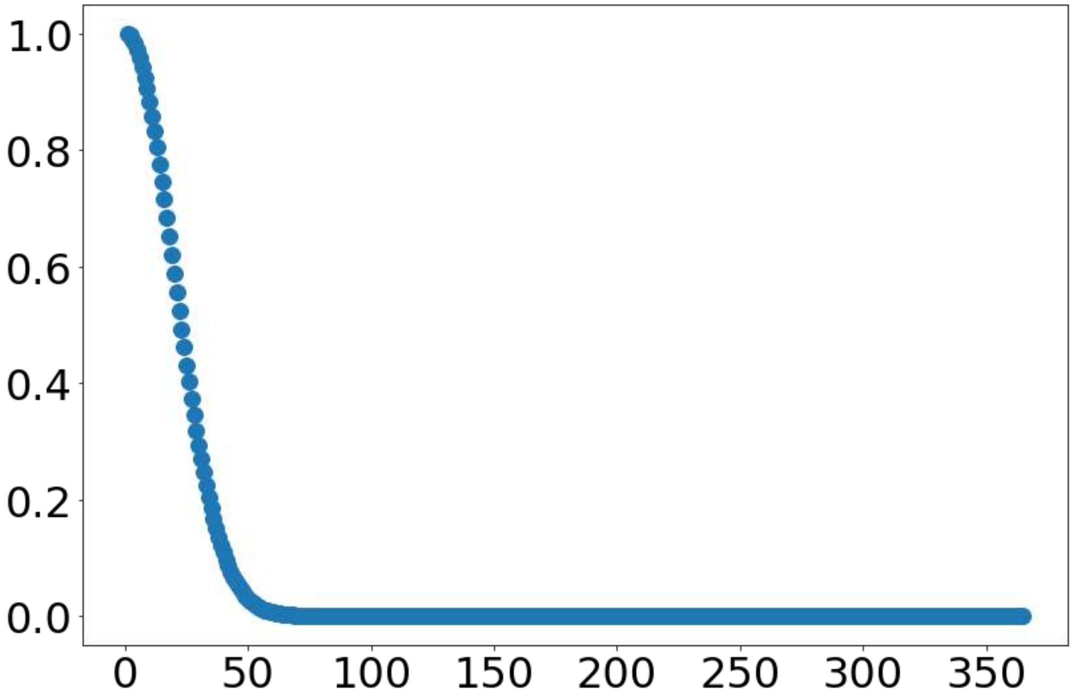
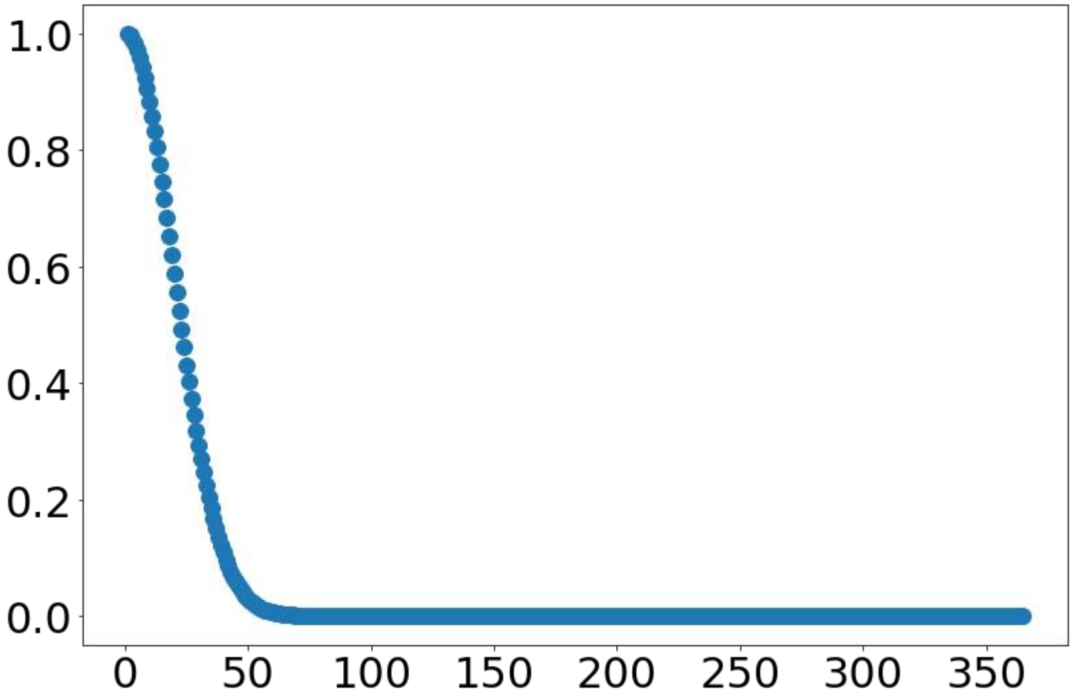
Probability That no Two People Have the Same Birthday



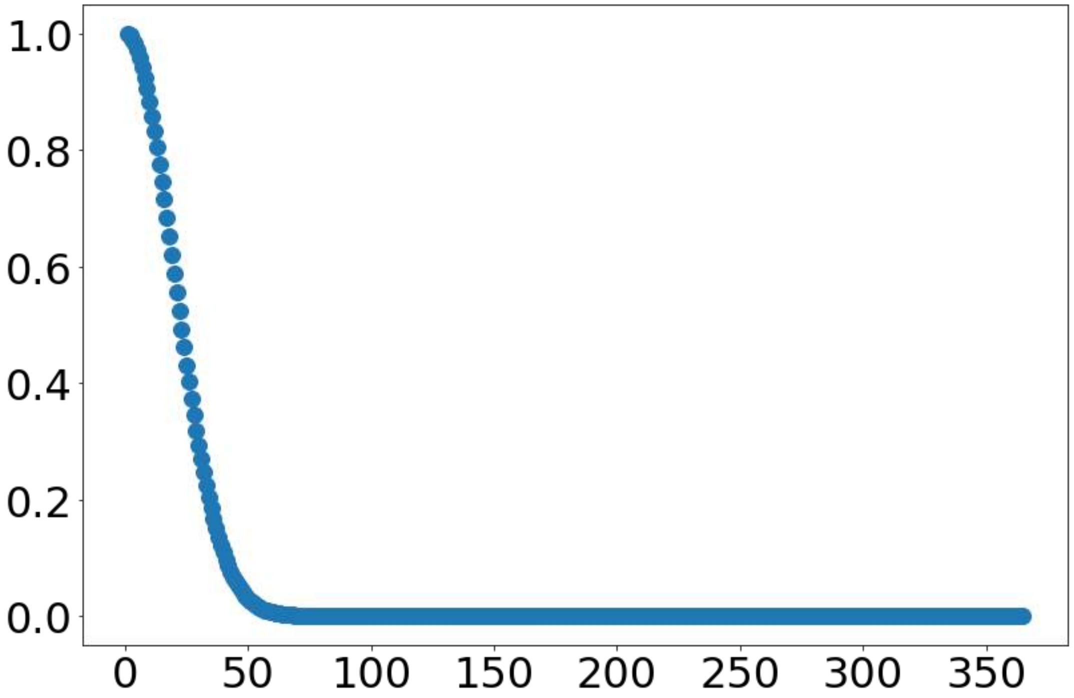
Probability That no Two People Have the Same Birthday

1 person: 1



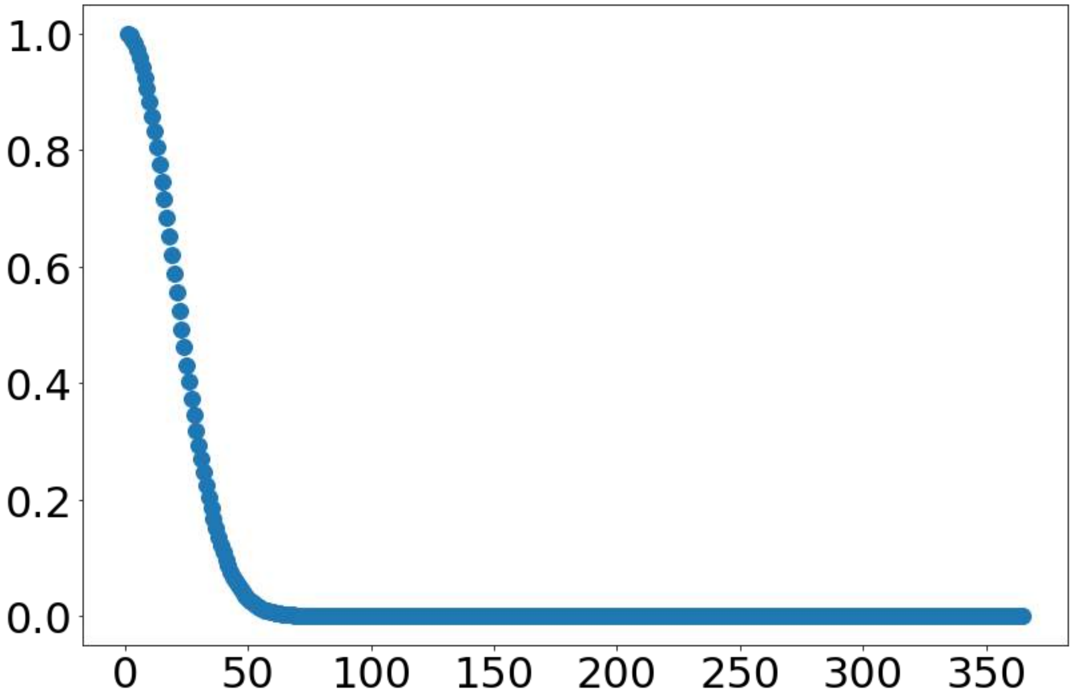
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997



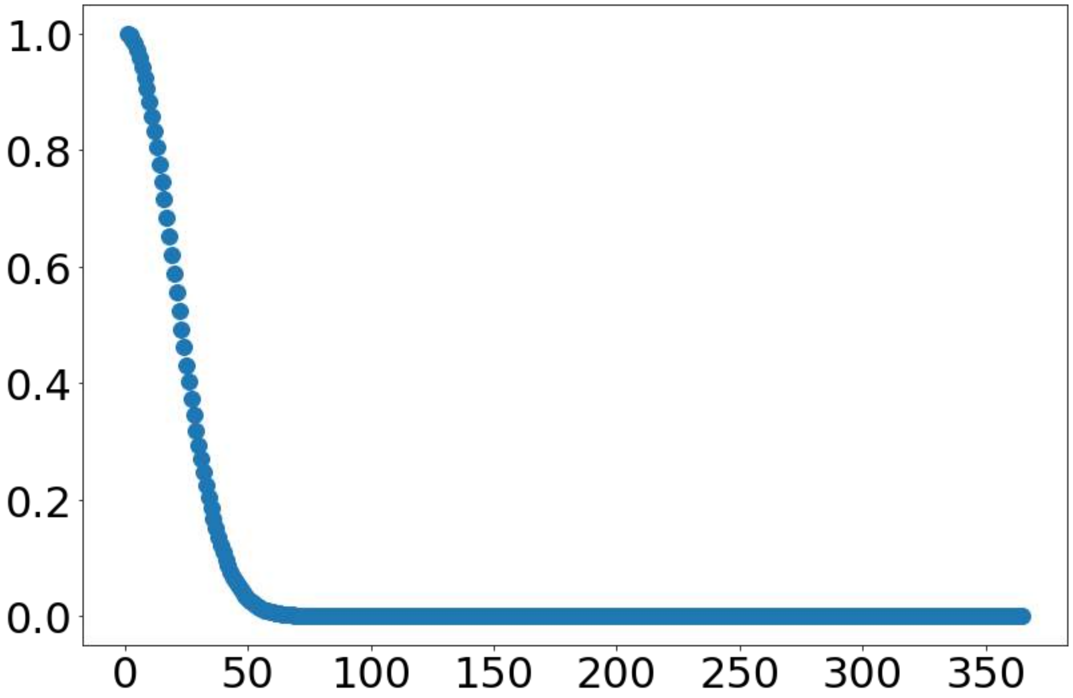
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992



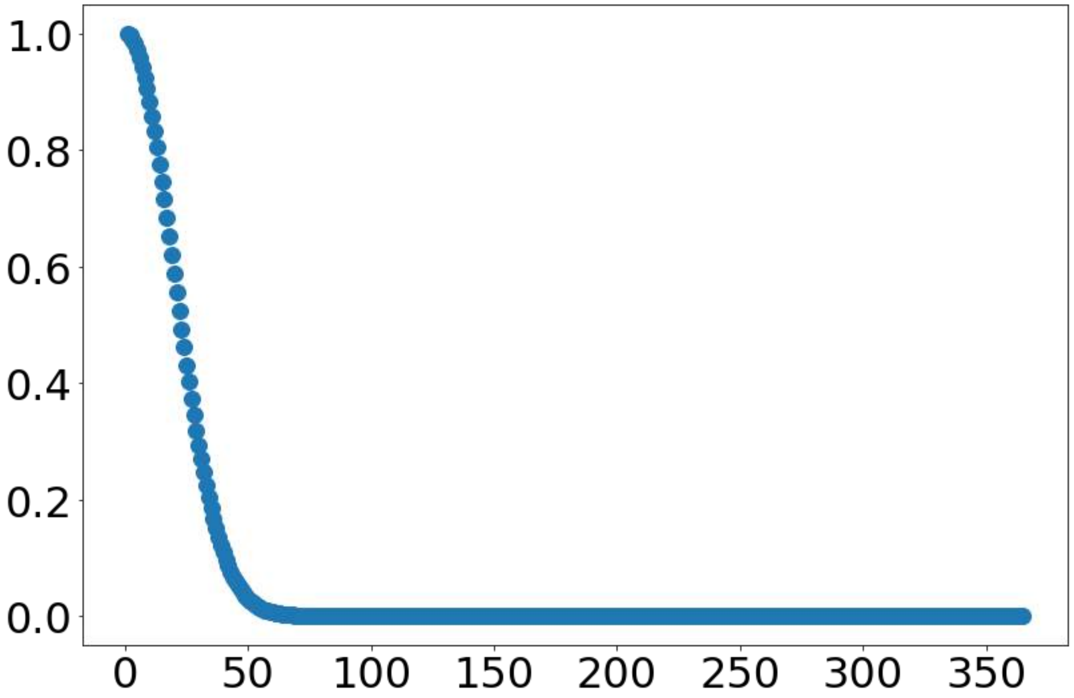
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984



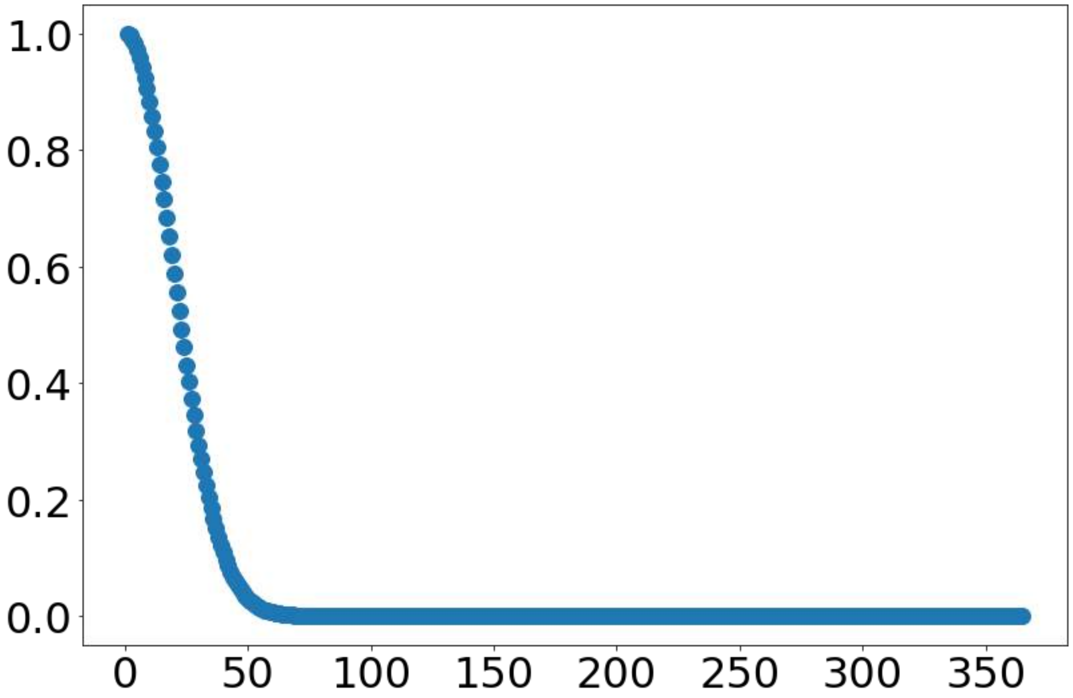
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984
5 people: 0.973



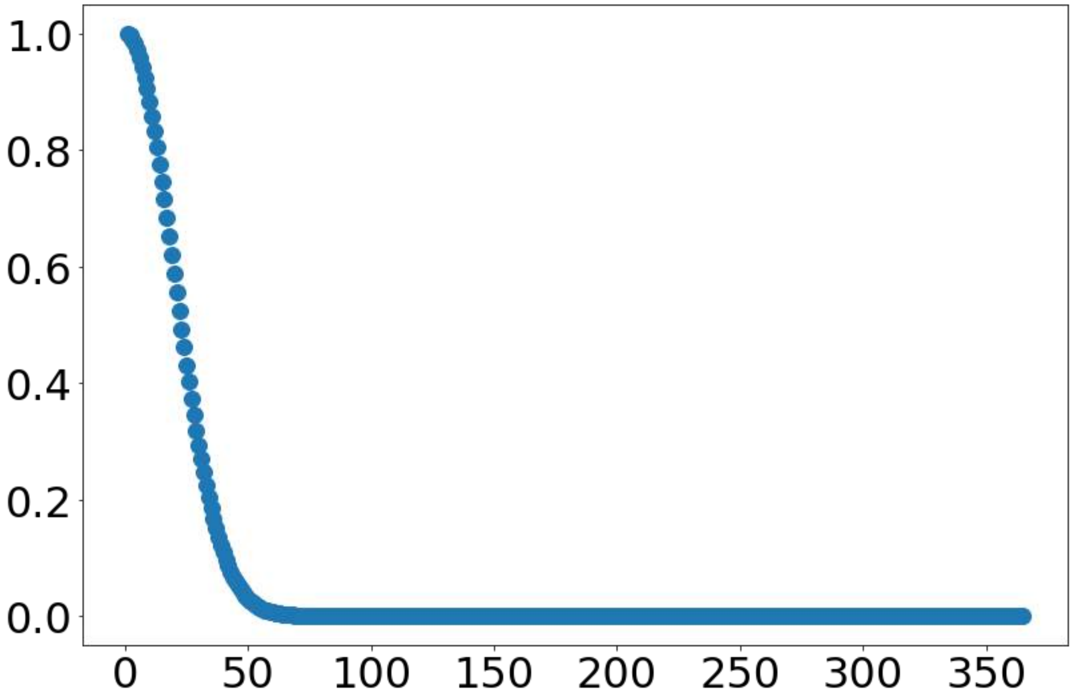
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984
5 people: 0.973
10 people: 0.883



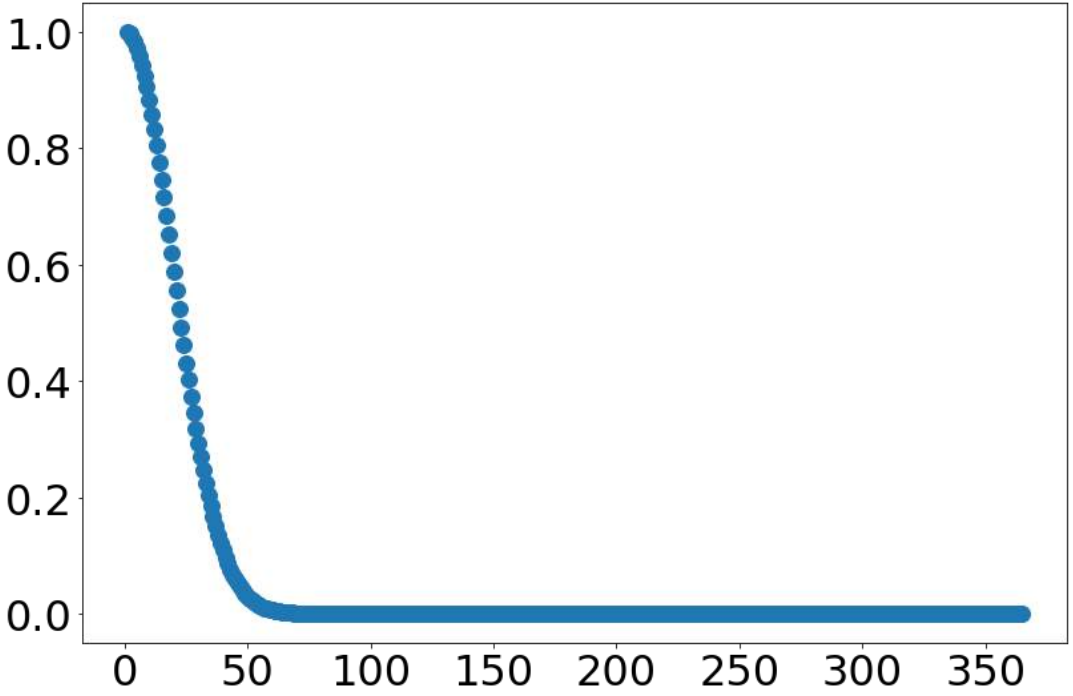
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984
5 people: 0.973
10 people: 0.883
20 people: 0.589



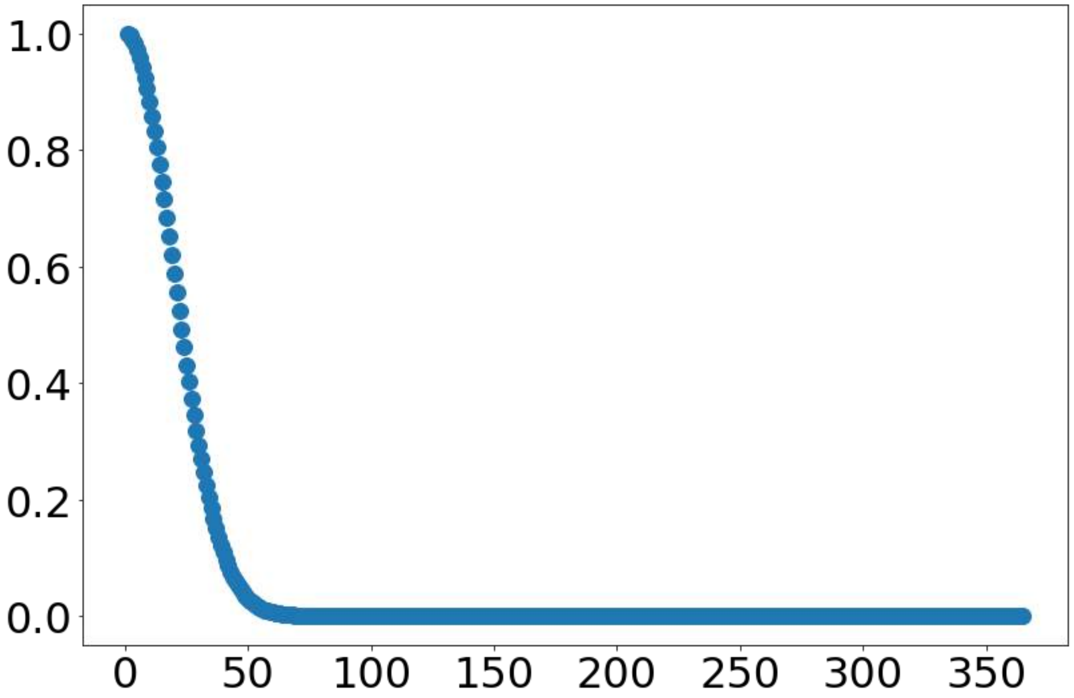
Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984
5 people: 0.973
10 people: 0.883
20 people: 0.589
23 people: 0.493



Probability That no Two People Have the Same Birthday

1 person: 1
2 people: 0.997
3 people: 0.992
4 people: 0.984
5 people: 0.973
10 people: 0.883
20 people: 0.589
23 people: 0.493
30 people: 0.294



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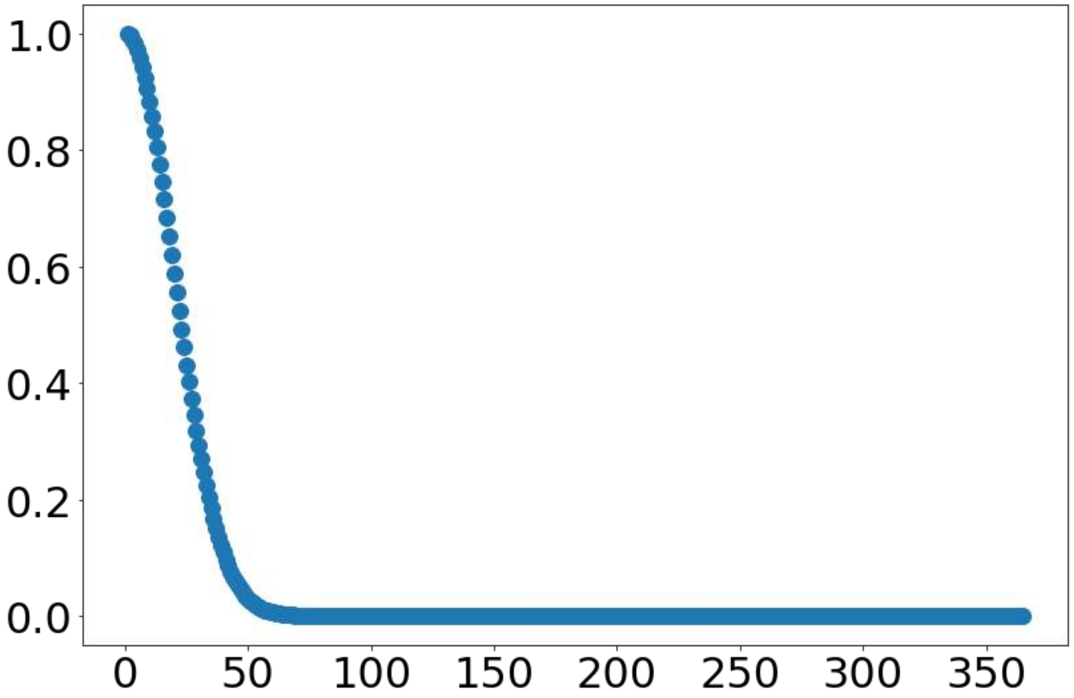
3 people: 0.992
4 people: 0.984
5 people: 0.973
10 people: 0.883
20 people: 0.589
23 people: 0.493
30 people: 0.294
50 people: 0.030



Probability That no Two People Have the Same Birthday

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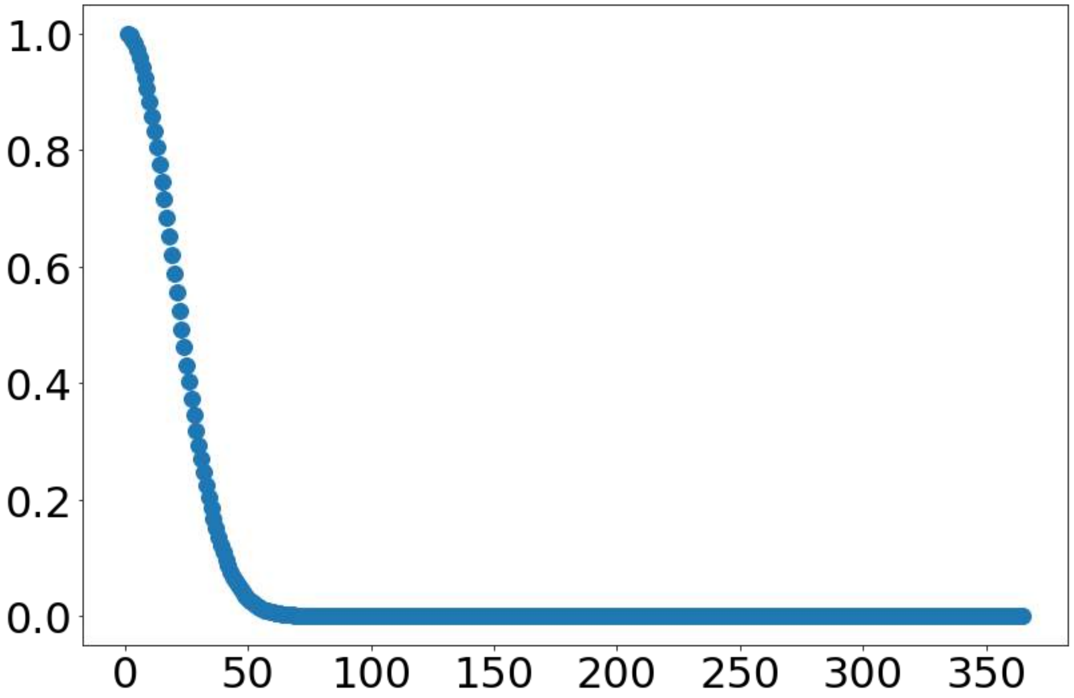
10 people: 0.883
20 people: 0.589
23 people: 0.493
30 people: 0.294
50 people: 0.030
100 people: 0.0000003



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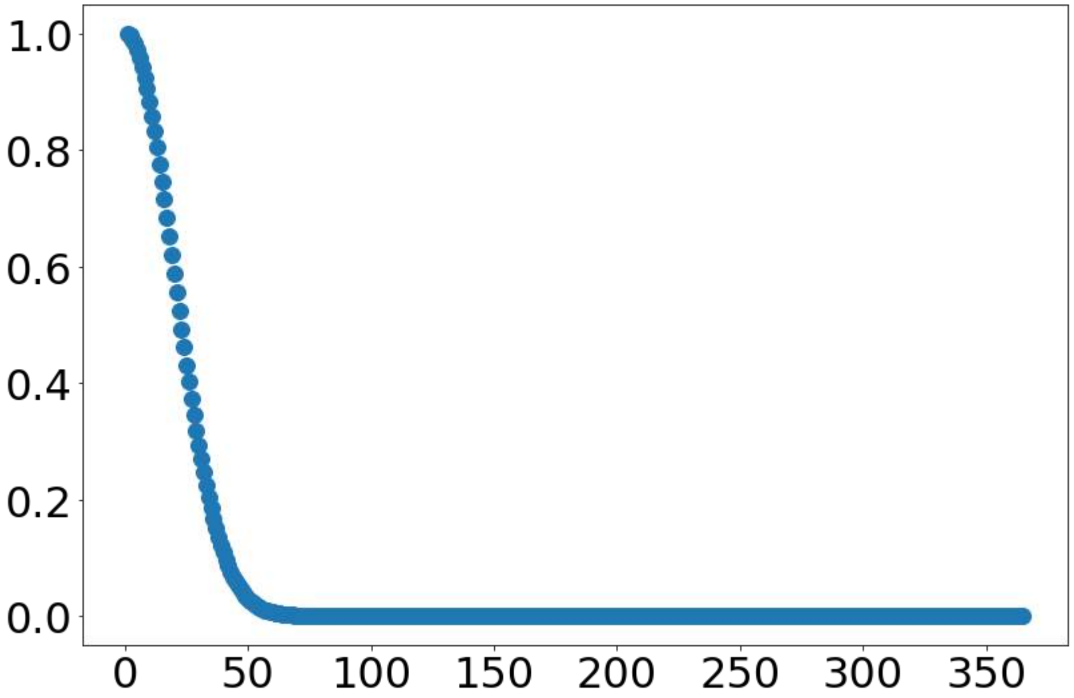
10 people: 0.883
20 people: 0.589
23 people: 0.493
30 people: 0.294
50 people: 0.030
100 people: 0.0000003
365 people: 0



