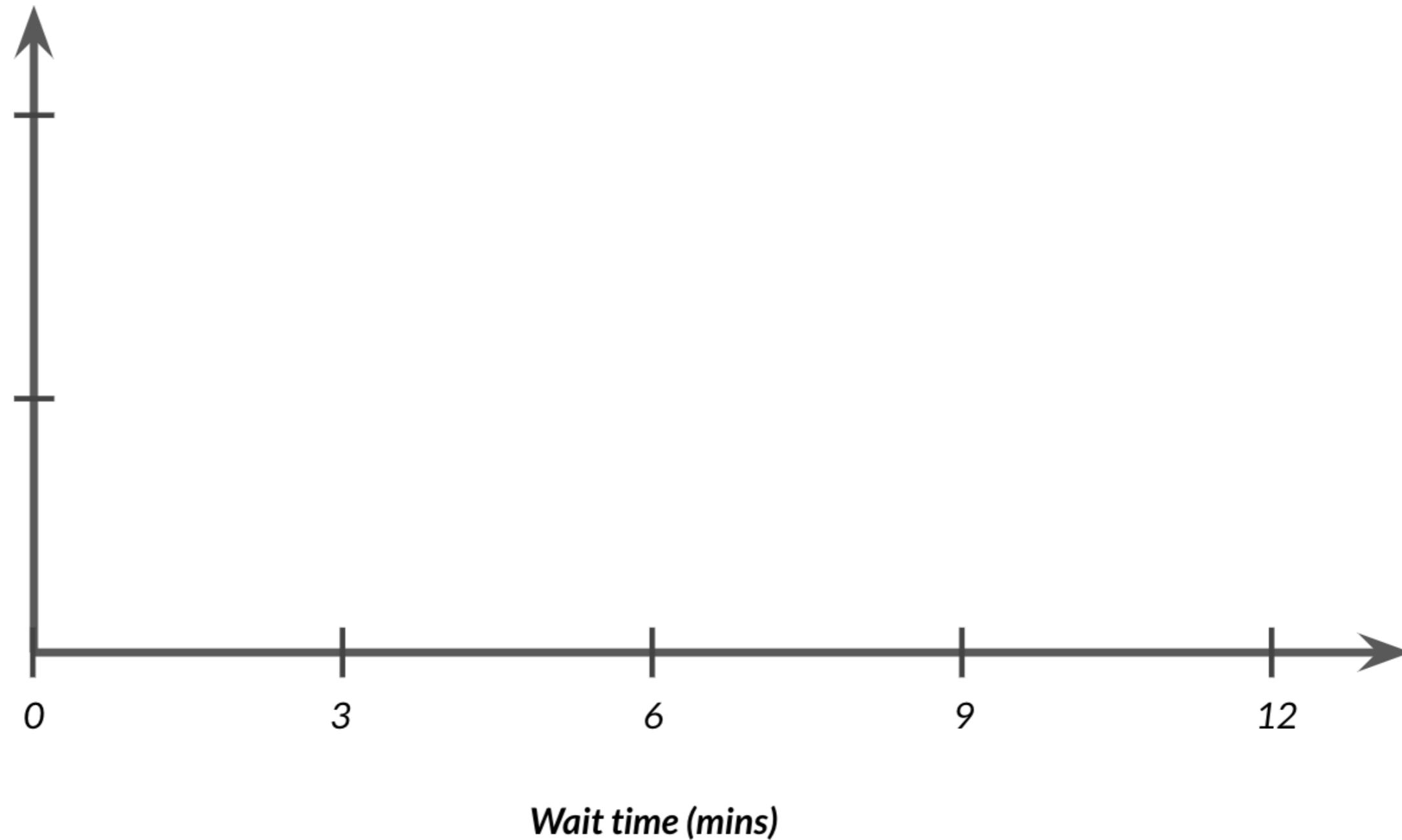
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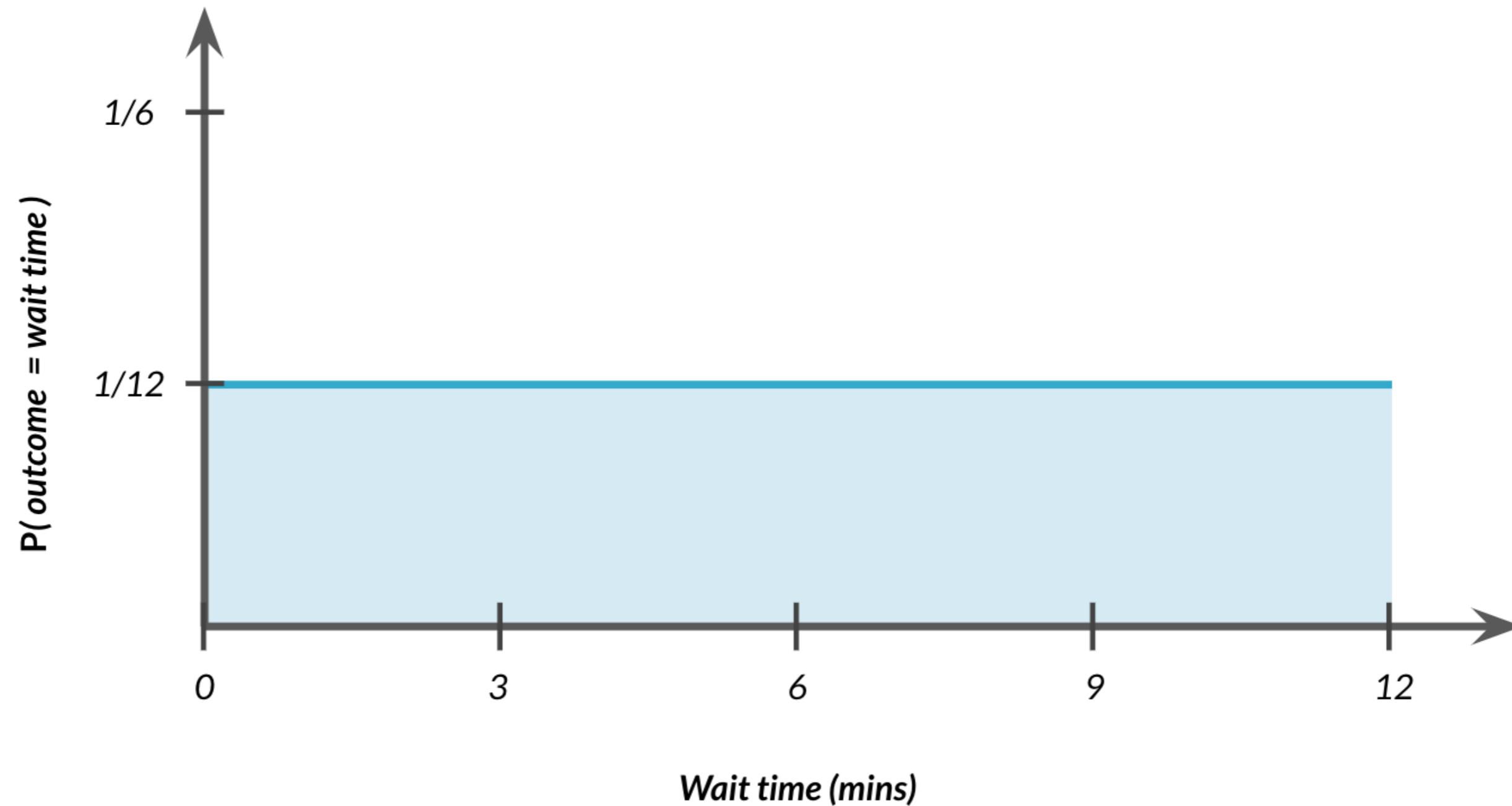
Waiting for the bus



