

What are the chances?

INTRODUCTION TO STATISTICS IN PYTHON



Maggie Matsui

Senior Content Developer, DataCamp

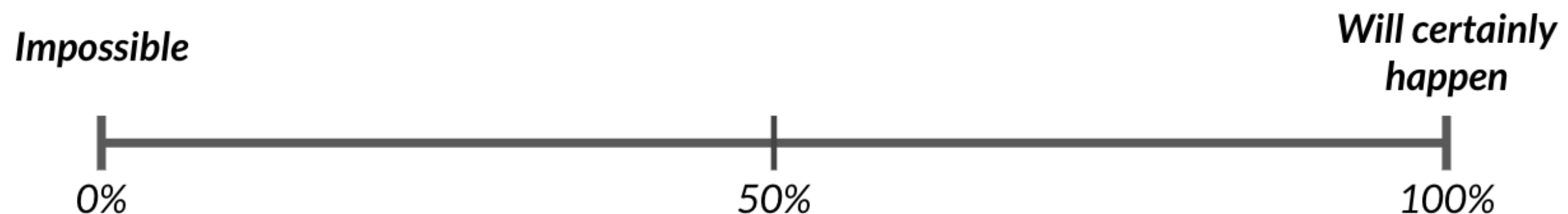
Measuring chance

What's the probability of an event?

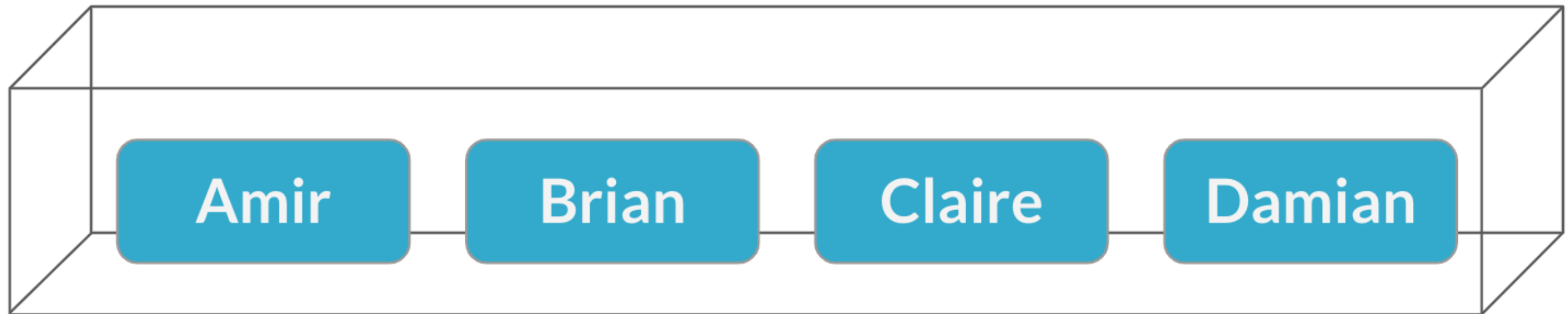
$$P(\text{event}) = \frac{\# \text{ ways event can happen}}{\text{total } \# \text{ of possible outcomes}}$$

Example: a coin flip

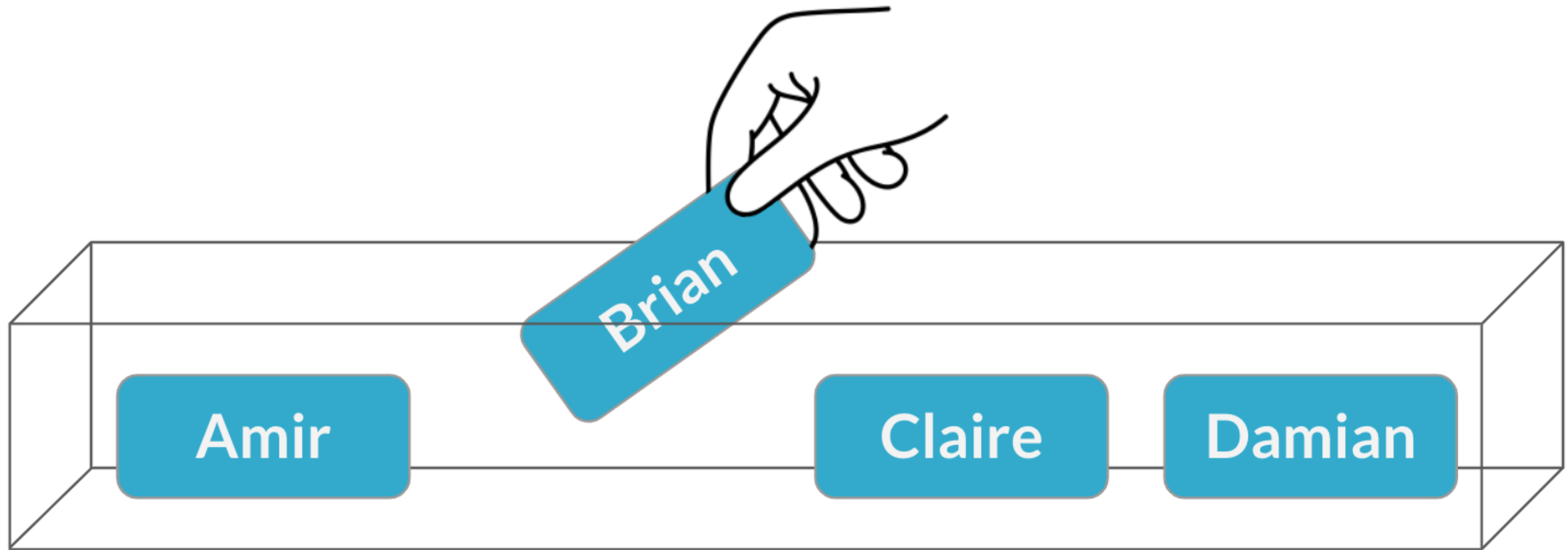
$$P(\text{heads}) = \frac{1 \text{ way to get heads}}{2 \text{ possible outcomes}} = \frac{1}{2} = 50\%$$



Assigning salespeople



Assigning salespeople



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

Sampling from a DataFrame

```
print(sales_counts)
```

	name	n_sales
0	Amir	178
1	Brian	128
2	Claire	75
3	Damian	69

```
sales_counts.sample()
```

	name	n_sales
1	Brian	128

```
sales_counts.sample()
```

	name	n_sales
2	Claire	75

Setting a random seed

```
np.random.seed(10)  
sales_counts.sample()
```

	name	n_sales
1	Brian	128

```
np.random.seed(10)  
sales_counts.sample()
```

	name	n_sales
1	Brian	128

```
np.random.seed(10)  
sales_counts.sample()
```

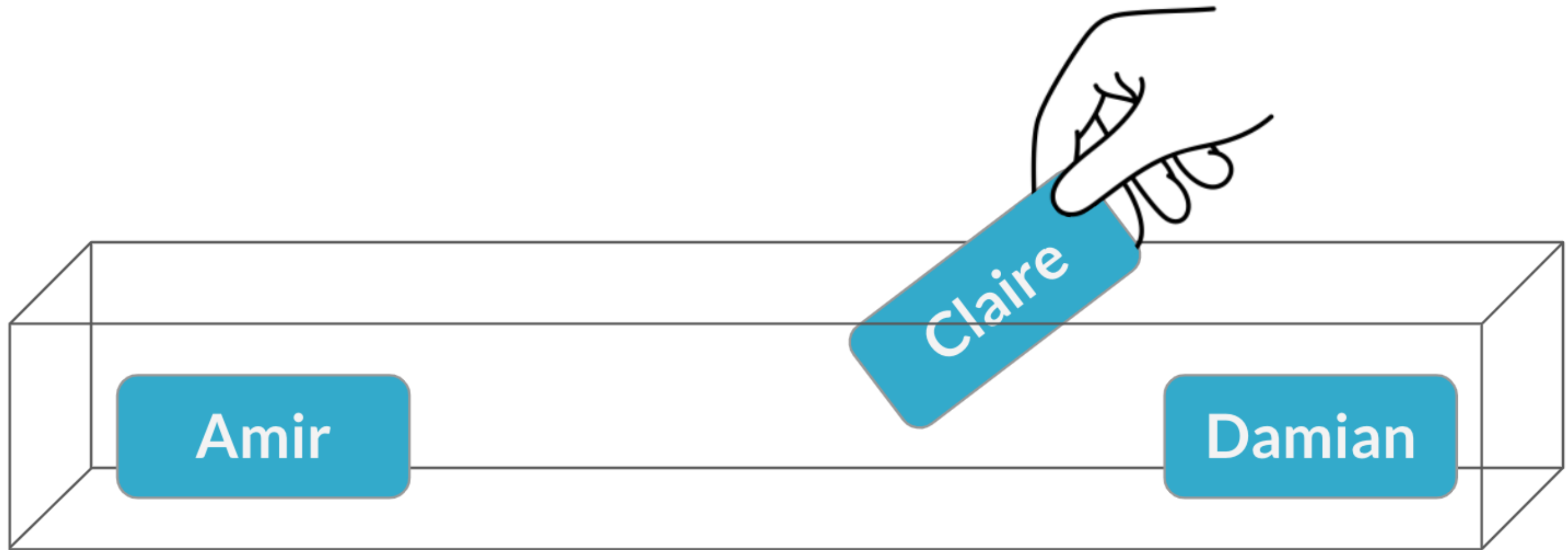
	name	n_sales
1	Brian	128

A second meeting

Sampling without replacement



A second meeting



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

Sampling twice in Python

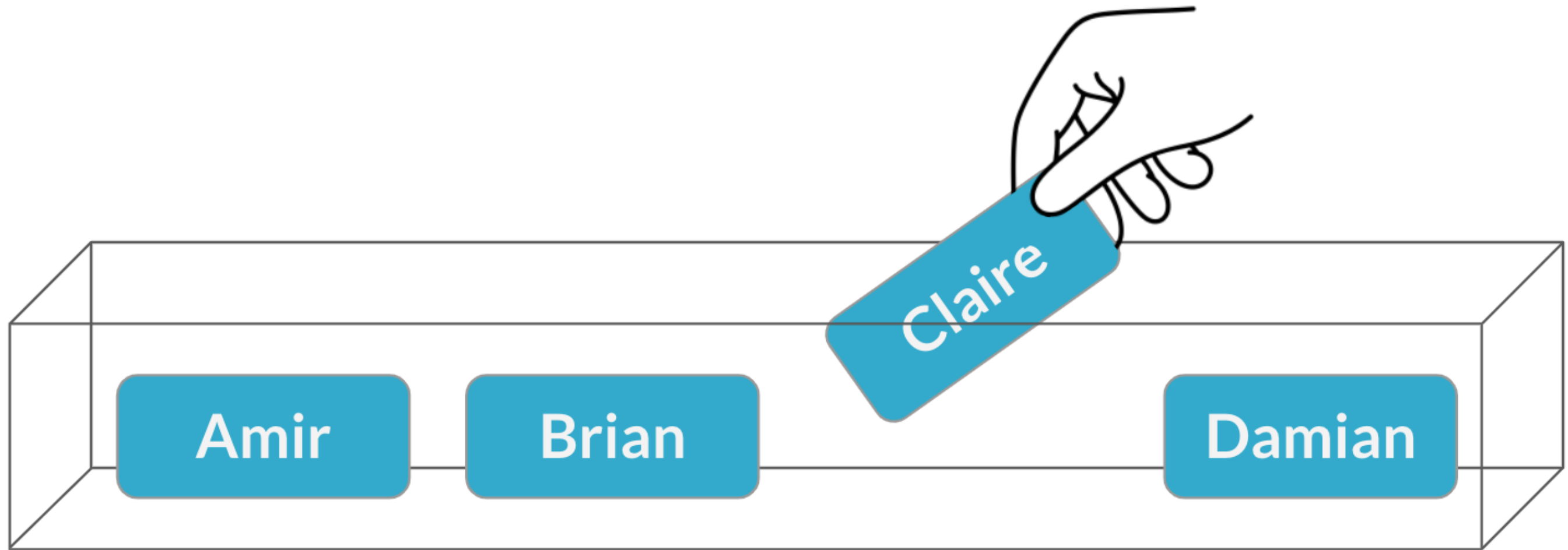
```
sales_counts.sample(2)
```

	name	n_sales
1	Brian	128
2	Claire	75

Sampling with replacement



Sampling with replacement



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

Sampling with/without replacement in Python

```
sales_counts.sample(5, replace = True)
```

```
   name  n_sales
1  Brian     128
2  Claire     75
1  Brian     128
3  Damian     69
0   Amir     178
```

Independent events

Two events are *independent* if the probability of the second event *isn't* affected by the outcome of the first event.

Sampling with Replacement

First pick

Second pick

Amir

Brian

Claire

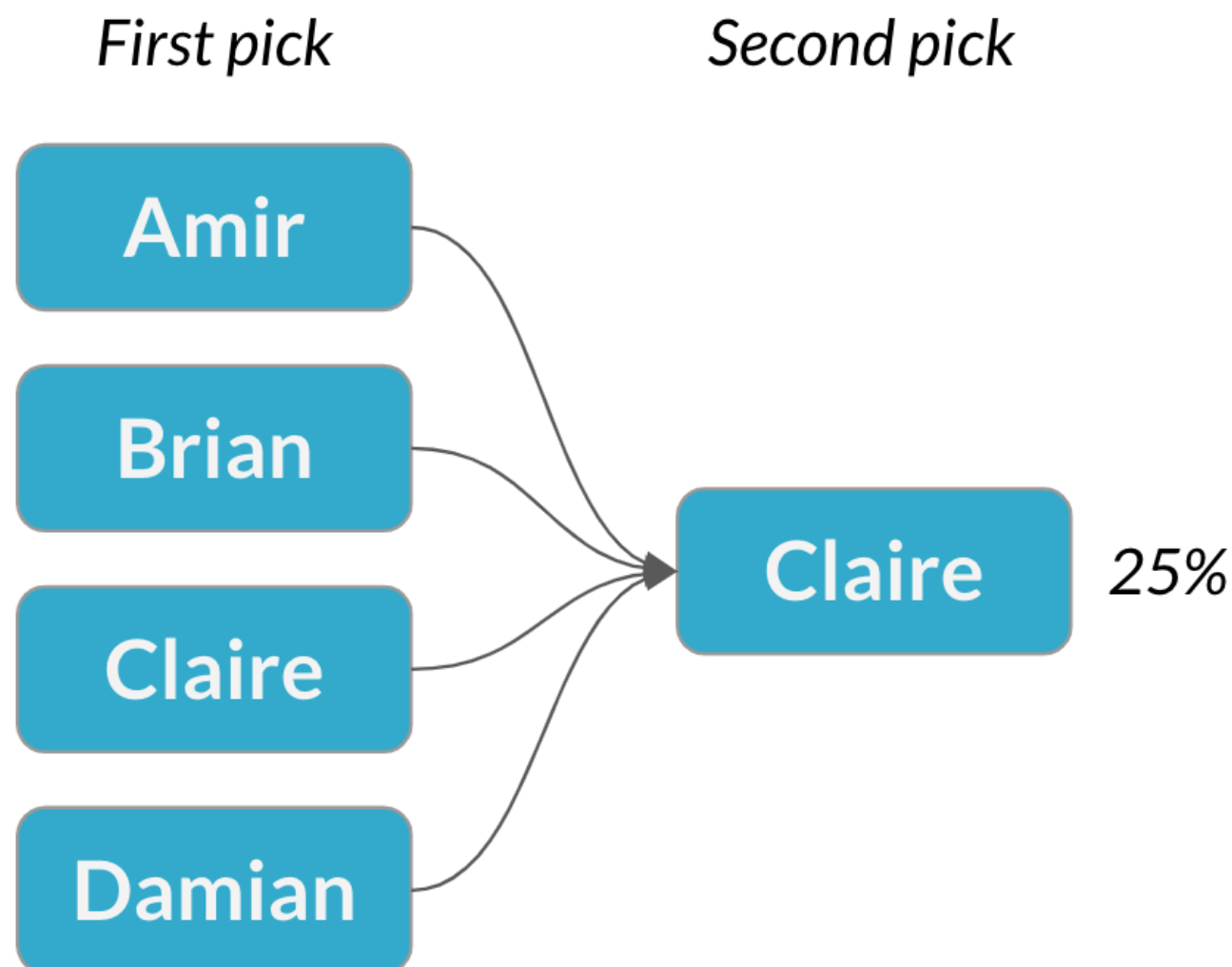
Damian

Independent events

Two events are *independent* if the probability of the second event *isn't* affected by the outcome of the first event.