Probability That no Two People Have the Same Birthday

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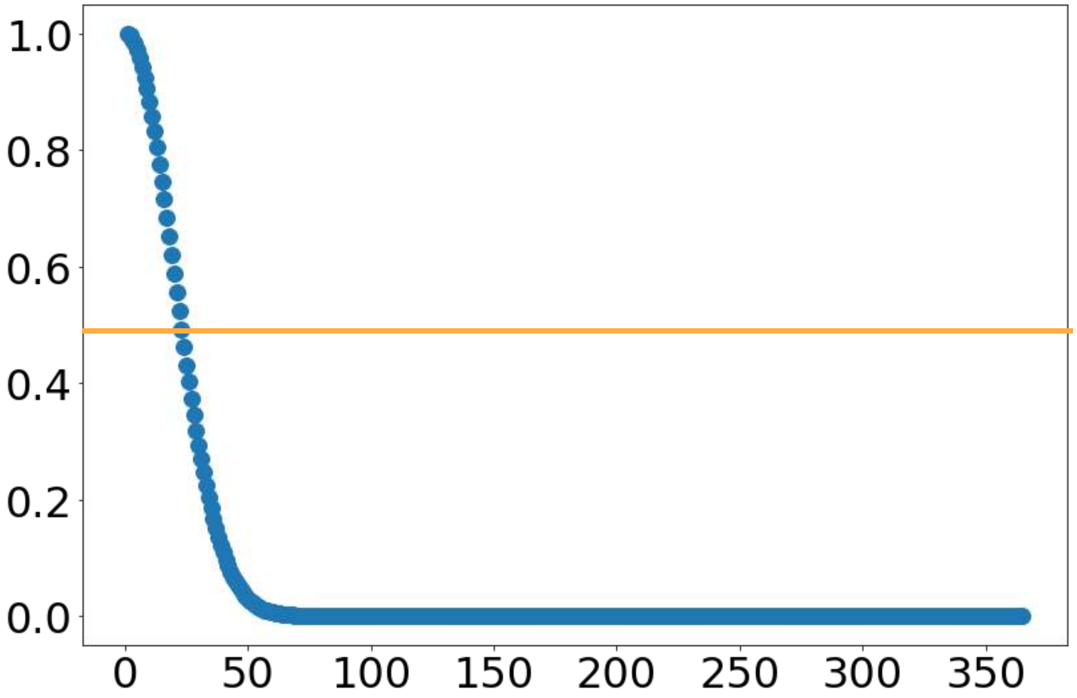
30 people: 0.294
50 people: 0.030
100 people: 0.0000003
365 people: 0



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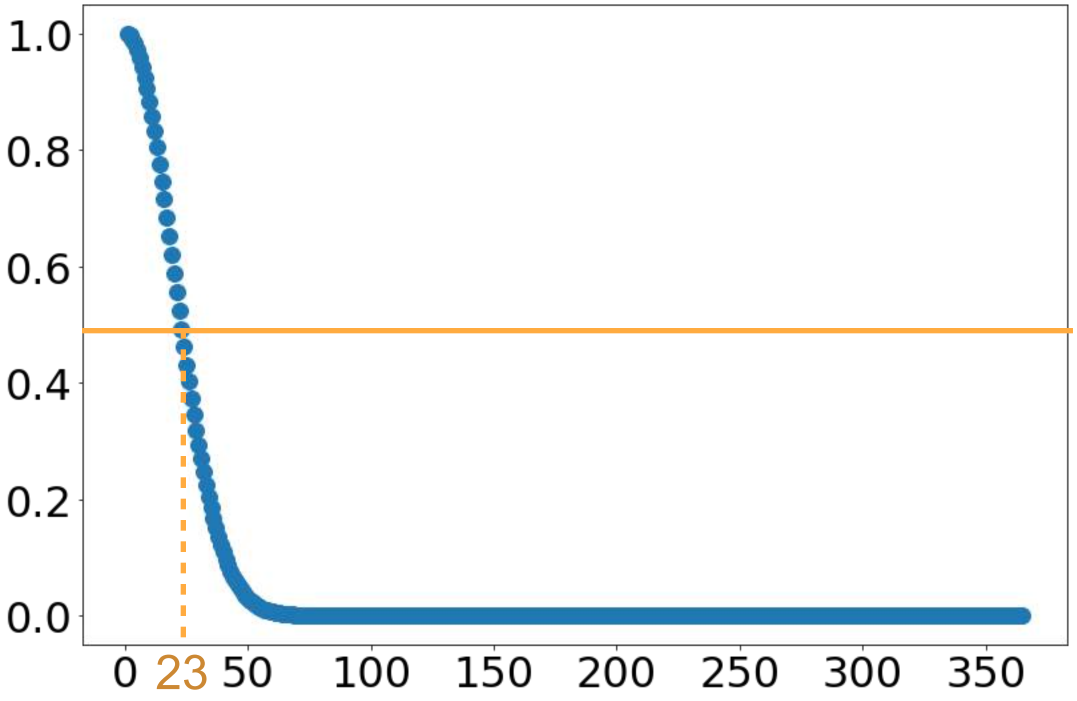

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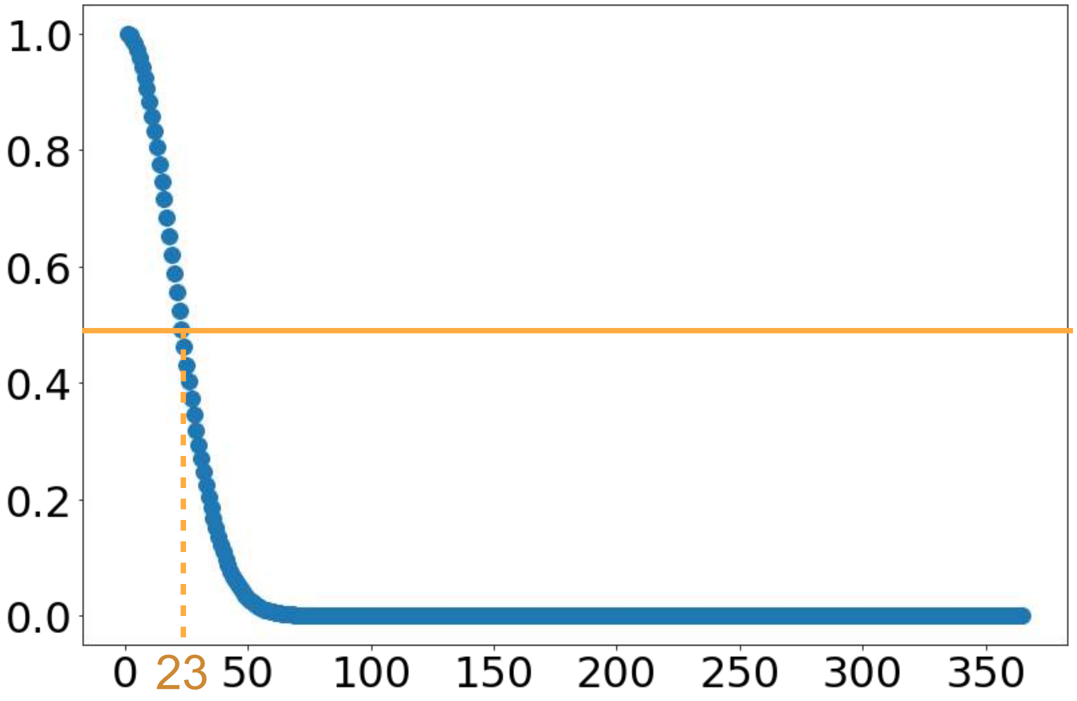


Introduction to probability

Conditional probability

DeepLearning.AI

Conditional Probability: Coin Example 1

50% 50%

Conditional Probability: Coin Example 1

50% 50%

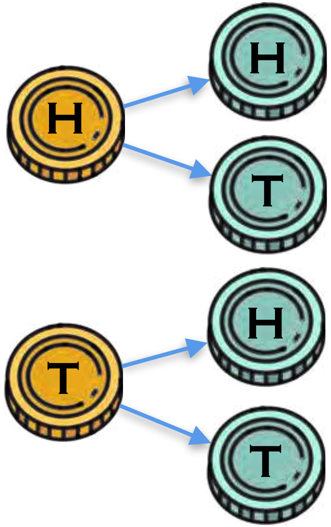
What is the probability of landing on heads twice?

Conditional Probability: Coin Example 1

50% 50%

What is the probability of landing on heads twice?

1st **2nd**

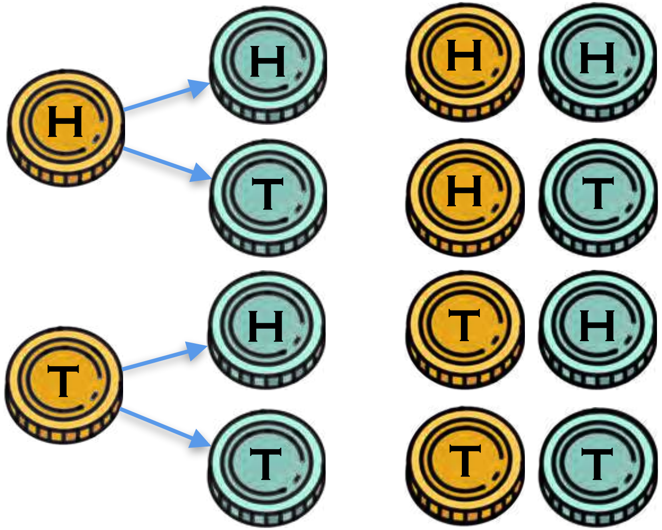


Conditional Probability: Coin Example 1

50% 50%

What is the probability of landing on heads twice?

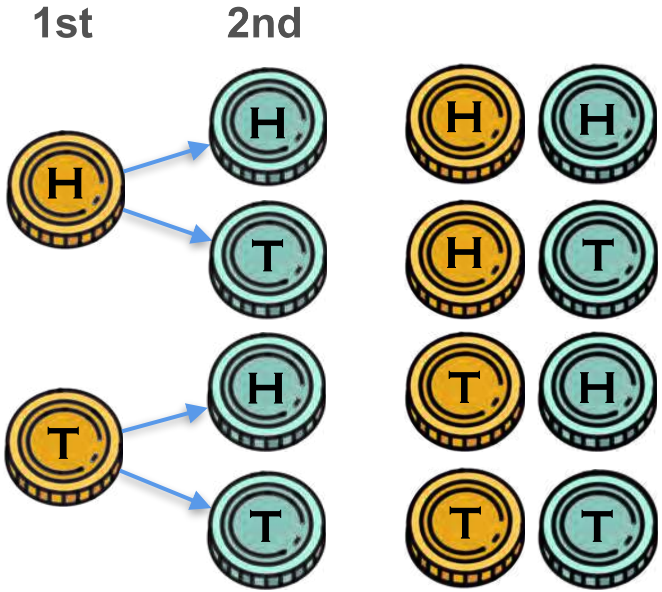
1st **2nd**



Conditional Probability: Coin Example 1

50% 50%

What is the probability of landing on heads twice?



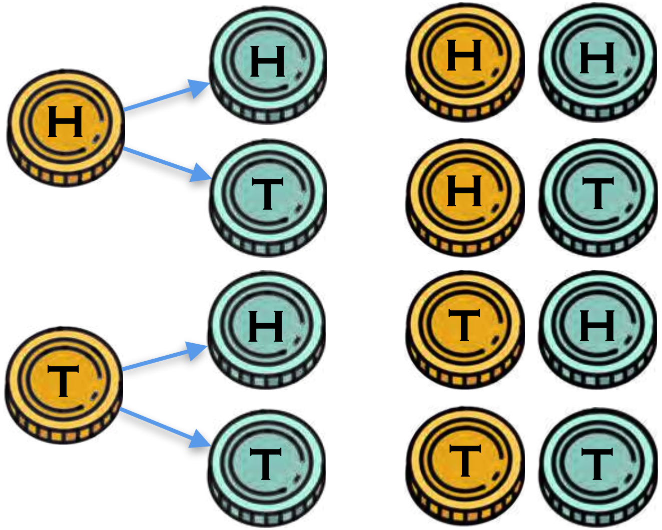
$$\mathbf{P}(HH) = \underline{\qquad\qquad\qquad}$$

Conditional Probability: Coin Example 1

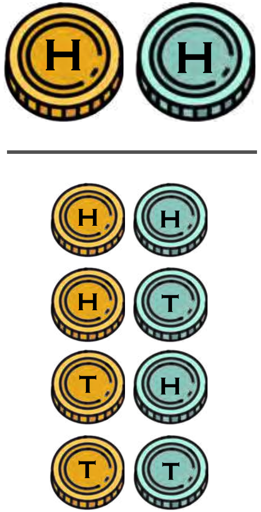
50% 50%

What is the probability of landing on heads twice?

1st **2nd**



$\mathbf{P}(HH) =$

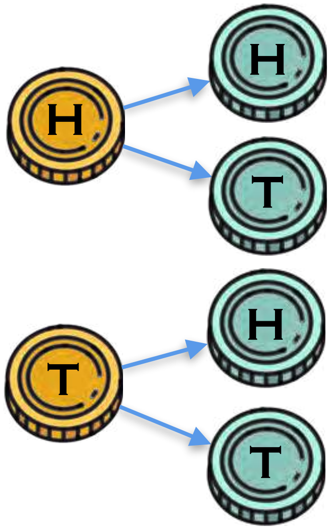


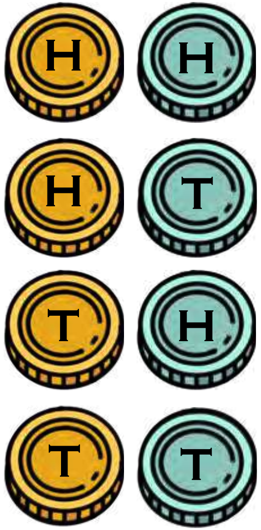
Conditional Probability: Coin Example 1

50% 50%

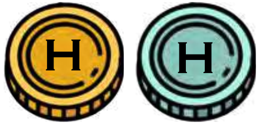
What is the probability of landing on heads twice?

1st **2nd**





$\mathbf{P}(HH) =$



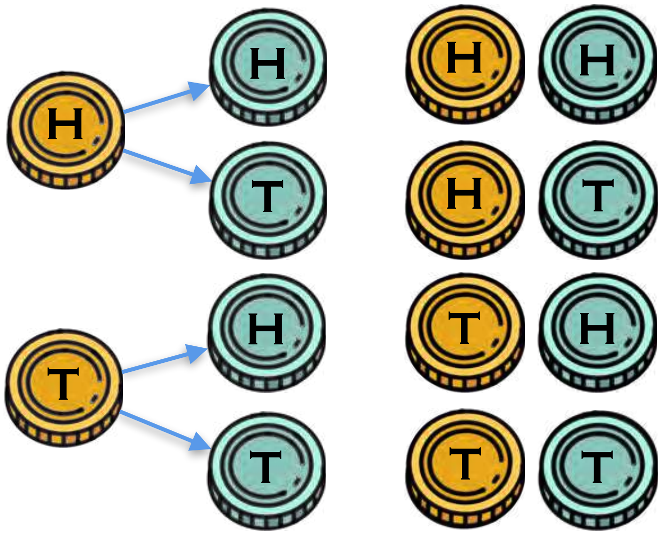
$= \frac{1}{4}$

Conditional Probability: Coin Example 1

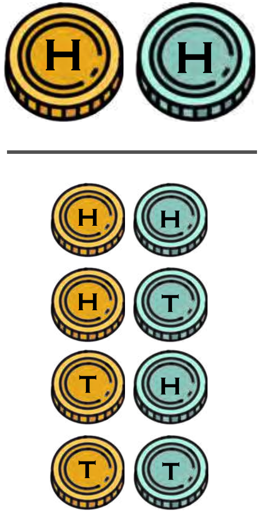
50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is heads**



$\mathbf{P}(HH) =$



$= \frac{1}{4}$

Conditional Probability: Coin Example 1

50% 50%

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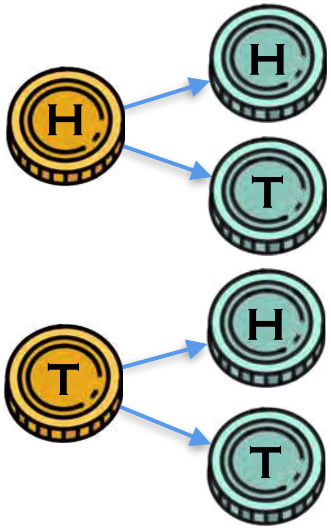
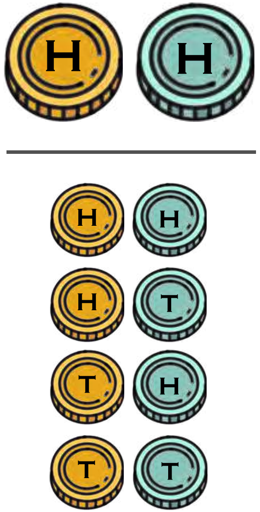


$\mathbf{P}(HH) =$  $= \frac{1}{4}$

Conditional Probability: Coin Example 1

50% 50%

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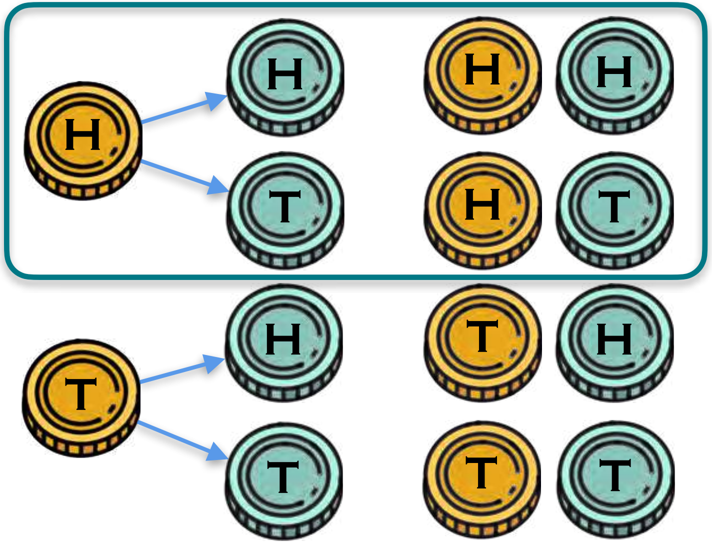

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$= \frac{1}{4}$

Conditional Probability: Coin Example 1

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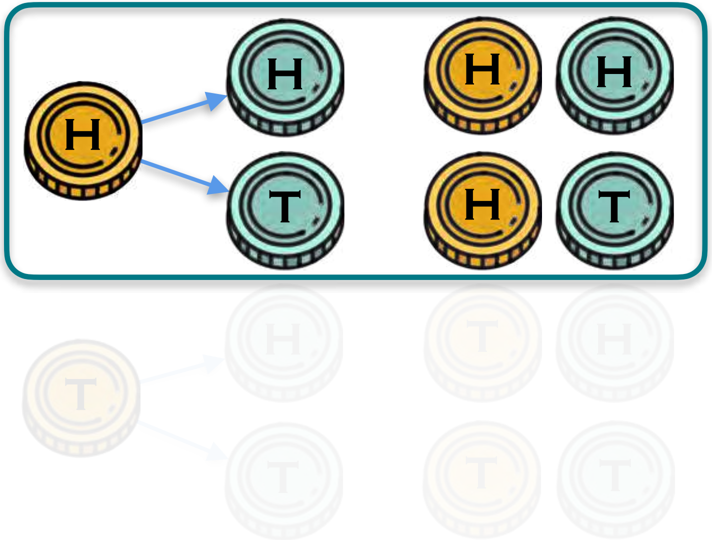
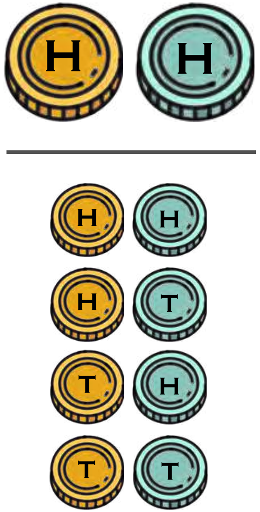


$\mathbf{P}(HH) =$



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Conditional Probability: Coin Example 1

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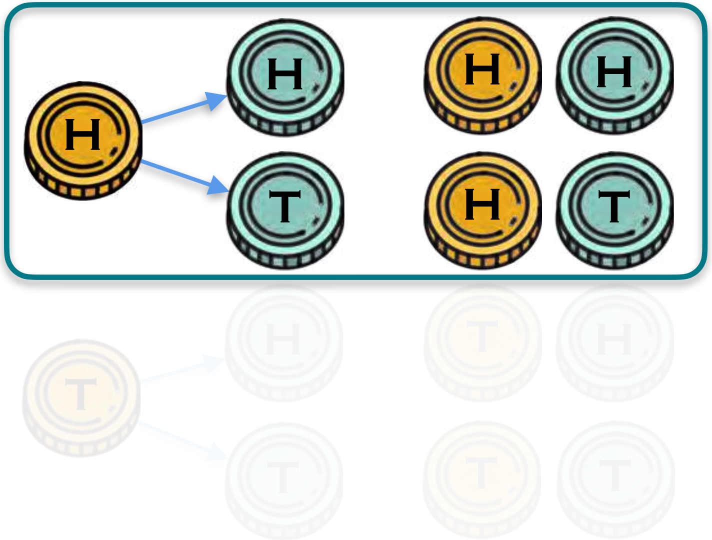
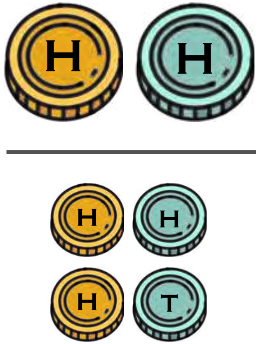


$\mathbf{P}(HH) =$



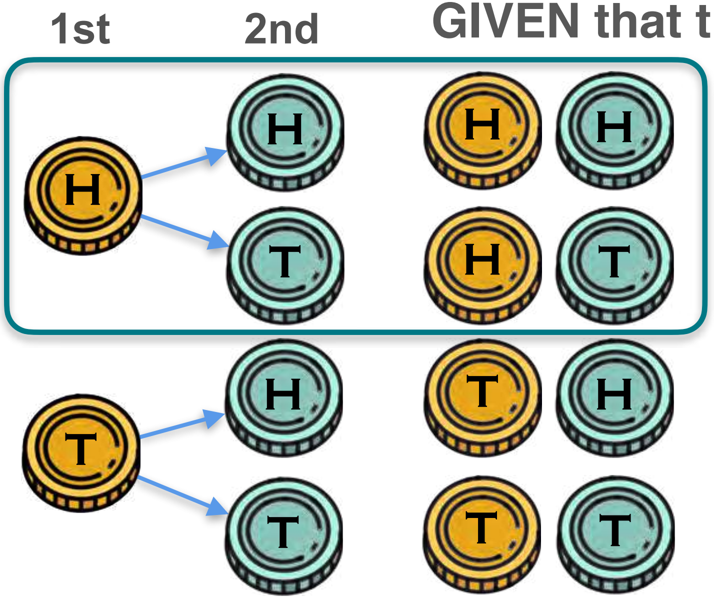
$= \frac{1}{4}$

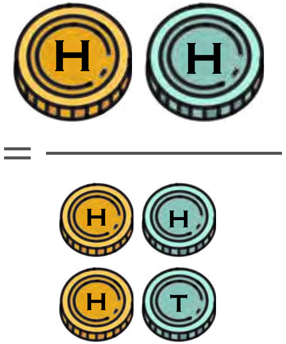
Conditional Probability: Coin Example 1

50% 50%

What is the probability of landing on heads twice?

GIVEN that the first one is heads





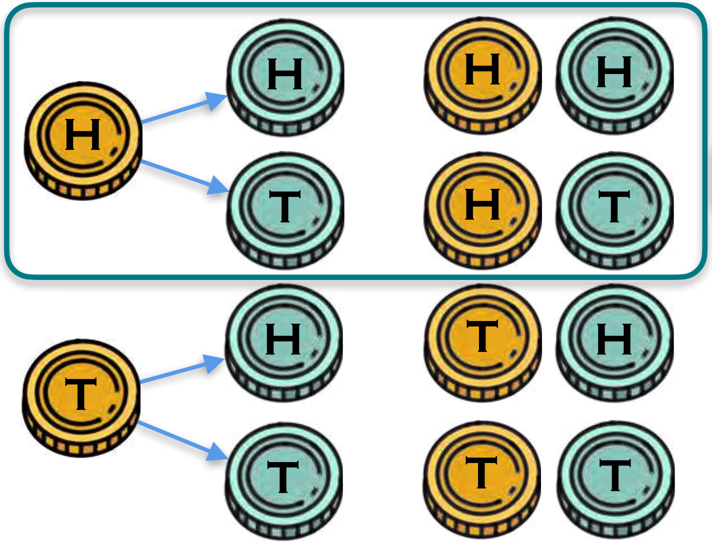
$$\mathbf{P}(HH \mid \text{1st is } H) = \frac{\quad}{\quad} = \frac{1}{2}$$

Conditional Probability: Coin Example 1

50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is heads**



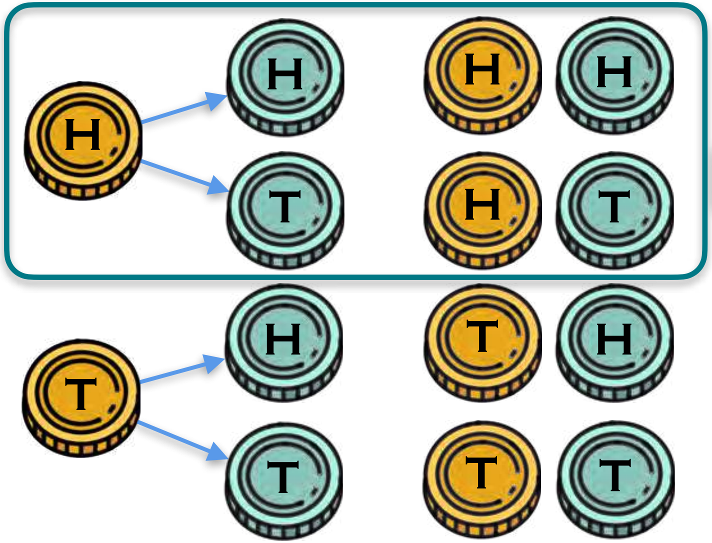
$$\boxed{\mathbf{P}(HH \mid \text{1st is } H)} = \frac{\text{[numerator coins]}}{\text{[denominator coins]}} = \frac{1}{2}$$

Conditional Probability: Coin Example 1

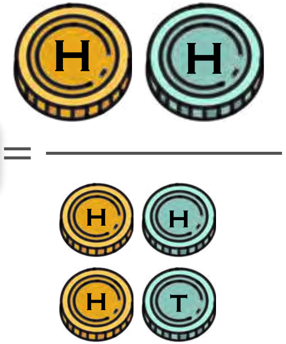
50% 50%

What is the probability of landing on heads twice?

1st 2nd **GIVEN that the first one is heads**



$\mathbf{P}(HH \mid \text{1st is } H) = \frac{1}{2}$



Conditional Probability: Coin Example 1

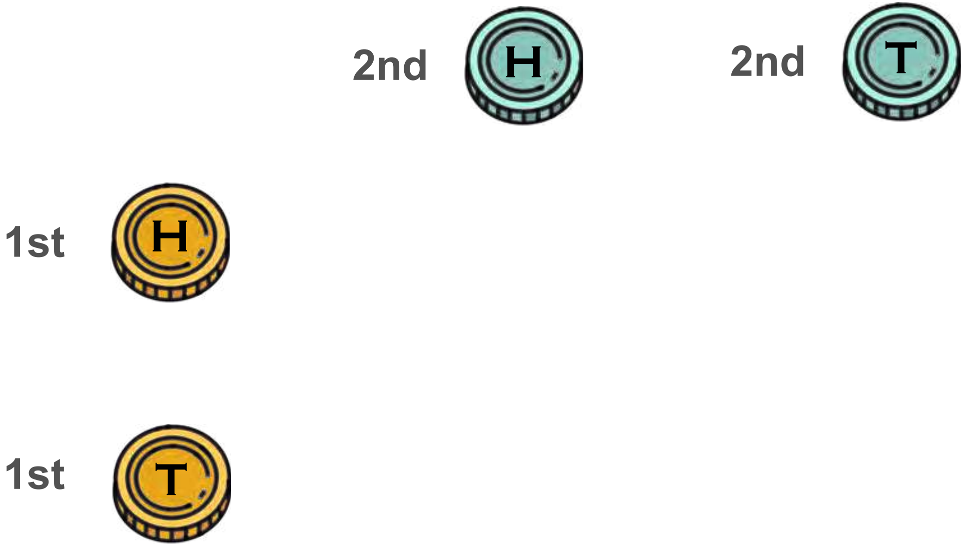
What is the probability of landing on heads twice?