Continuous uniform distribution

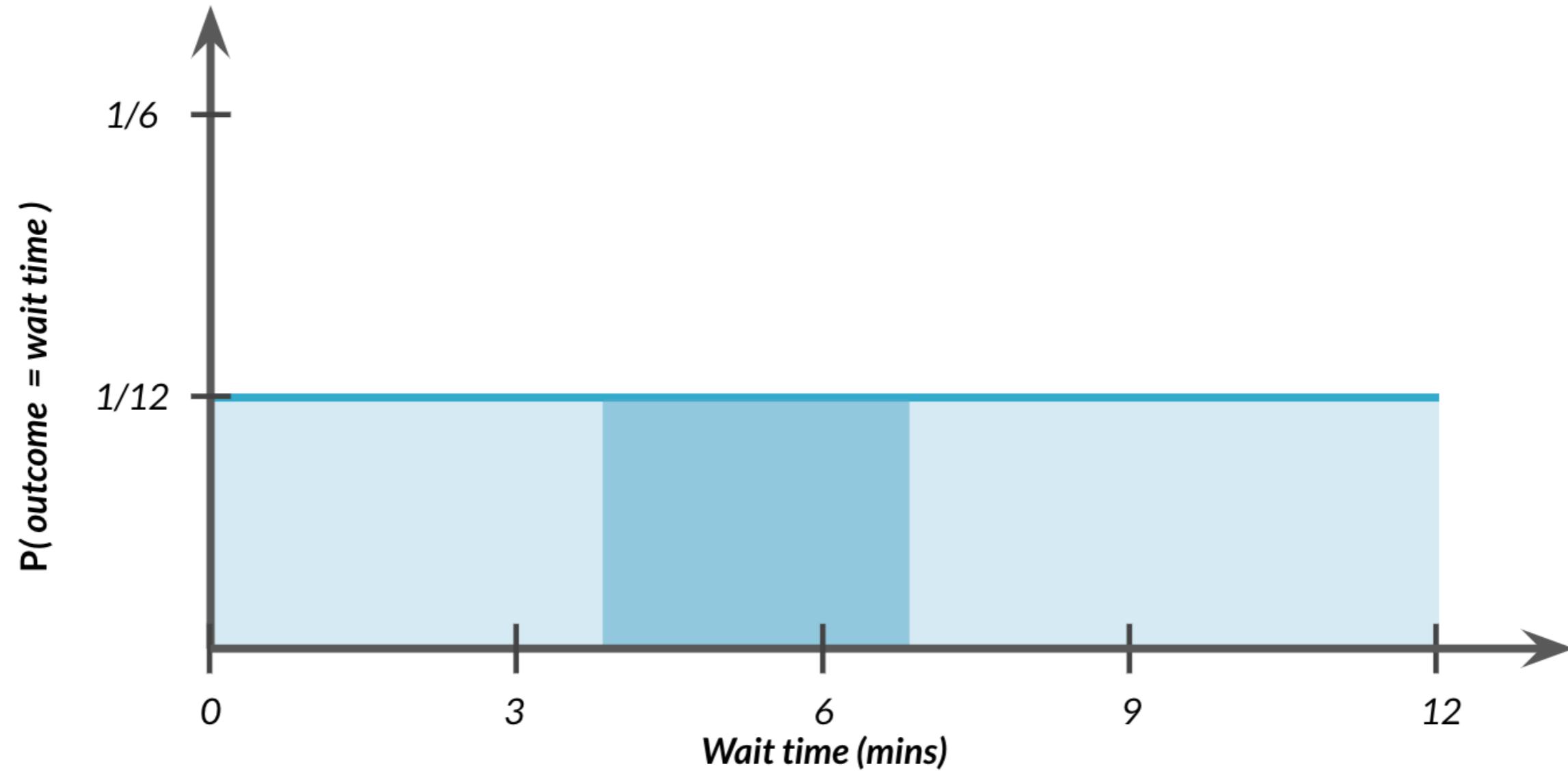


Continuous uniform distribution



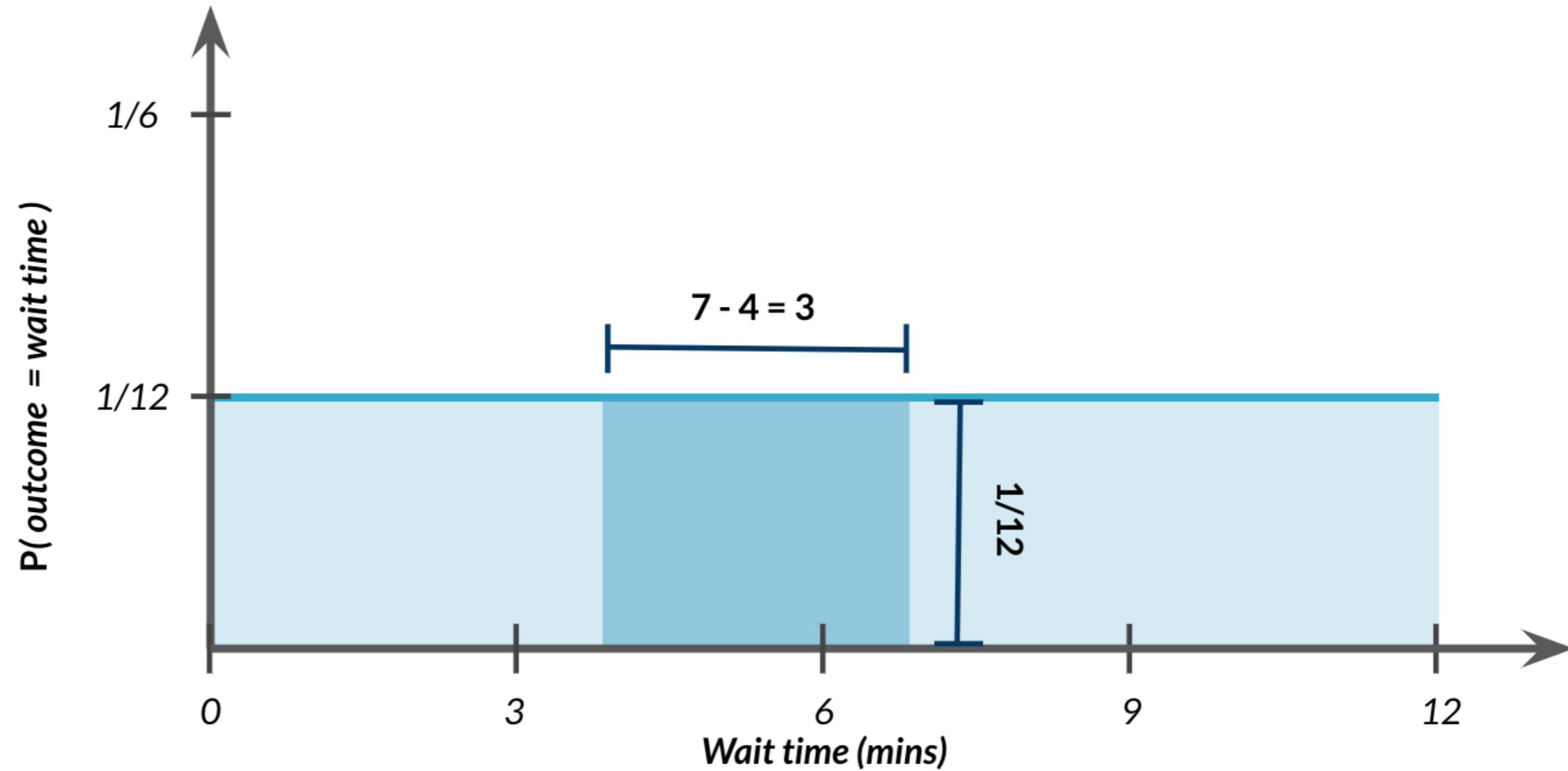
Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = ?$$



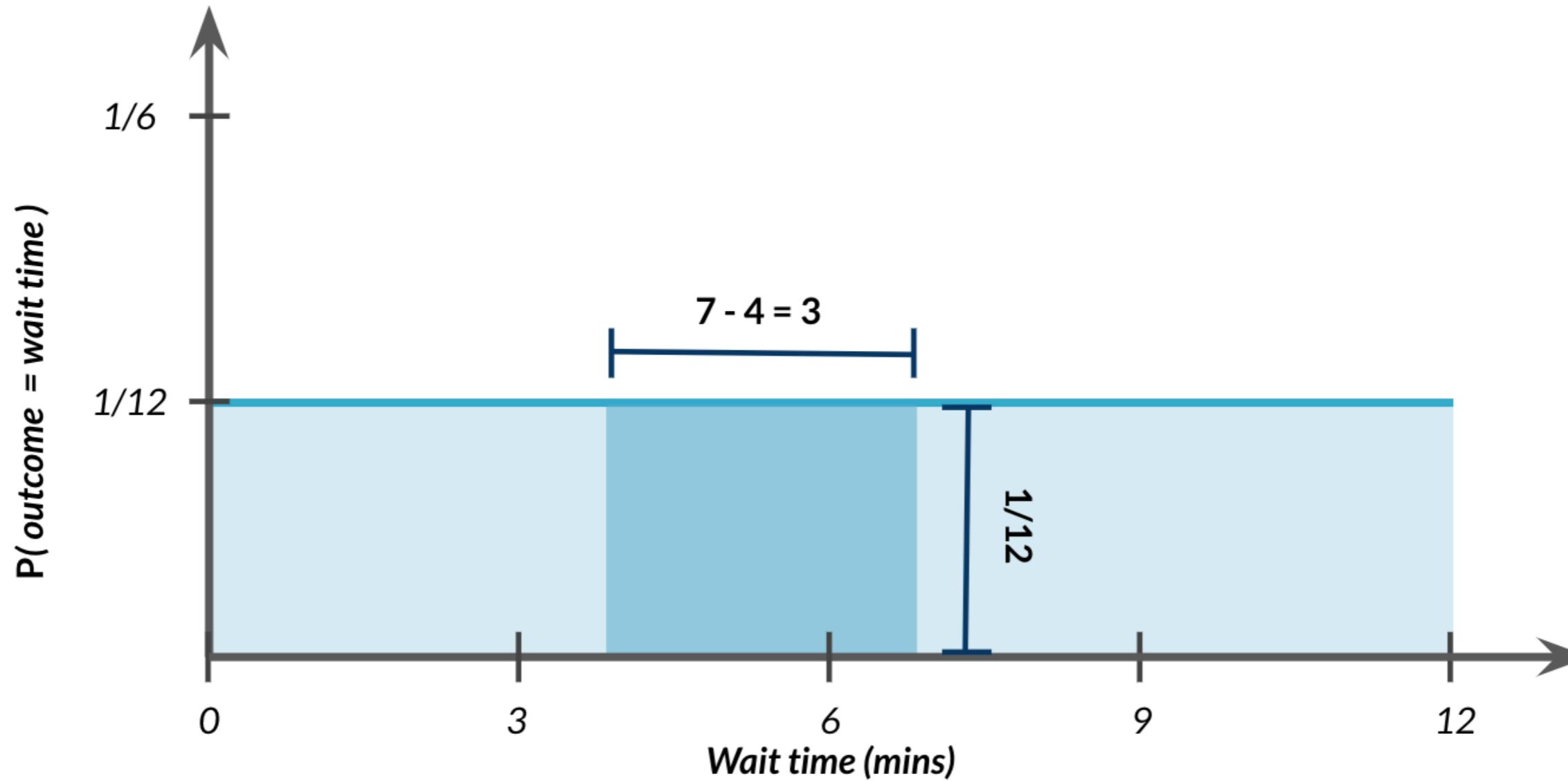
Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = ?$$