Sampling with replacement = each pick is independent

Sampling with Replacement



Dependent events

Two events are *dependent* if the 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

Two events are **dependent** if the 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

Claire

0%

Dependent events

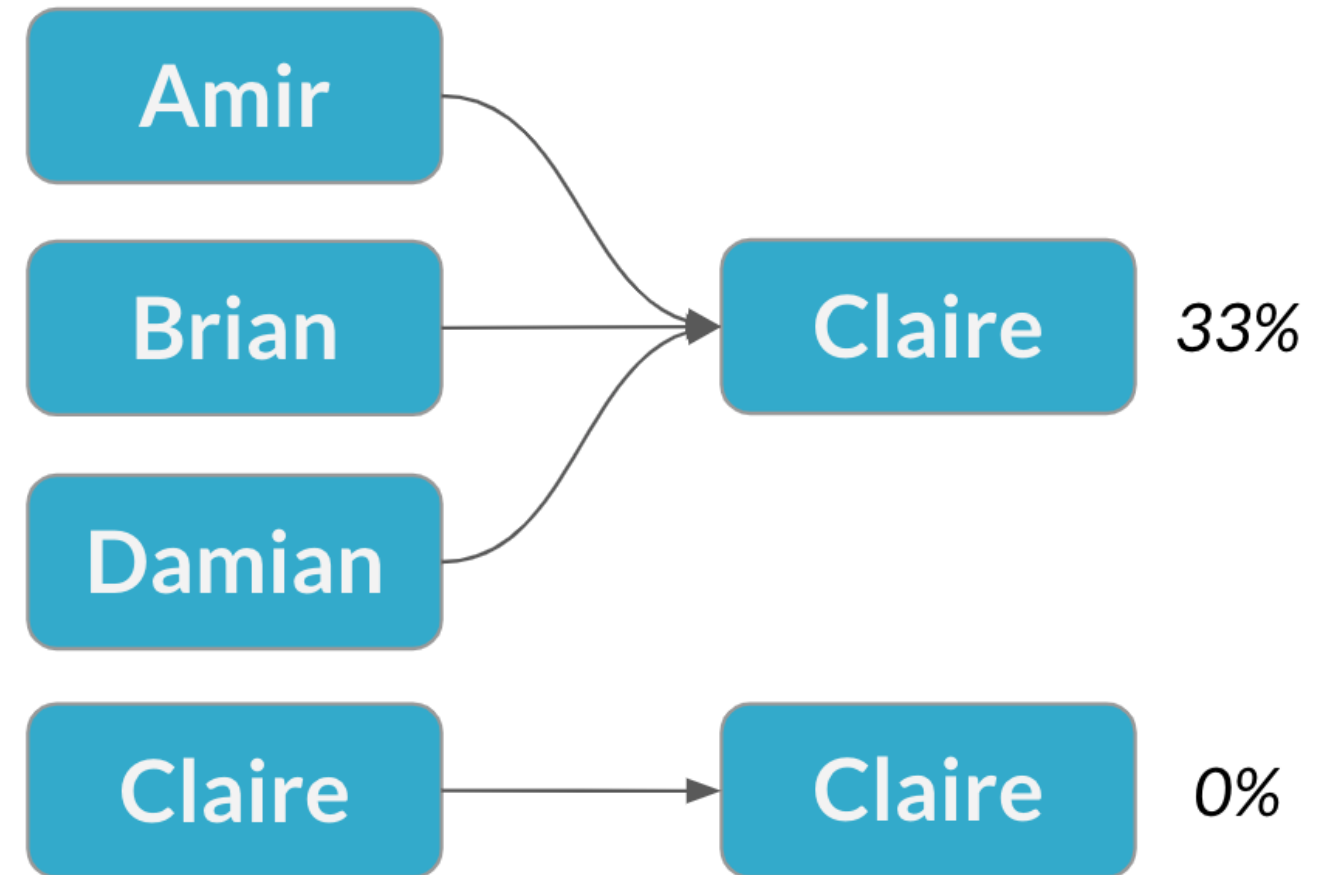
Two events are **dependent** if the probability of the second event **is** affected by the outcome of the first event.

Sampling without replacement = each pick is dependent

Sampling without Replacement

First pick

Second pick



Let's practice!