GIVEN that the first one is heads

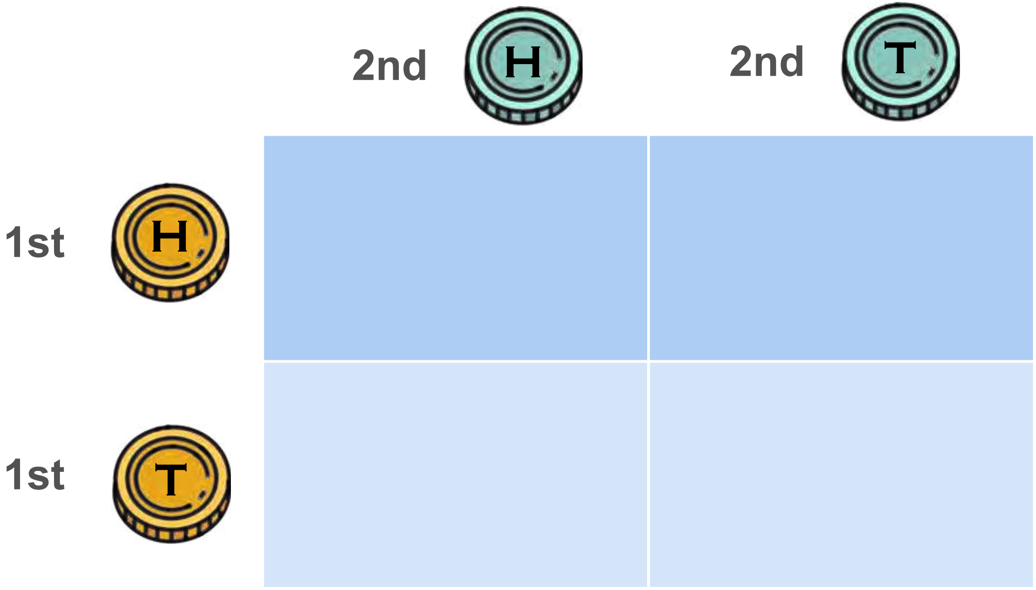
$$\mathbf{P}(HH \,\boxed{|\, \text{1st is } H)}$$

Conditional Probability: Coin Example 1

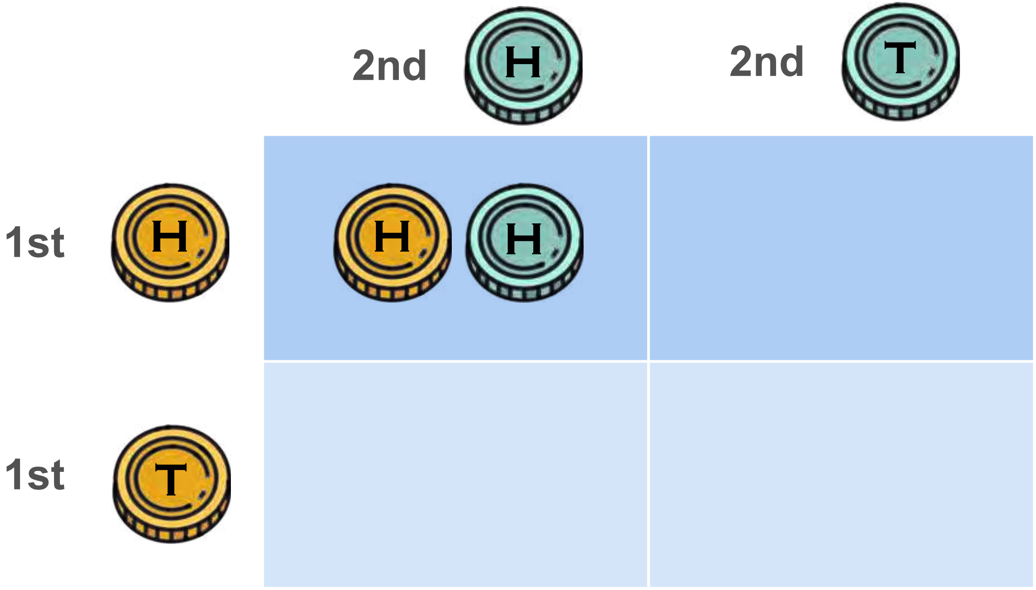
Conditional Probability: Coin Example 1



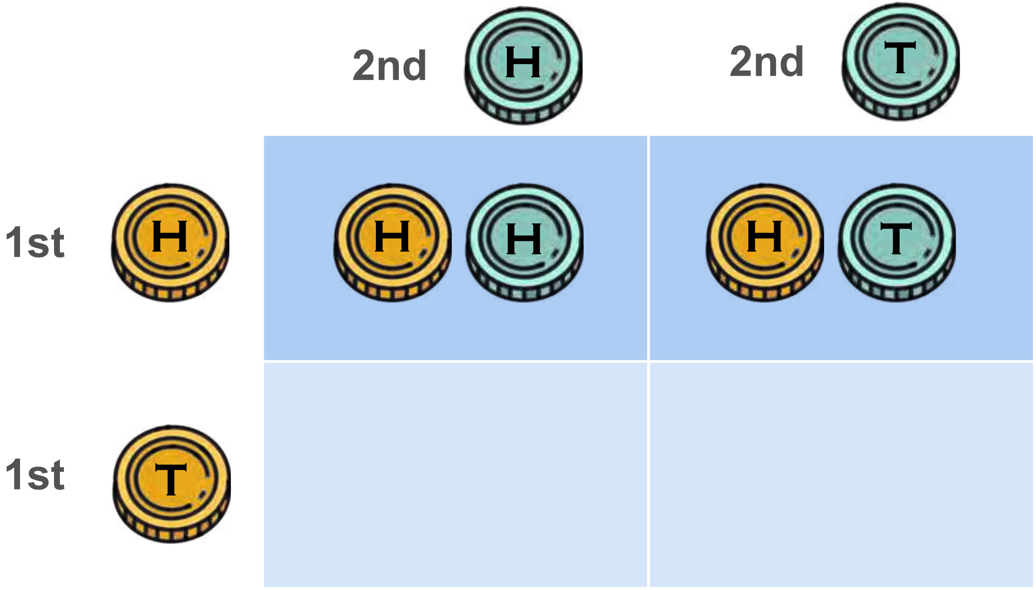
Conditional Probability: Coin Example 1



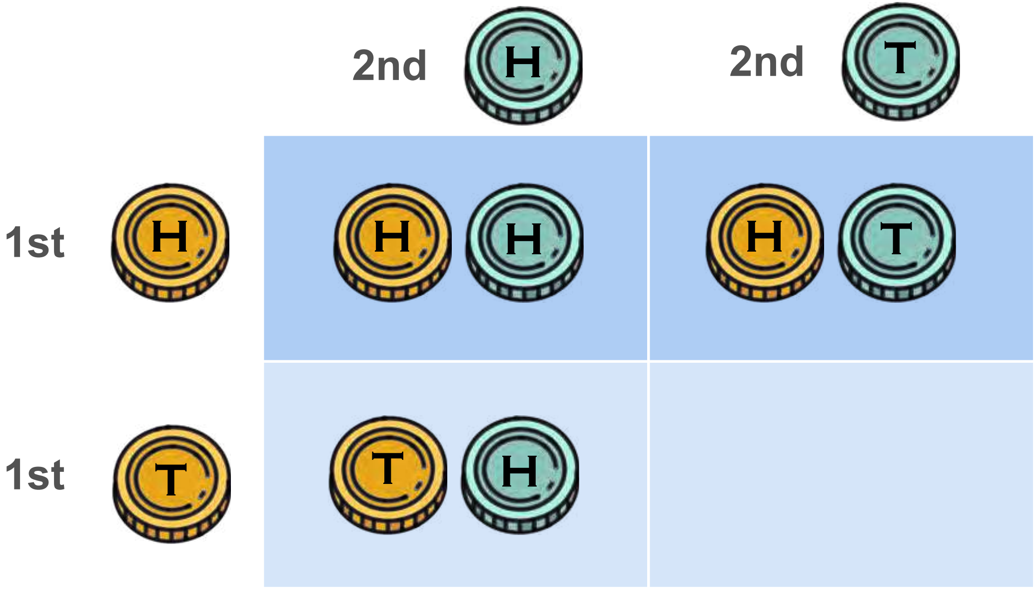
Conditional Probability: Coin Example 1



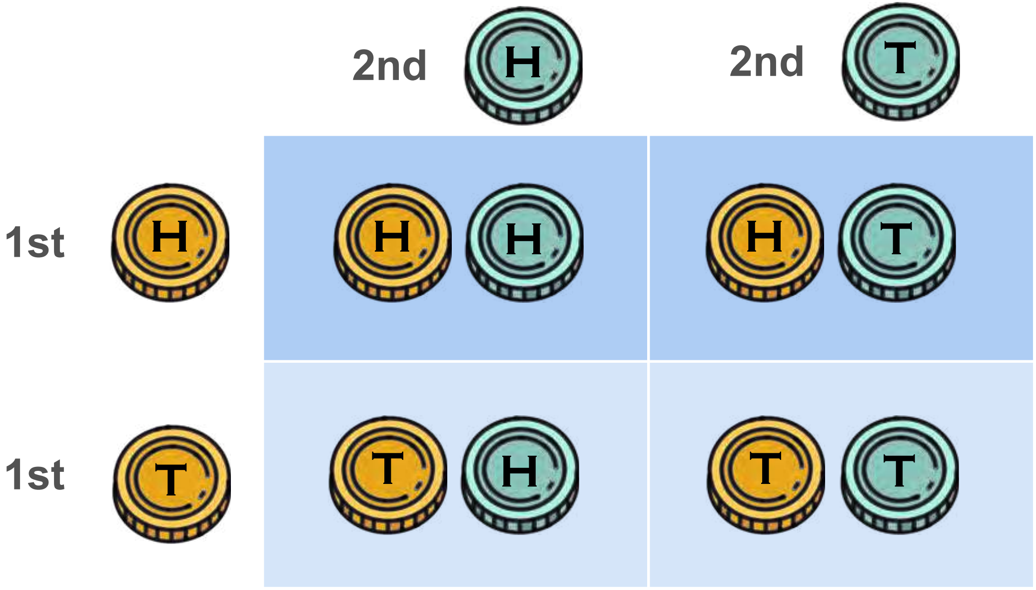
Conditional Probability: Coin Example 1



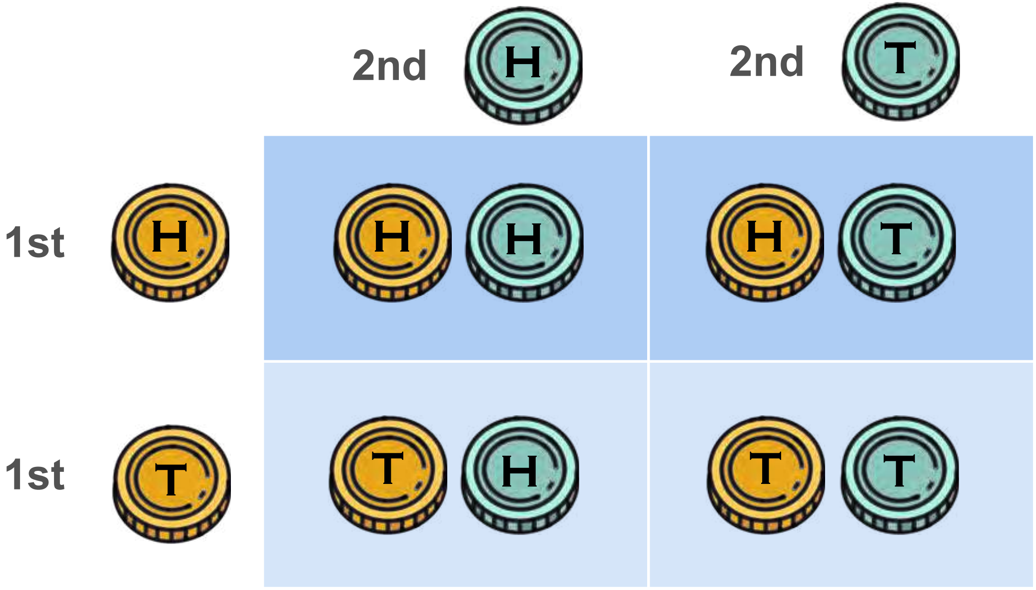
Conditional Probability: Coin Example 1



Conditional Probability: Coin Example 1

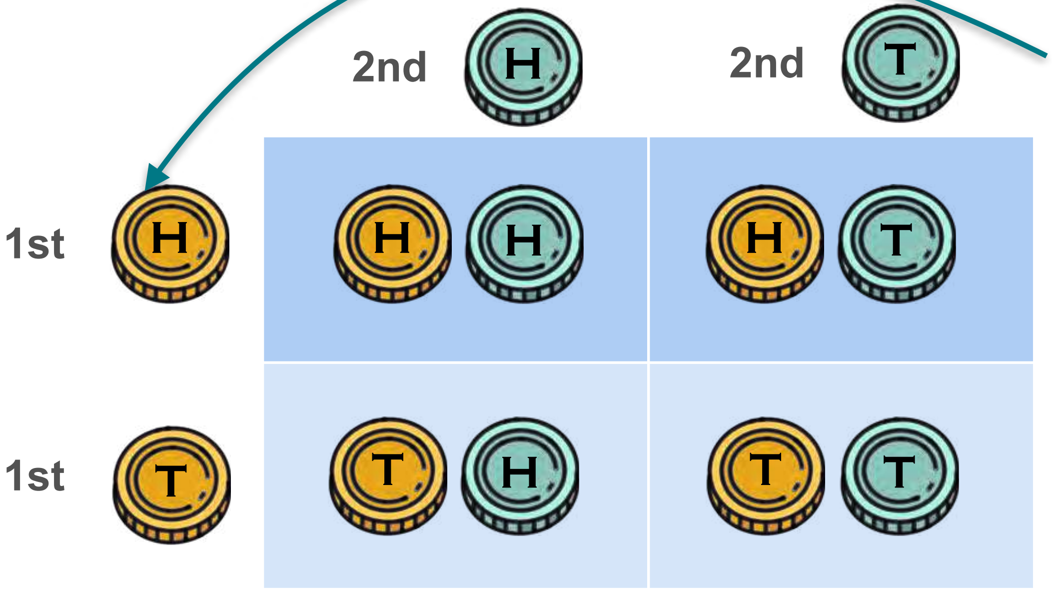


Conditional Probability: Coin Example 1



Probability of landing on heads twice

Conditional Probability: Coin Example 1



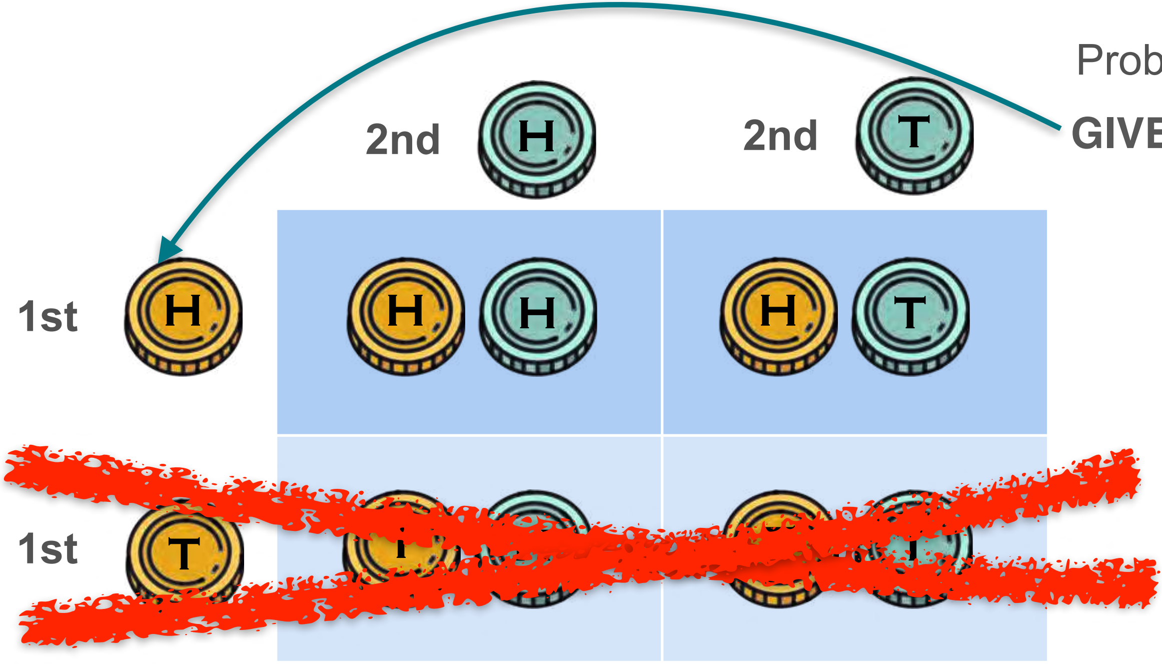
Probability of landing on heads twice

GIVEN that the first one is heads

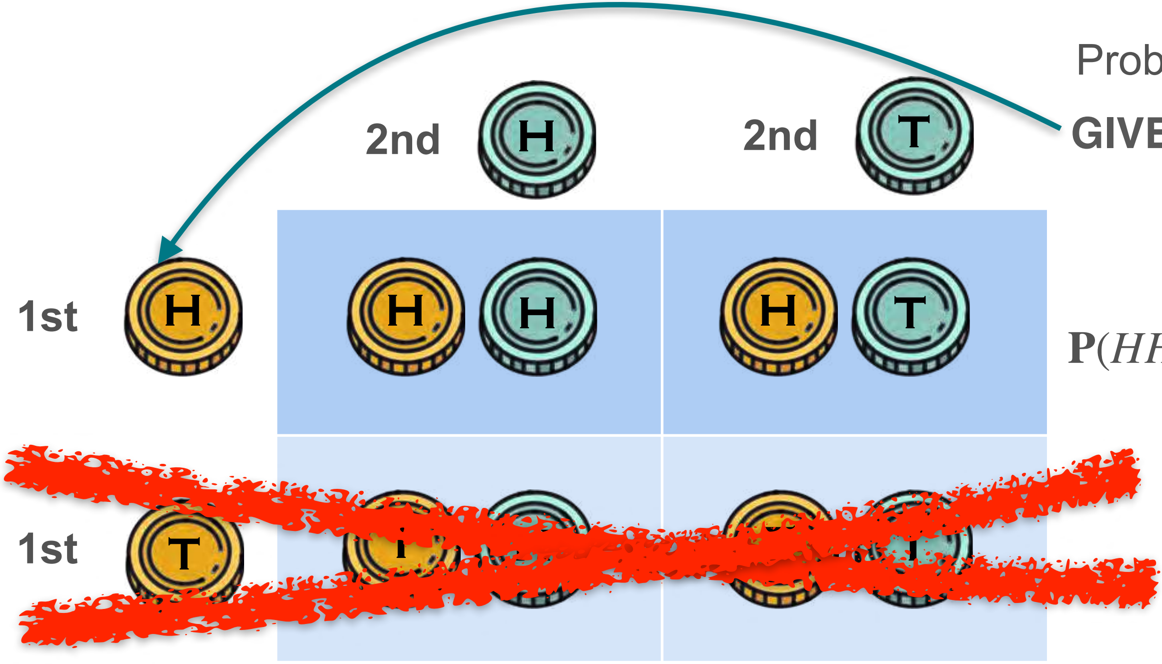
Conditional Probability: Coin Example 1

Probability of landing on heads twice

GIVEN that the first one is heads



Conditional Probability: Coin Example 1

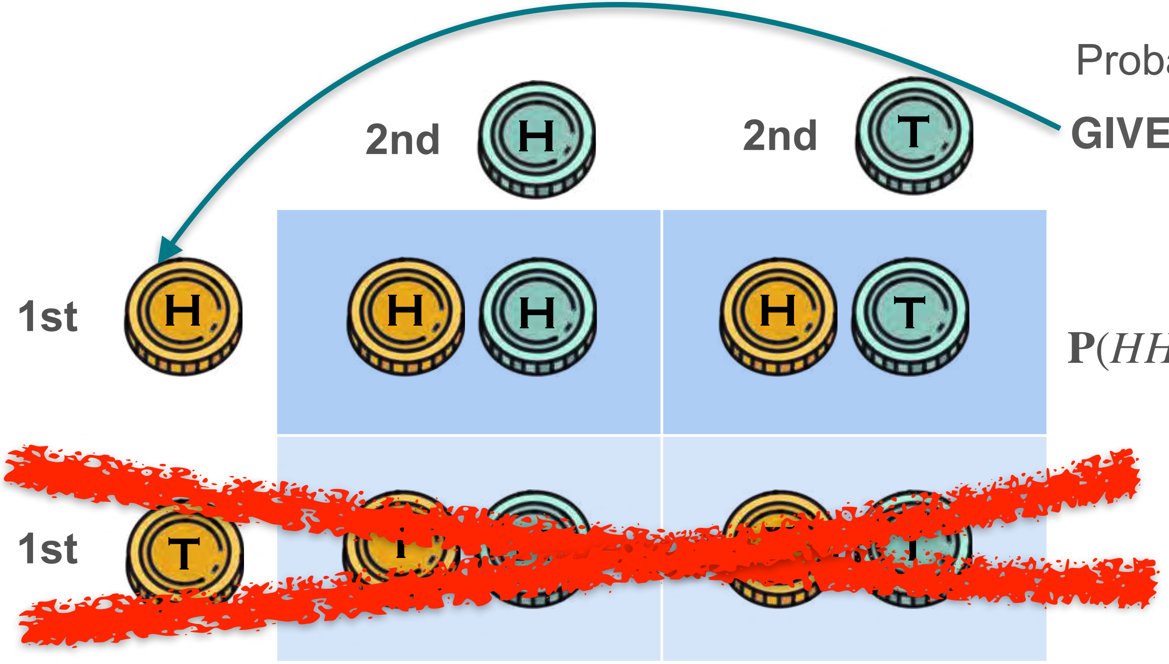


Probability of landing on heads twice

GIVEN that the first one is heads

$\mathbf{P}(HH \,|\, \text{1st is } H) = \underline{\hspace{3cm}}$

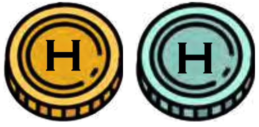
Conditional Probability: Coin Example 1



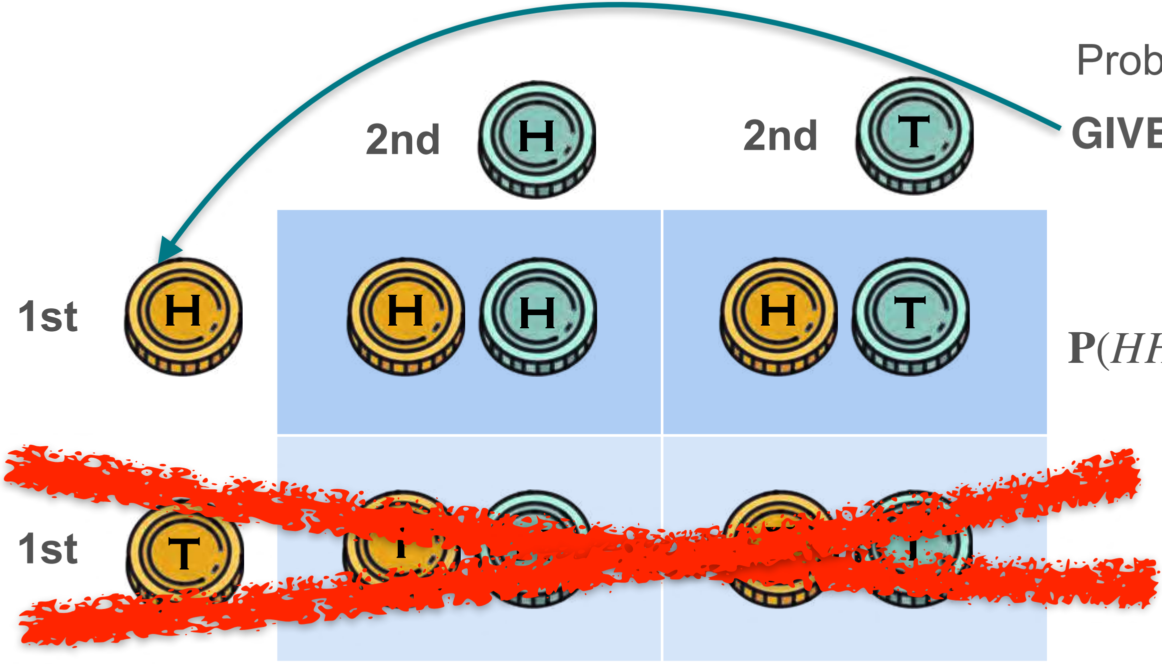
Probability of landing on heads twice

GIVEN that the first one is heads

$$\mathbf{P}(HH \mid \text{1st is } H) = $$



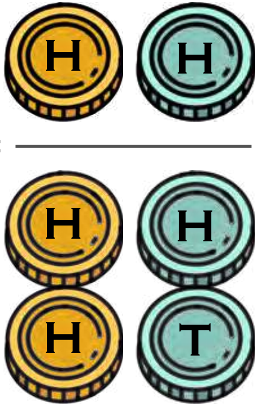
Conditional Probability: Coin Example 1



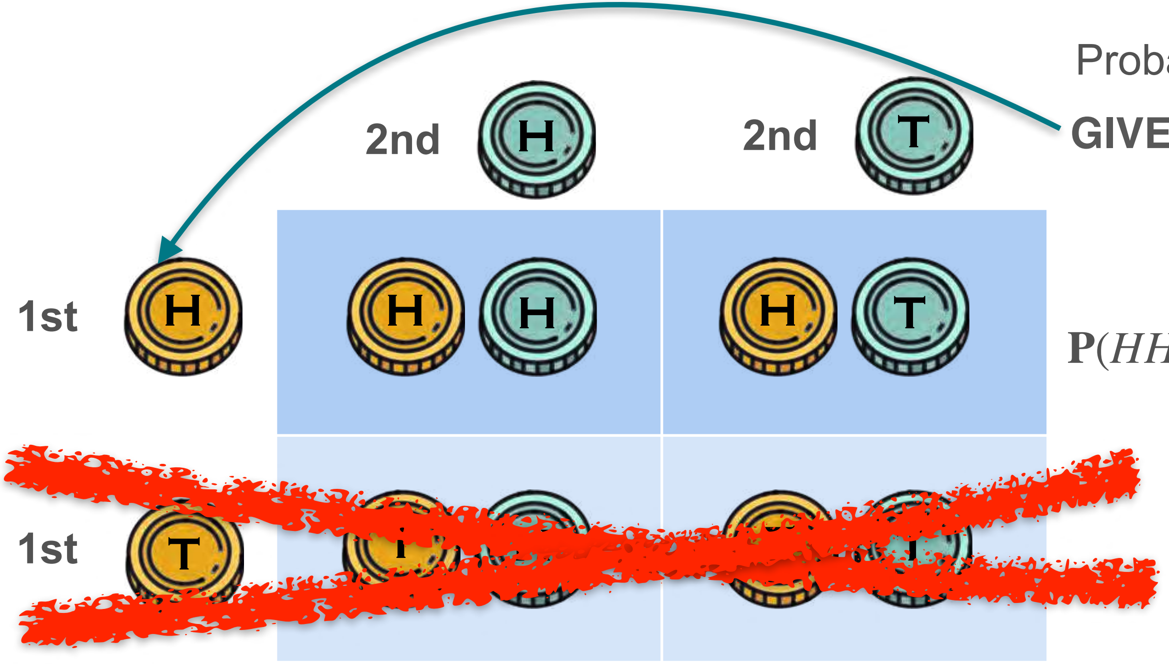
Probability of landing on heads twice

GIVEN that the first one is heads

$\mathbf{P}(HH \,|\, \text{1st is } H) =$



Conditional Probability: Coin Example 1



Probability of landing on heads twice

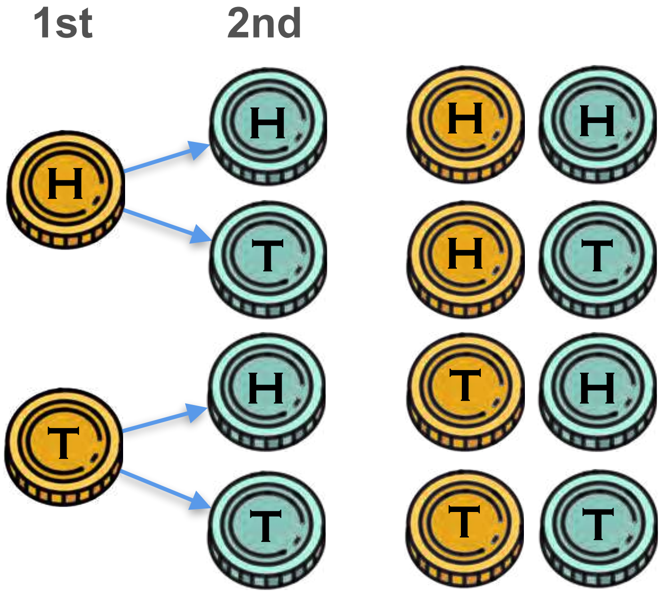
GIVEN that the first one is heads

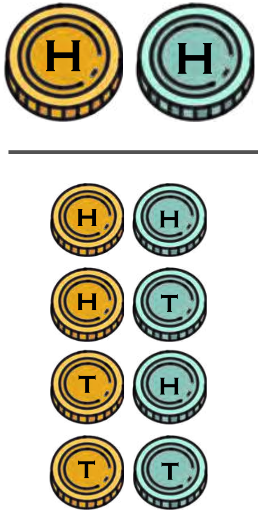
$$\mathbf{P}(HH \mid \text{1st is } H) = \frac{HH}{\begin{matrix} HH \\ HT \end{matrix}} = \frac{1}{2}$$

Conditional Probability: Coin Example 2

50% 50%

What is the probability of landing on heads twice?





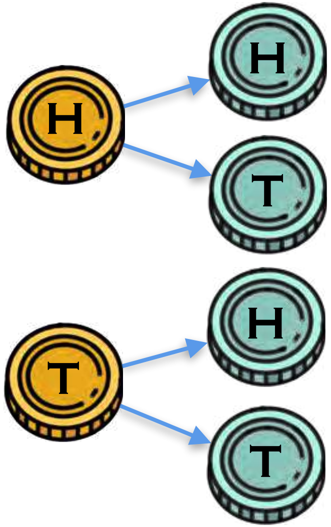
$$\mathbf{P}(HH) = \frac{1}{4}$$

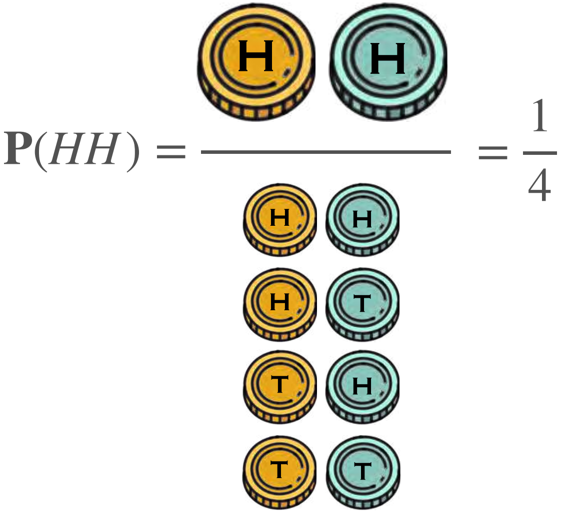
Conditional Probability: Coin Example 2

50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is tails**



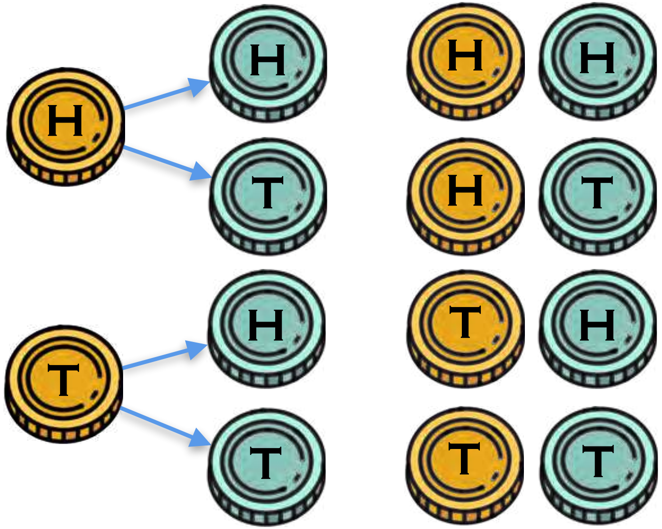


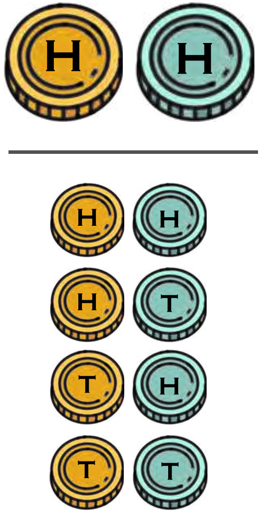
Conditional Probability: Coin Example 2

50% 50%

What is the probability of landing on heads twice?

1st 2nd **GIVEN that the first one is tails**



$\mathbf{P}(HH) =$  $= \frac{1}{4}$

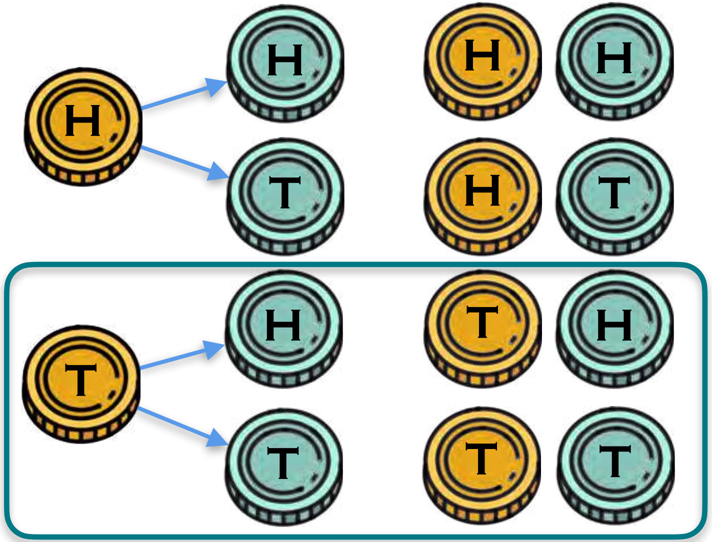
Conditional Probability: Coin Example 2

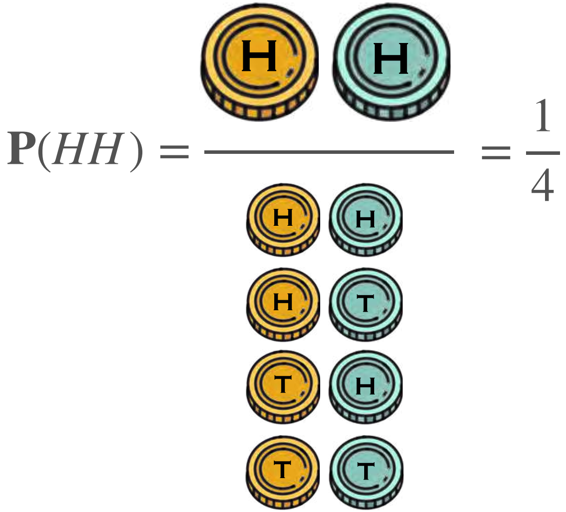
50% 50%

What is the probability of landing on heads twice?