Probability still = area

$$P(4 \leq \text{wait time} \leq 7) = 3 \times 1/12 = 3/12$$

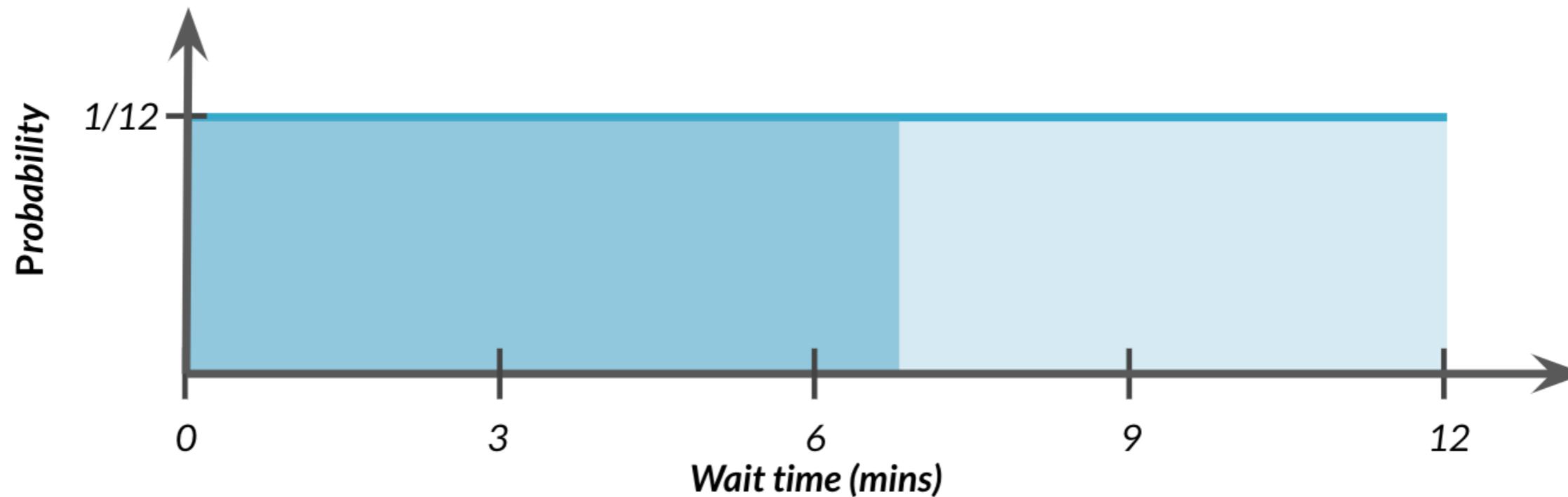


Waiting seven minutes or less

$$P(\text{wait time} \leq 7) = ?$$

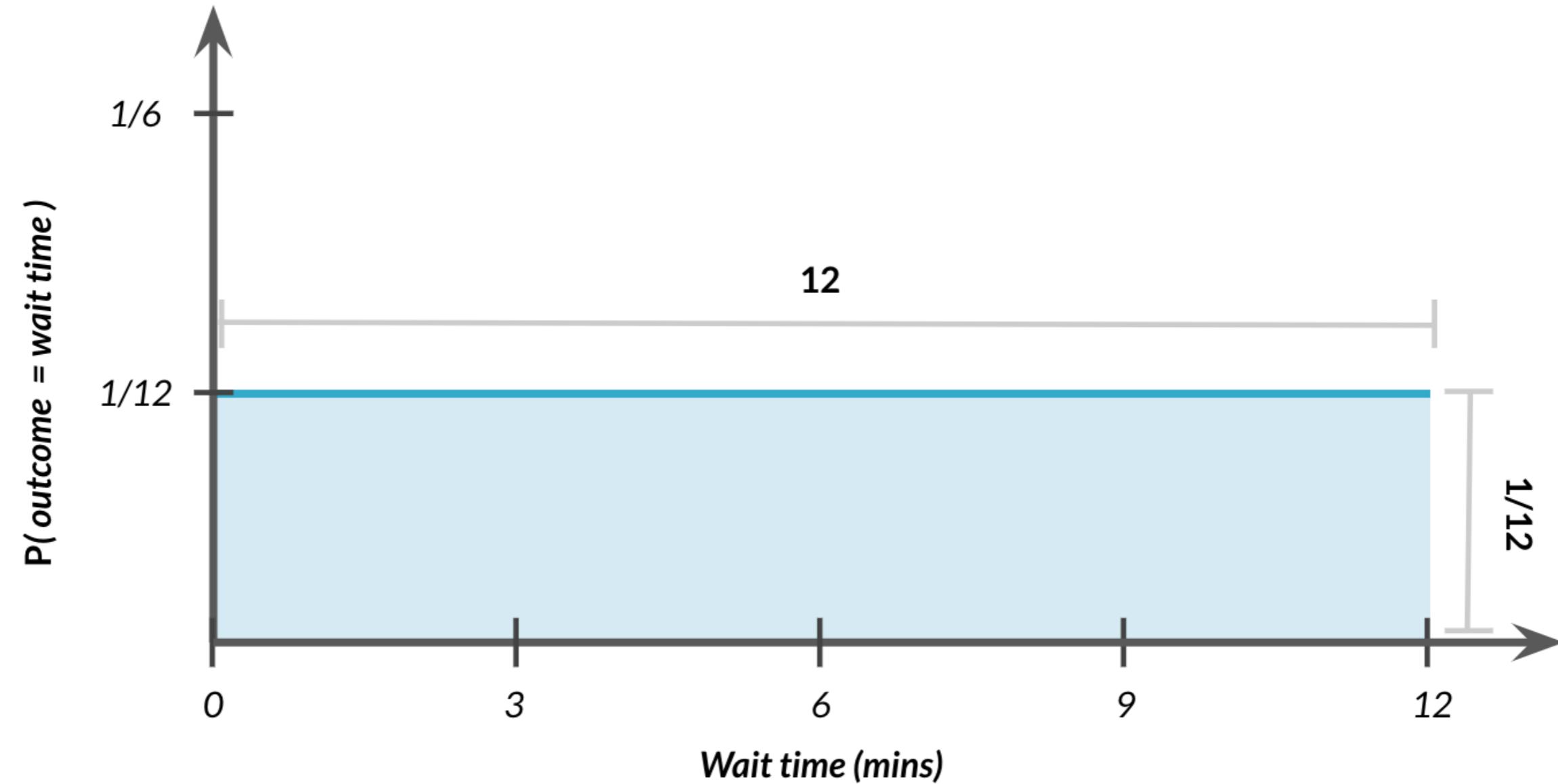
$$P(\text{wait time} \leq 7) = \frac{7 - 0}{12}$$