INTRODUCTION TO STATISTICS IN PYTHON

Discrete distributions

INTRODUCTION TO STATISTICS IN PYTHON



Maggie Matsui

Content Developer, DataCamp

Rolling the dice



Rolling the dice



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



$\frac{1}{6}$



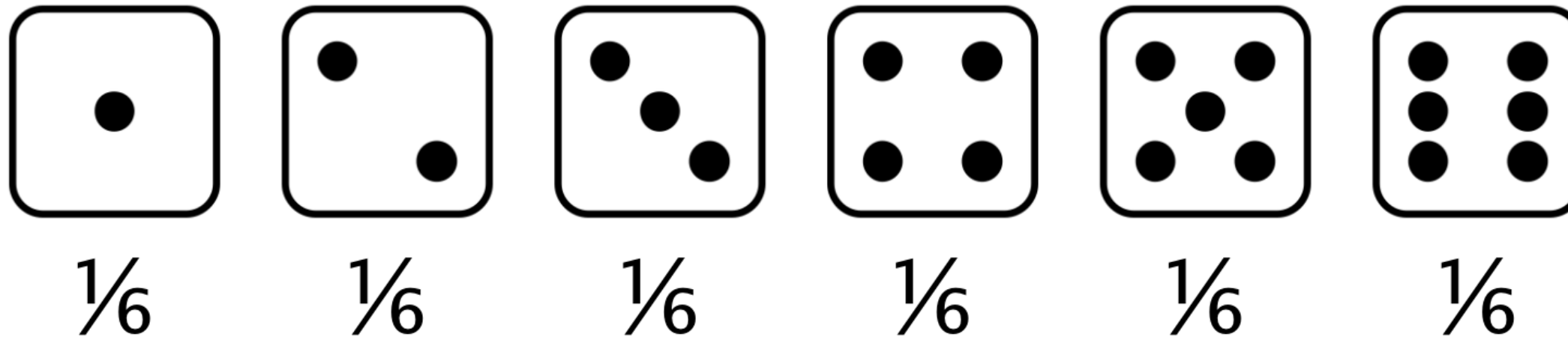
$\frac{1}{6}$

Choosing salespeople



Probability distribution

Describes the probability of each possible outcome in a scenario



Expected value: mean of a probability distribution

Expected value of a fair die roll =

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

Visualizing a probability distribution



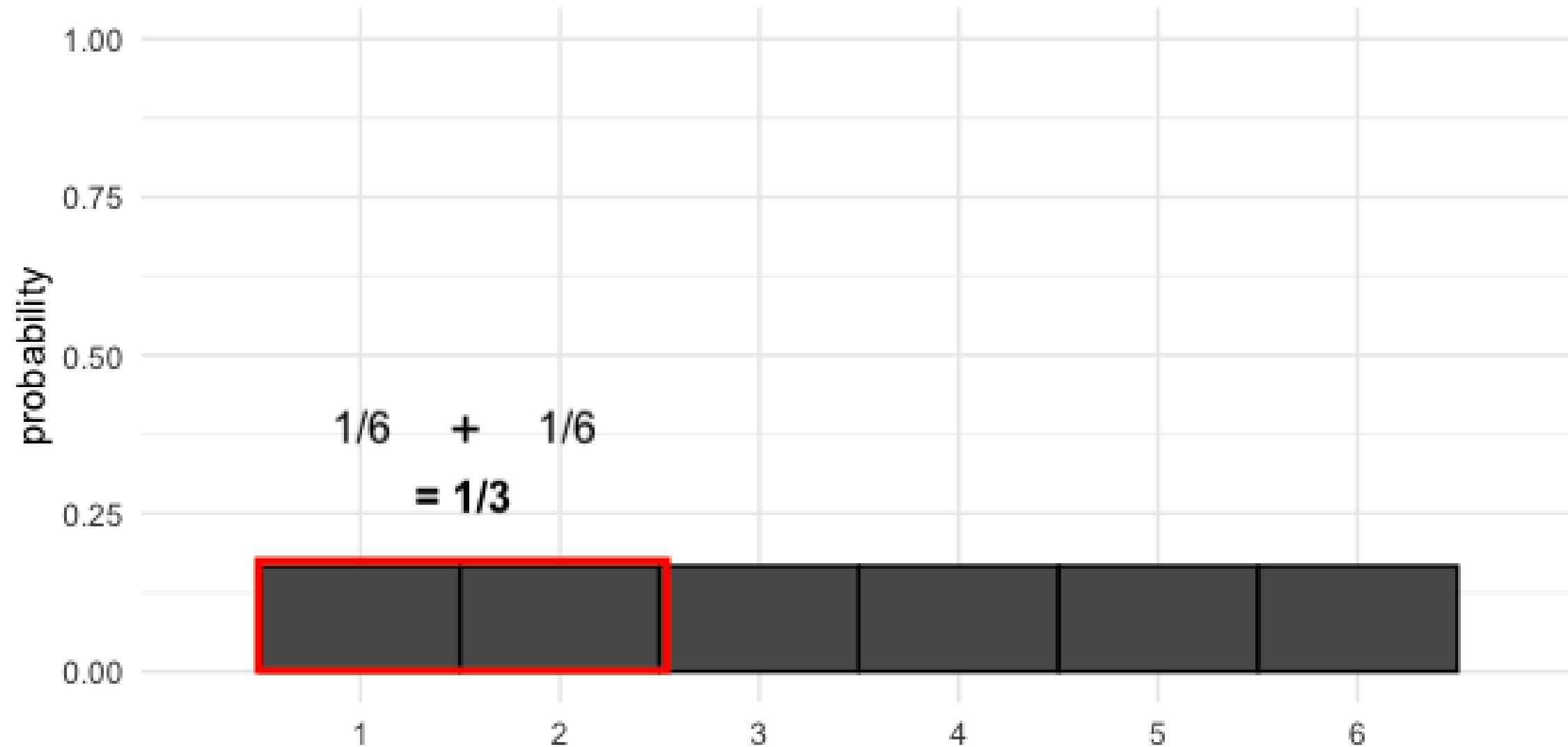
Probability = area

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

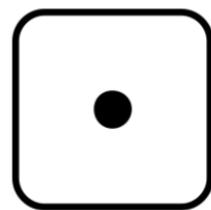


Probability = area

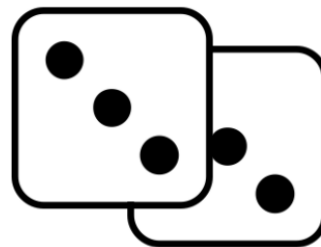
$$P(\text{die roll}) \leq 2 = 1/3$$



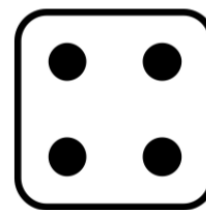
Uneven die



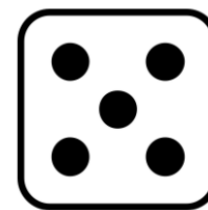
$\frac{1}{6}$



$\frac{1}{3}$



$\frac{1}{6}$



$\frac{1}{6}$

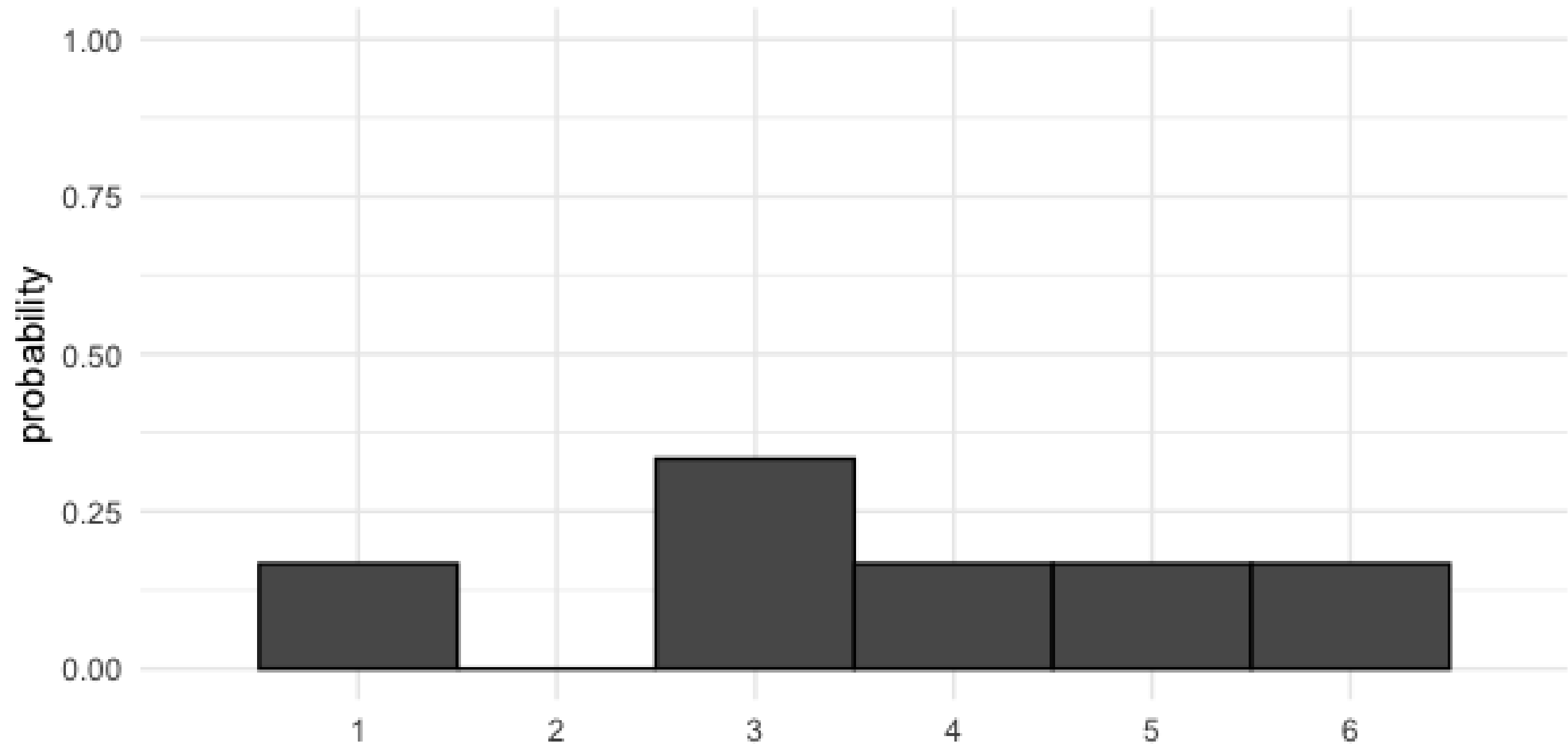


$\frac{1}{6}$

Expected value of uneven die roll =

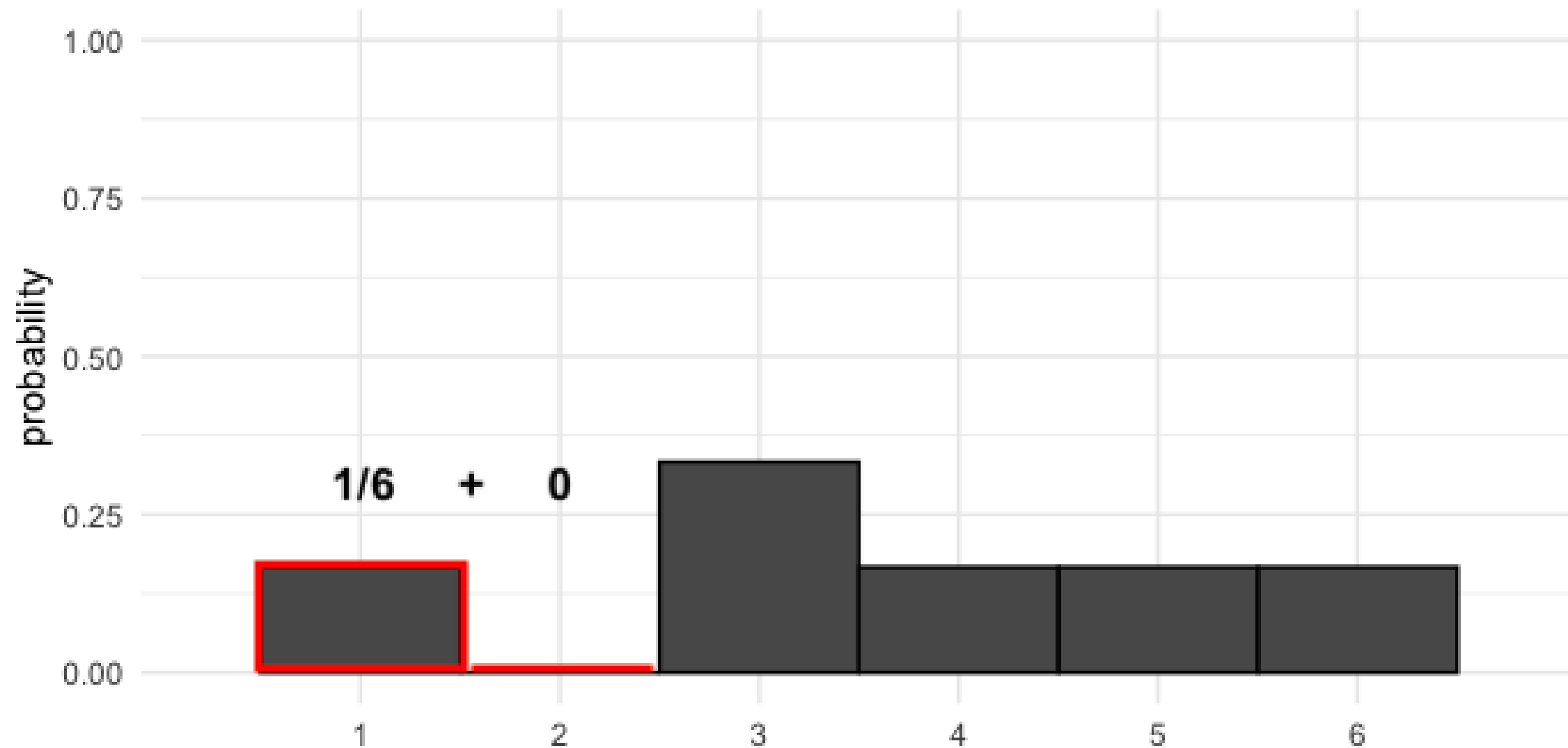
$$(1 \times \frac{1}{6}) + (2 \times 0) + (3 \times \frac{1}{3}) + (4 \times \frac{1}{6}) + (5 \times \frac{1}{6}) + (6 \times \frac{1}{6}) = 3.67$$

Visualizing uneven probabilities



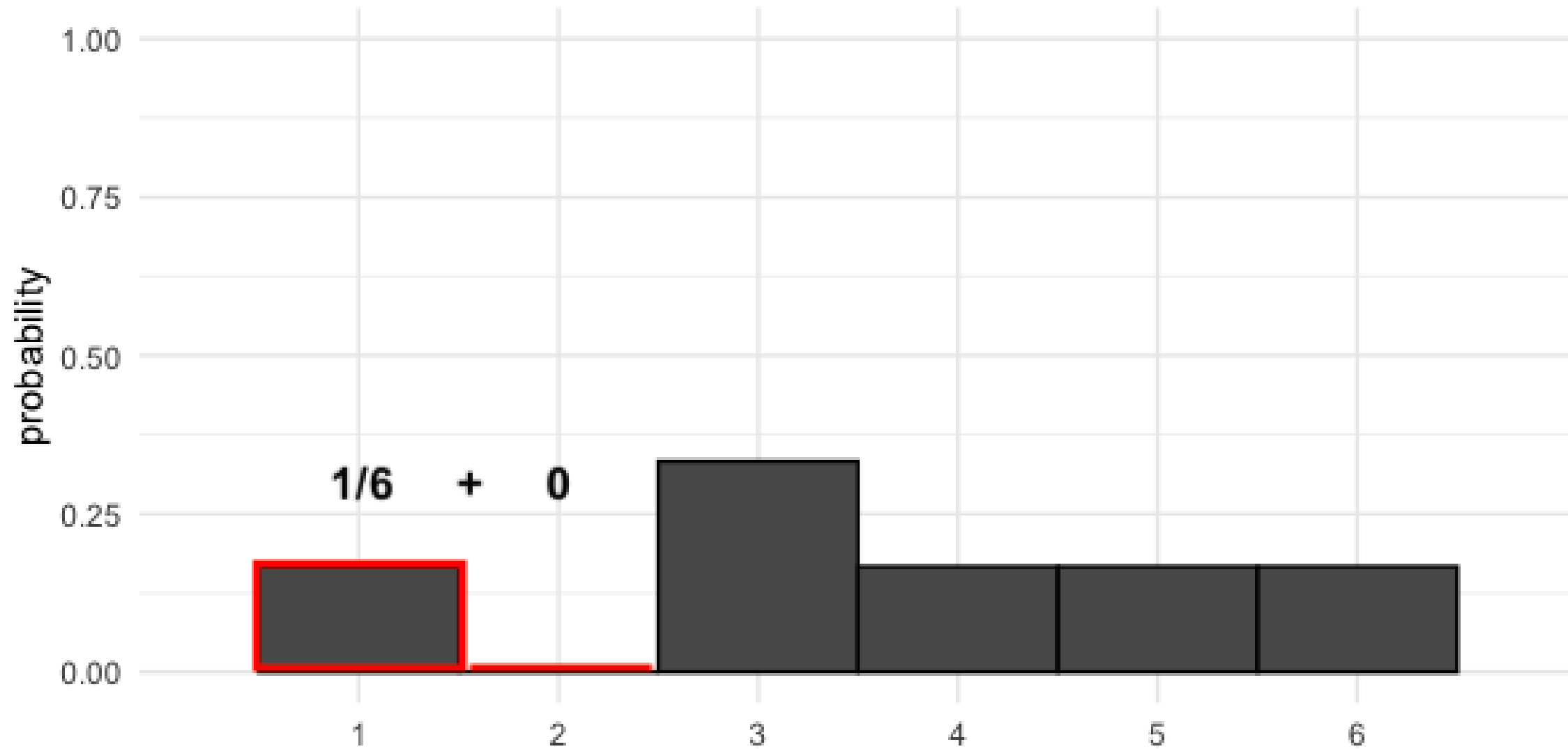
Adding areas

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



Adding areas

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



Discrete probability distributions

Describe probabilities for discrete outcomes

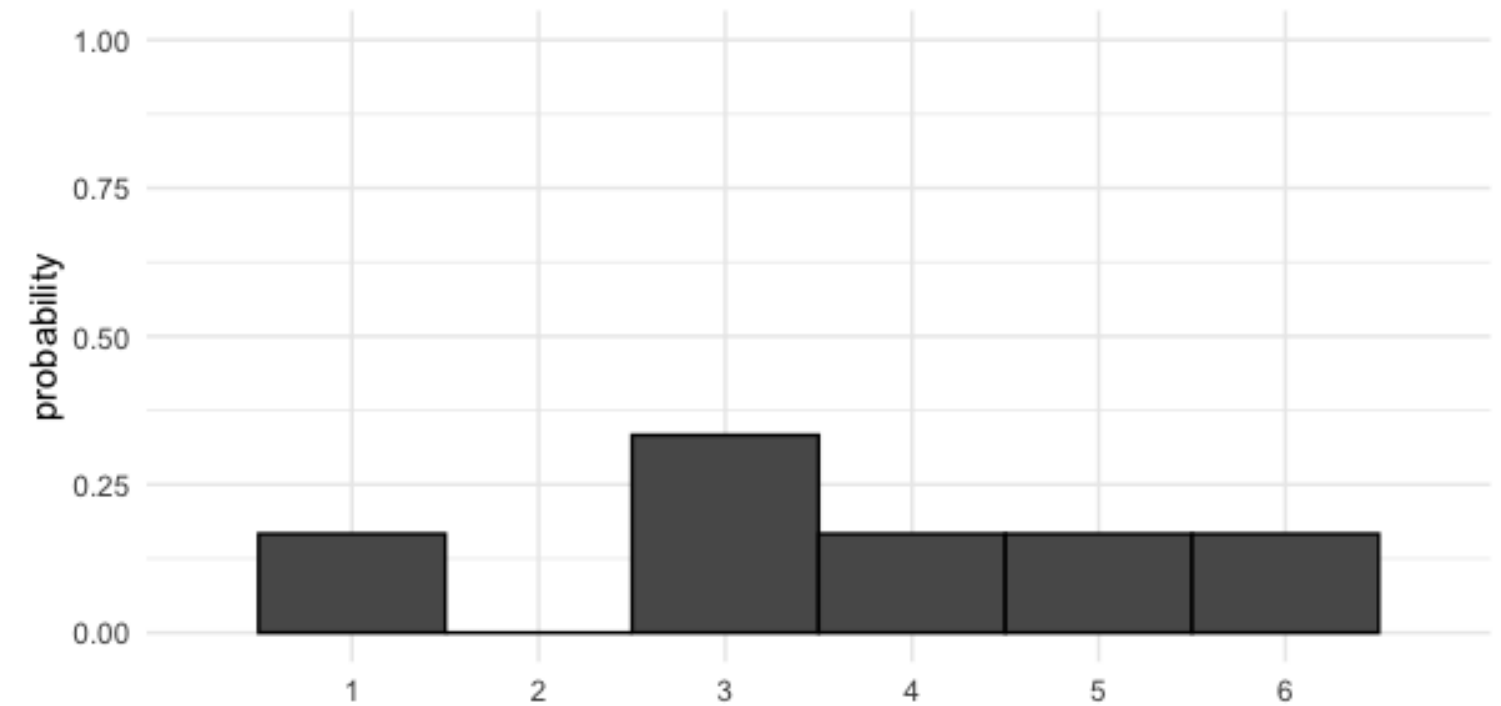
Fair die



Discrete uniform

distribution

Uneven die



Sampling from discrete distributions

```
print(die)
```

	number	prob
0	1	0.166667
1	2	0.166667
2	3	0.166667
3	4	0.166667
4	5	0.166667
5	6	0.166667

```
np.mean(die['number'])
```

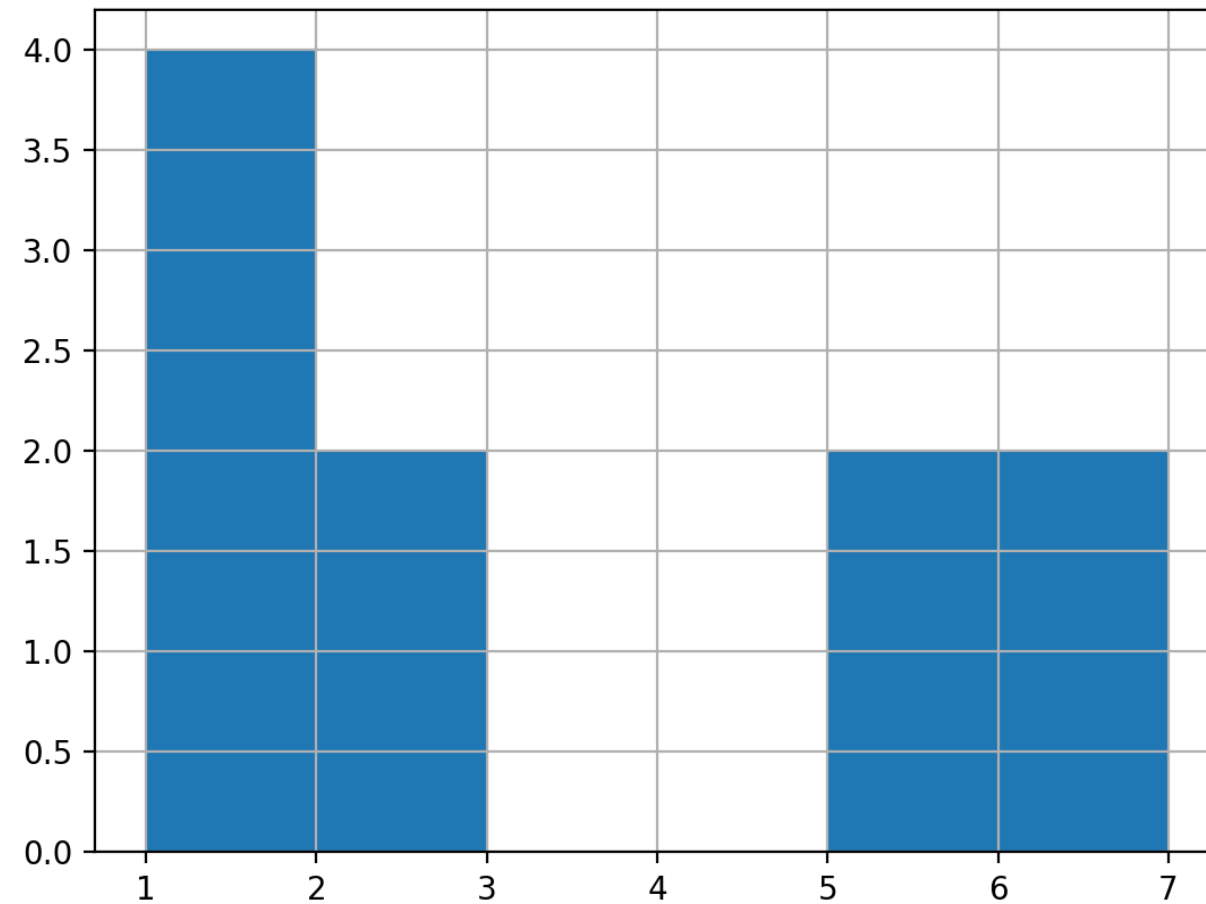
```
3.5
```

```
rolls_10 = die.sample(10, replace = True)  
rolls_10
```

	number	prob
0	1	0.166667
0	1	0.166667
4	5	0.166667
1	2	0.166667
0	1	0.166667
0	1	0.166667
5	6	0.166667
5	6	0.166667
...		