GIVEN that the first one is tails

1st **2nd**



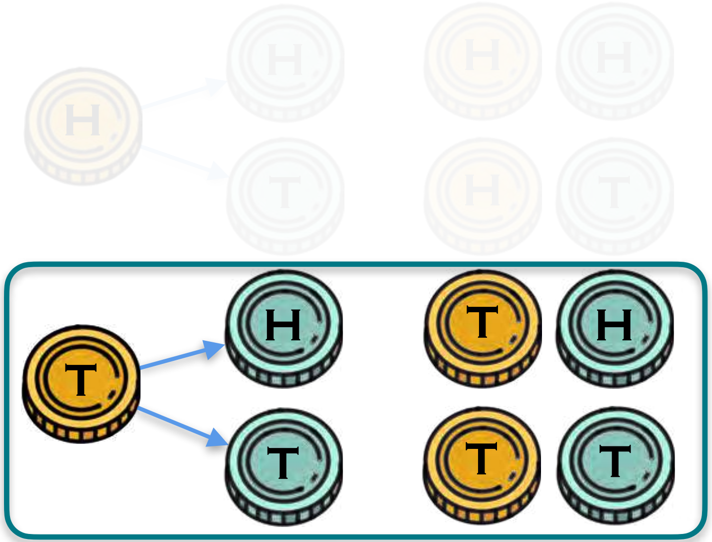


Conditional Probability: Coin Example 2

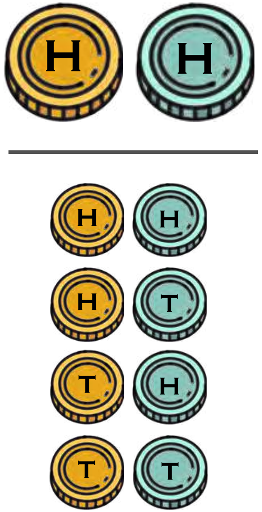
50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is tails**



$$P(HH) = \frac{\quad}{\quad} = \frac{1}{4}$$

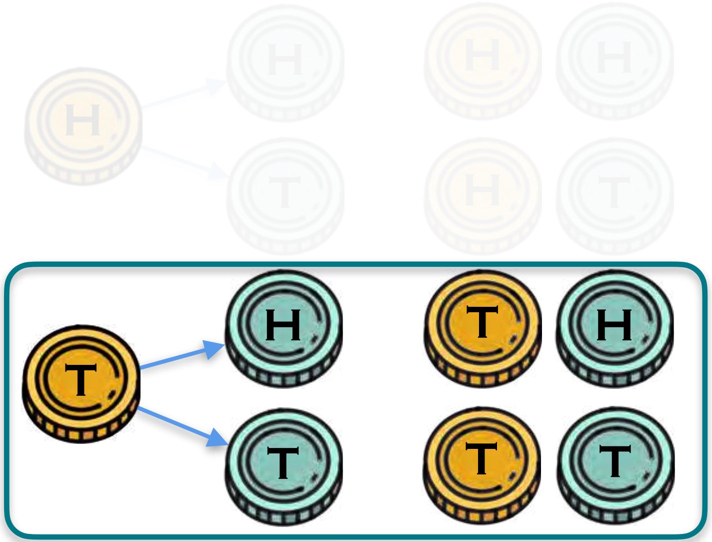


Conditional Probability: Coin Example 2

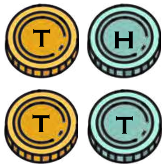
50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is tails**



$$\mathbf{P}(HH) = \frac{\quad}{\quad} = \frac{1}{4}$$

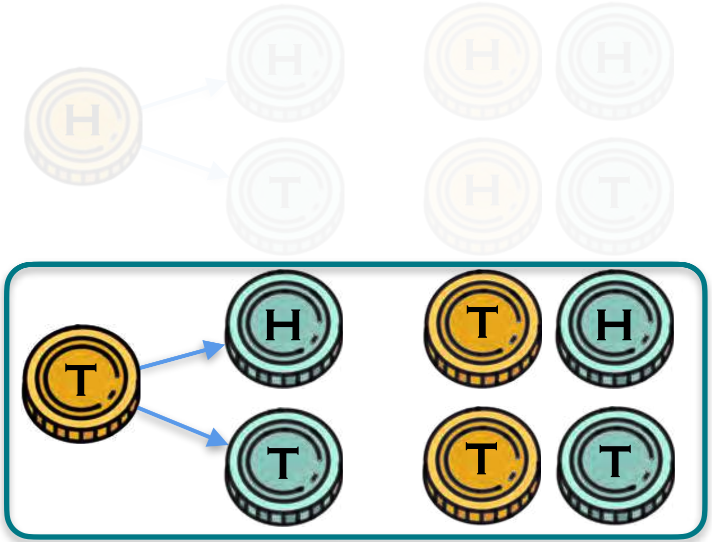


Conditional Probability: Coin Example 2

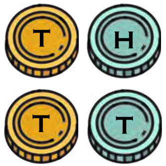
50%   50%

What is the probability of landing on heads twice?

1st   **2nd**   **GIVEN that the first one is tails**



$$\mathbf{P}(HH) = \underline{\hspace{3cm}} = \frac{1}{4}$$

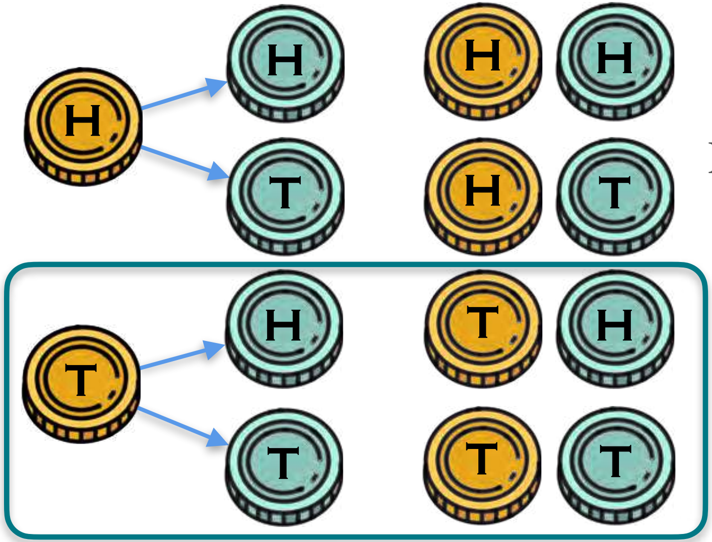


Conditional Probability: Coin Example 2

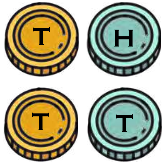
50% 50%

What is the probability of landing on heads twice?