$$P(\text{wait time} \leq 7) = \frac{7}{12} = 58.33\%$$



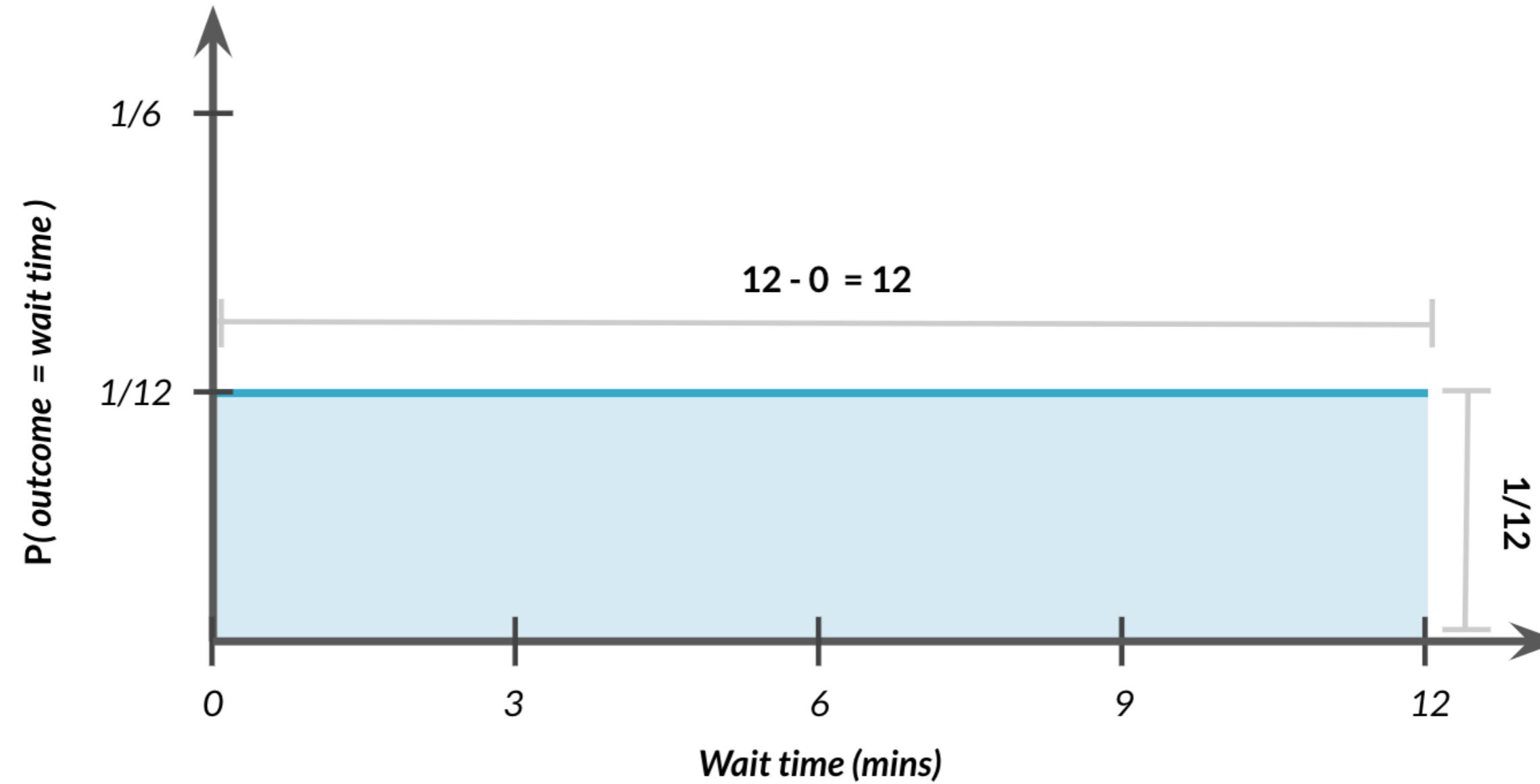
Total area = 1

$$P(0 \leq \text{wait time} \leq 12) = ?$$



Total area = 1