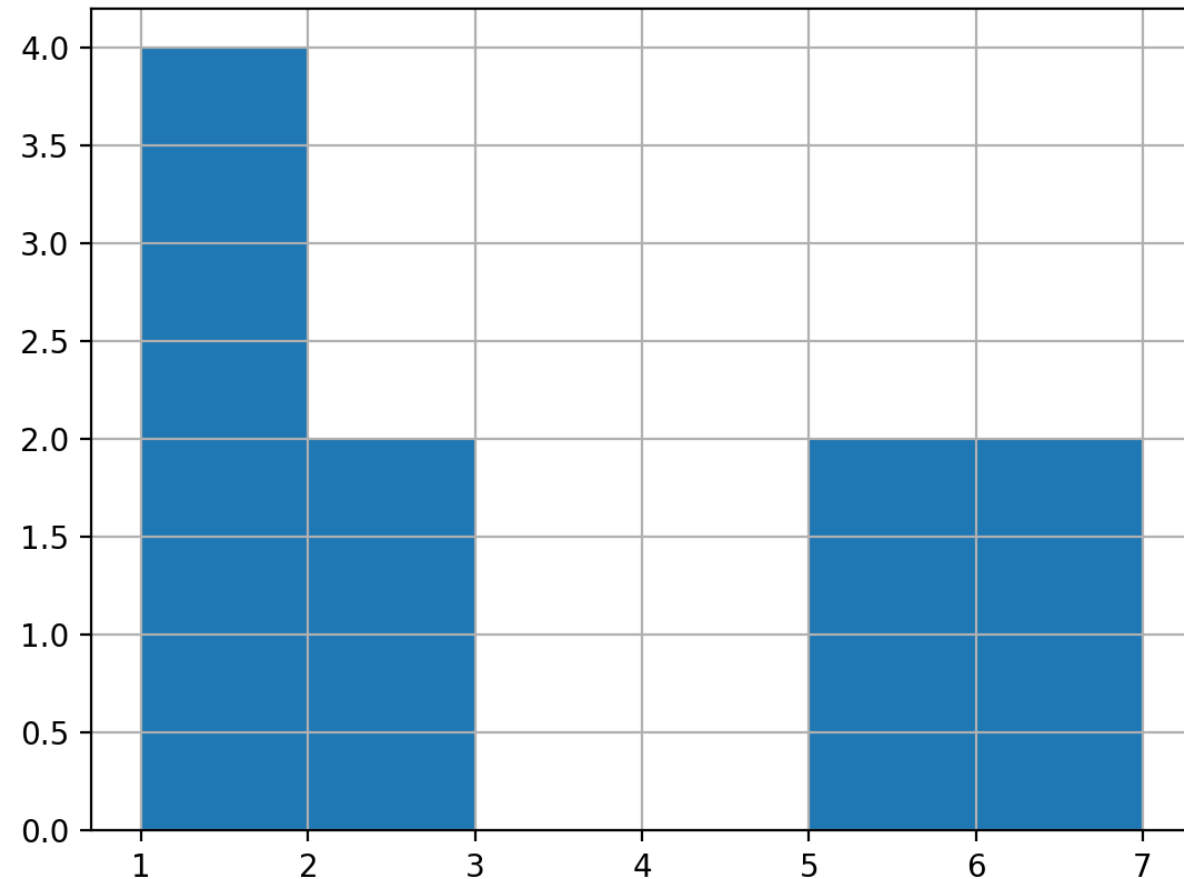
Visualizing a sample

```
rolls_10['number'].hist(bins=np.linspace(1,7,7))  
plt.show()
```



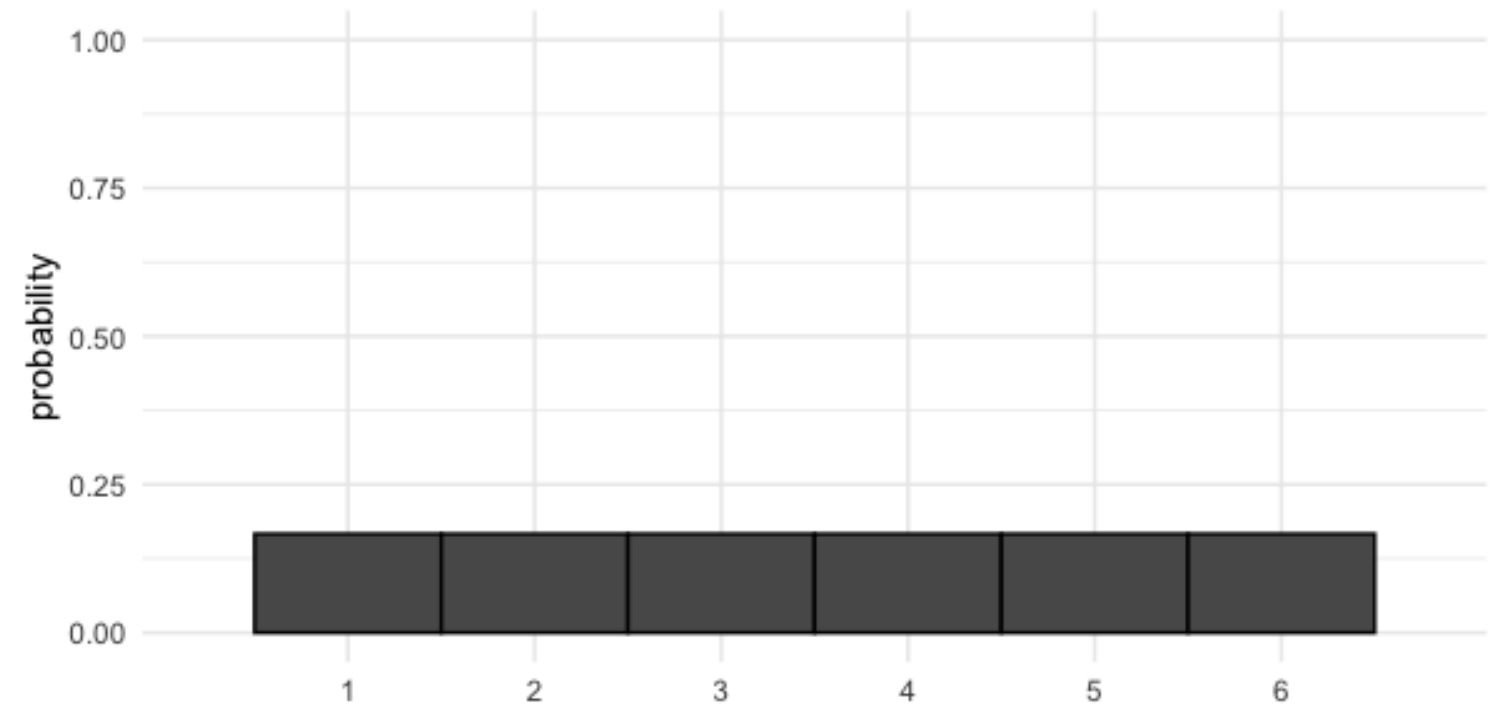
Sample distribution vs. theoretical distribution

Sample of 10 rolls



```
np.mean(rolls_10['number']) = 3.0
```

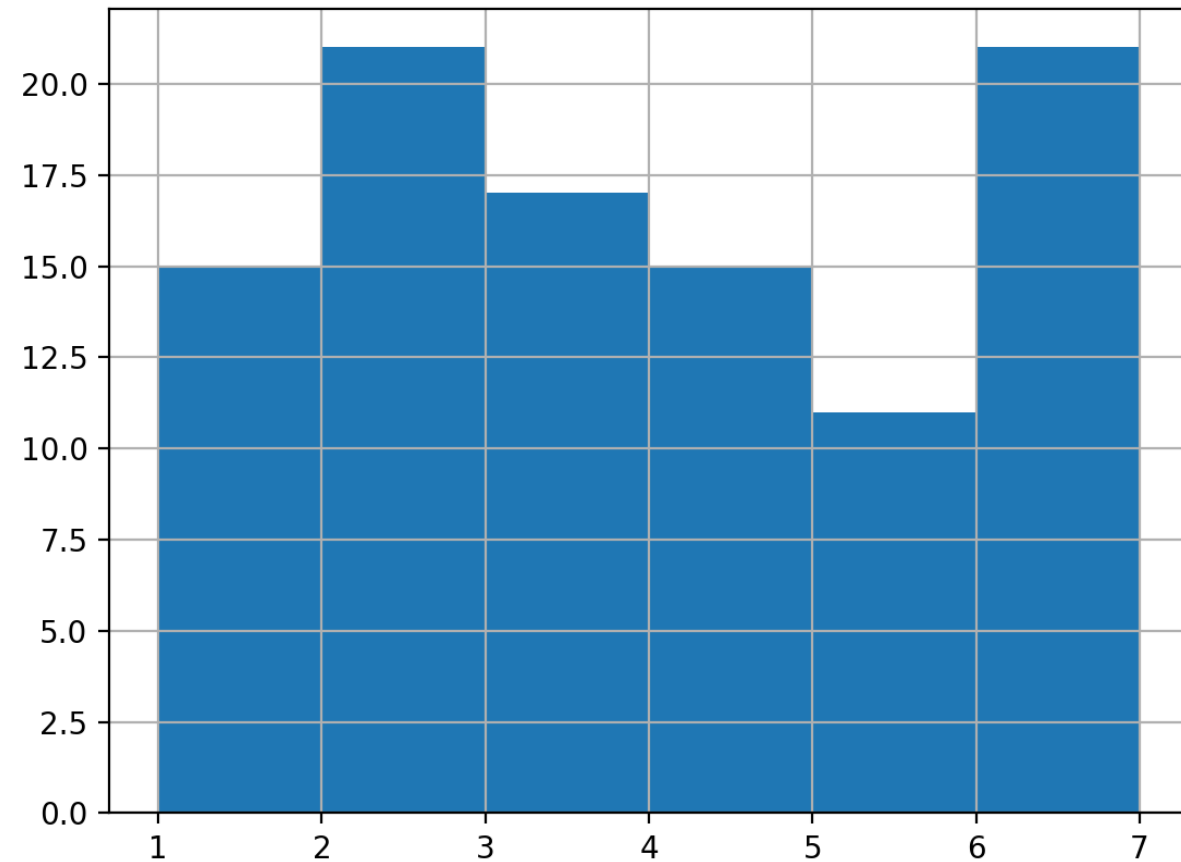
Theoretical probability distribution



```
mean(die['number']) = 3.5
```

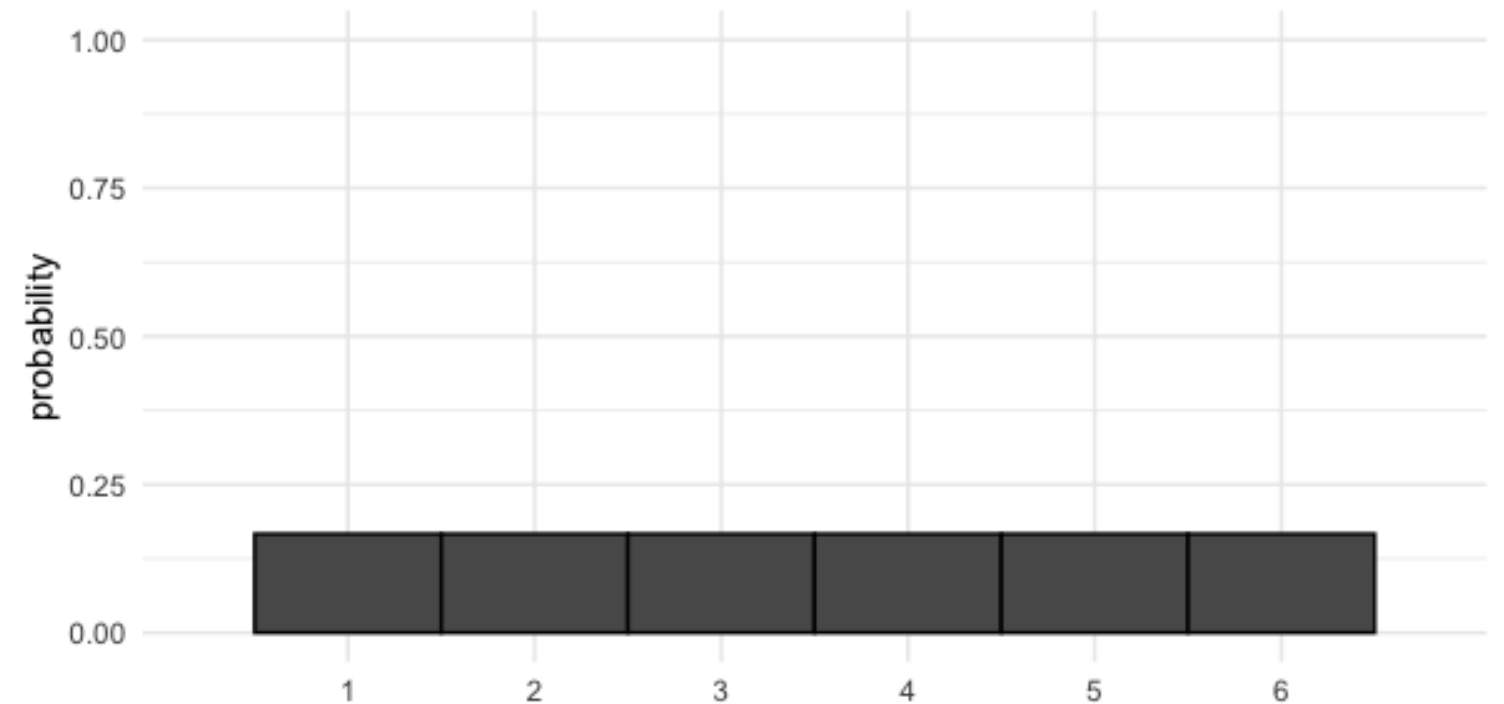
A bigger sample

Sample of 100 rolls



```
np.mean(rolls_100['number']) = 3.4
```

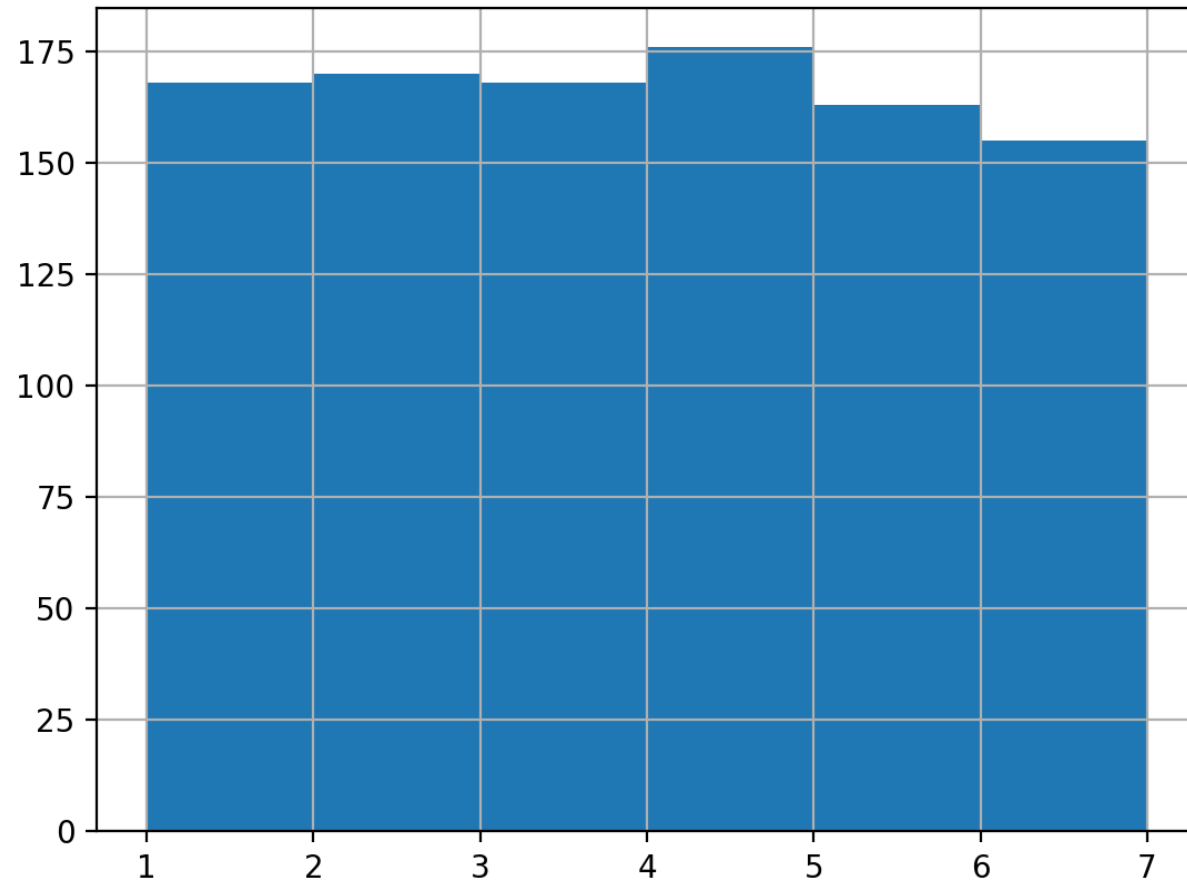
Theoretical probability distribution



```
mean(die['number']) = 3.5
```

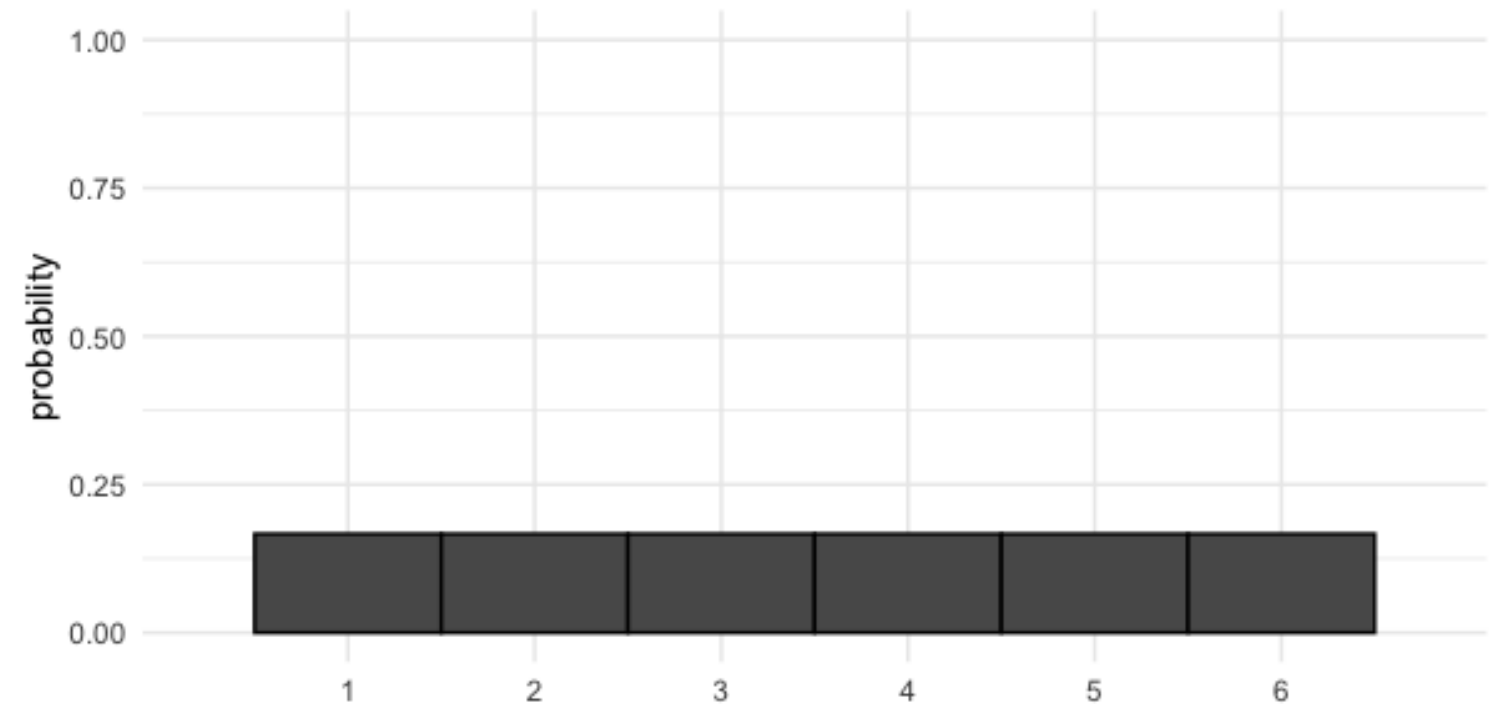
An even bigger sample

Sample of 1000 rolls



```
np.mean(rolls_1000['number']) = 3.48
```

Theoretical probability distribution



```
mean(die['number']) = 3.5
```

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	3.40
1000	3.48

Let's practice!