1st **2nd** **GIVEN that the first one is tails**

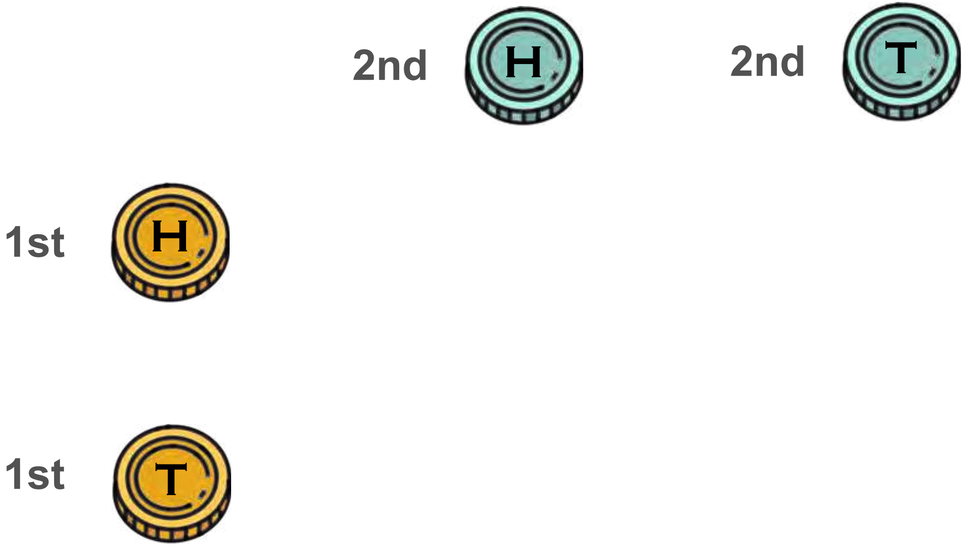


$$\mathbf{P}(HH \mid \text{1st is } T) = \frac{0}{} = 0$$

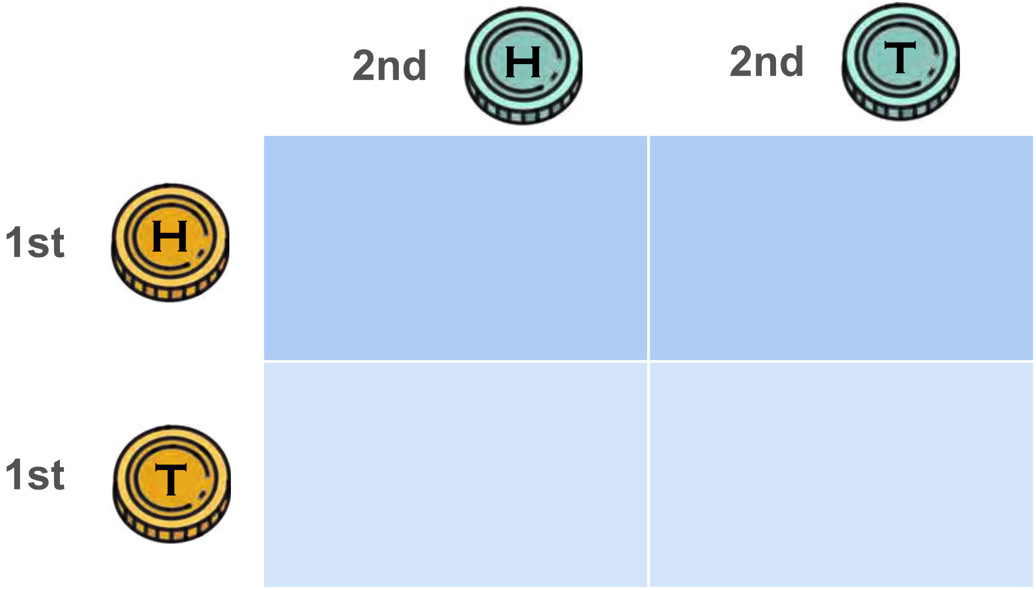


Conditional Probability: Coin Example 2

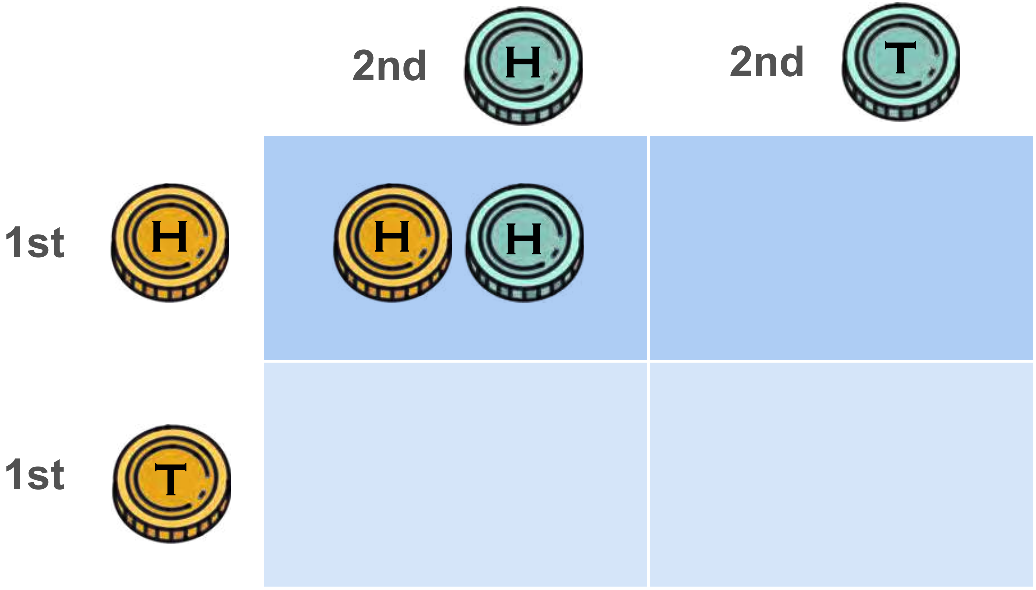
Conditional Probability: Coin Example 2



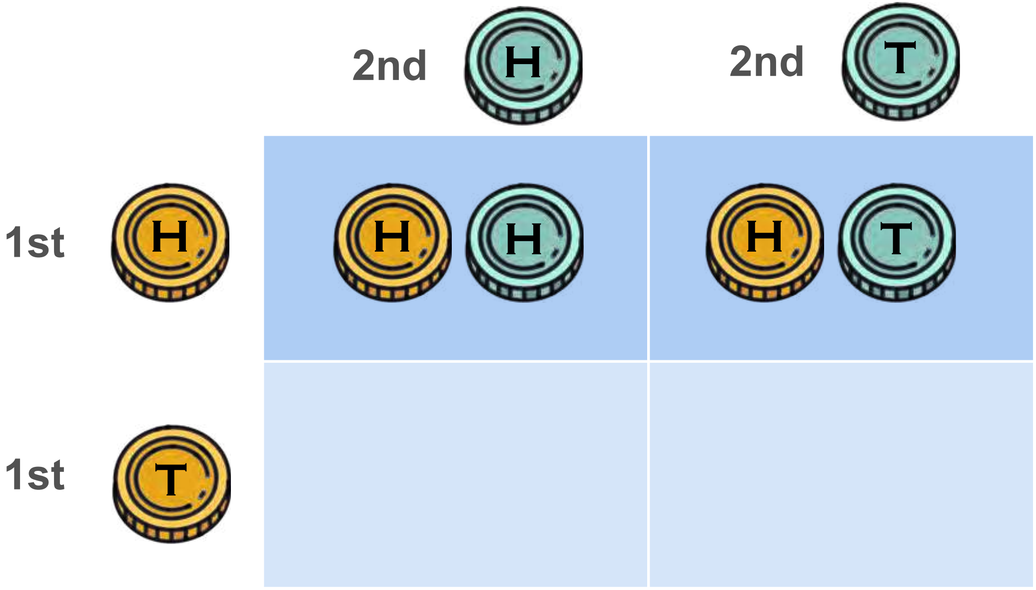
Conditional Probability: Coin Example 2



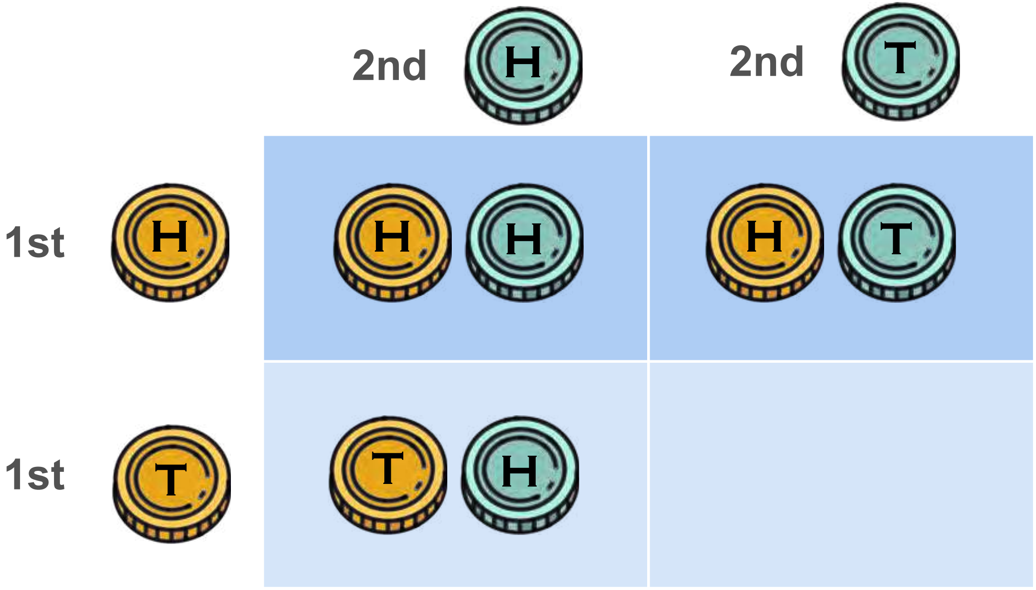
Conditional Probability: Coin Example 2



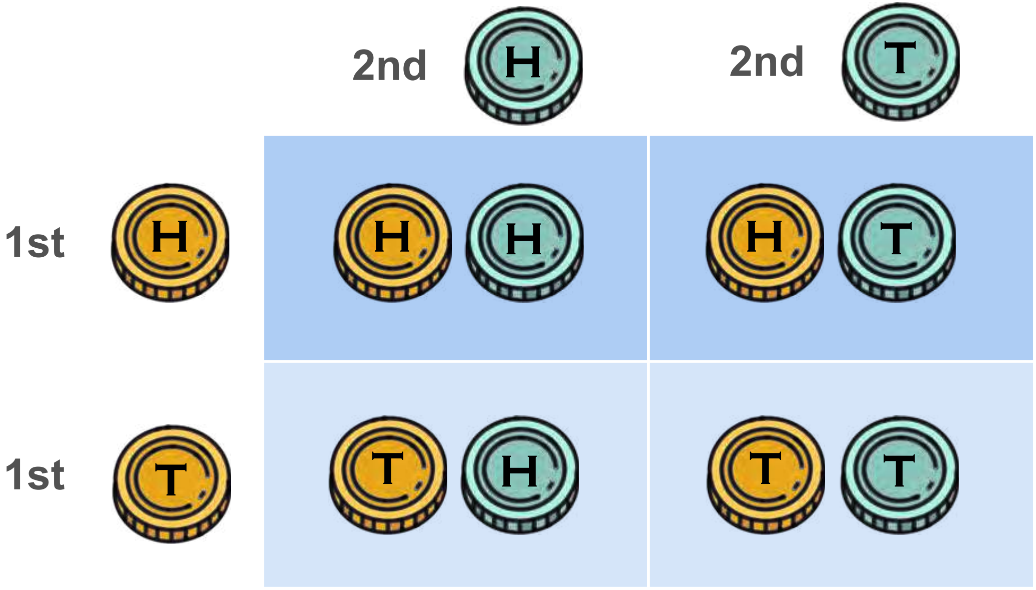
Conditional Probability: Coin Example 2



Conditional Probability: Coin Example 2

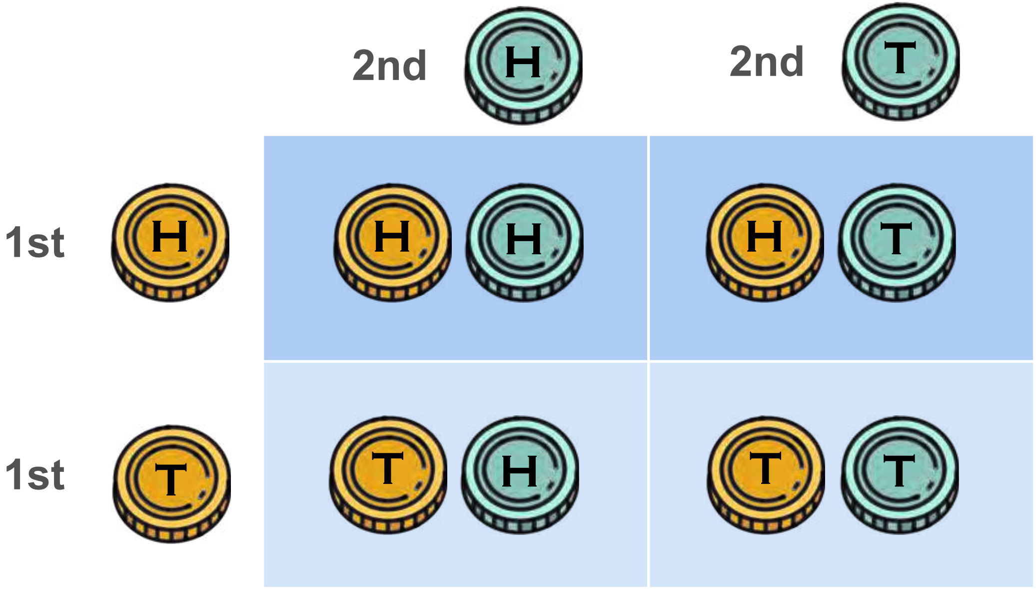


Conditional Probability: Coin Example 2



Conditional Probability: Coin Example 2

Probability of landing on heads twice

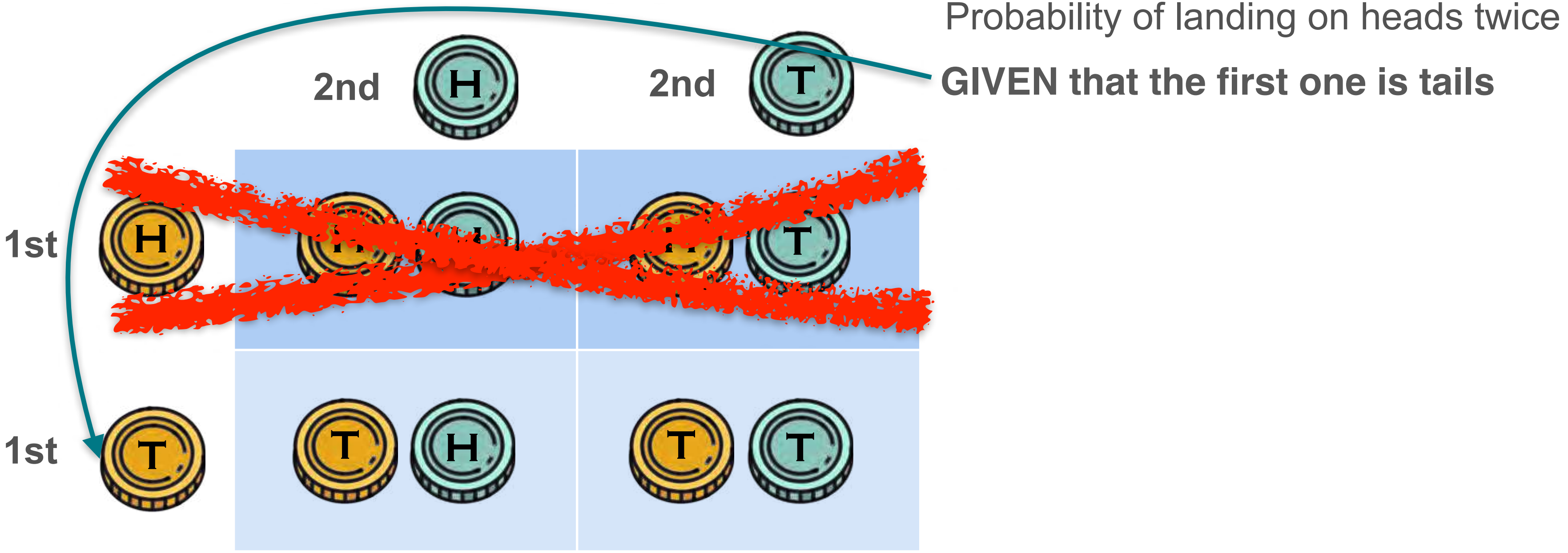


Conditional Probability: Coin Example 2

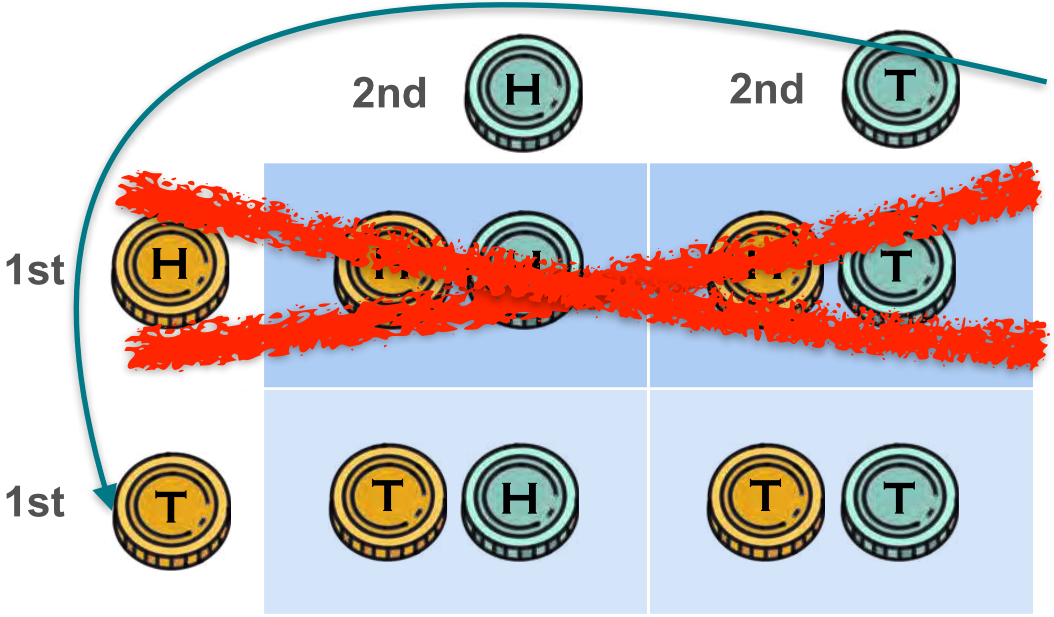
Probability of landing on heads twice

GIVEN that the first one is tails

Conditional Probability: Coin Example 2



Conditional Probability: Coin Example 2

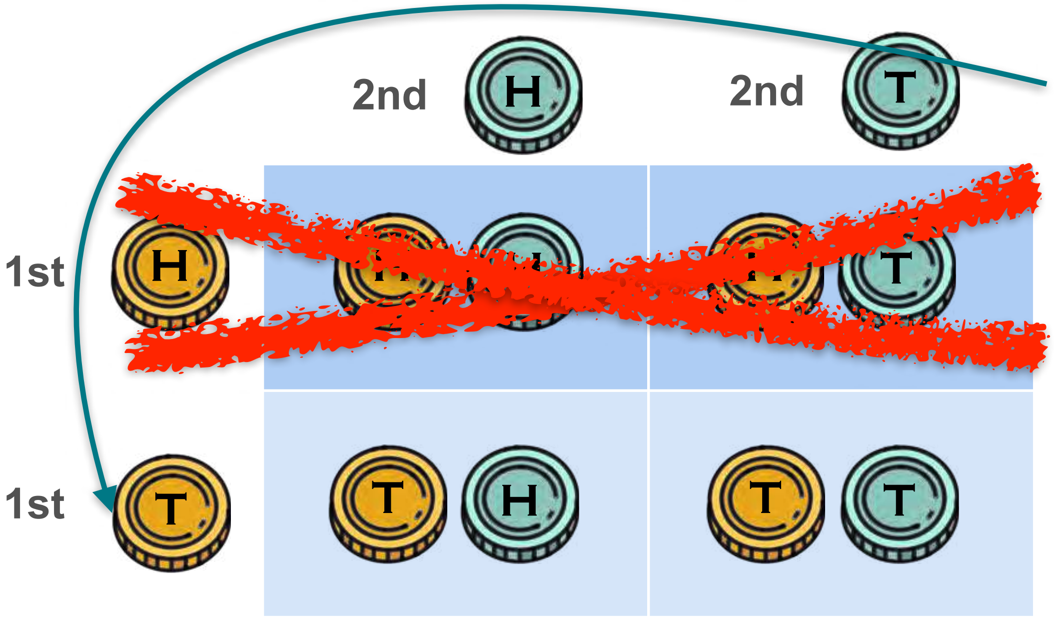


Probability of landing on heads twice

GIVEN that the first one is tails

$\mathbf{P}(HH \mid \text{1st is } T) = \_\_\_\_\_\_$

Conditional Probability: Coin Example 2

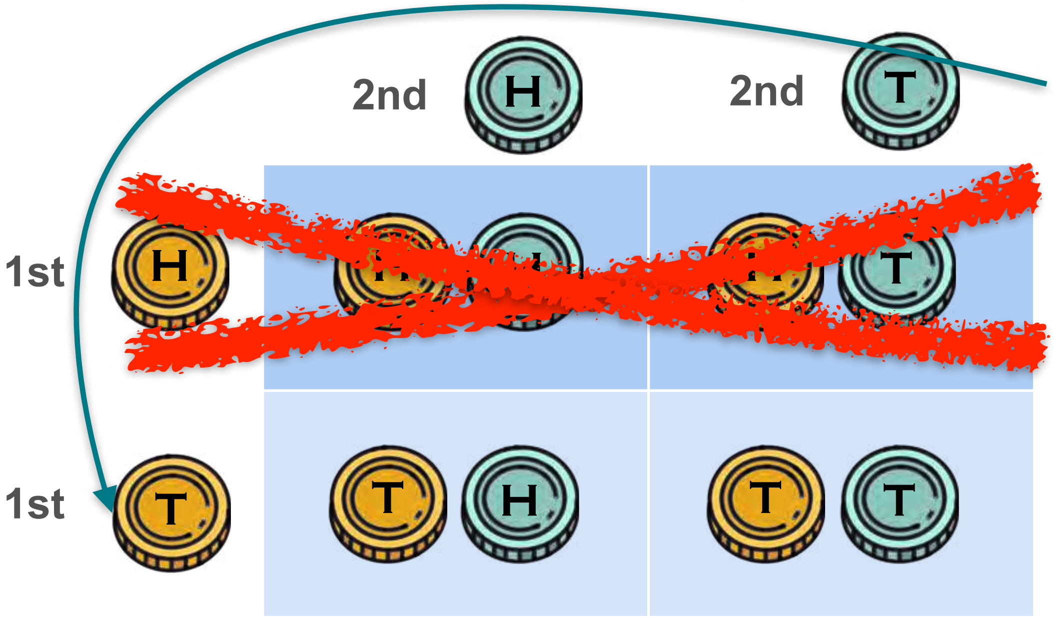


Probability of landing on heads twice

GIVEN that the first one is tails

$\mathbf{P}(HH \mid \text{1st is } T) = \underline{\qquad\qquad}$

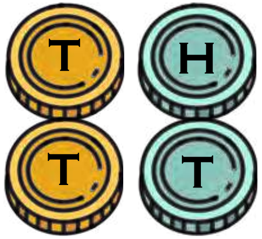
Conditional Probability: Coin Example 2



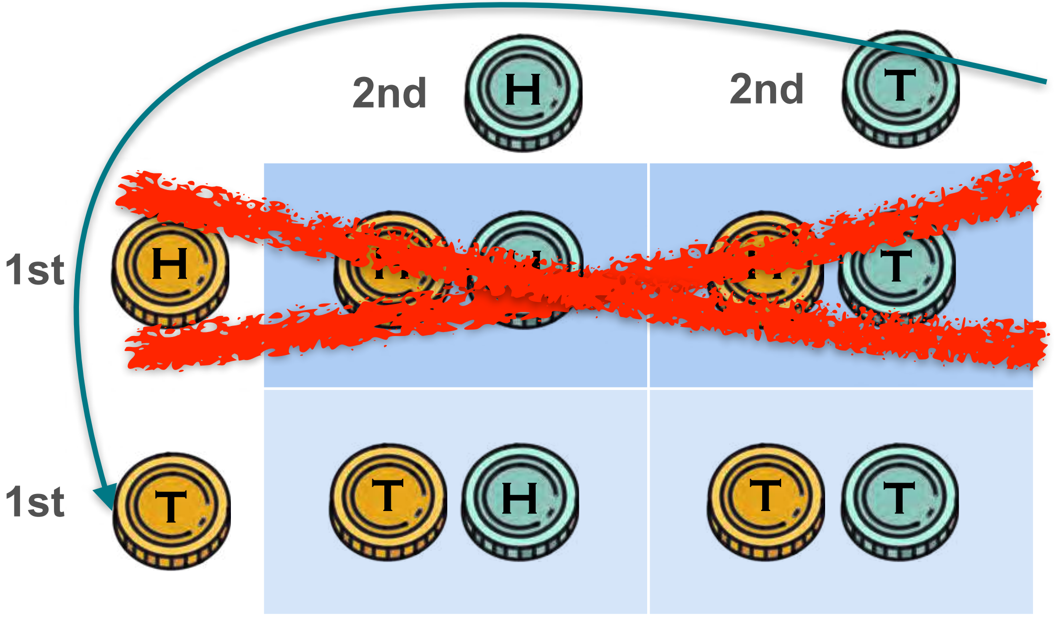
Probability of landing on heads twice

GIVEN that the first one is tails

$\mathbf{P}(HH \mid \text{1st is } T) = \overline{}$



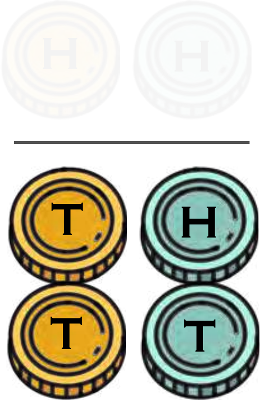
Conditional Probability: Coin Example 2



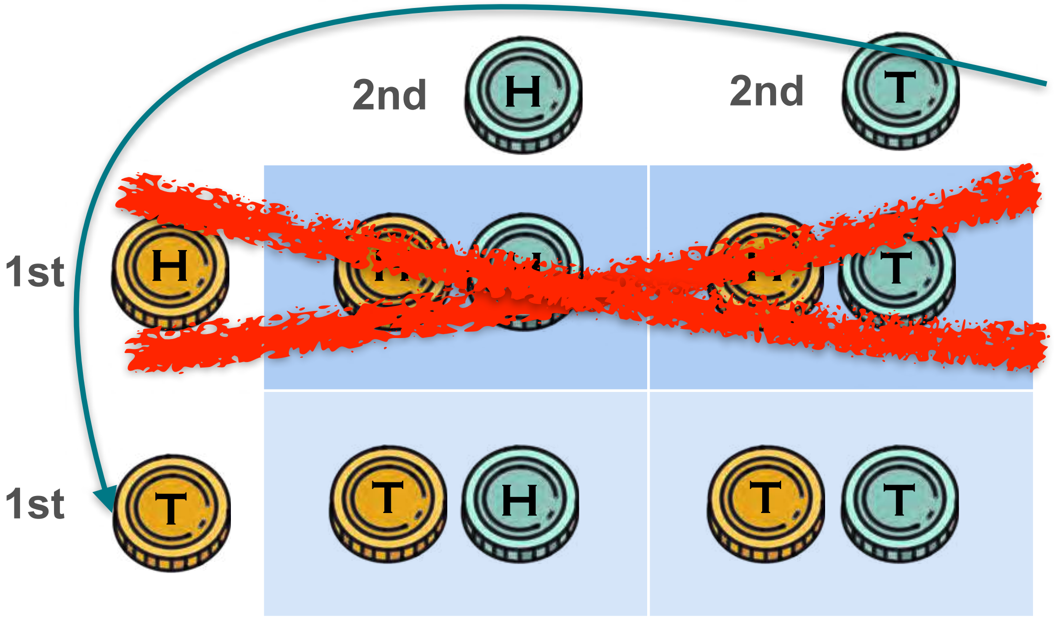
Probability of landing on heads twice

GIVEN that the first one is tails

$$\mathbf{P}(HH \mid \text{1st is } T) = $$



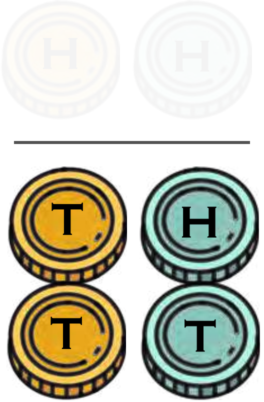
Conditional Probability: Coin Example 2



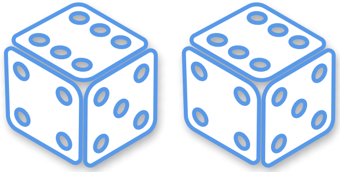
Probability of landing on heads twice

GIVEN that the first one is tails

$$\mathbf{P}(HH \mid \text{1st is } T) = \frac{\qquad}{\qquad} = 0$$

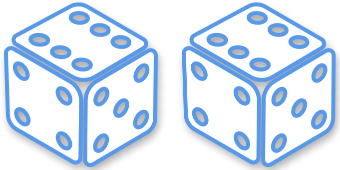


Conditional Probability: Dice Example 1



What is the probability that the sum is 10?

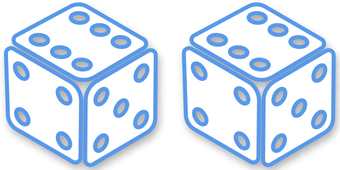
Conditional Probability: Dice Example 1



What is the probability that the sum is 10?

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

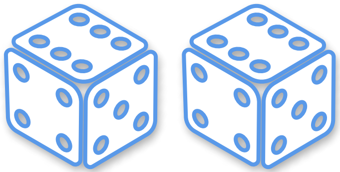
Conditional Probability: Dice Example 1



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

Conditional Probability: Dice Example 1

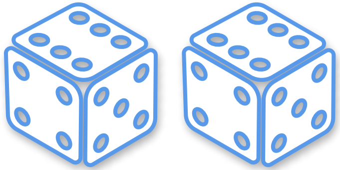


1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	$\boxed{4,6}$
5,1	5,2	5,3	5,4	$\boxed{5,5}$	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

What is the probability that the sum is 10?

$$\mathbf{P}(\text{sum} = 10) = \underline{\hspace{6cm}}$$

Conditional Probability: Dice Example 1



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

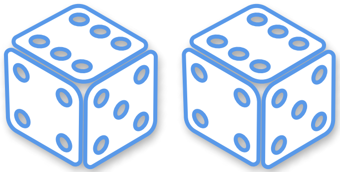
4,6

5,5

6,4

$$\mathbf{P}(\text{sum} = 10) = \underline{\qquad\qquad\qquad}$$

Conditional Probability: Dice Example 1



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

4,6

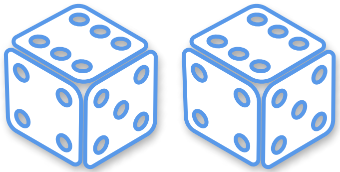
5,5

6,4

P(sum = 10) =

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 1



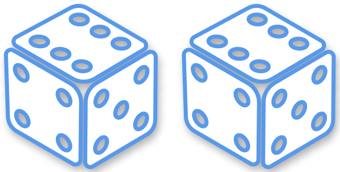
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

$$\mathbf{P}(\text{sum} = 10) = \frac{\{6{,}4\},\ \{5{,}5\},\ \{4{,}6\}}{\text{all 36 outcomes}} = \frac{3}{36}$$

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 1



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

4,6

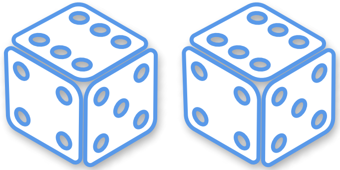
5,5

6,4

$$\mathbf{P}(\text{sum} = 10) = \frac{\text{4,6 \; 5,5 \; 6,4}}{\text{(all 36 outcomes)}} = \frac{1}{12}$$

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

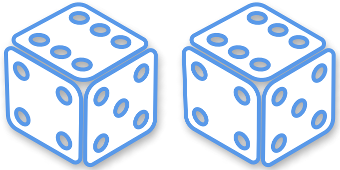
Conditional Probability: Dice Example 1



What is the probability that the sum is 10?

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 1

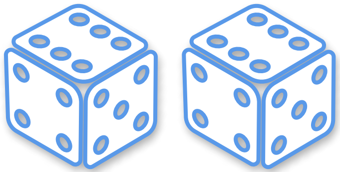


What is the probability that the sum is 10?

GIVEN that the first one is 6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	**4,6**
5,1	5,2	5,3	5,4	**5,5**	5,6
6,1	6,2	6,3	**6,4**	6,5	6,6

Conditional Probability: Dice Example 1



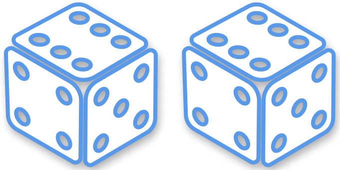
What is the probability that the sum is 10?

GIVEN that the first one is 6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	**4,6**
5,1	5,2	5,3	5,4	**5,5**	5,6
6,1	6,2	6,3	**6,4**	6,5	6,6

$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is } 6) = \_\_\_\_\_\_\_\_\_\_$$

Conditional Probability: Dice Example 1



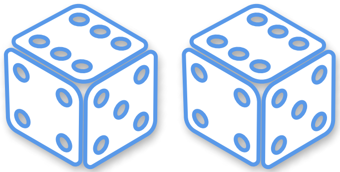
What is the probability that the sum is 10?

GIVEN that the first one is 6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 6}) = \underline{\hspace{6cm}}$$

Conditional Probability: Dice Example 1



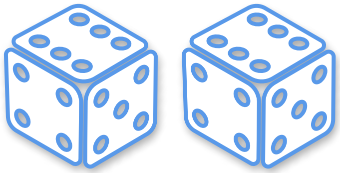
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

GIVEN that the first one is 6

$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 6}) = \underline{\hspace{6cm}}$$

Conditional Probability: Dice Example 1



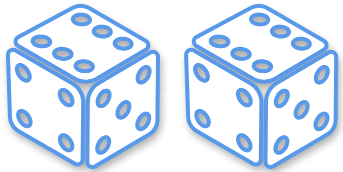
What is the probability that the sum is 10?

GIVEN that the first one is 6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

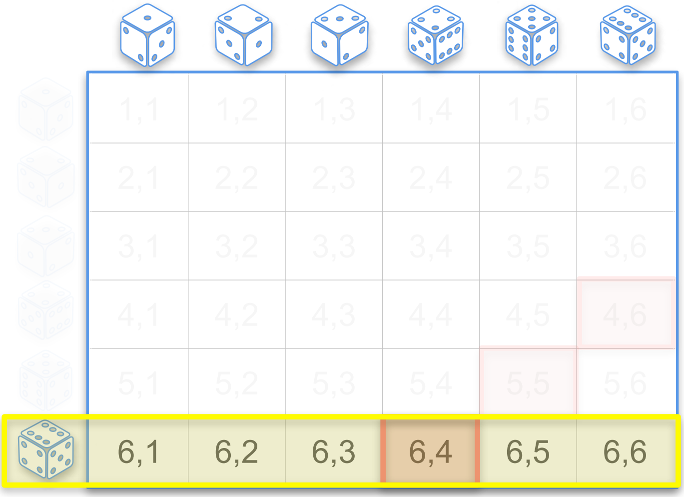
$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 6}) = \frac{\qquad\qquad}{\boxed{6,1 \quad 6,2 \quad 6,3 \quad 6,4 \quad 6,5 \quad 6,6}}$$

Conditional Probability: Dice Example 1



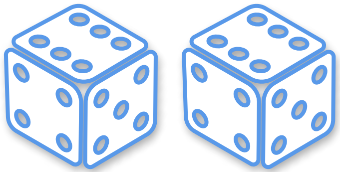
What is the probability that the sum is 10?

GIVEN that the first one is 6



$$P(\text{sum} = 10 \mid \text{1st is 6}) = \frac{\boxed{6,4}}{\boxed{6,1 \quad 6,2 \quad 6,3 \quad 6,4 \quad 6,5 \quad 6,6}}$$

Conditional Probability: Dice Example 1



What is the probability that the sum is 10?

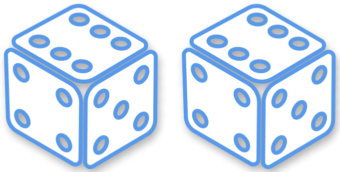
GIVEN that the first one is 6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$P(\text{sum} = 10 \mid \text{1st is 6}) = \frac{\boxed{6,4}}{\boxed{6,1 \quad 6,2 \quad 6,3 \quad 6,4 \quad 6,5 \quad 6,6}}$$

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

Conditional Probability: Dice Example 2



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	$\boxed{4,6}$
5,1	5,2	5,3	5,4	$\boxed{5,5}$	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

What is the probability that the sum is 10?

4,6

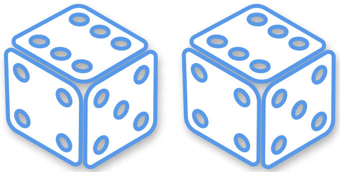
5,5

6,4

$$\mathbf{P}(\text{sum} = 10) = \frac{\boxed{6,4}\ \boxed{5,5}\ \boxed{4,6}}{\text{(all 36 outcomes)}} = \frac{3}{36}$$

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

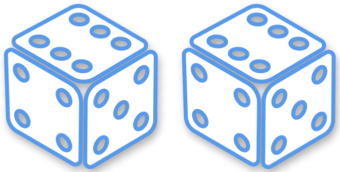
Conditional Probability: Dice Example 2



What is the probability that the sum is 10?

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 2

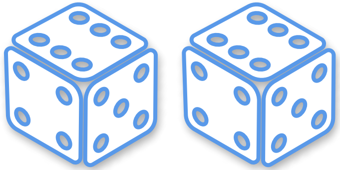


What is the probability that the sum is 10?

GIVEN that the first one is 1

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	$\boxed{4,6}$
5,1	5,2	5,3	5,4	$\boxed{5,5}$	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

Conditional Probability: Dice Example 2



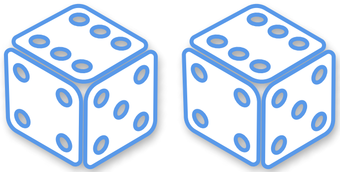
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

GIVEN that the first one is 1

$$P(\text{sum} = 10 \mid \text{1st is 1}) = \_\_\_\_\_\_\_\_\_\_\_\_$$

Conditional Probability: Dice Example 2



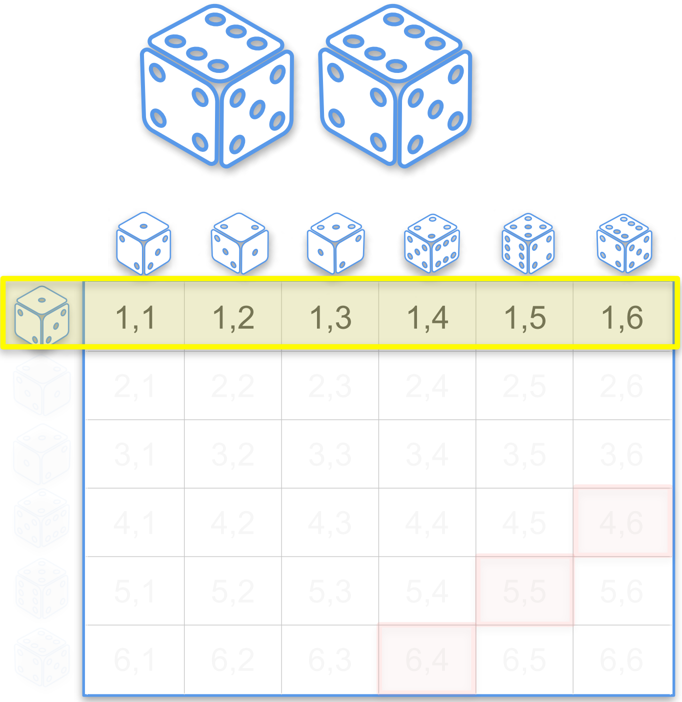
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

GIVEN that the first one is 1

$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 1}) = \underline{\hspace{6cm}}$$

Conditional Probability: Dice Example 2

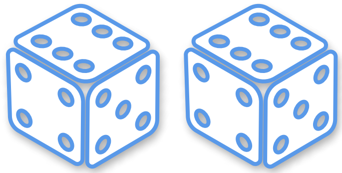


What is the probability that the sum is 10?

GIVEN that the first one is 1

$\mathbf{P}(\text{sum} = 10 \mid \text{1st is } 1) =$ ______

Conditional Probability: Dice Example 2



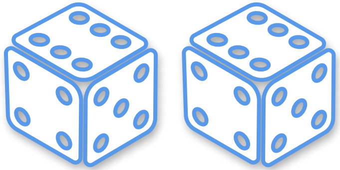
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

What is the probability that the sum is 10?

GIVEN that the first one is 1

$$P(\text{sum} = 10 \mid \text{1st is 1}) = \frac{}{\boxed{1,1 \quad 1,2 \quad 1,3 \quad 1,4 \quad 1,5 \quad 1,6}}$$

Conditional Probability: Dice Example 2



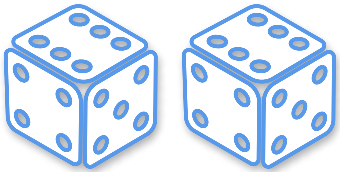
What is the probability that the sum is 10?

GIVEN that the first one is 1

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

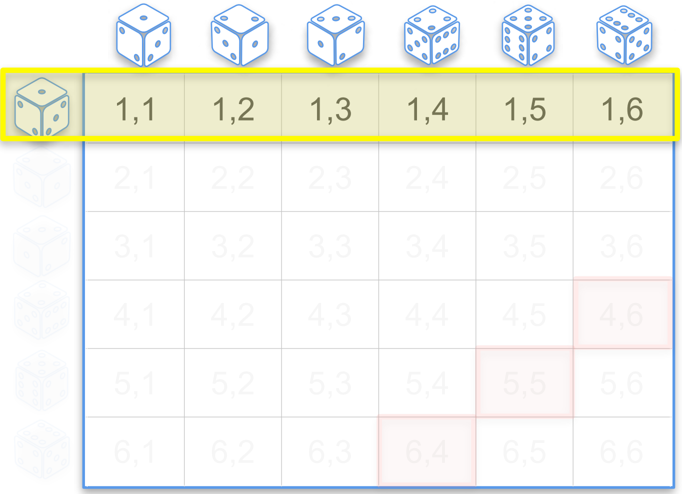
$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 1}) = \frac{\boxed{1,1 \quad 1,2 \quad 1,3 \quad 1,4 \quad 1,5 \quad 1,6}}{\boxed{1,1 \quad 1,2 \quad 1,3 \quad 1,4 \quad 1,5 \quad 1,6}}$$

Conditional Probability: Dice Example 2



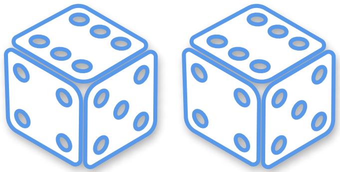
What is the probability that the sum is 10?

GIVEN that the first one is 1



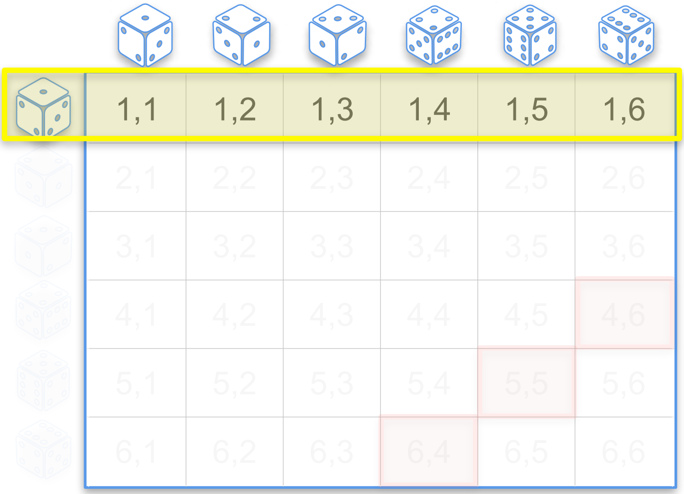
$$P(\text{sum} = 10 \mid \text{1st is 1}) = \frac{0}{\boxed{1,1 \quad 1,2 \quad 1,3 \quad 1,4 \quad 1,5 \quad 1,6}}$$

Conditional Probability: Dice Example 2



What is the probability that the sum is 10?

GIVEN that the first one is 1



$$P(\text{sum} = 10 \mid \text{1st is } 1) = \frac{0}{\boxed{1,1 \quad 1,2 \quad 1,3 \quad 1,4 \quad 1,5 \quad 1,6}}$$

$$= 0$$

Product Rule (for Independent Events)

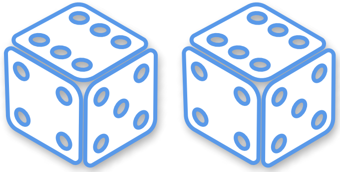
$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B)$$

Product Rule (for Independent Events)

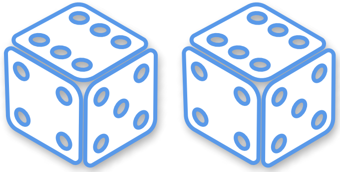
When A and B independent

$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B)$$

Conditional Probability: Dice Example 3

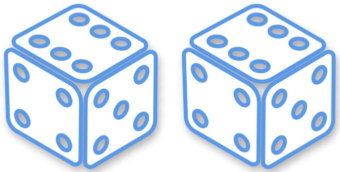


Conditional Probability: Dice Example 3

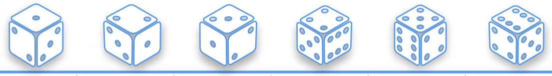


What is the probability that
the first is 6 **AND** the sum = 10?

Conditional Probability: Dice Example 3

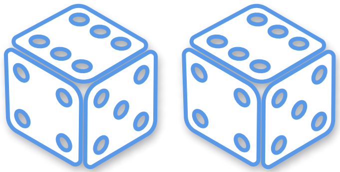


What is the probability that
the first is 6 **AND** the sum = 10?



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

Conditional Probability: Dice Example 3

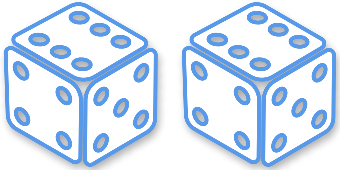


What is the probability that
the first is 6 **AND** the sum = 10?

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

$$\mathbf{P}(\text{1st is 6} \cap \text{sum = 10}) = \underline{\qquad\qquad\qquad\qquad}$$

Conditional Probability: Dice Example 3

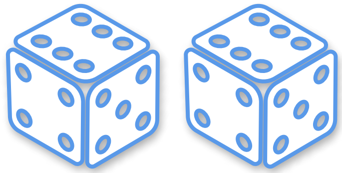


What is the probability that
the first is 6 **AND** the sum = 10?

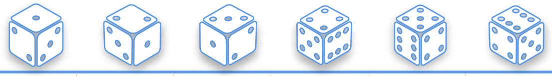
1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{1st is } 6 \cap \text{sum} = 10) = \frac{\boxed{6,4}}{\qquad\qquad}$$

Conditional Probability: Dice Example 3



What is the probability that
the first is 6 **AND** the sum = 10?



1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

$$\mathbf{P}(\text{1st is } 6 \cap \text{sum} = 10) = \frac{\boxed{6,4}}{\text{(all 36 outcomes, table below)}}$$

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$= \frac{1}{36}$$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is } 6 \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is } 6)$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is } 6 \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is } 6)$

6,1 6,2 6,3 6,4 6,5 6,6

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

6,1	6,2	6,3	6,4	6,5	6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

6,1	6,2	6,3	6,4	6,5	6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\frac{6}{36}$$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum = 10}) =$

$\mathbf{P}(\text{1st is 6})$

6,1	6,2	6,3	6,4	6,5	6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

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

Conditional Probability: Dice Example 3

	⚀	⚁	⚂	⚃	⚄	⚅
⚀	1,1	1,2	1,3	1,4	1,5	1,6
⚁	2,1	2,2	2,3	2,4	2,5	2,6
⚂	3,1	3,2	3,3	3,4	3,5	3,6
⚃	4,1	4,2	4,3	4,4	4,5	4,6
⚄	5,1	5,2	5,3	5,4	5,5	5,6
⚅	6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$ $\qquad\qquad$ $\mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$

6,1	6,2	6,3	6,4	6,5	6,6

divided by

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

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

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

6,1 6,2 6,3 6,4 6,5 6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

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

$\mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$

6,4

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$

$\mathbf{P}(\text{1st is 6})$

6,1 6,2 6,3 6,4 6,5 6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

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

$\mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$

6,4

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) =$$

$$\mathbf{P}(\text{1st is 6}) \qquad \mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$$

6,1	6,2	6,3	6,4	6,5	6,6

over

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

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

6,4

over

6,1	6,2	6,3	6,4	6,5	6,6

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

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{1st is } 6 \cap \text{sum} = 10) =$$

$$\mathbf{P}(\text{1st is } 6) \bullet \mathbf{P}(\text{sum} = 10 \mid \text{1st } 6)$$

6,1	6,2	6,3	6,4	6,5	6,6

over

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

•

6,4

over

6,1	6,2	6,3	6,4	6,5	6,6

$$\frac{1}{6} \bullet \frac{1}{6} = \frac{1}{36}$$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

=

6,1	6,2	6,3	6,4	6,5	6,6

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

•

6,4

6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) = \mathbf{P}(\text{1st is 6}) \bullet \mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$$

Conditional Probability: Dice Example 3

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	$\boxed{6,4}$	6,5	6,6

=

6,1	6,2	6,3	6,4	6,5	6,6

over

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

•

6,4

over

6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{1st is 6} \cap \text{sum} = 10) = \mathbf{P}(\text{1st is 6}) \bullet \mathbf{P}(\text{sum} = 10 \mid \text{1st 6})$$

$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B \mid A)$$

The General Product Rule

$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B \mid A)$$

The General Product Rule

$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B \mid A)$$

When independent

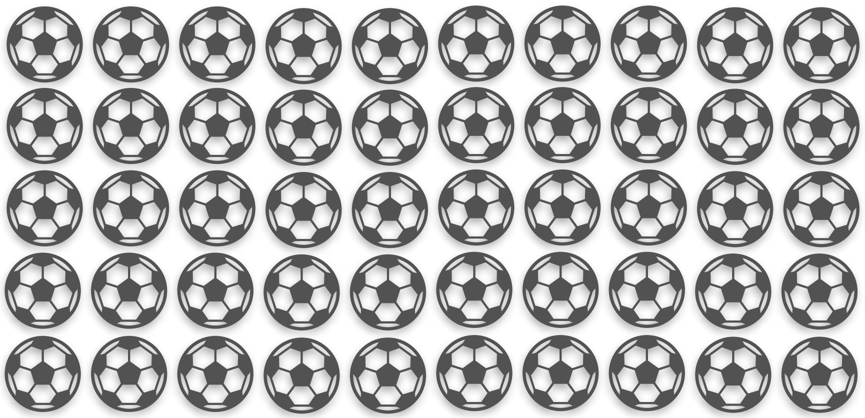
$$\mathbf{P}(B \mid A) = \mathbf{P}(B)$$