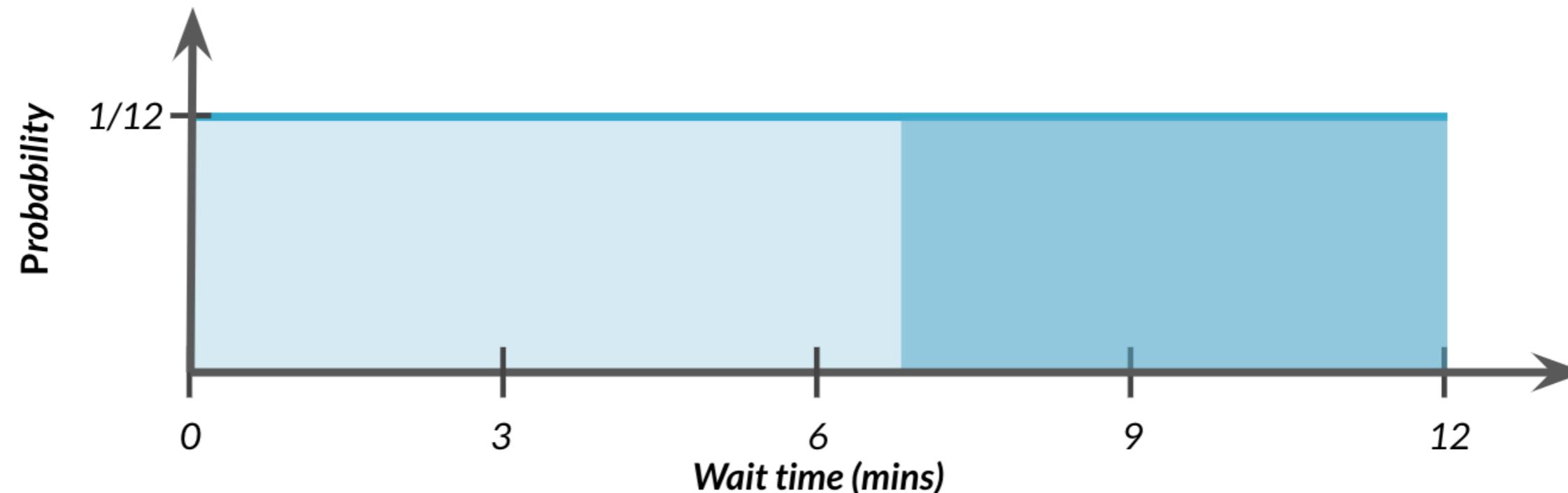
$$P(0 \leq \text{outcome} \leq 12) = 12 \times 1/12 = 1$$



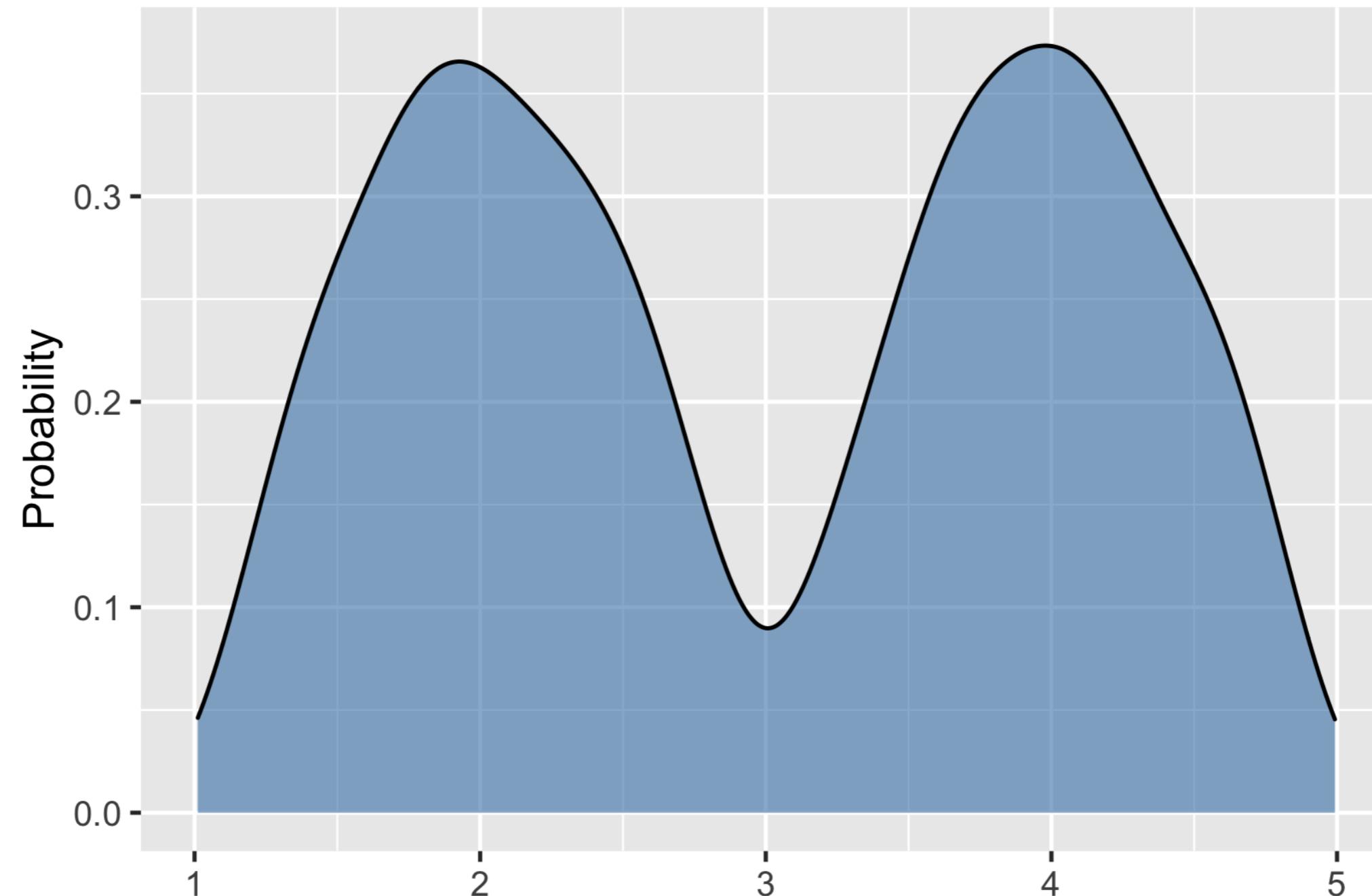
Probability of waiting more than seven minutes