INTRODUCTION TO STATISTICS IN PYTHON

Continuous distributions

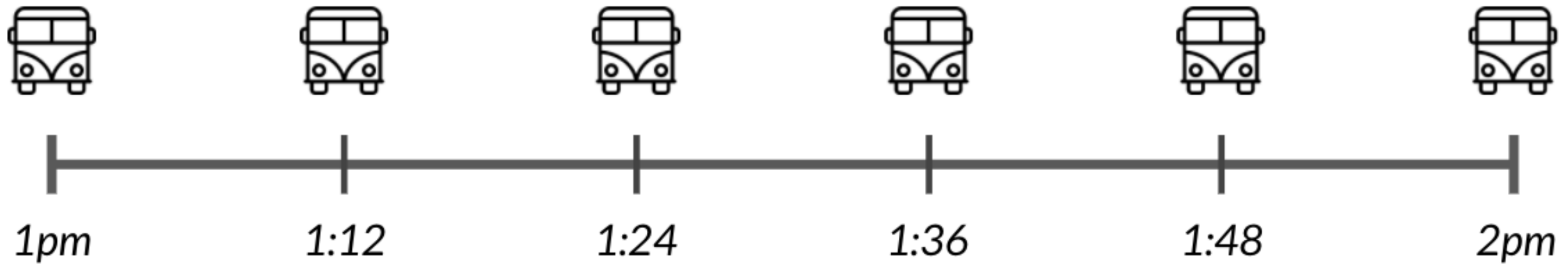
INTRODUCTION TO STATISTICS IN PYTHON



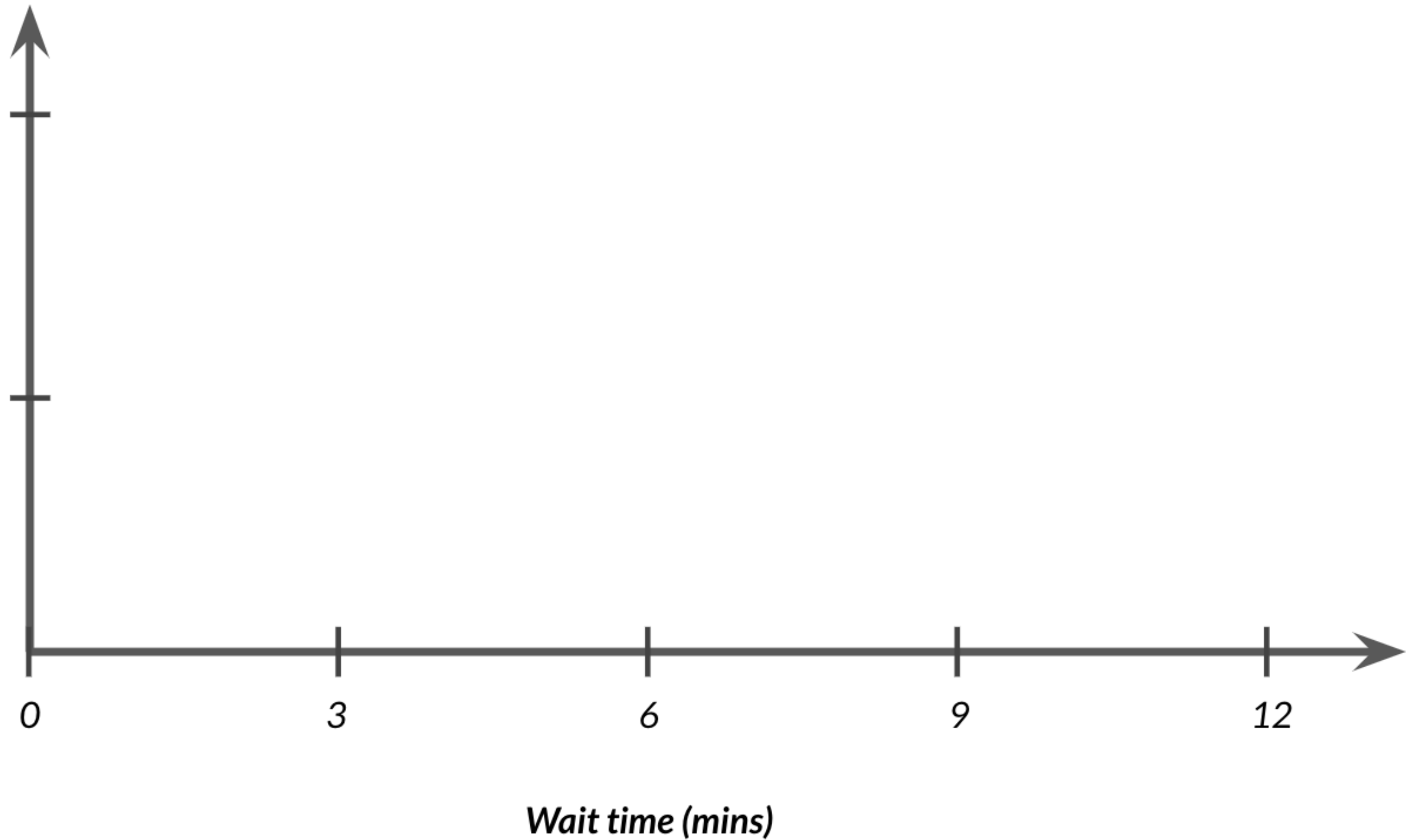
Maggie Matsui

Content Developer, DataCamp

Waiting for the bus



Continuous uniform distribution



Continuous uniform distribution



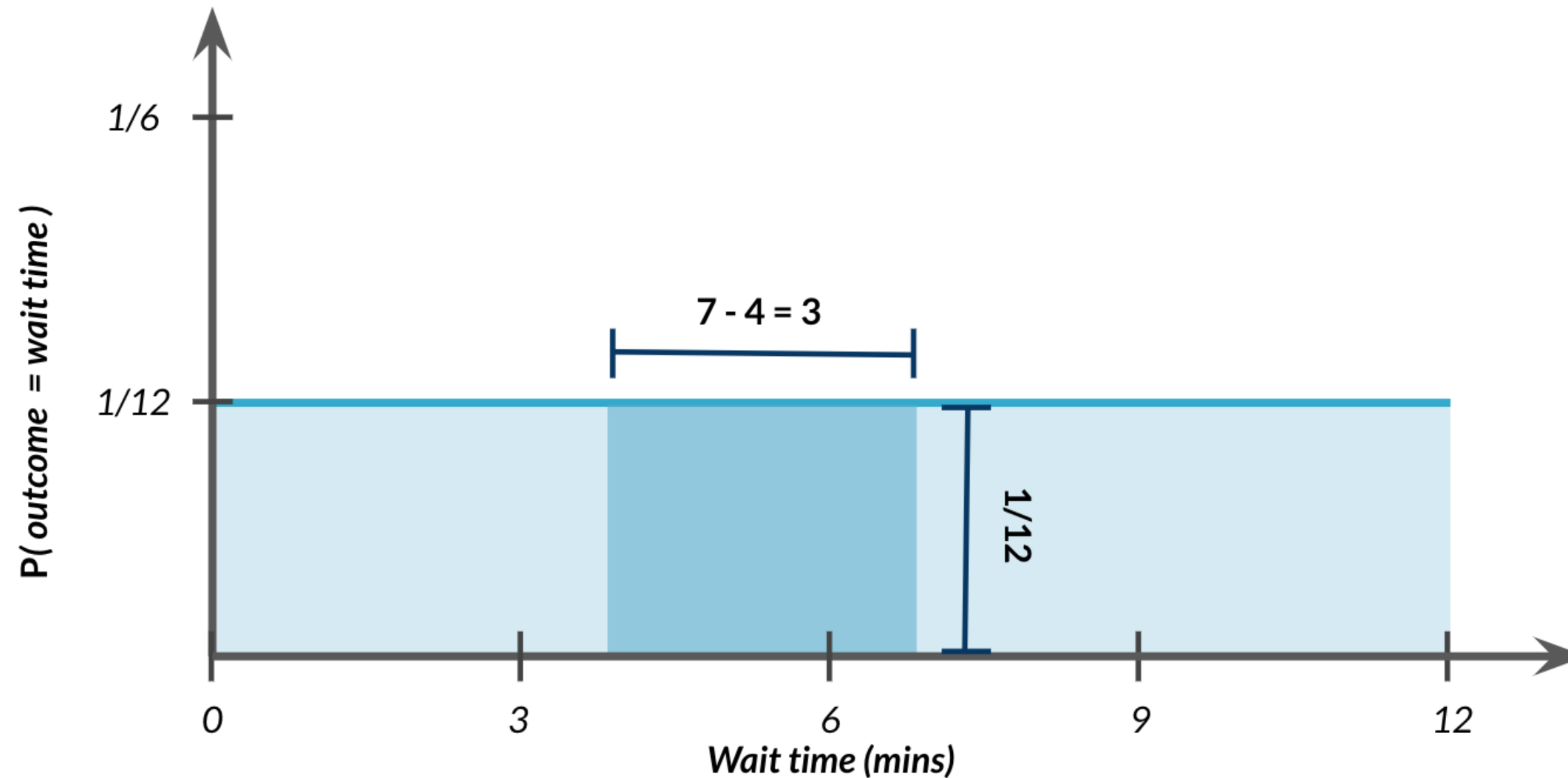
Probability still = area

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



Probability still = area

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



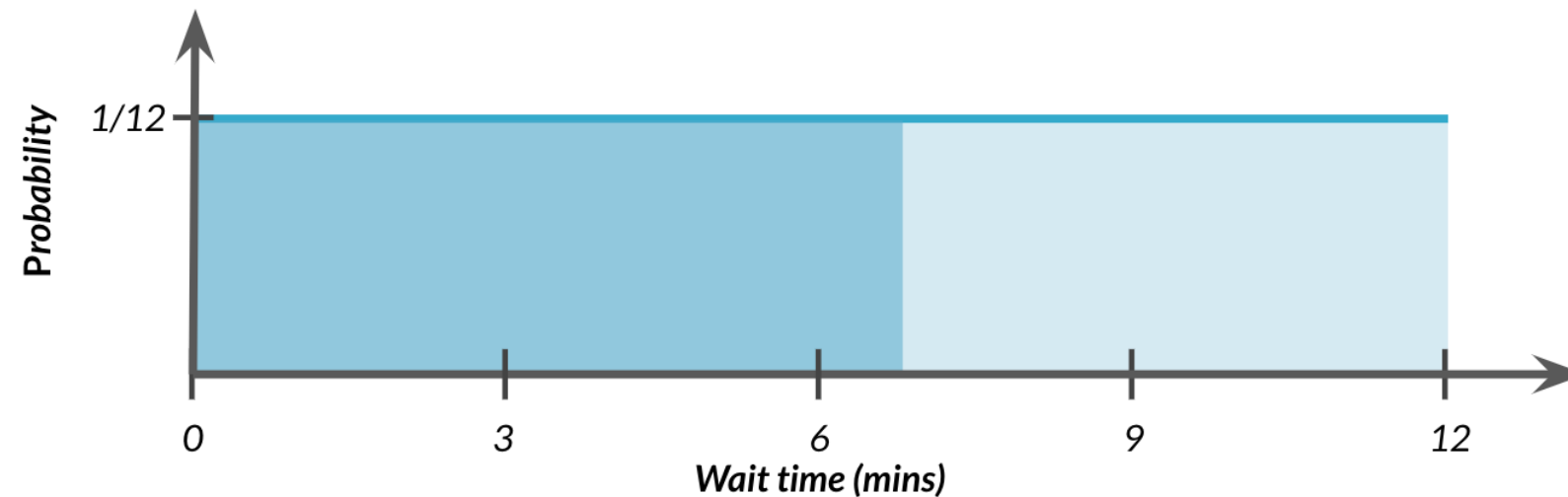
Probability still = area

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



Uniform distribution in Python

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

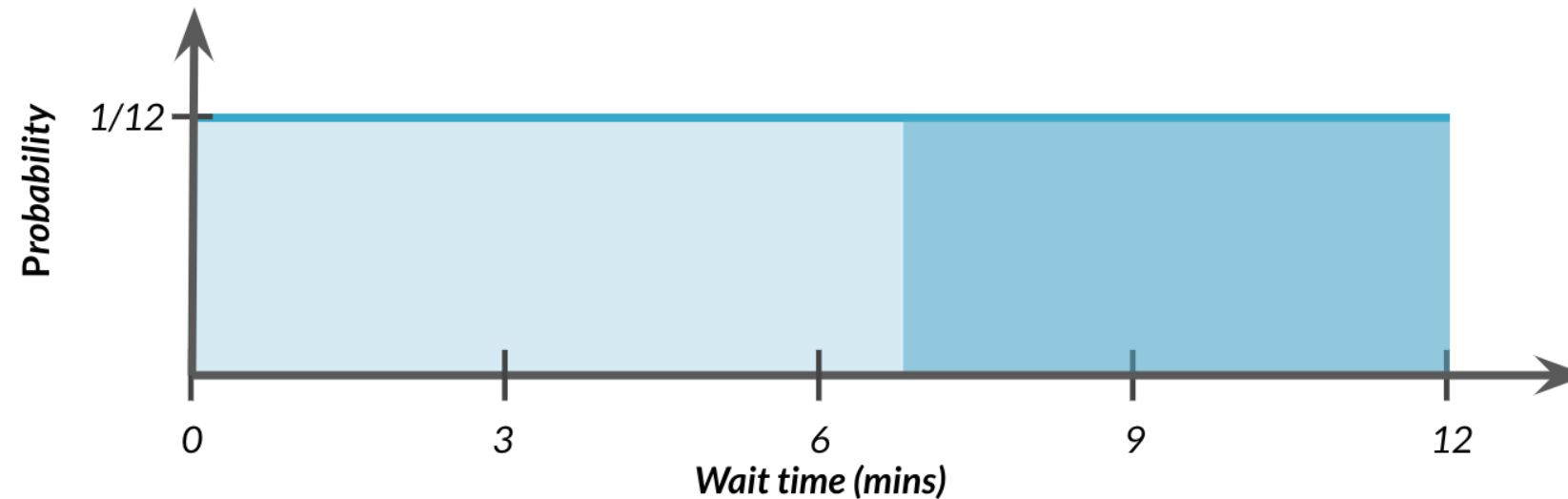


```
from scipy.stats import uniform  
uniform.cdf(7, 0, 12)
```

```
0.5833333
```