Quiz 1

Quiz 1

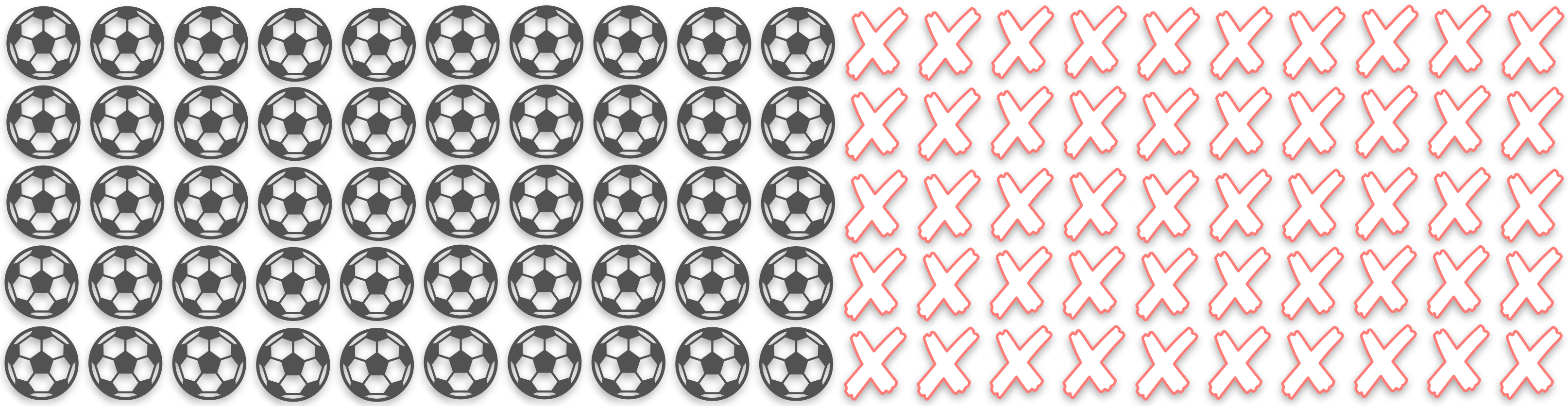
100 kids

Quiz 1



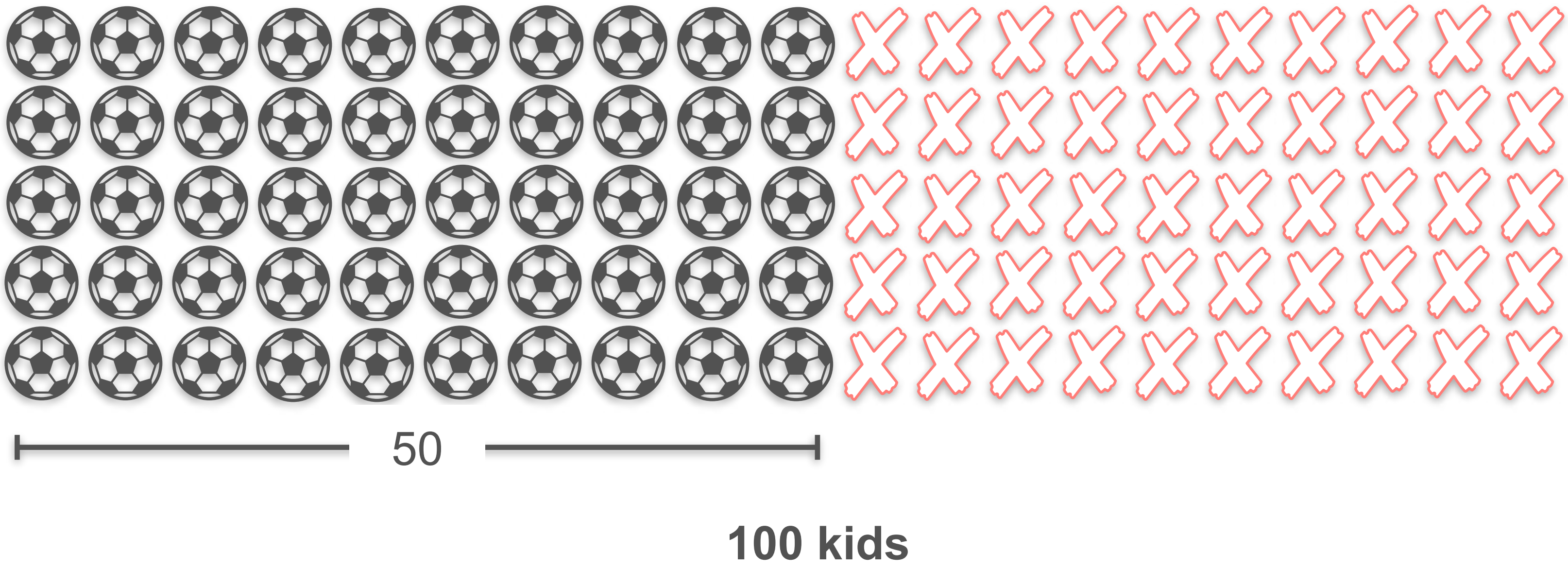
100 kids

Quiz 1

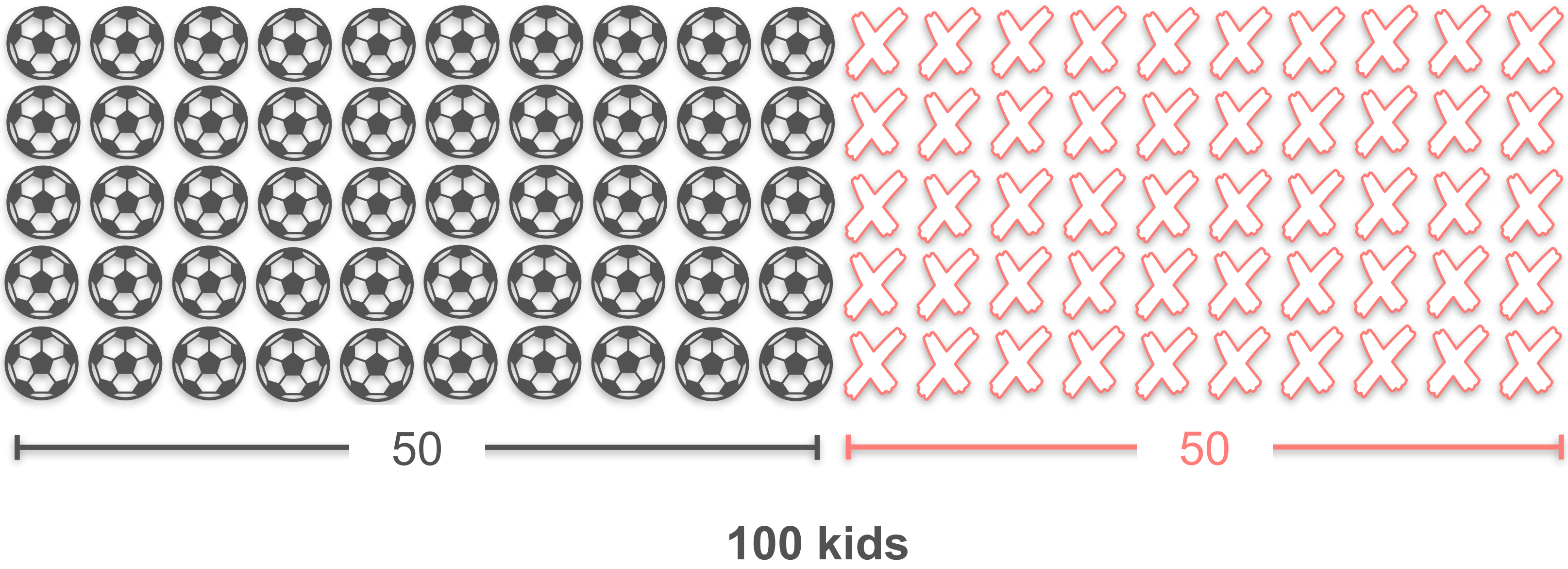


100 kids

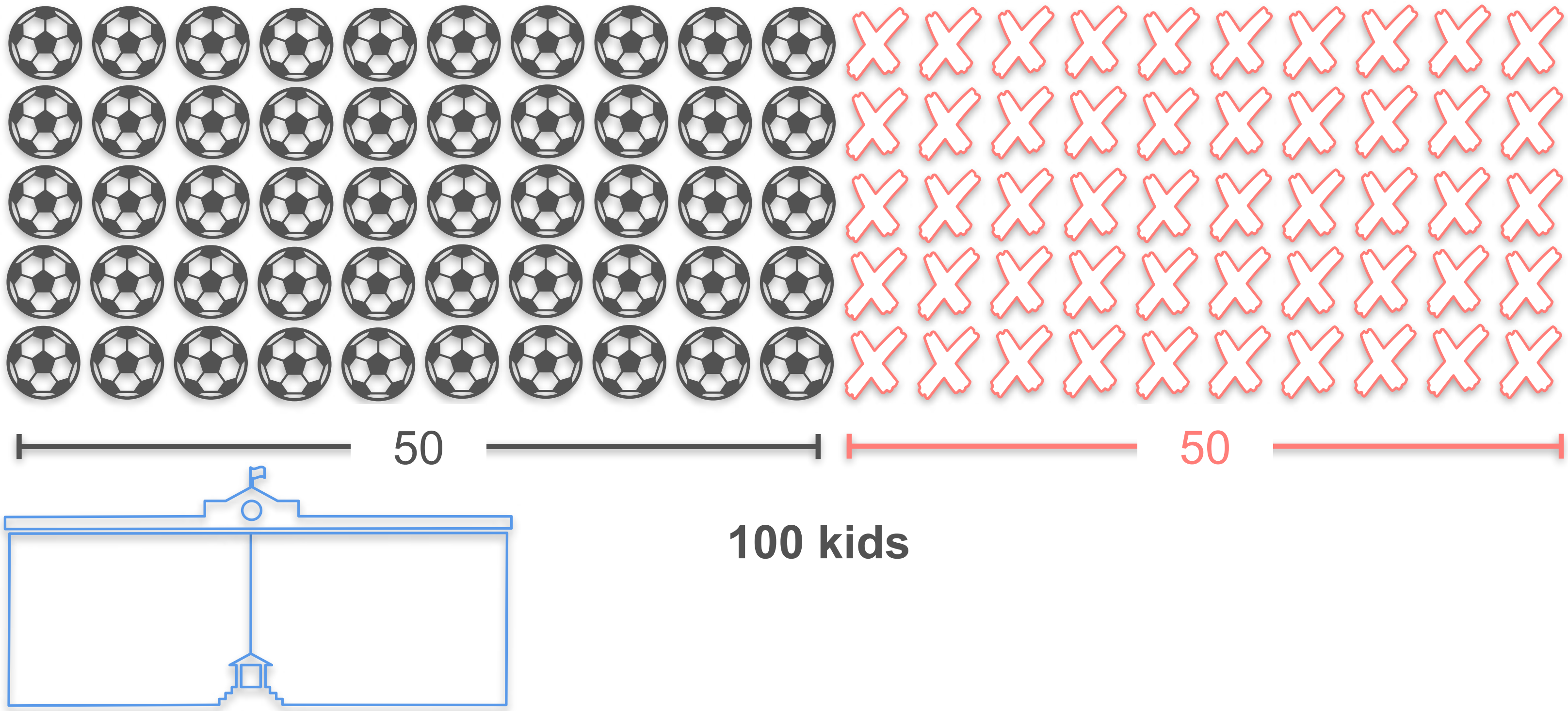
Quiz 1



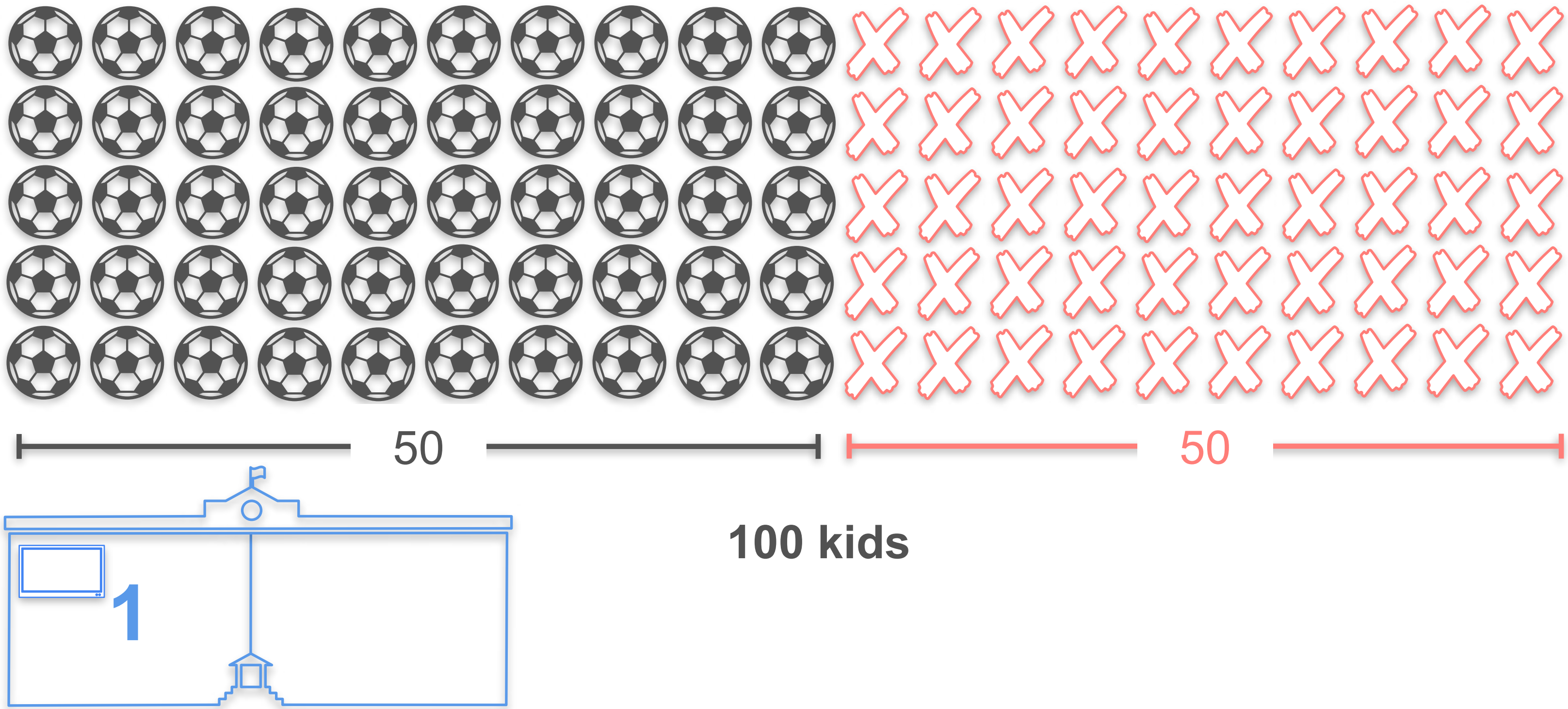
Quiz 1



Quiz 1

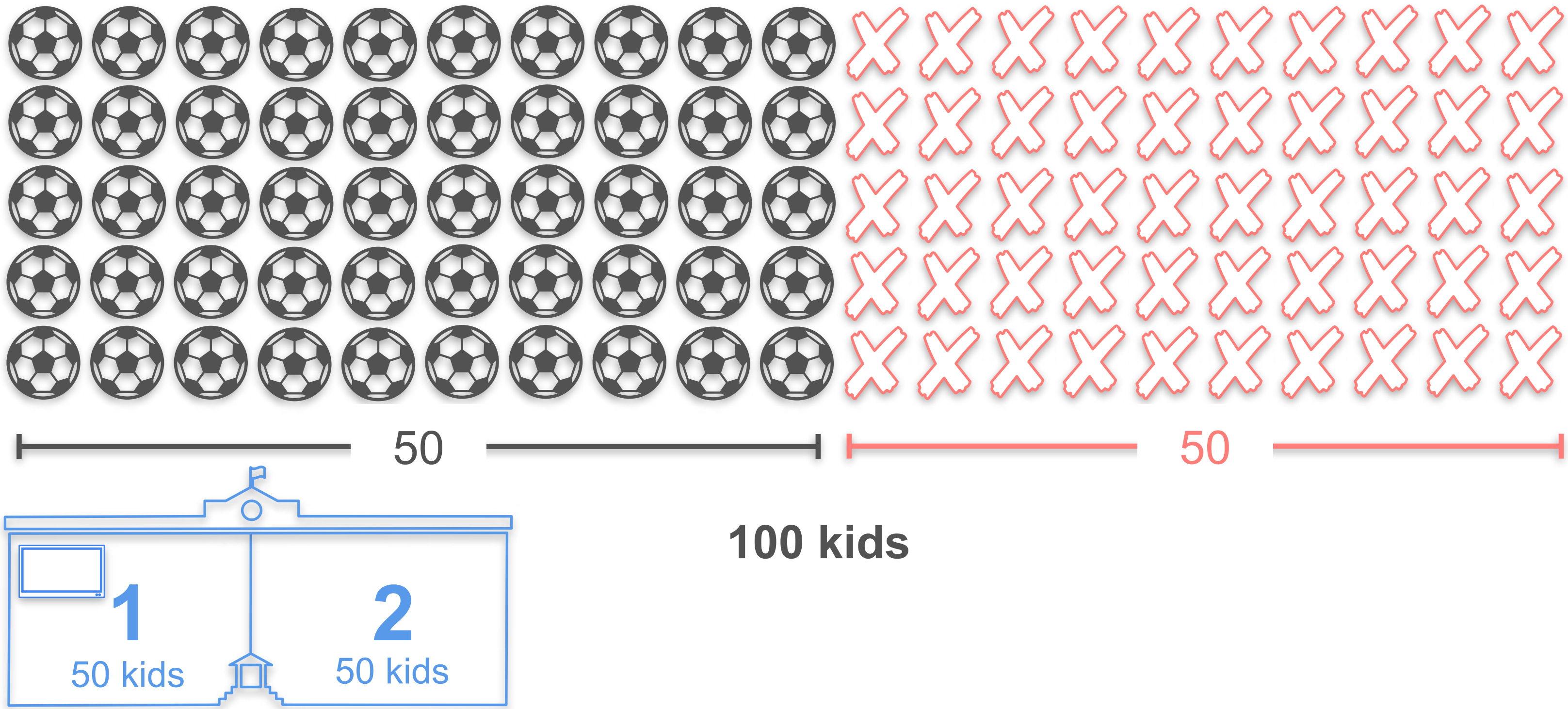


Quiz 1



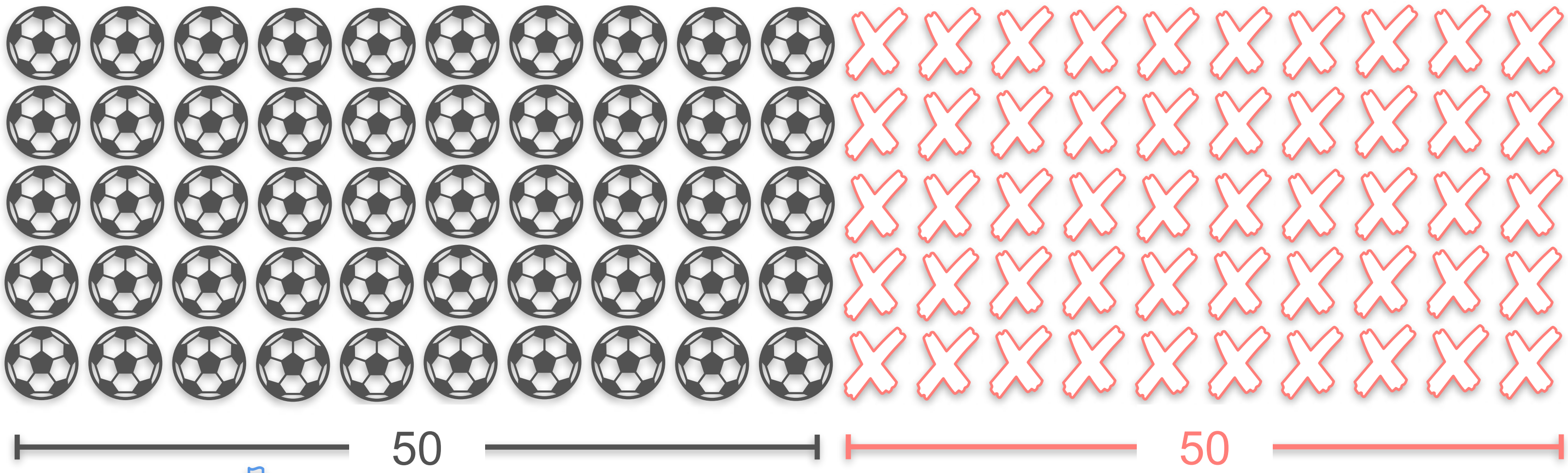
100 kids

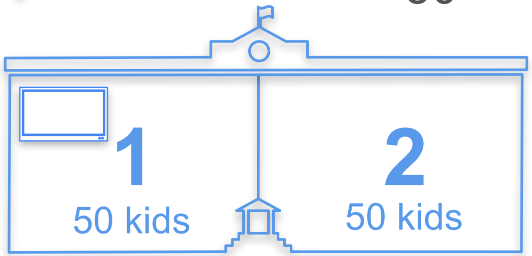
Quiz 1



100 kids

Quiz 1

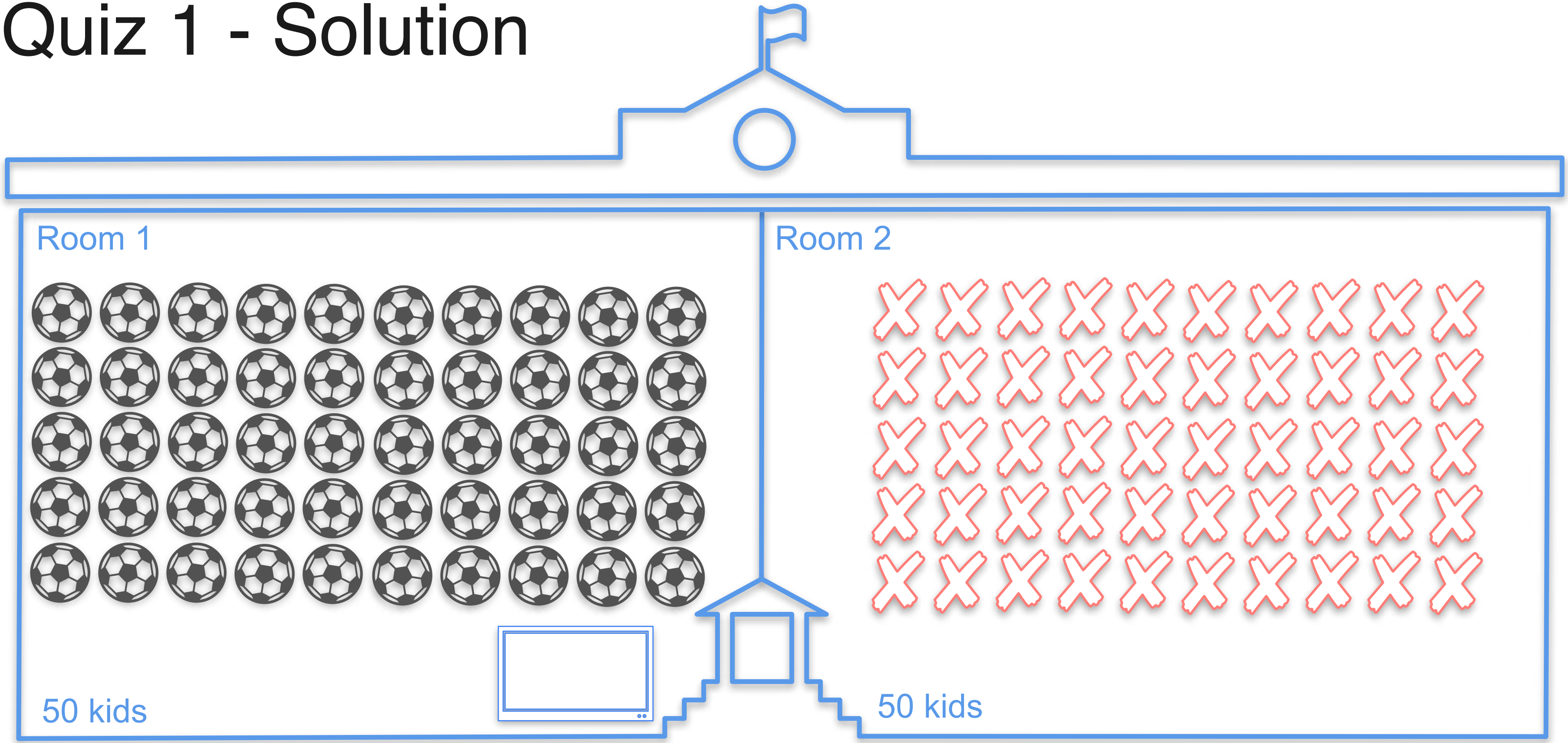




100 kids

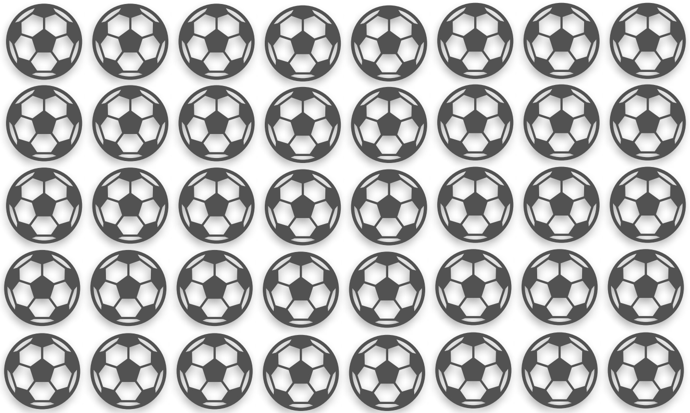
How many kids in room 1 like soccer?