$$P(\text{wait time} \geq 7) = 1 - \frac{7}{12}$$

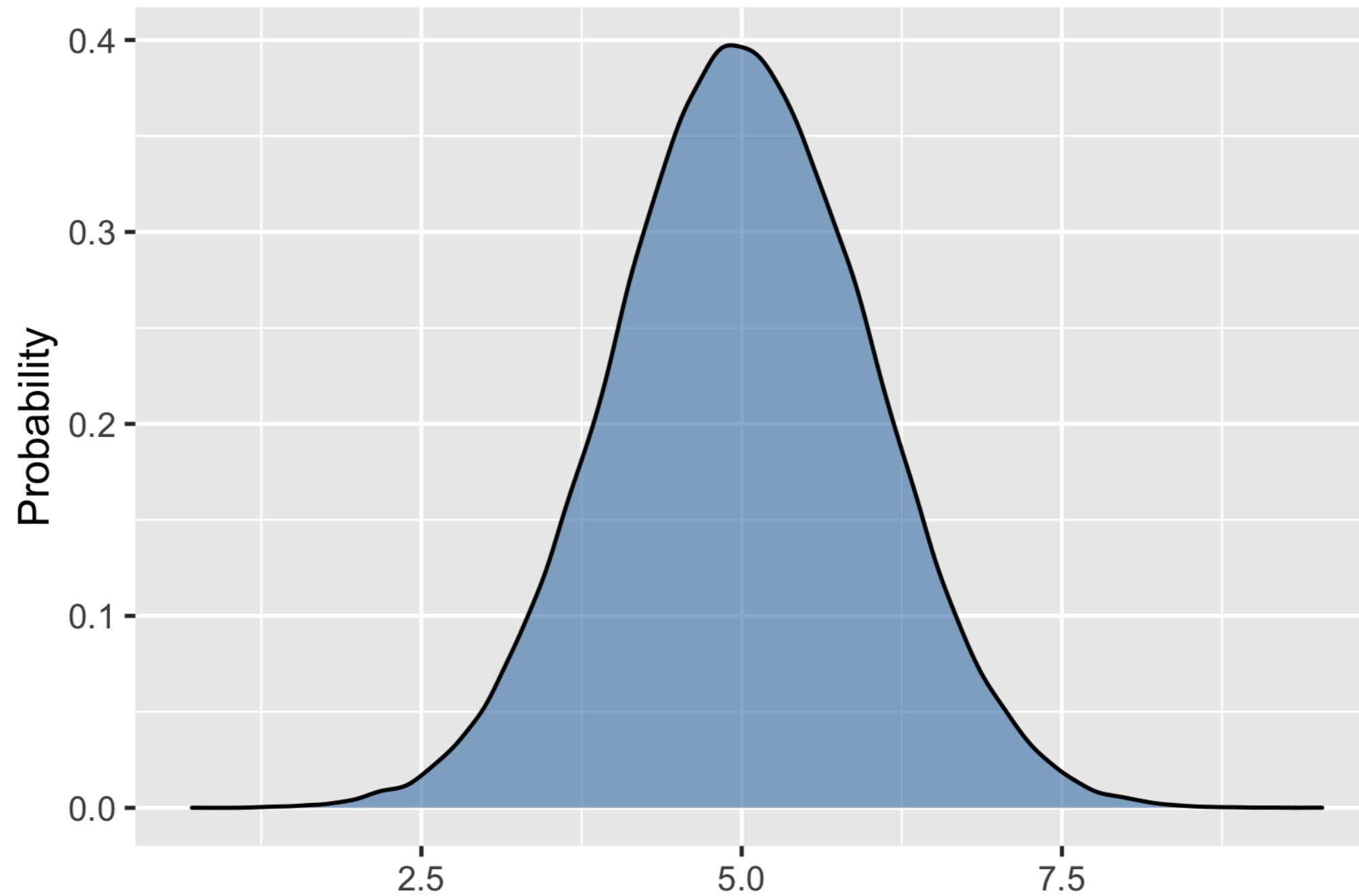
$$P(\text{wait time} \geq 7) = \frac{5}{12} = 41.67\%$$