"Greater than" probabilities

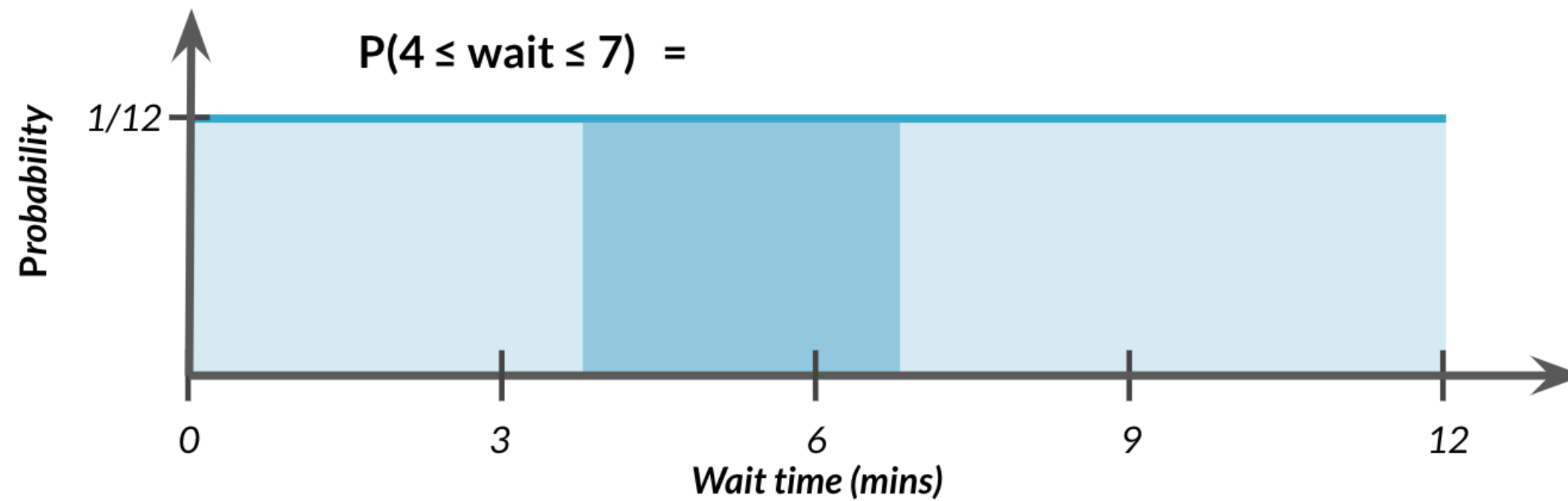
$$P(\text{wait time} \geq 7) = 1 - P(\text{wait time} \leq 7)$$



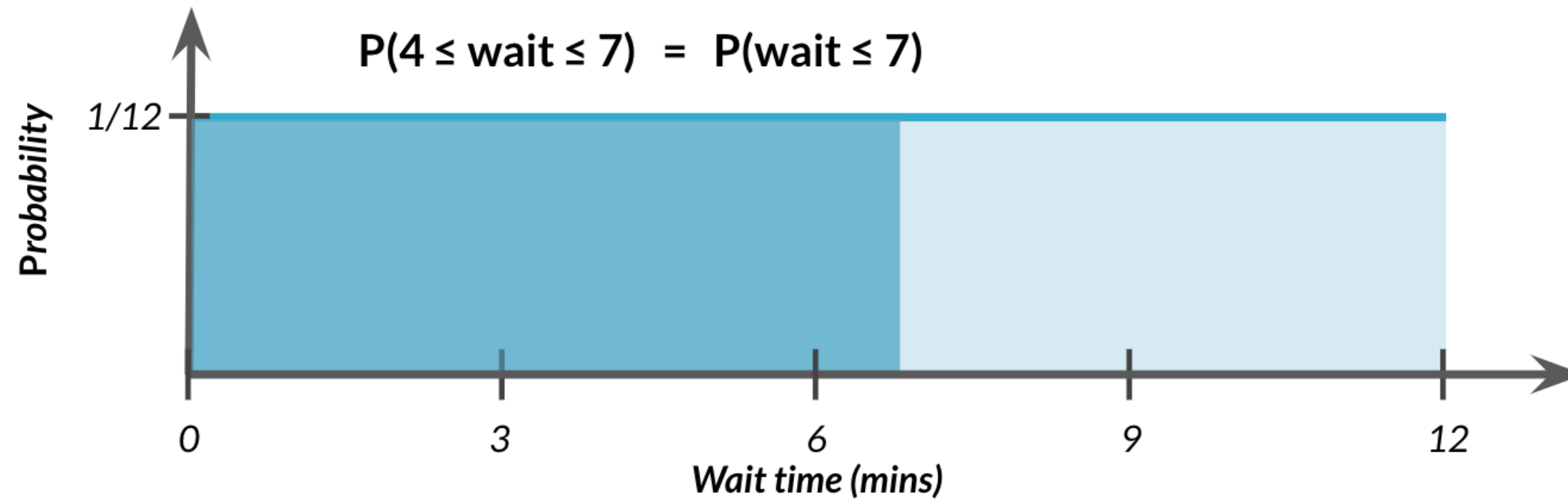
```
from scipy.stats import uniform
1 - uniform.cdf(7, 0, 12)
```

```
0.4166667
```

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



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



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

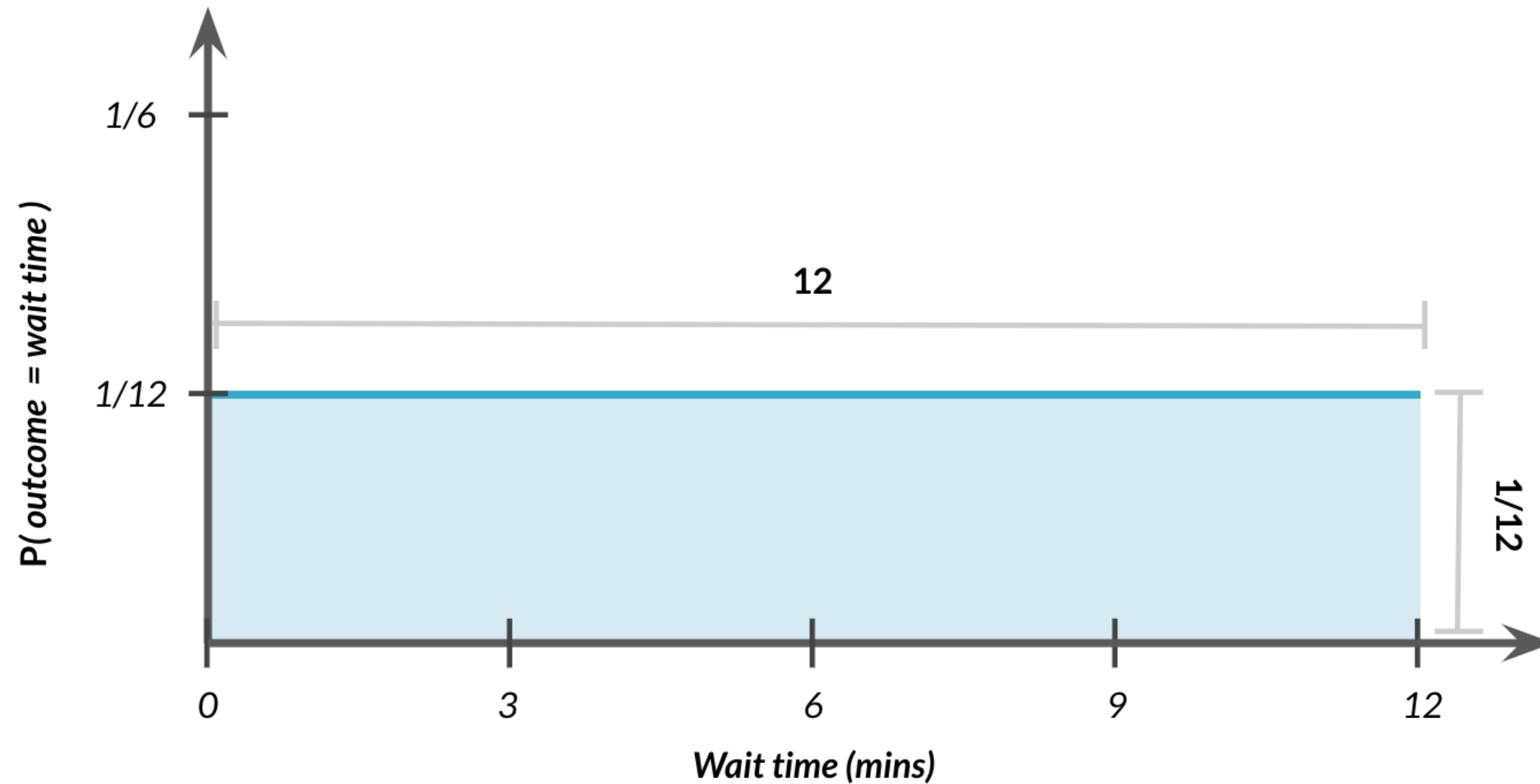


```
from scipy.stats import uniform
uniform.cdf(7, 0, 12) - uniform.cdf(4, 0, 12)
```

0.25

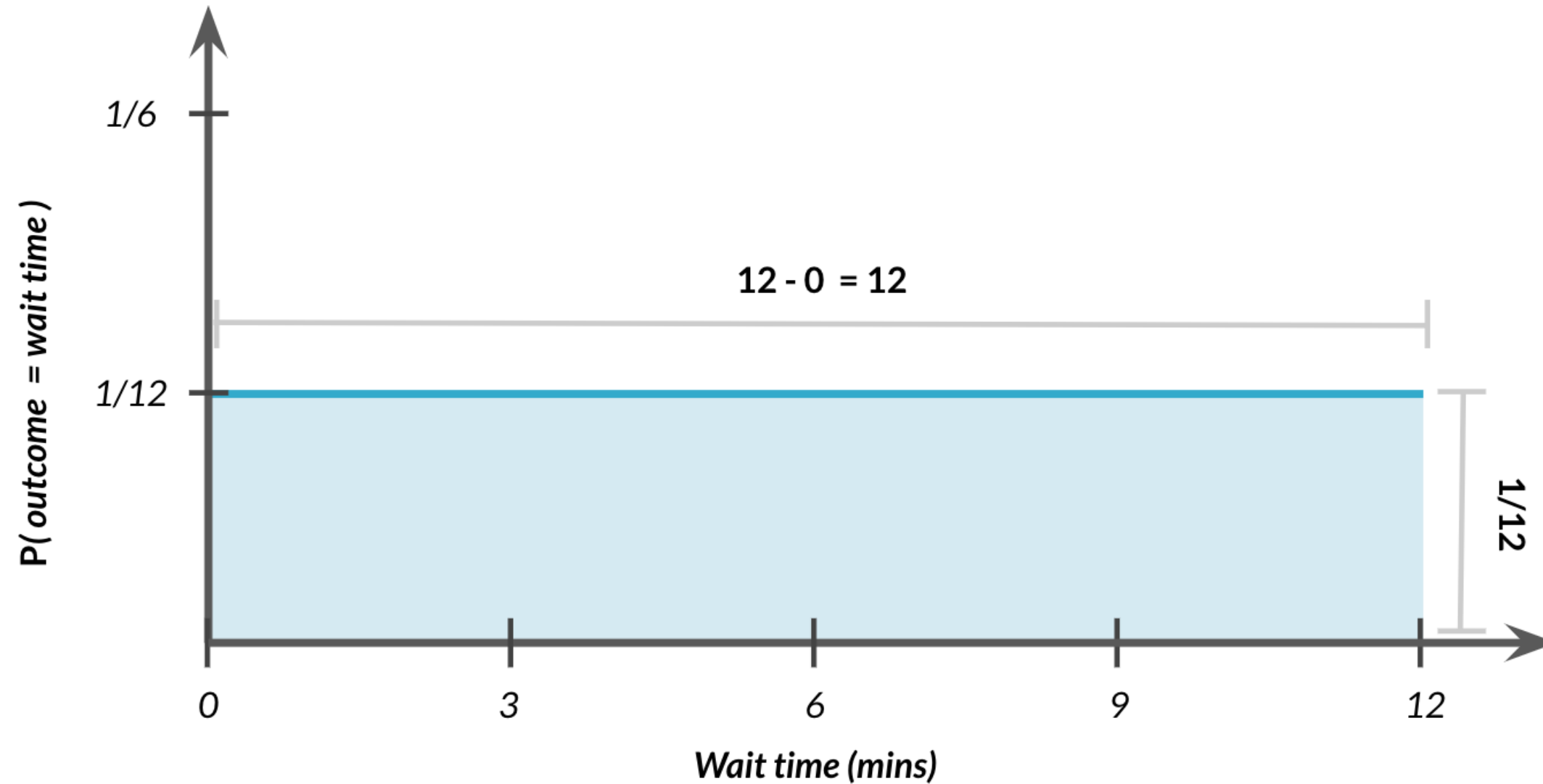
Total area = 1

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



Total area = 1

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

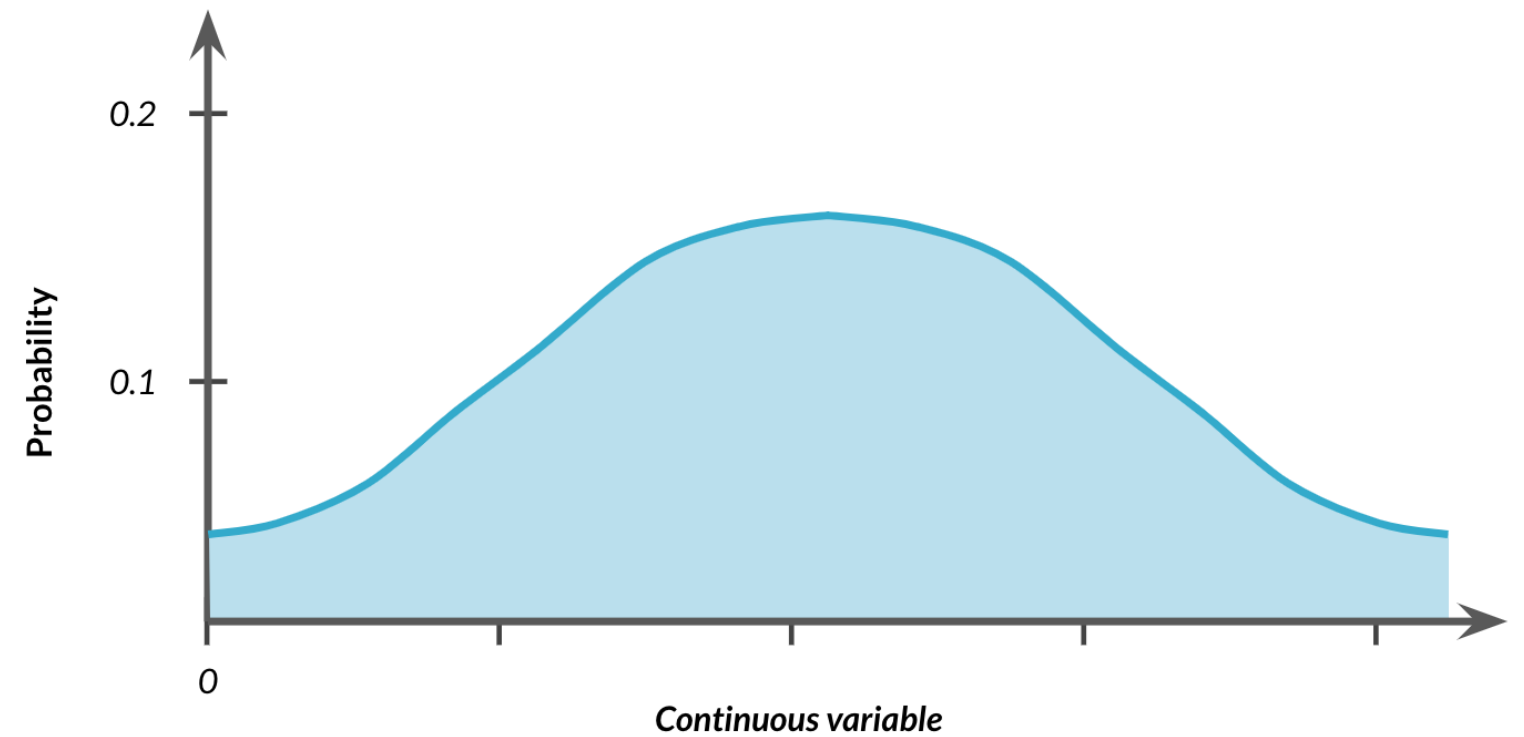
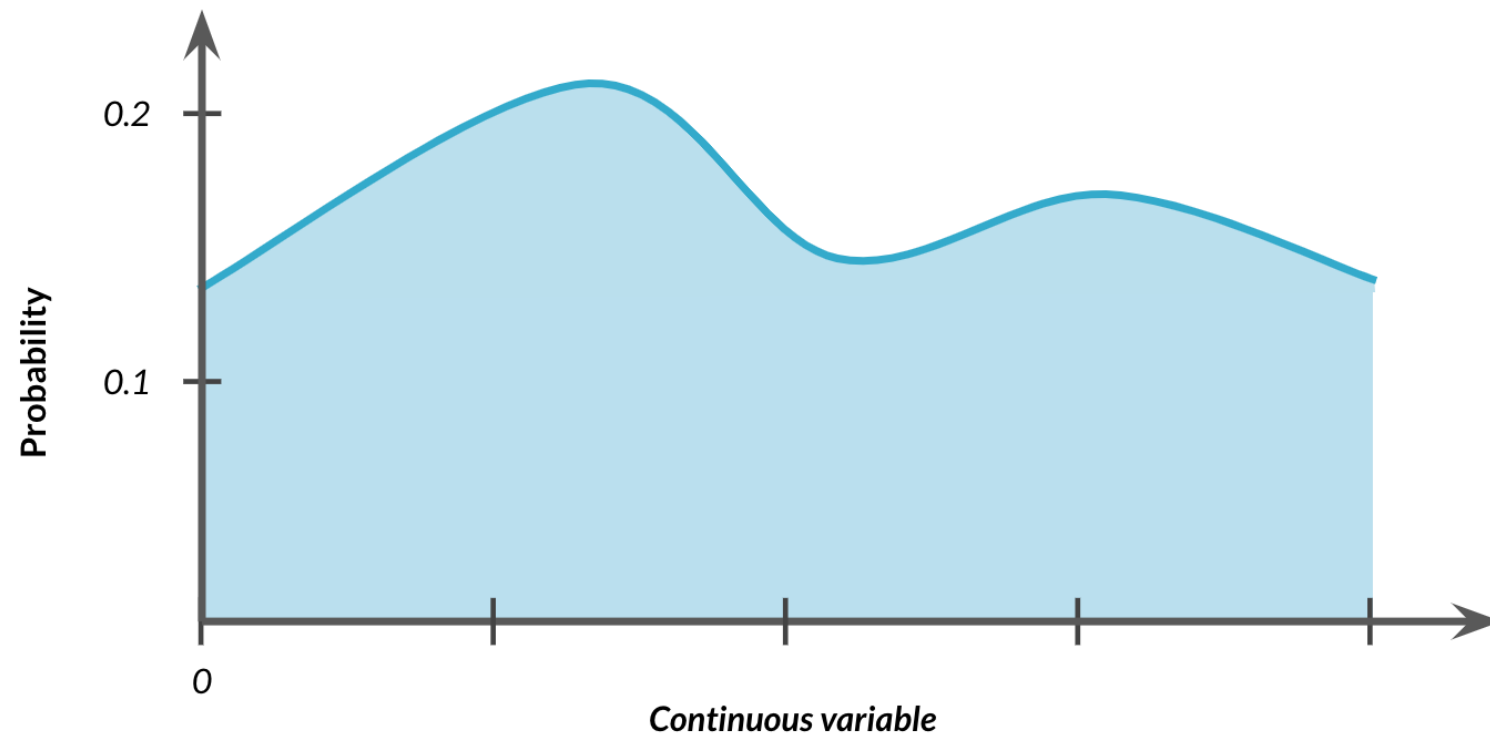


Generating random numbers according to uniform distribution

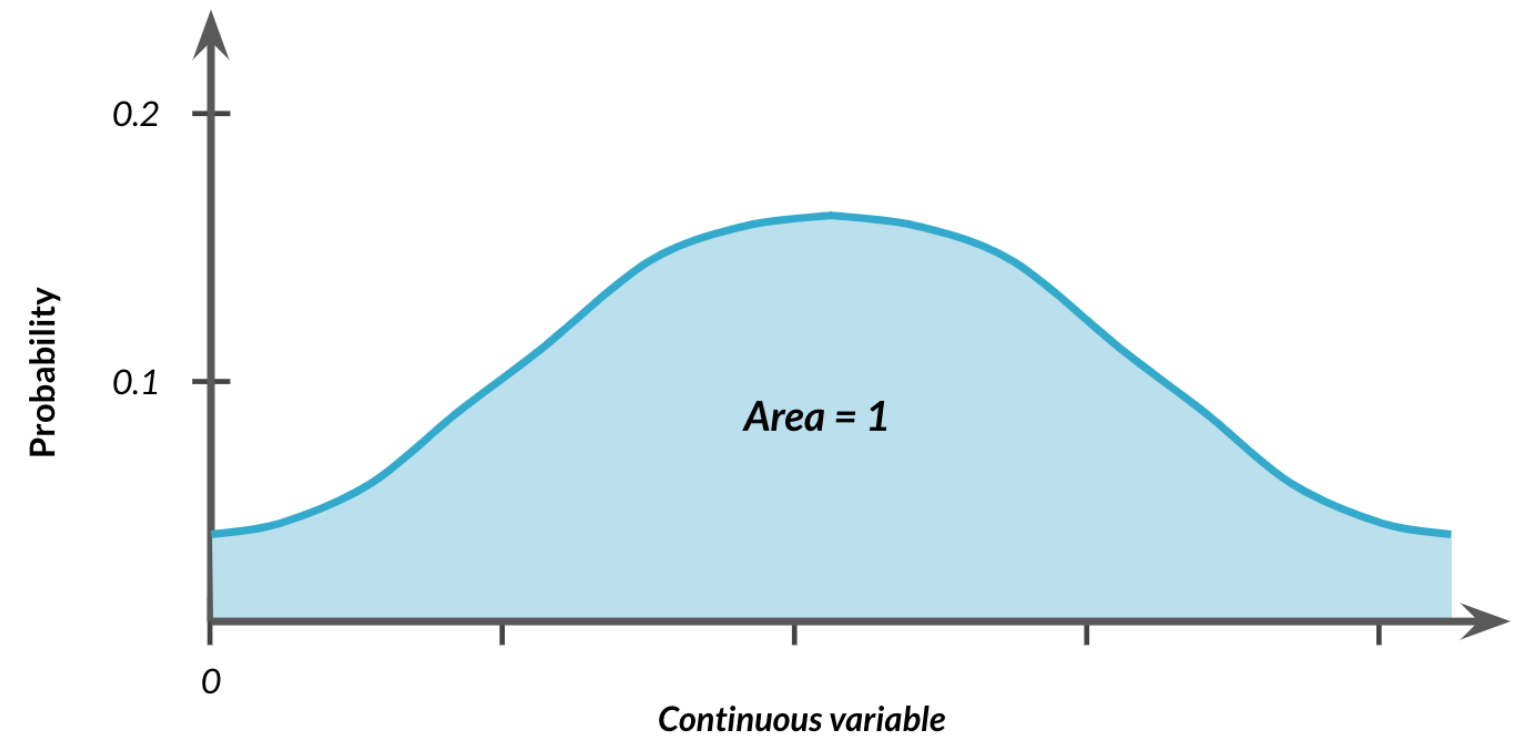
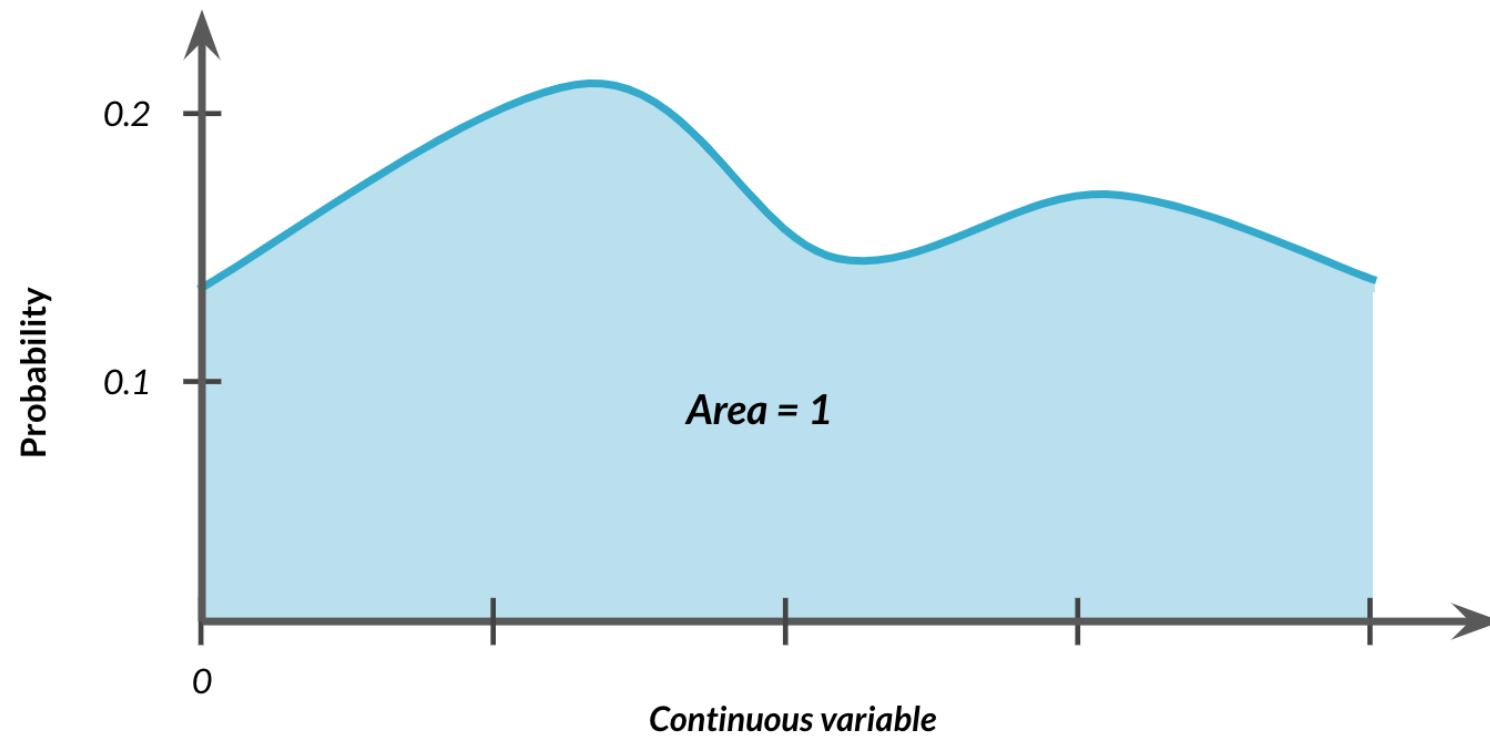
```
from scipy.stats import uniform  
uniform.rvs(0, 5, size=10)
```

```
array([1.89740094, 4.70673196, 0.33224683, 1.0137103 , 2.31641255,  
       3.49969897, 0.29688598, 0.92057234, 4.71086658, 1.56815855])
```