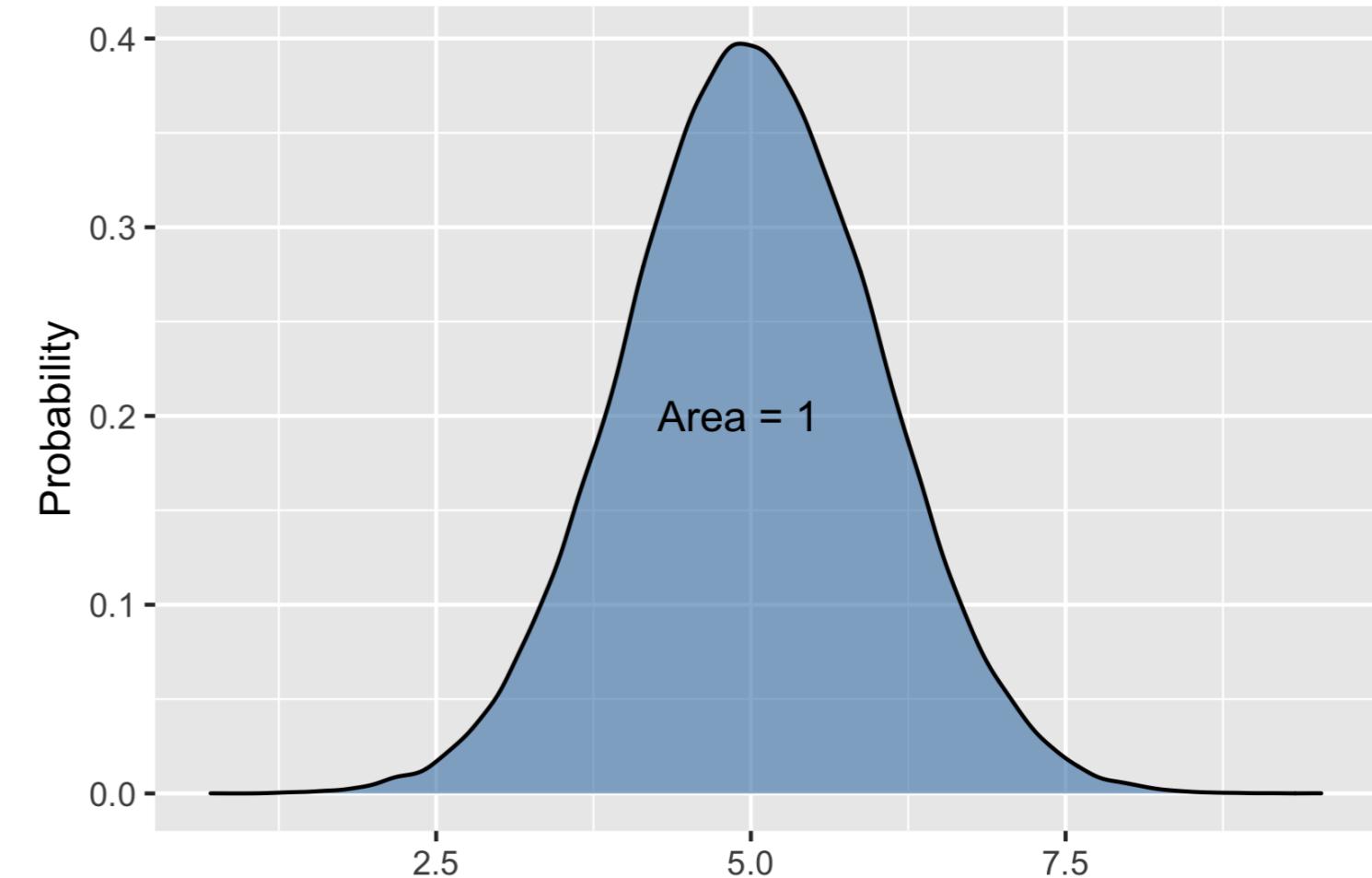
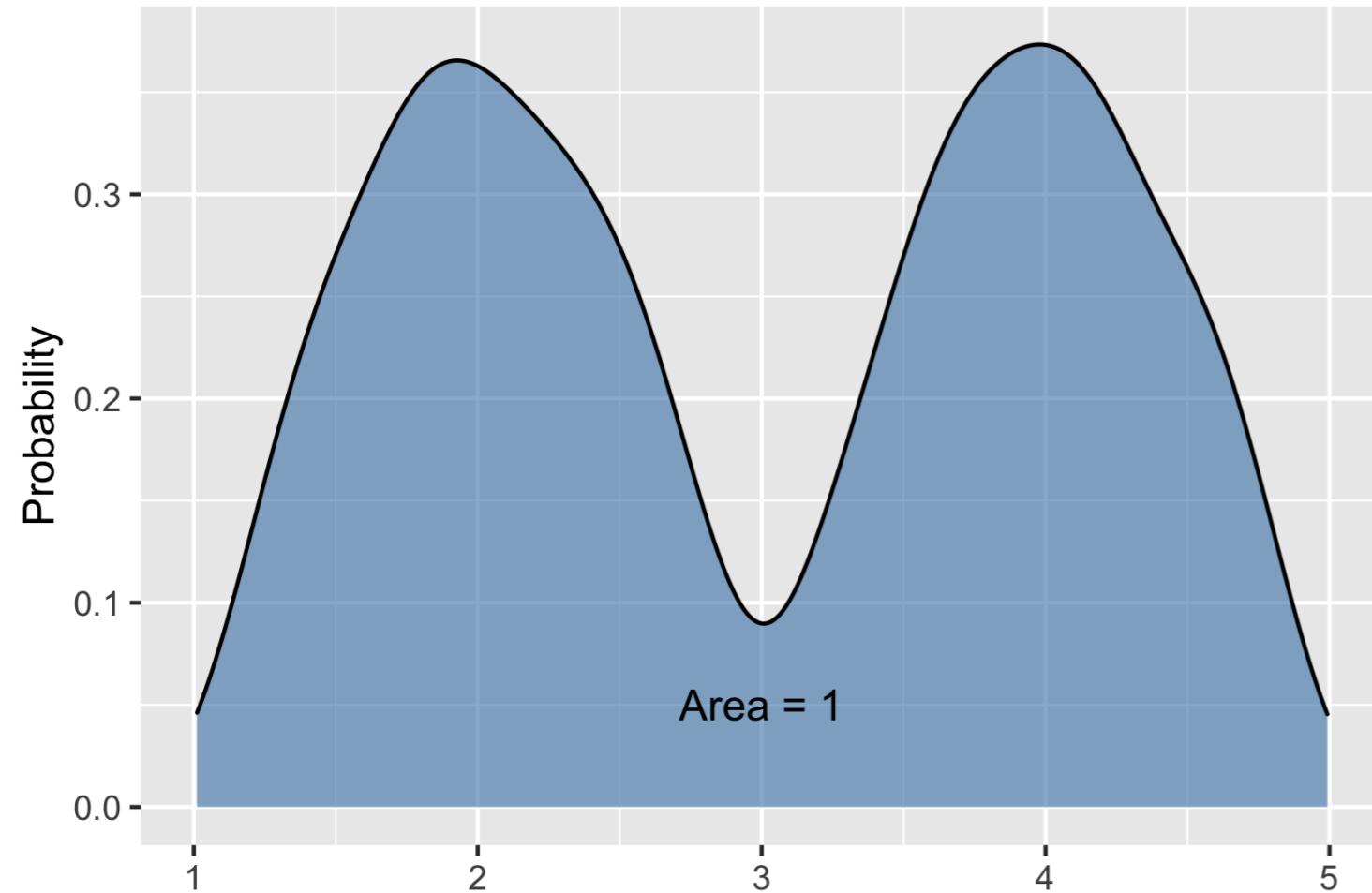
Bimodal distribution



The normal distribution



Total area still = 1



Let's practice!

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