Other continuous distributions

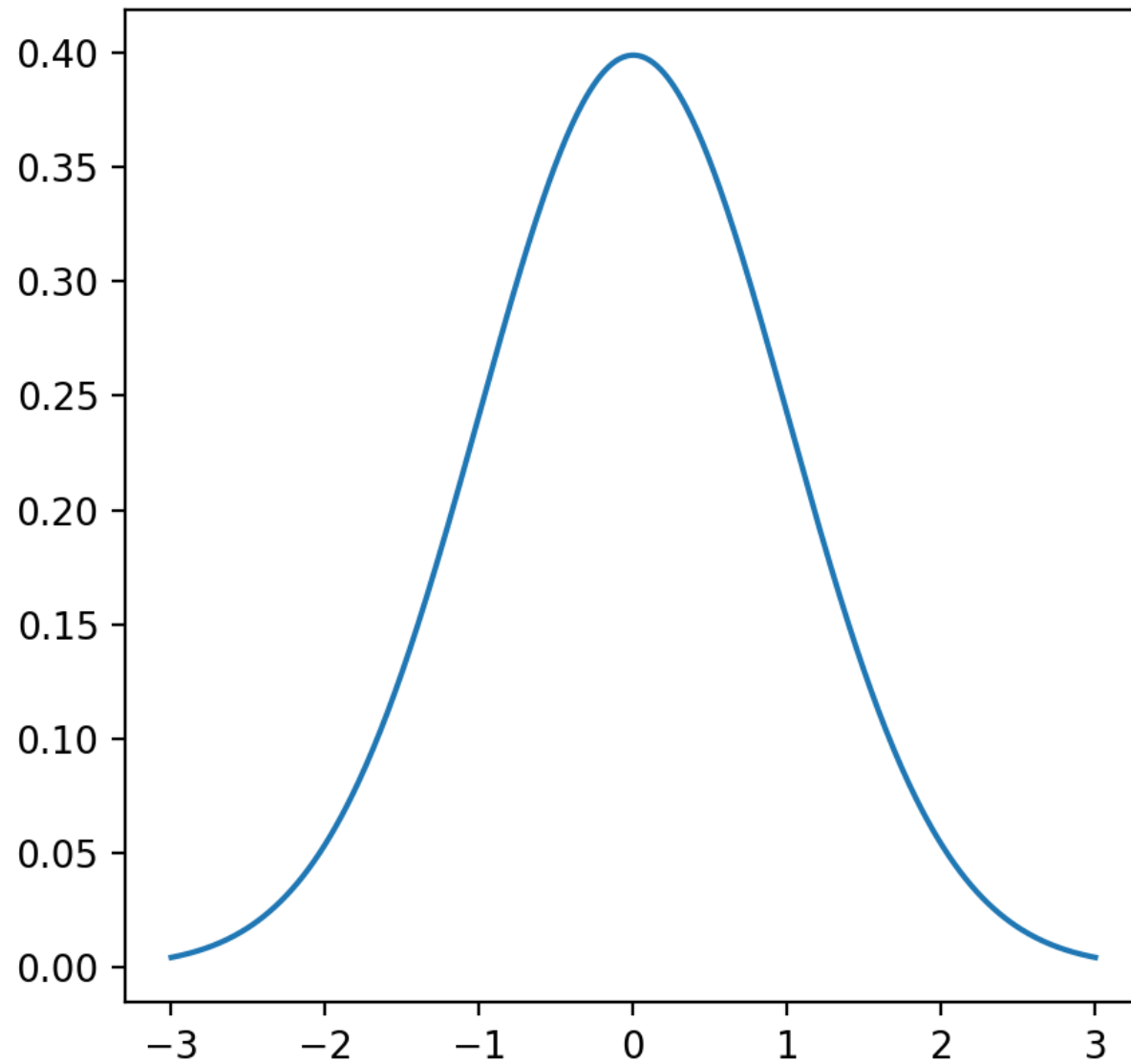


Other continuous distributions

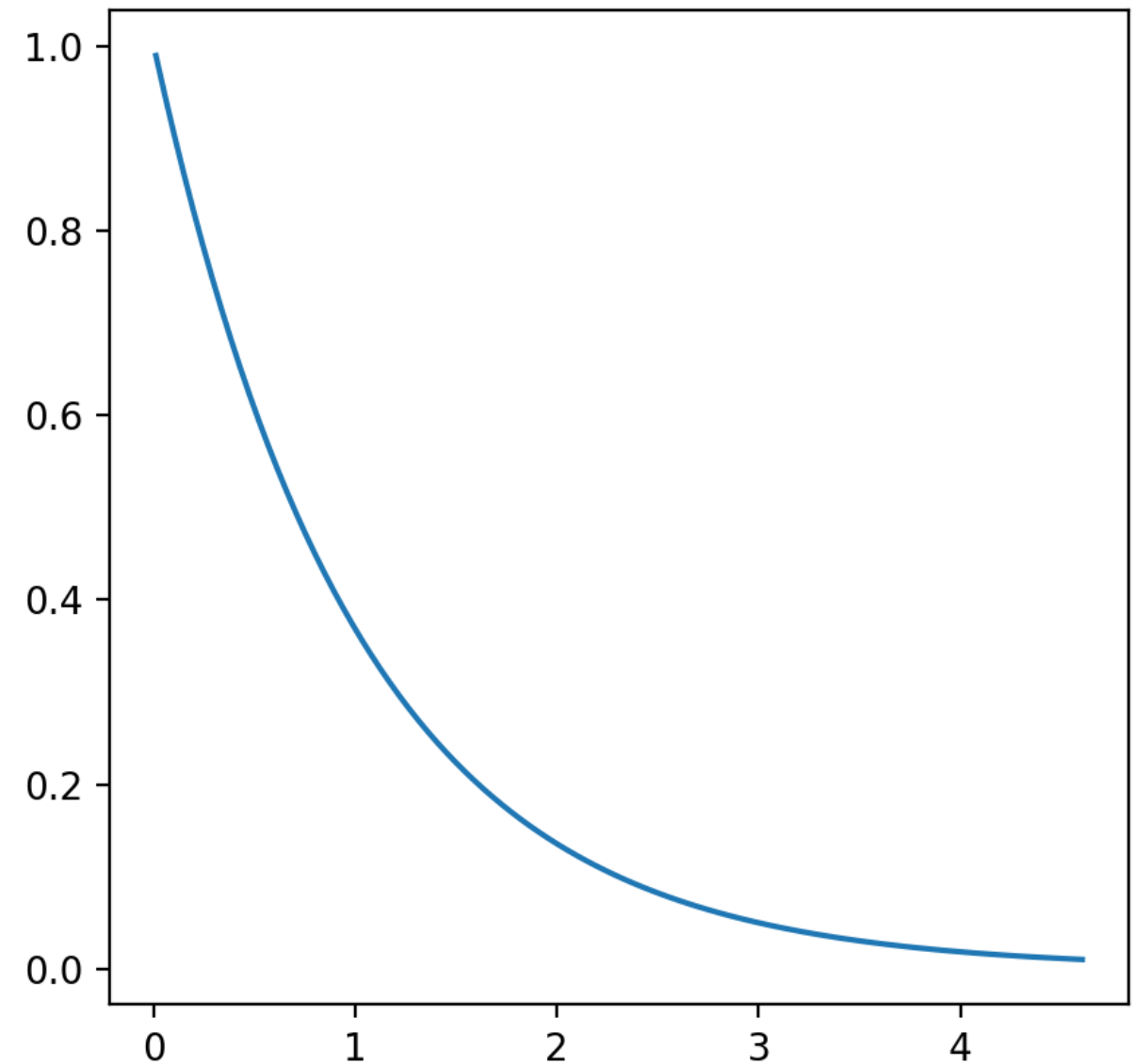


Other special types of distributions

Normal distribution



Exponential distribution



Let's practice!

INTRODUCTION TO STATISTICS IN PYTHON

The binomial distribution

INTRODUCTION TO STATISTICS IN PYTHON



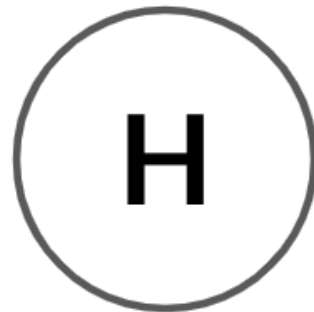
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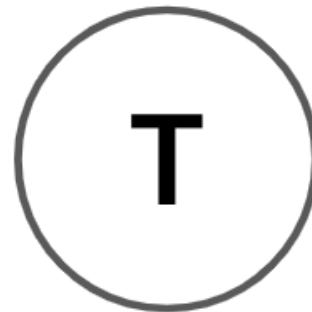
Coin flipping



50%



50%



Binary outcomes

H

T

1

0

Success

Failure

Win

Loss

A single flip

```
binom.rvs(# of coins, probability of heads/success, size=# of trials)
```

1 = head, 0 = tails

```
from scipy.stats import binom  
binom.rvs(1, 0.5, size=1)
```

```
array([1])
```

One flip many times

```
binom.rvs(1, 0.5, size=8)
```

```
array([0, 1, 1, 0, 1, 0, 1, 1])
```

```
binom.rvs(1, 0.5, size = 8)
```

Flip 1 coin with 50% chance of success 8 times

Many flips one time

```
binom.rvs(8, 0.5, size=1)
```

```
array([5])
```

```
binom.rvs(8, 0.5, size = 1)
```

Flip 8 coins with 50% chance of success 1 time

Many flips many times

```
binom.rvs(3, 0.5, size=10)
```

```
array([0, 3, 2, 1, 3, 0, 2, 2, 0, 0])
```

```
binom.rvs(3, 0.5, size = 10)
```

Flip 3 coins with 50% chance of success 10 times

Other probabilities

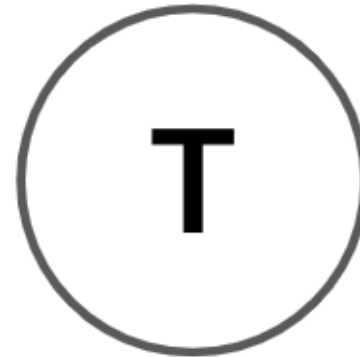
```
binom.rvs(3, 0.25, size=10)
```

```
array([1, 1, 1, 1, 0, 0, 2, 0, 1, 0])
```

25%



75%



Binomial distribution

Probability distribution of the number of successes in a sequence of independent trials

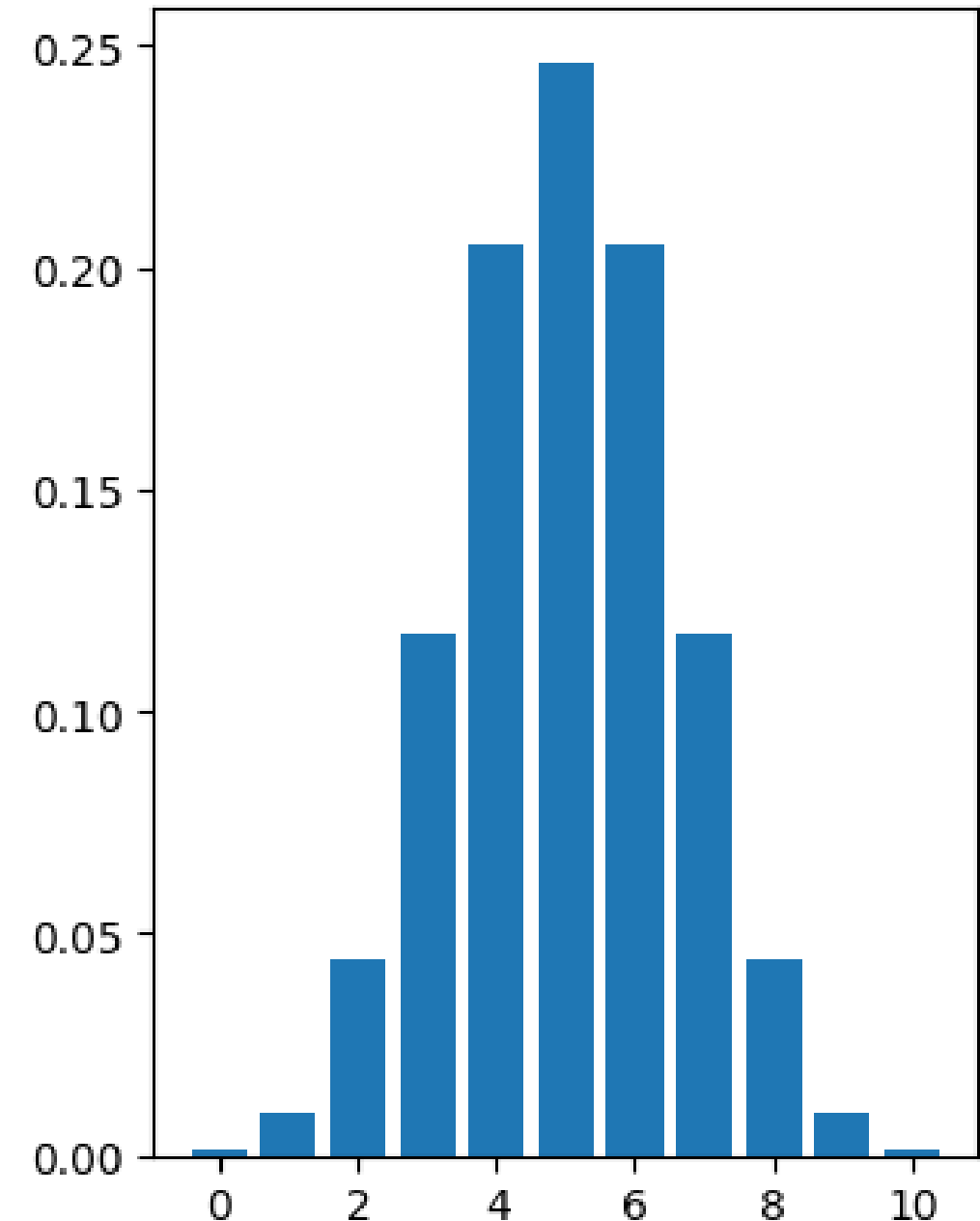
E.g. Number of heads in a sequence of coin flips

Described by n and p

- n : total number of trials
- p : probability of success

```
binom.rvs( $p$ 3,  $p$ 0.5, size =  $n$ 10)
```

Flip 3 coins with 50% chance of success 10 times



What's the probability of 7 heads?

$P(\text{heads} = 7)$

```
# binom.pmf(num heads, num trials, prob of heads)
binom.pmf(7, 10, 0.5)
```

```
0.1171875
```

What's the probability of 7 or fewer heads?

$P(\text{heads} \leq 7)$

```
binom.cdf(7, 10, 0.5)
```

```
0.9453125
```

What's the probability of more than 7 heads?

$P(\text{heads} > 7)$

```
1 - binom.cdf(7, 10, 0.5)
```

```
0.0546875
```

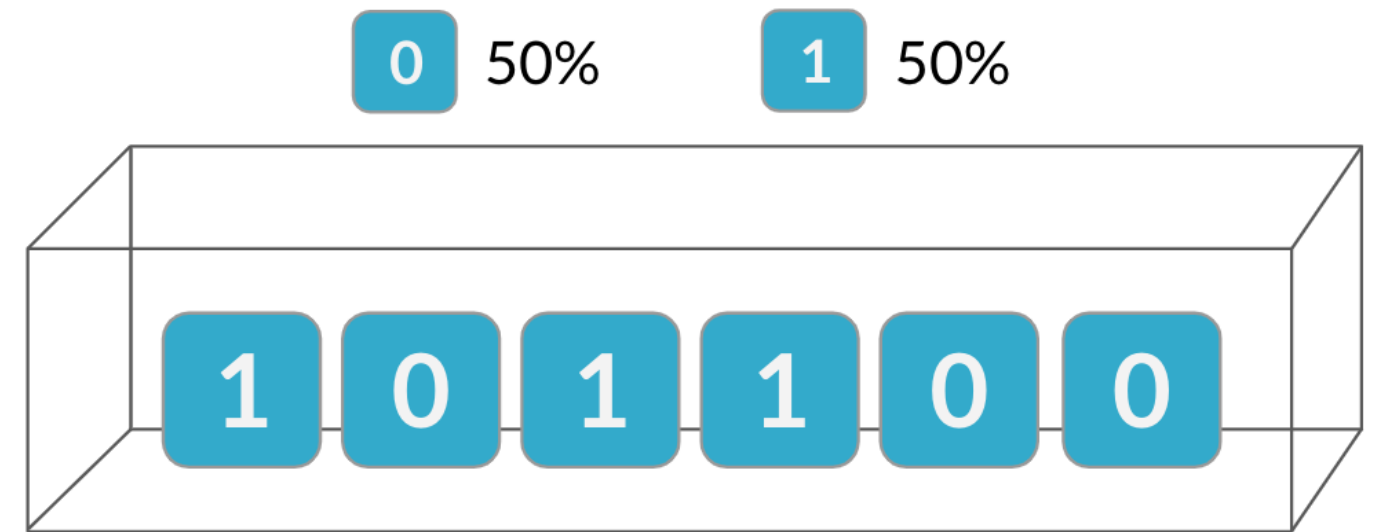
Expected value

$$\text{Expected value} = n \times p$$

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

Independence

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

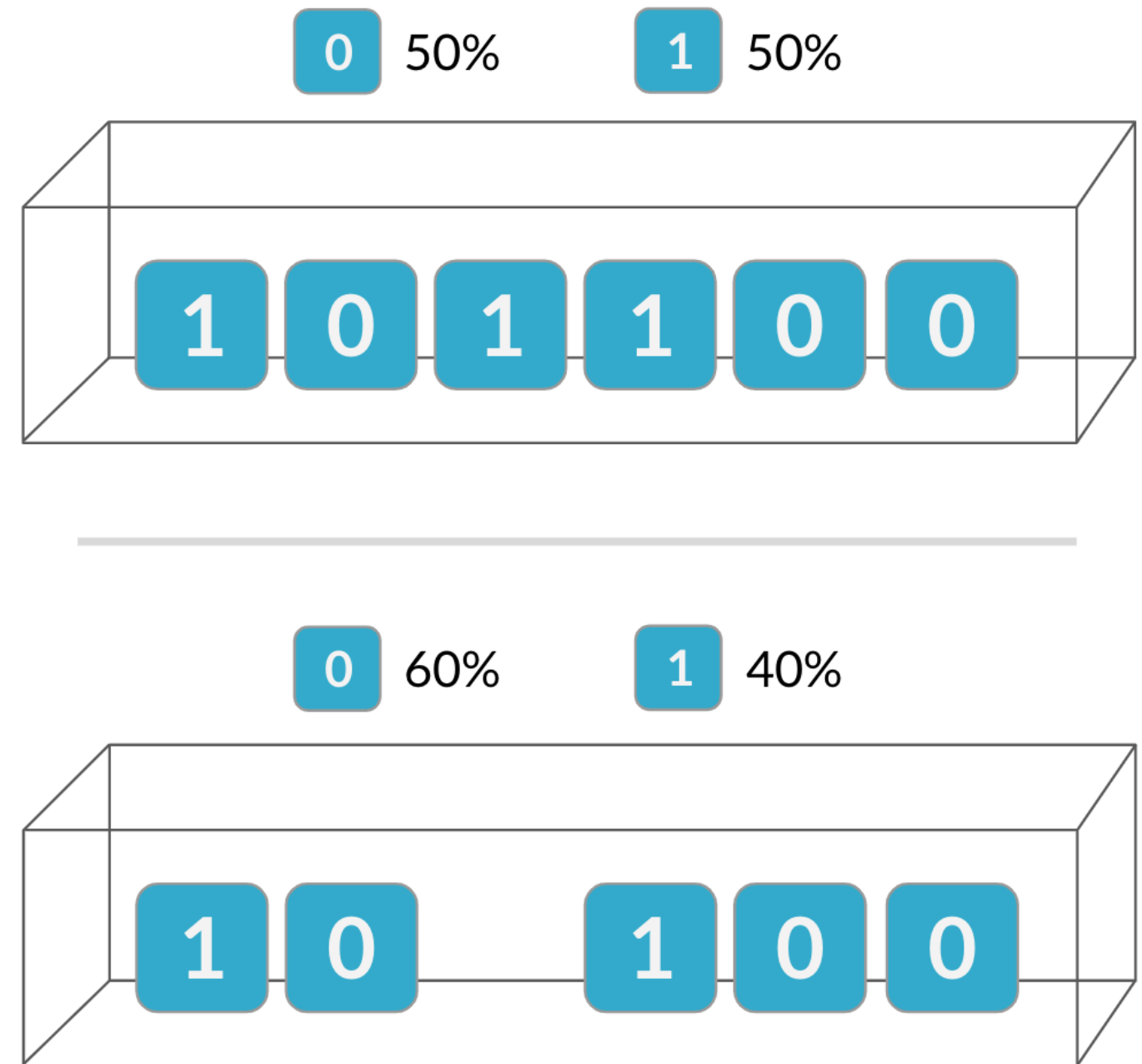


Independence

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

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

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



Let's practice!

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