Quiz 1 - Solution

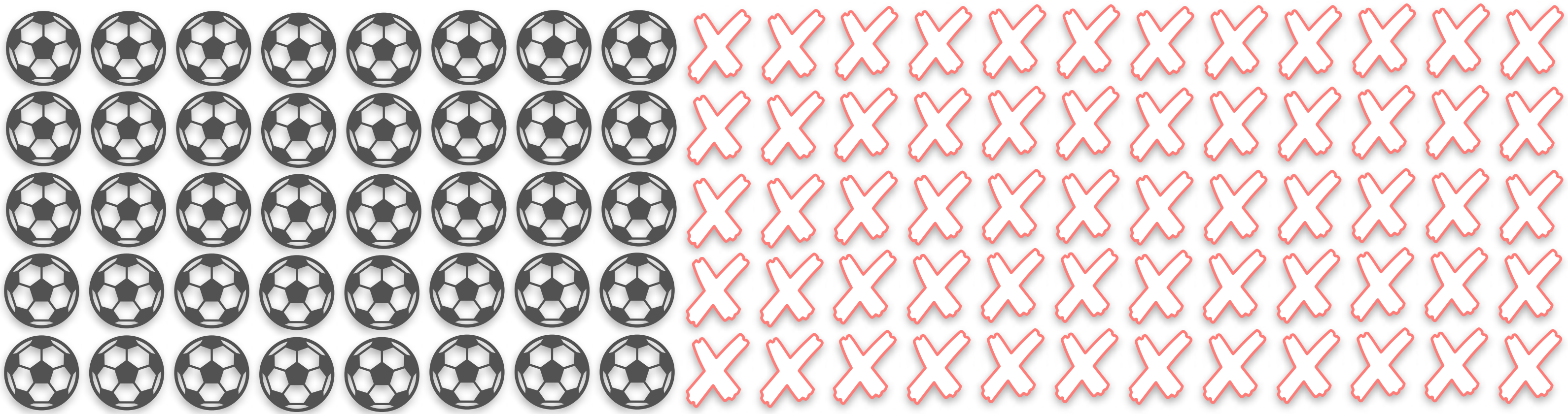


Quiz 2

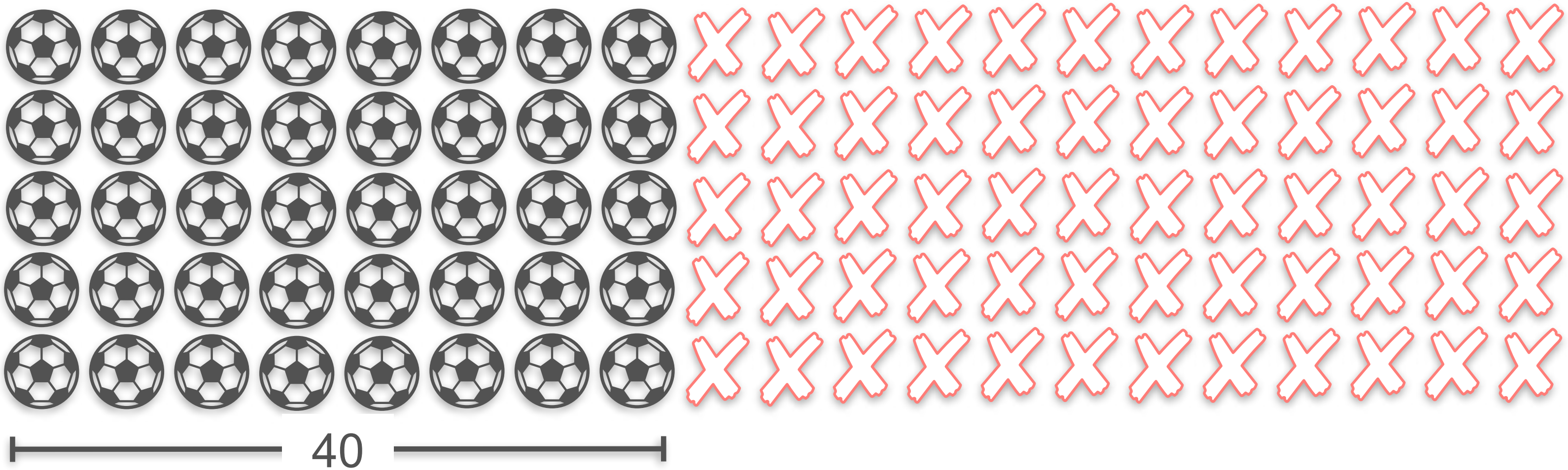
Quiz 2



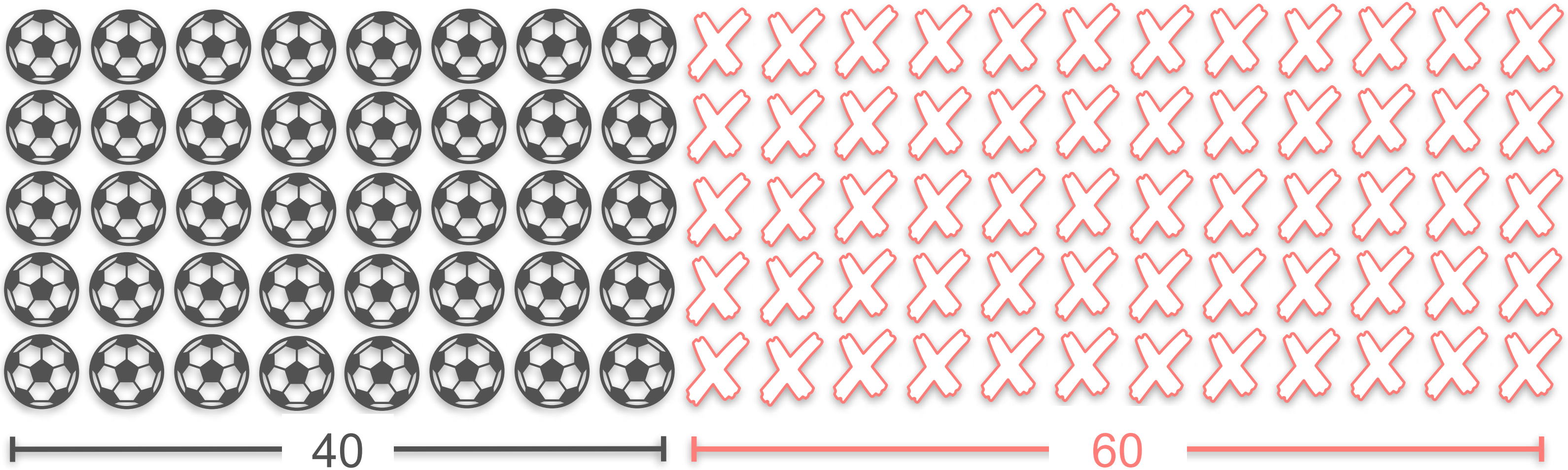
Quiz 2



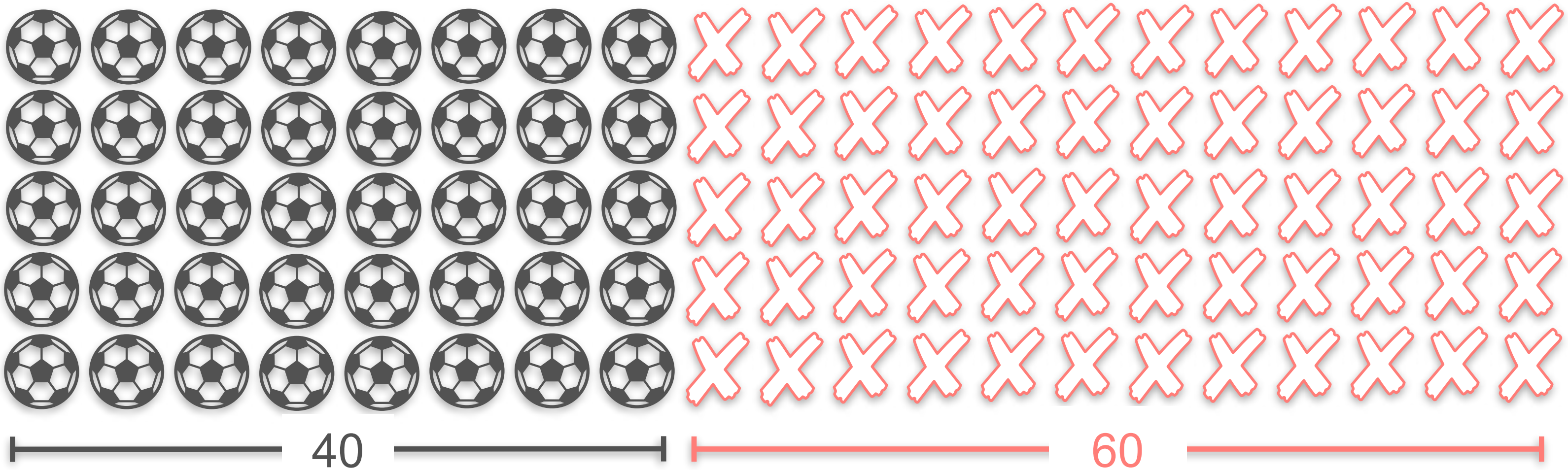
Quiz 2



Quiz 2

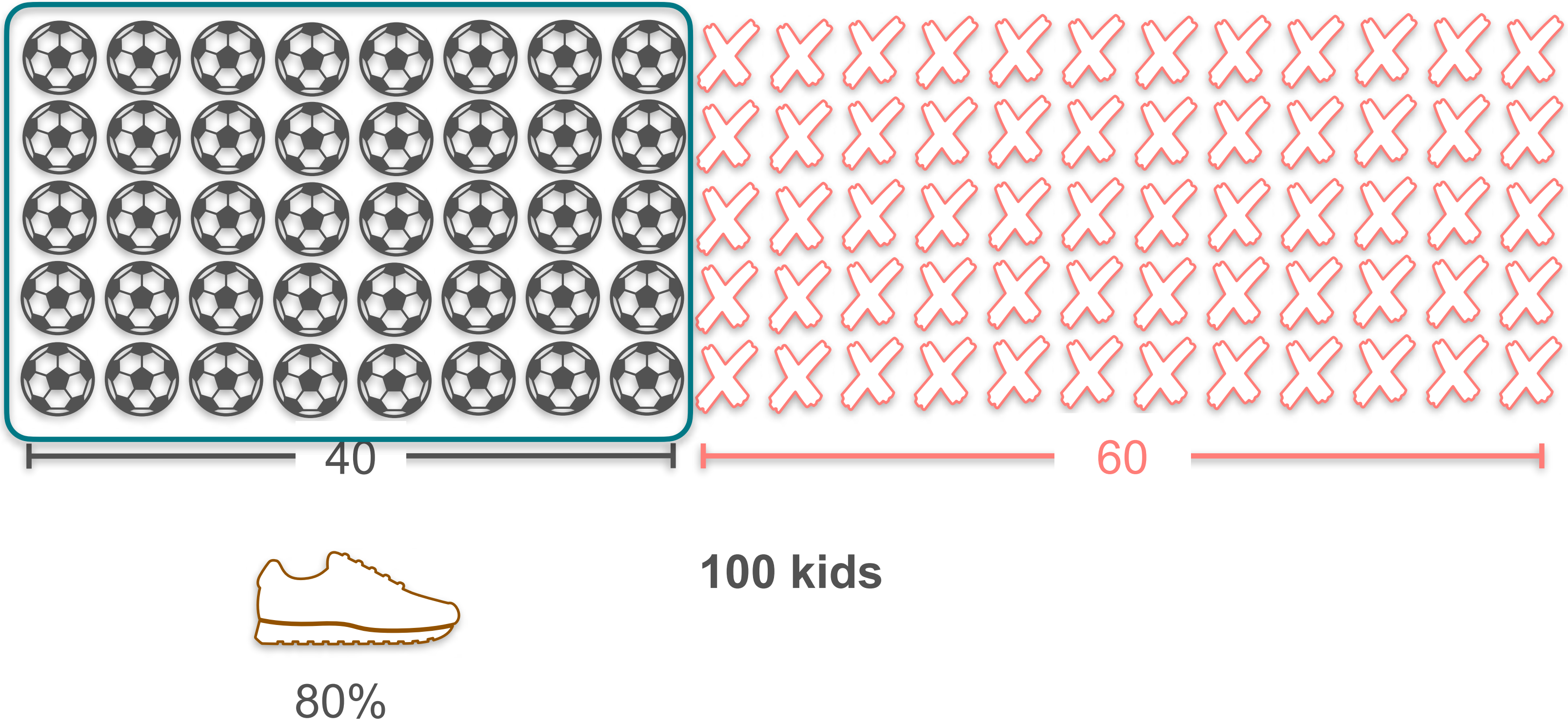


Quiz 2

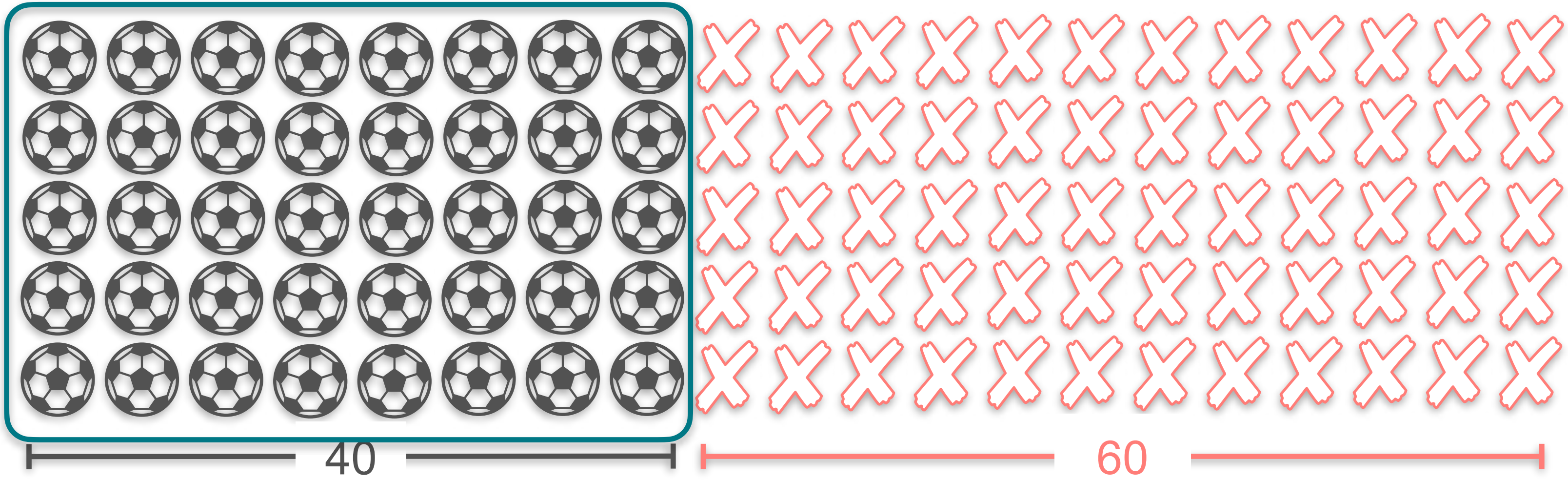


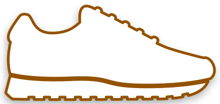
100 kids

Quiz 2



Quiz 2

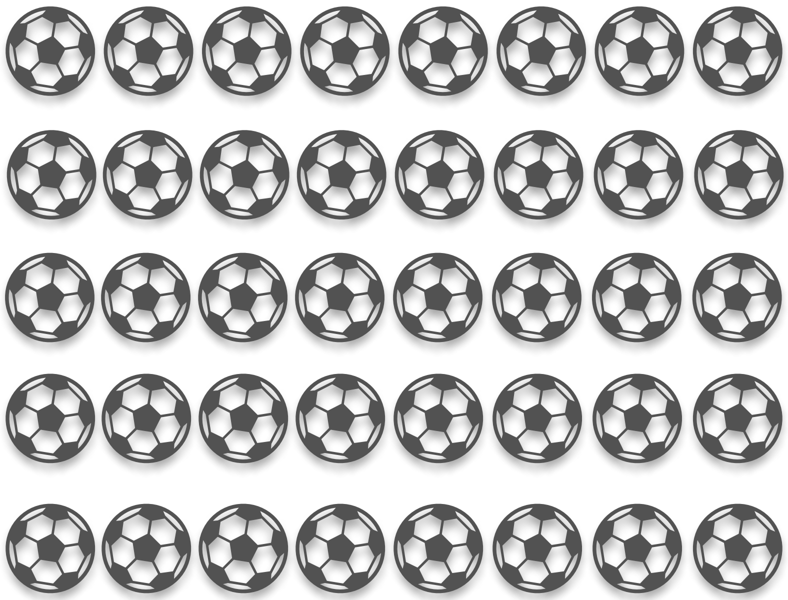




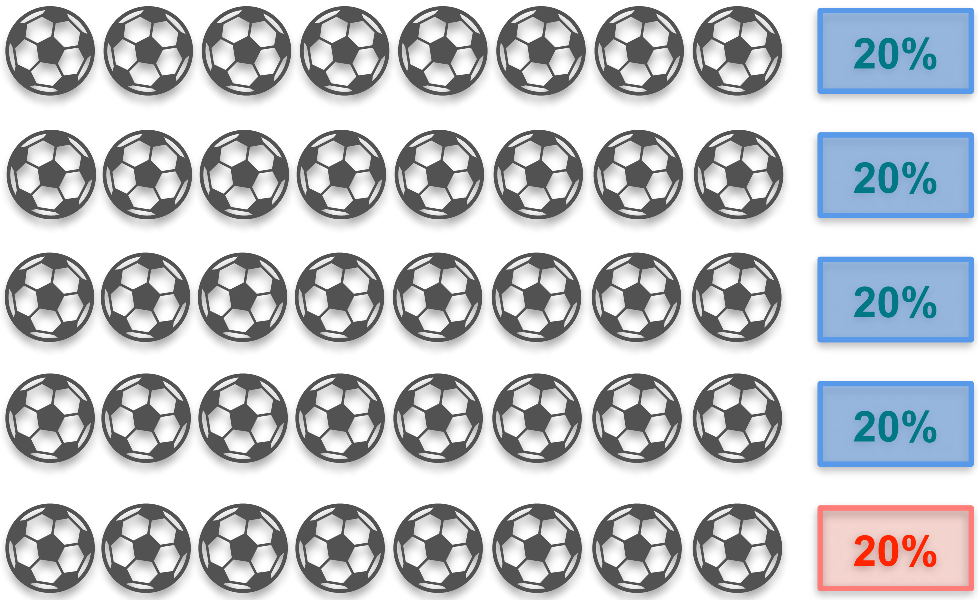
100 kids

How many kids play soccer and wear running shoes

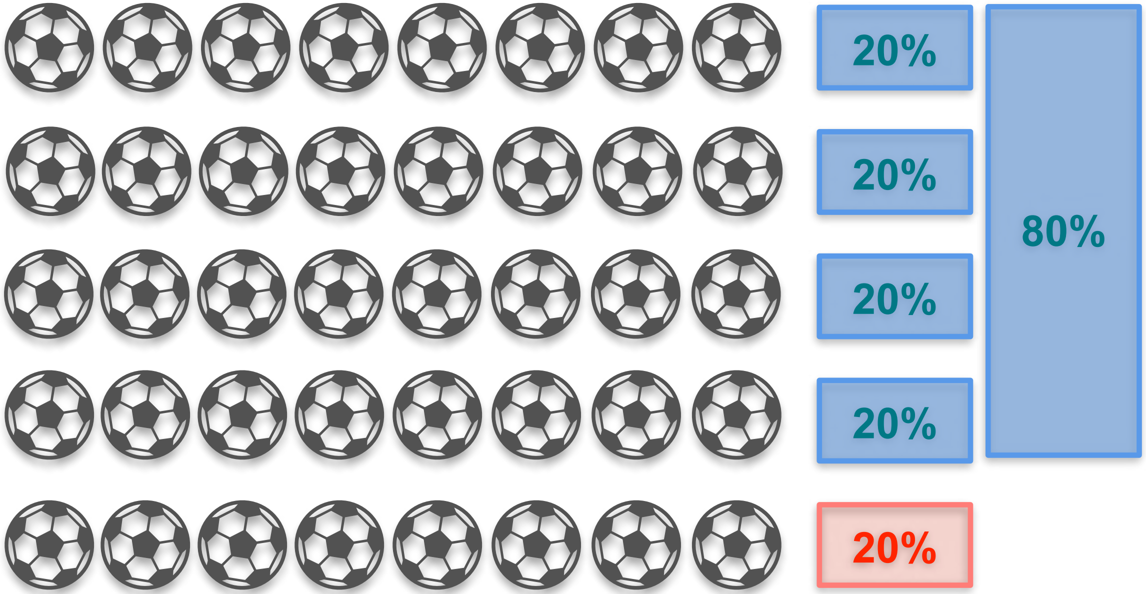
Quiz 2 - Solution



Quiz 2 - Solution



Quiz 2 - Solution



Quiz 2 - Solution

Conditional Probability

Conditional Probability

Conditional Probability

$\mathbf{P}(\mathrm{S}) = 0.4$

Conditional Probability

$P(S) = 0.4$

Conditional Probability

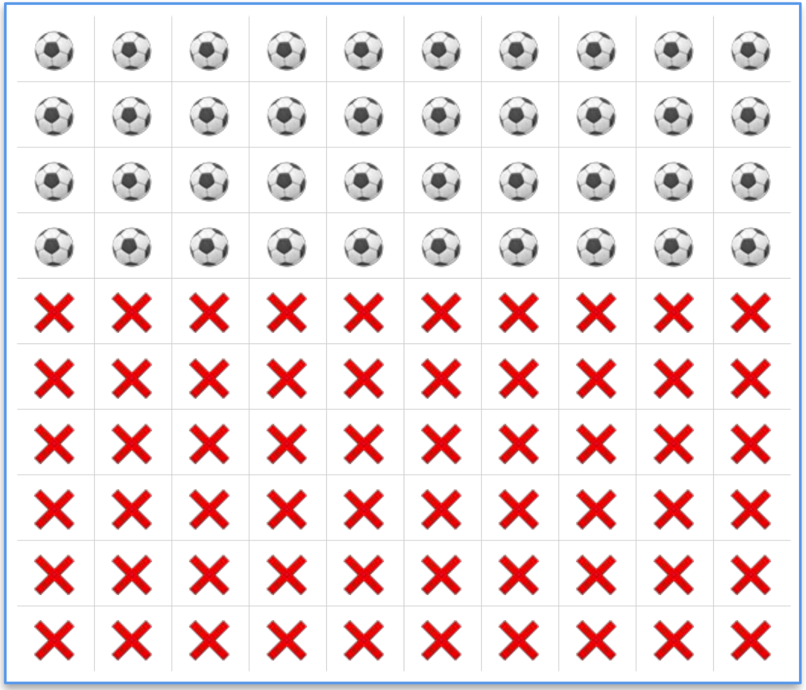
$P(S) = 0.4$

$P(\text{not } S) = 0.6$

Conditional Probability

$\mathbf{P}(\mathrm{S}) = 0.4$

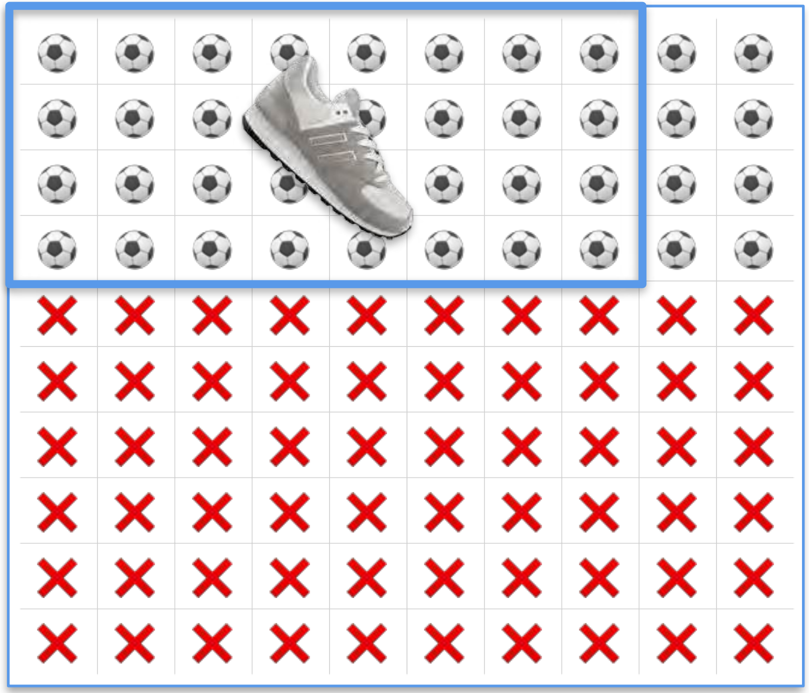
$\mathbf{P}(\text{not S}) = 0.6$



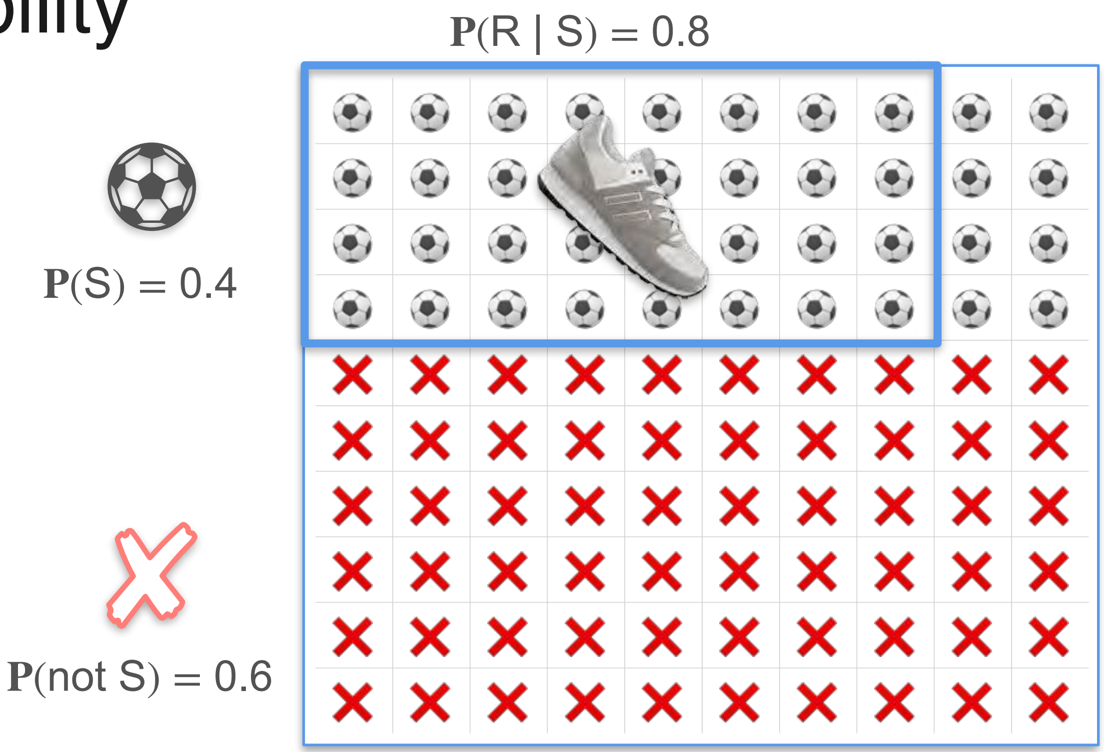
Conditional Probability

$P(S) = 0.4$

$P(\text{not } S) = 0.6$

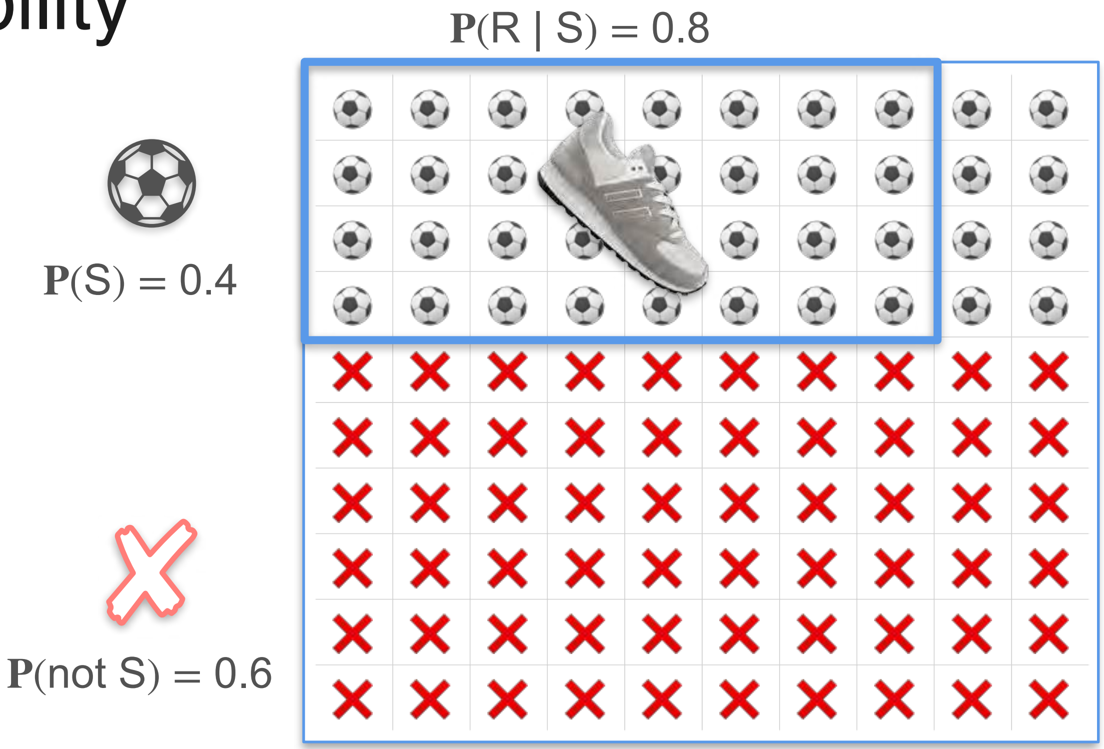


Conditional Probability

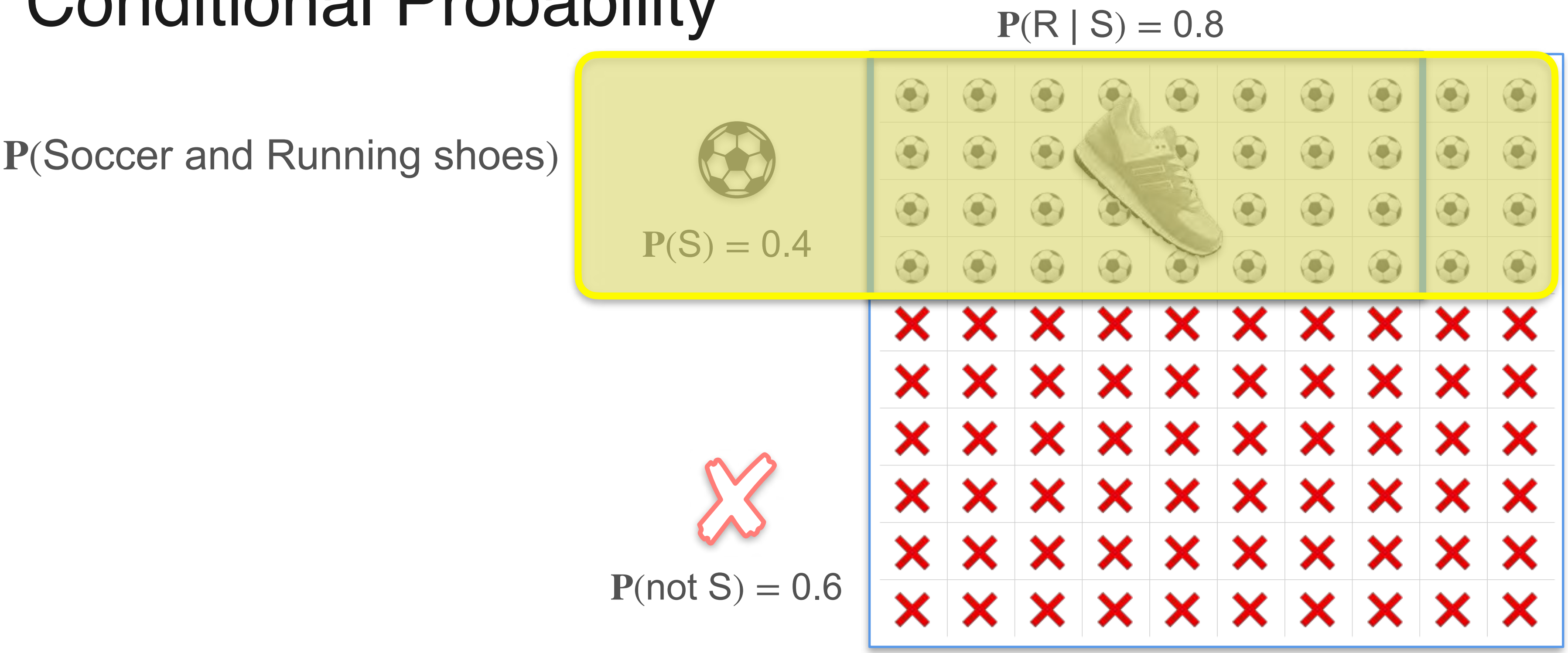


Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

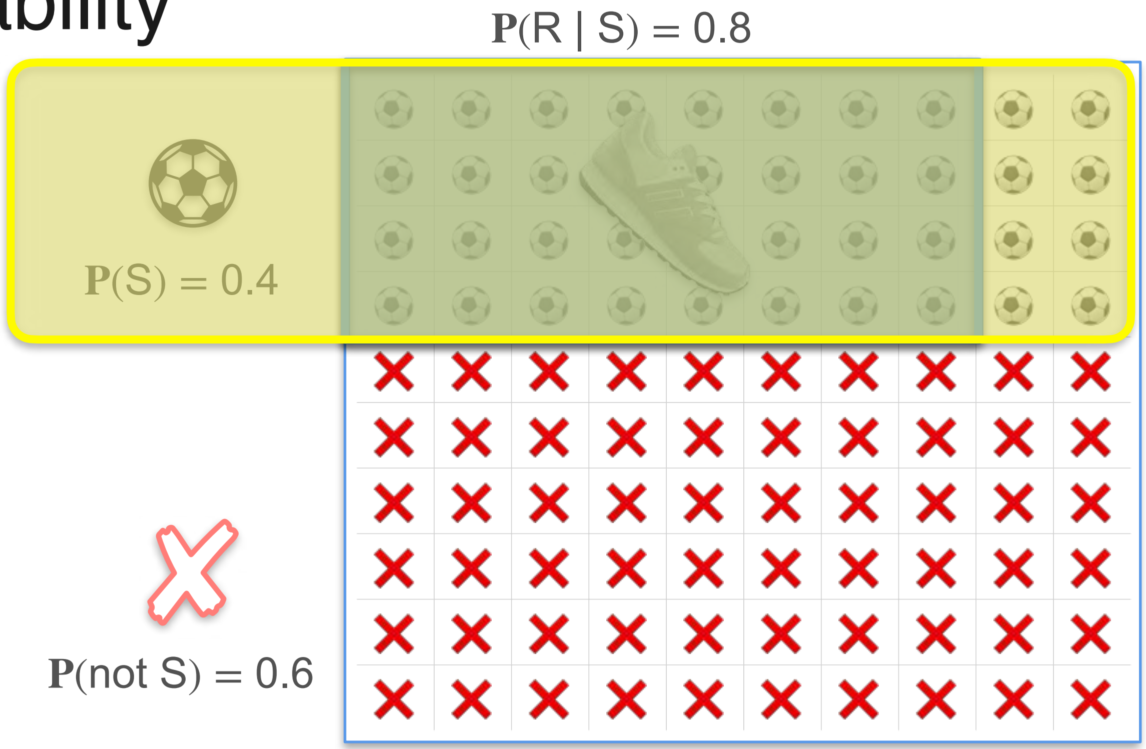


Conditional Probability



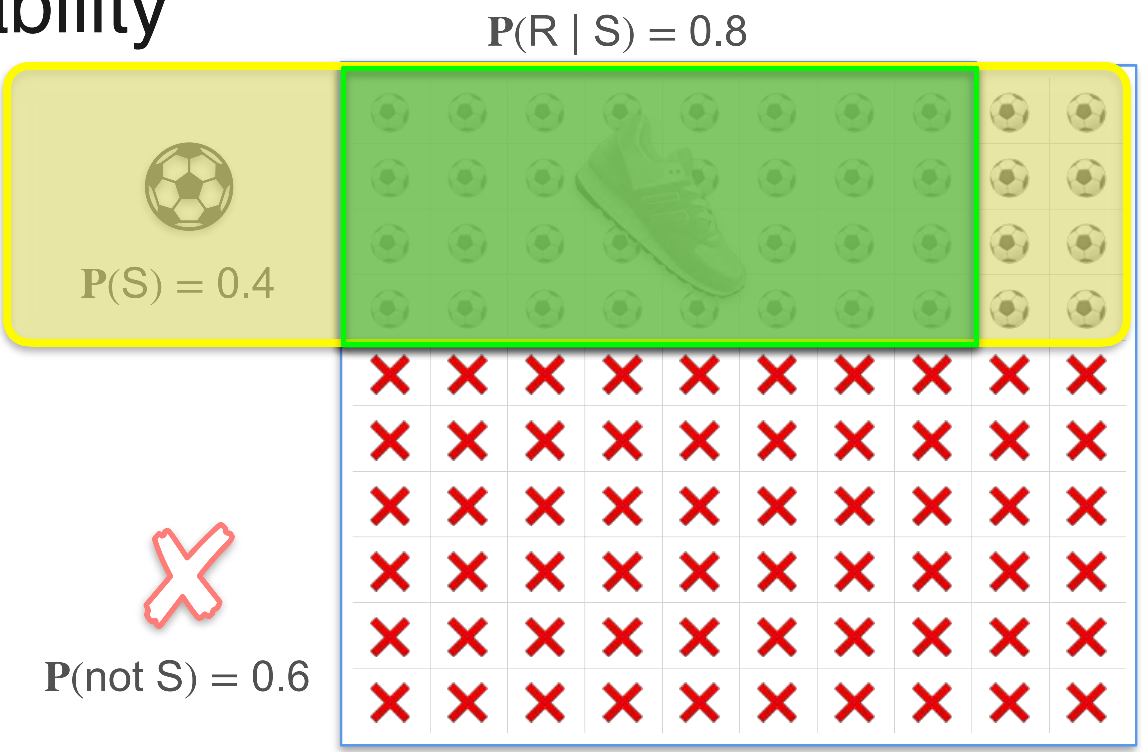
Conditional Probability

$\mathbf{P}(\text{Soccer and Running shoes})$



Conditional Probability

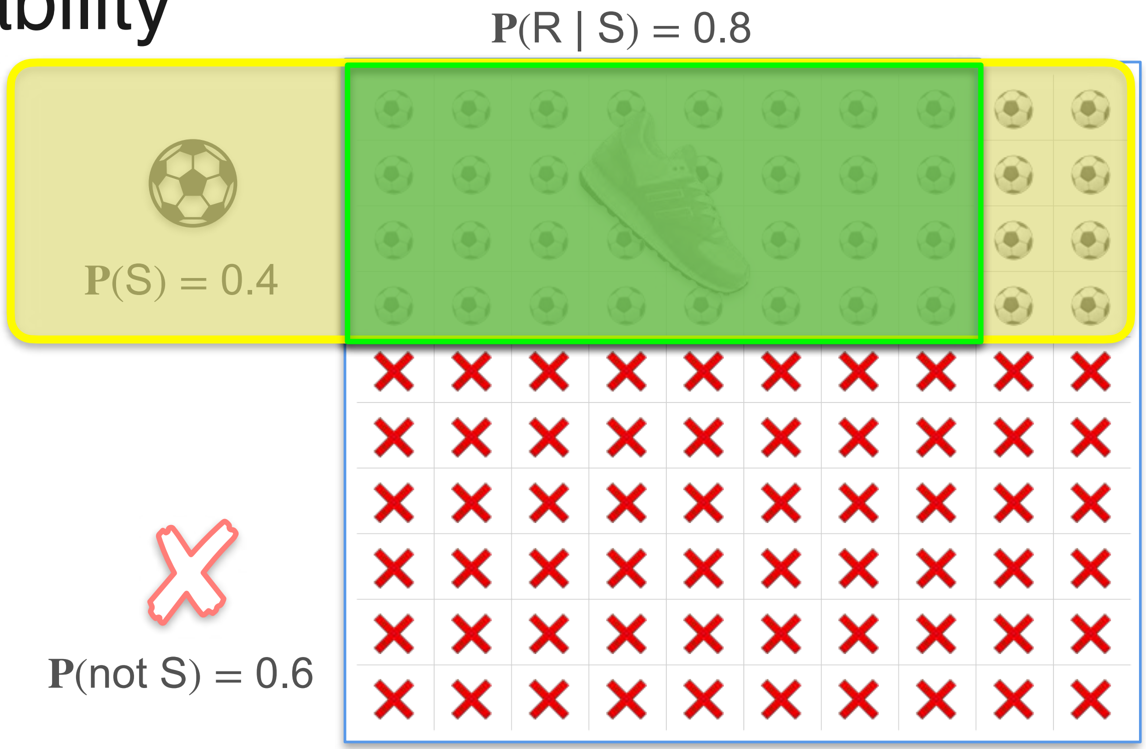
$\mathbf{P}(\text{Soccer and Running shoes})$



Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

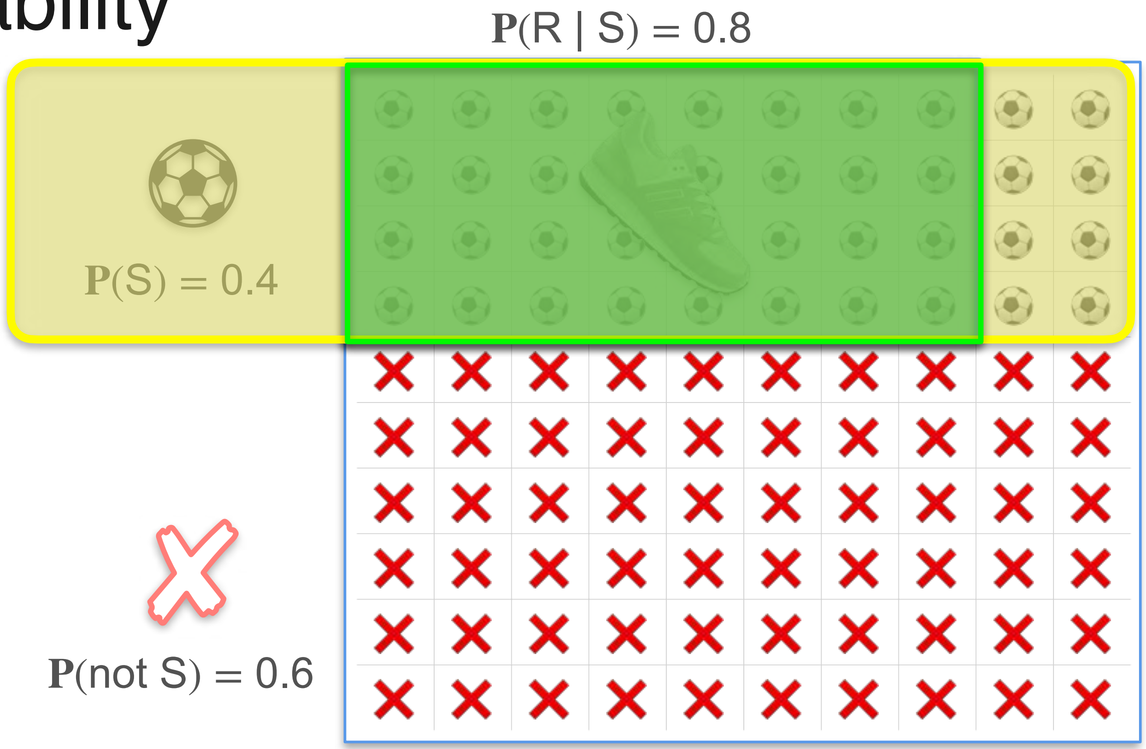
$\mathbf{P}(S \cap R) =$



Conditional Probability

$\mathbf{P}(\text{Soccer and Running shoes})$

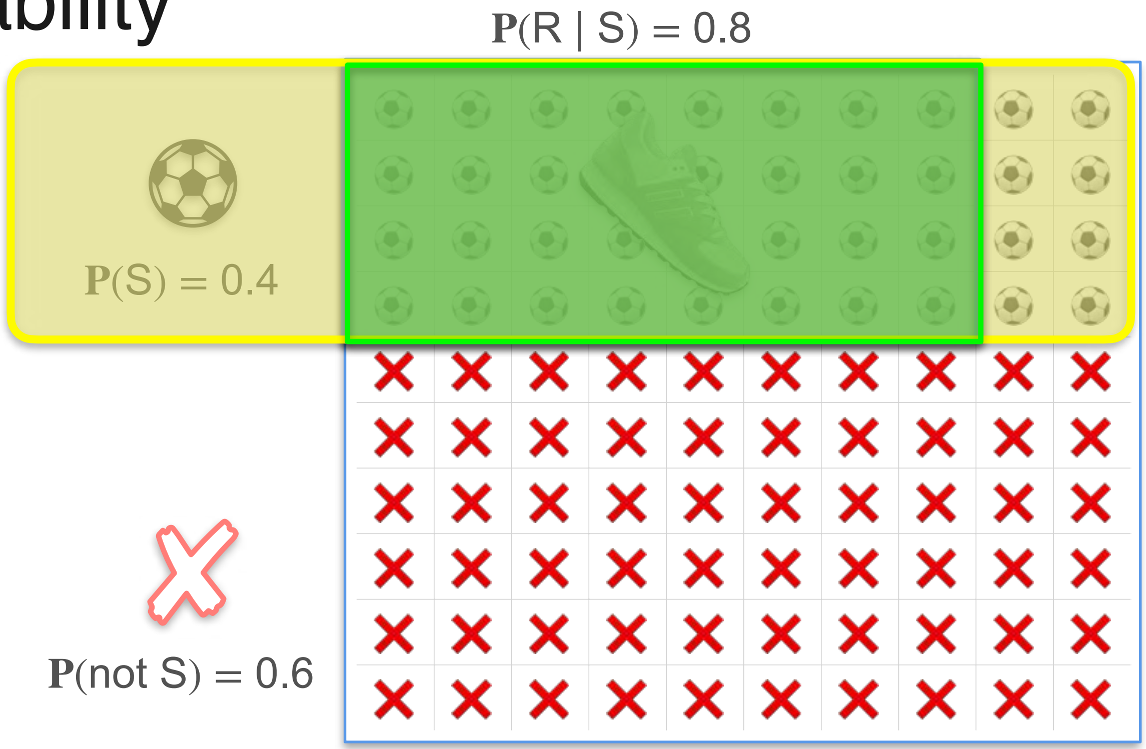
$\mathbf{P}(S \cap R) = \quad \mathbf{P}(S)$



Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

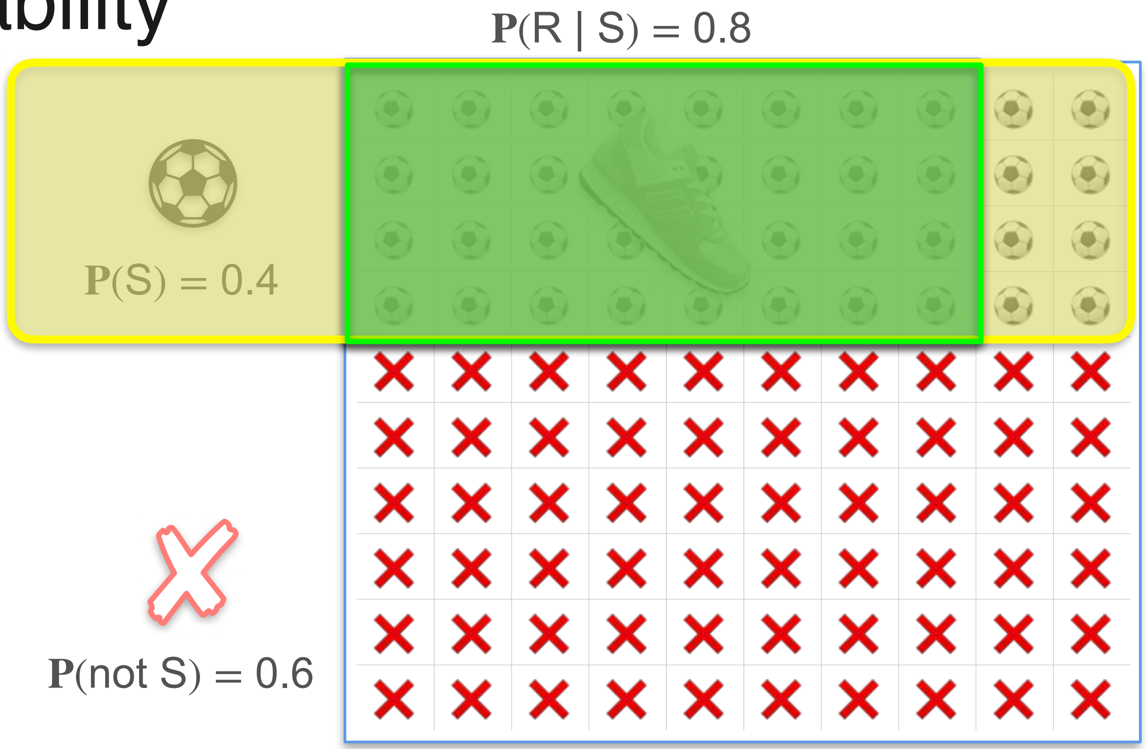
$\mathbf{P}(S \cap R) = \quad \mathbf{P}(S)$



Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

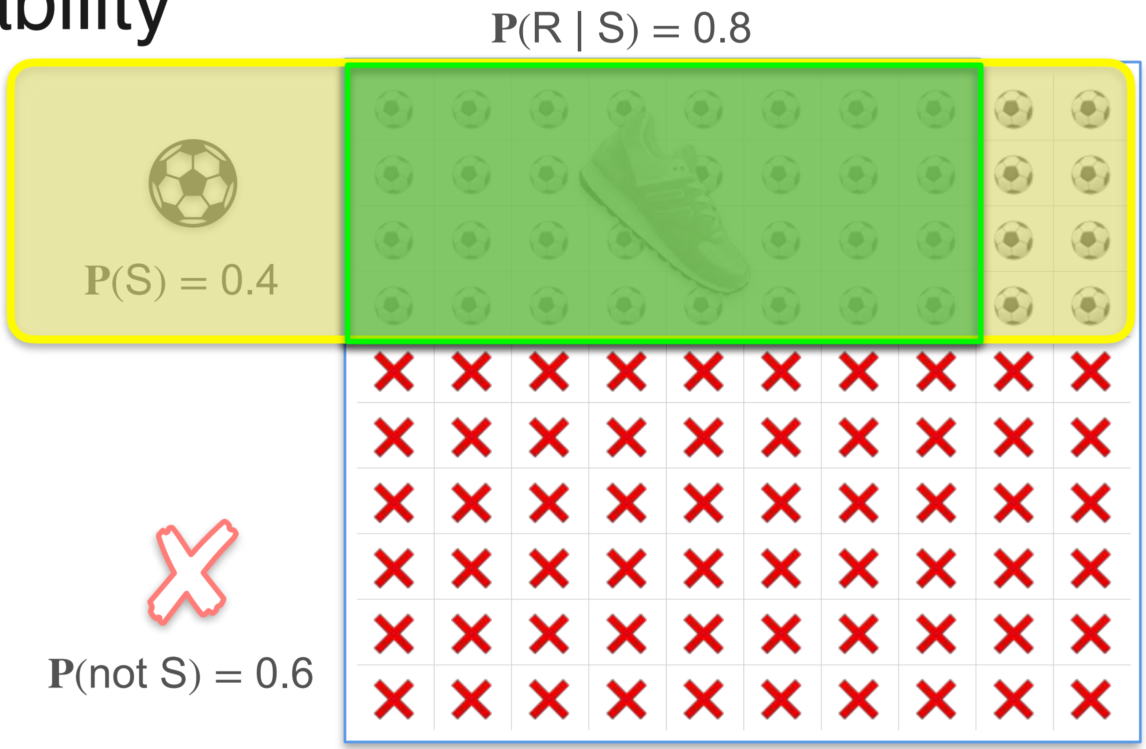
$\mathbf{P}(S \cap R) = \quad \mathbf{P}(S) \;\bullet$



Conditional Probability

P(Soccer and Running shoes)

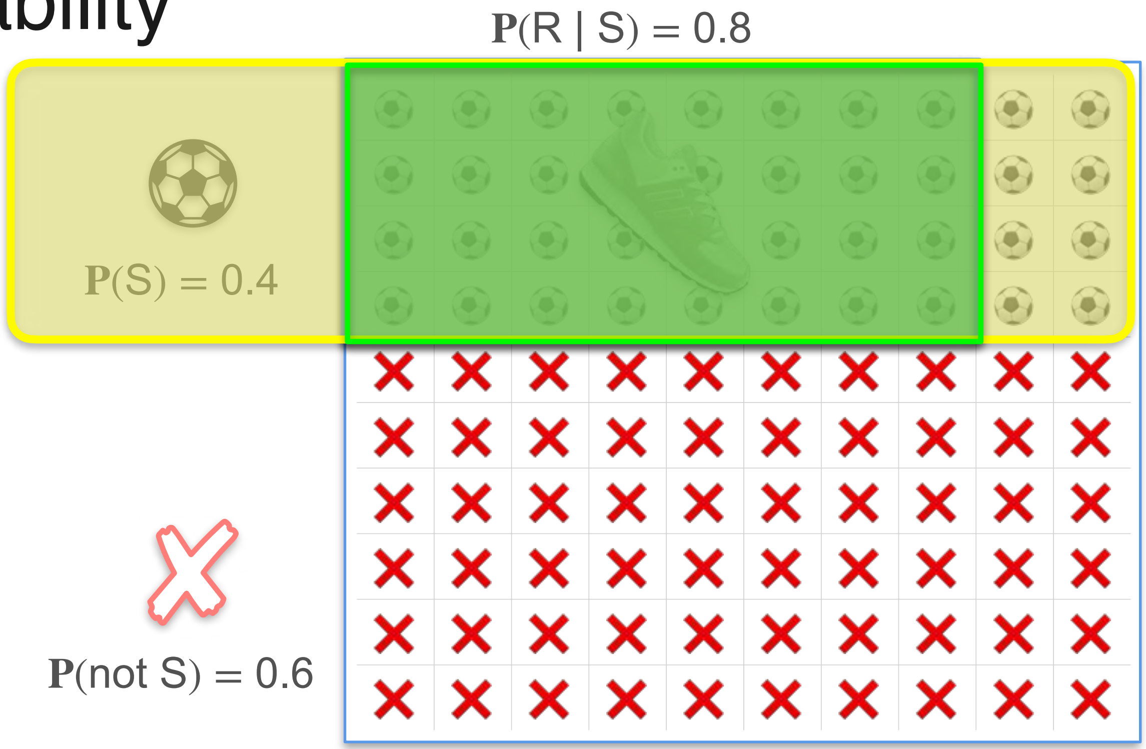
$P(S \cap R) = P(S) \bullet P(R \mid S)$



Conditional Probability

P(Soccer and Running shoes)

$P(S \cap R) = P(S) \bullet P(R \mid S)$

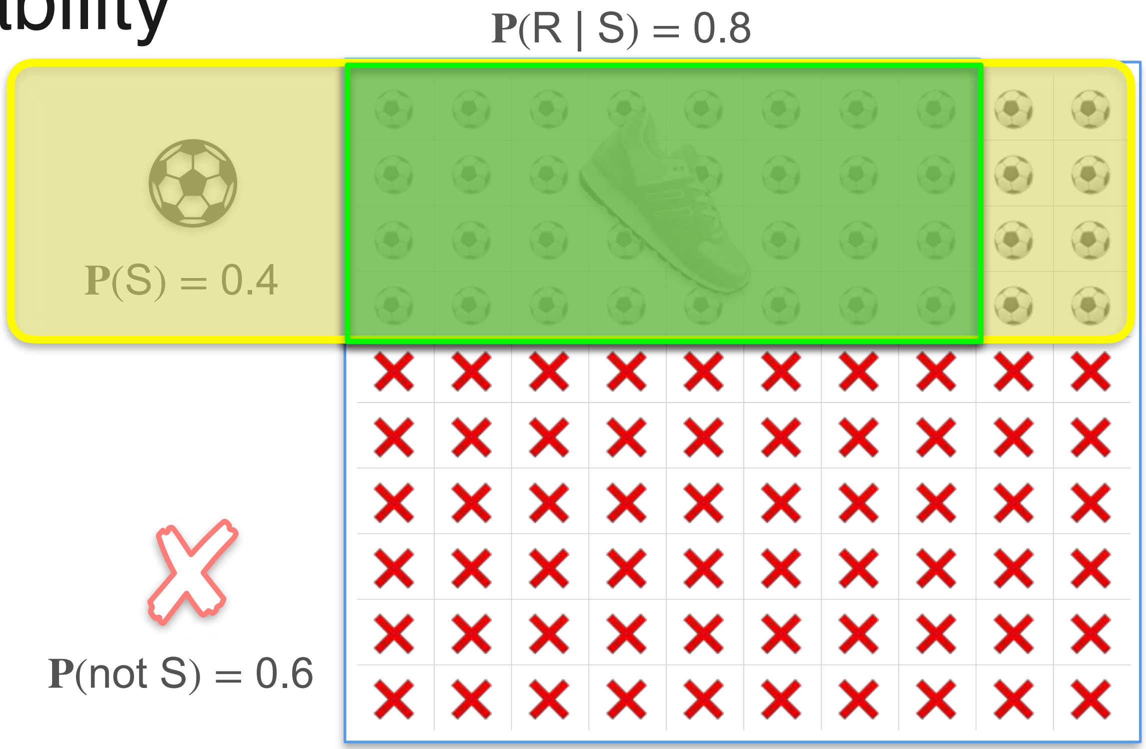


Conditional Probability

P(Soccer and Running shoes)

$$P(S \cap R) = P(S) \bullet P(R \mid S)$$

$$= 0.4$$

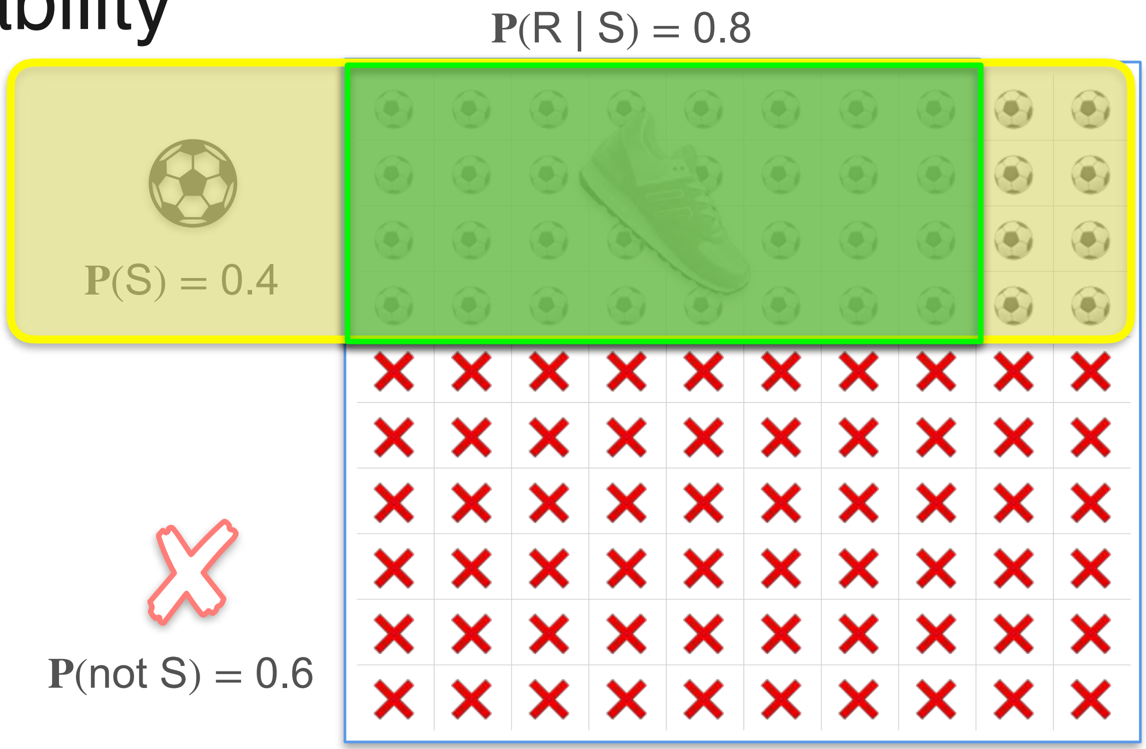


Conditional Probability

P(Soccer and Running shoes)

$P(S \cap R) = P(S) \bullet P(R \mid S)$

$= 0.4 \bullet$

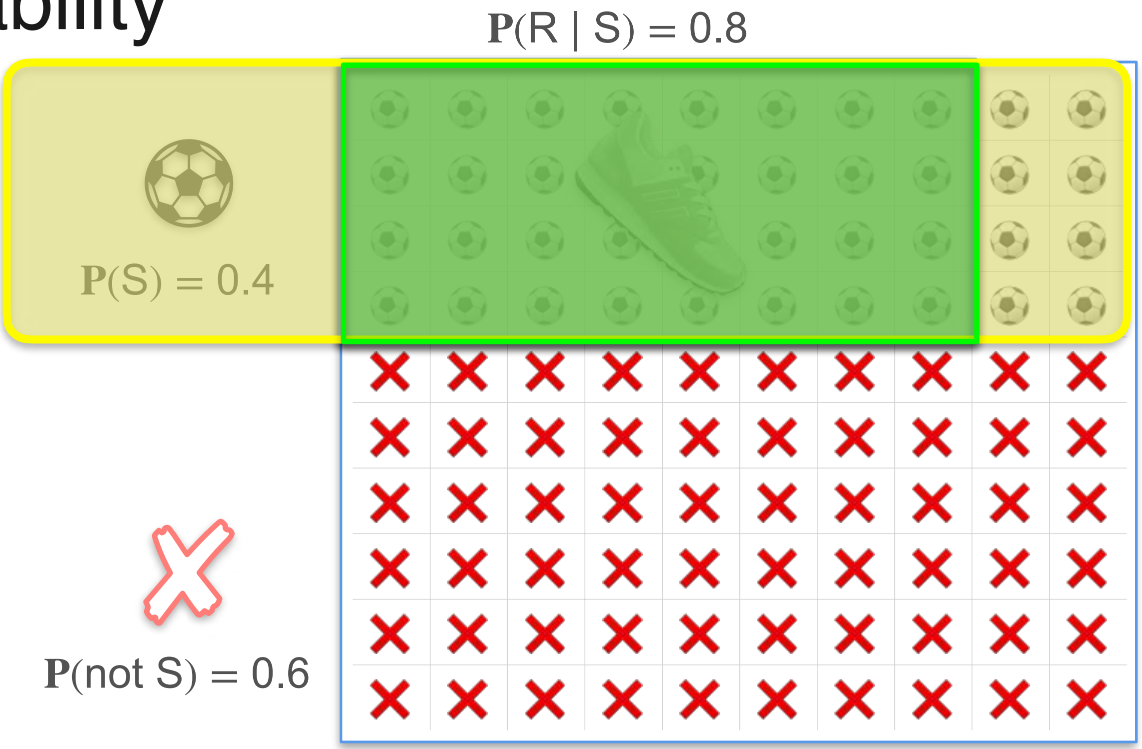


Conditional Probability

P(Soccer and Running shoes)

$$P(S \cap R) = P(S) \bullet P(R \mid S)$$

$$= 0.4 \bullet 0.8$$



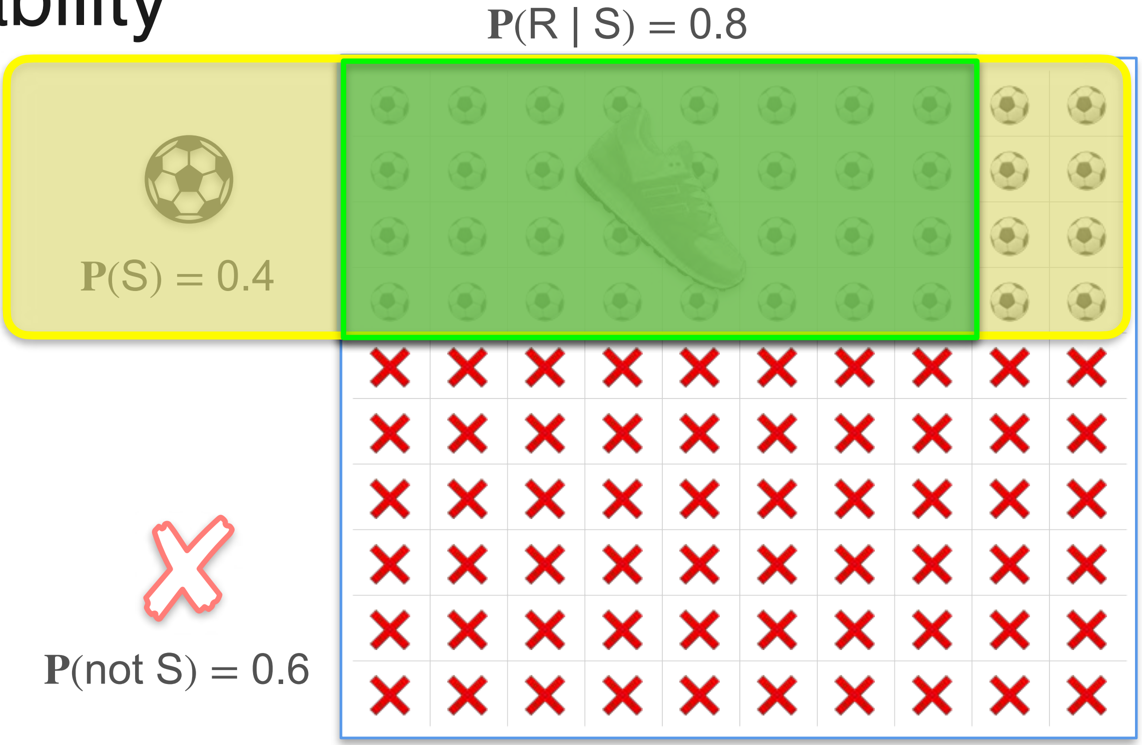
Conditional Probability

P(Soccer and Running shoes)

$$P(S \cap R) = P(S) \bullet P(R \mid S)$$

$$= 0.4 \bullet 0.8$$

$$= 0.32$$



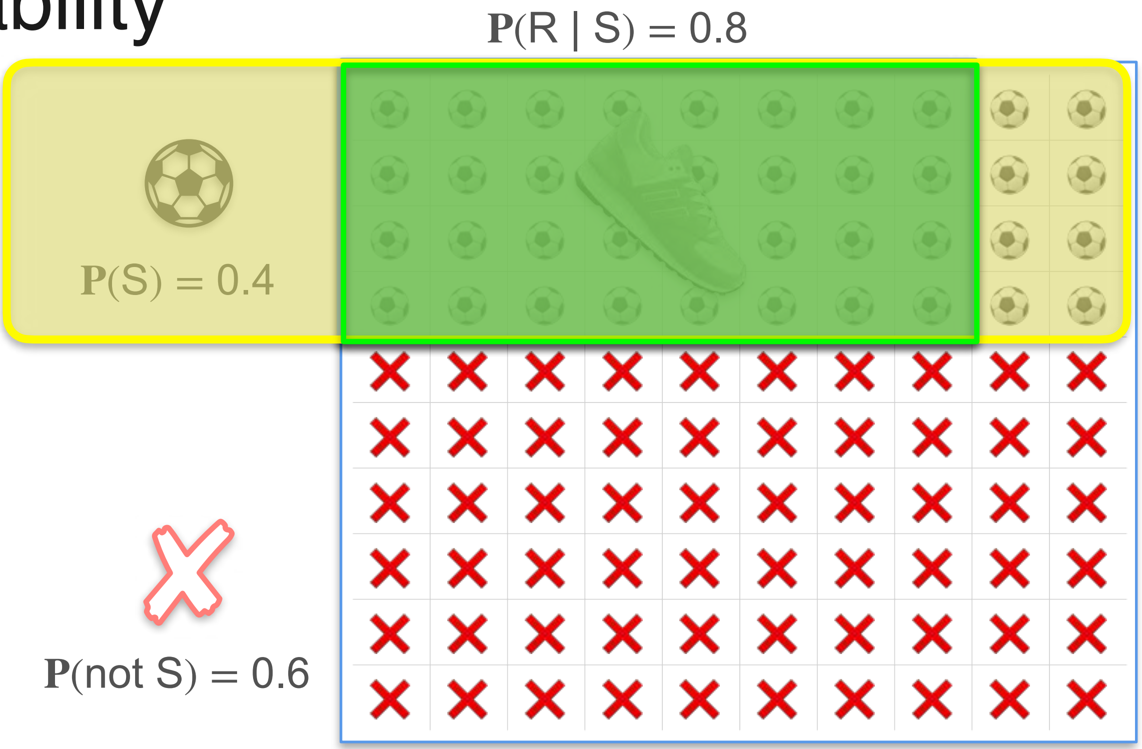
Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = \mathbf{P}(S) \bullet \mathbf{P}(R \mid S)$

$= 0.4 \bullet 0.8$

$= 0.32$



Conditional Probability

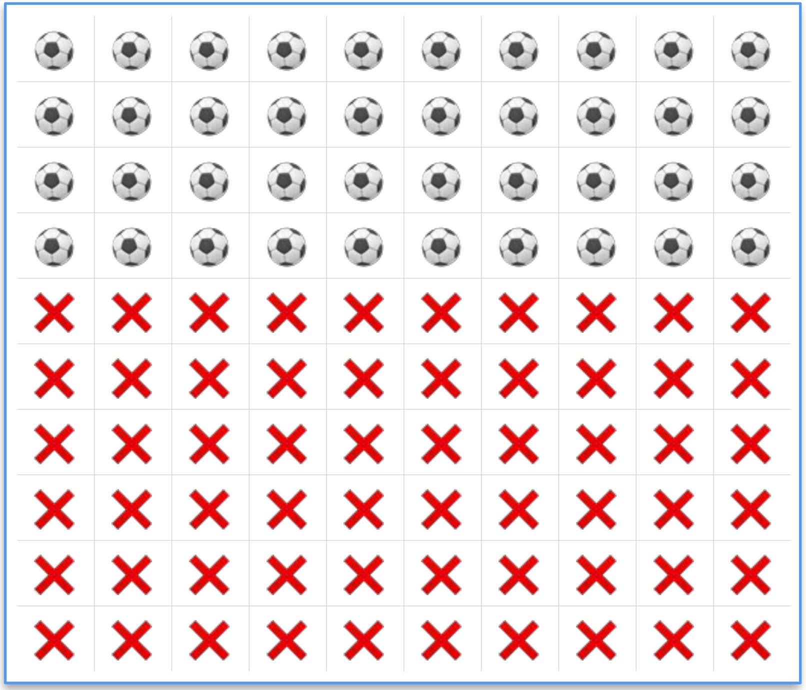
$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



Conditional Probability

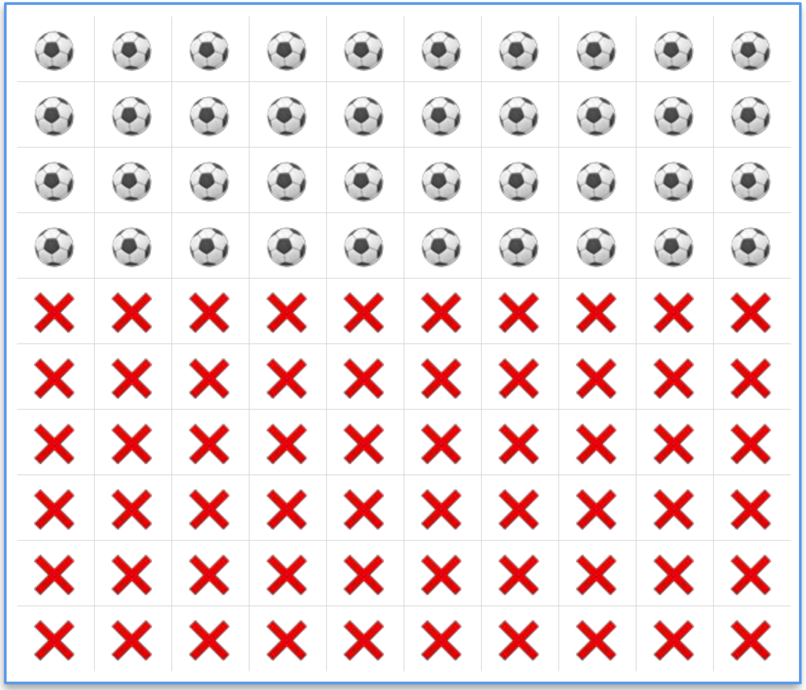
$\mathbf{P}(R \mid S) = 0.8$

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(\text{not } S) = 0.6$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

Conditional Probability

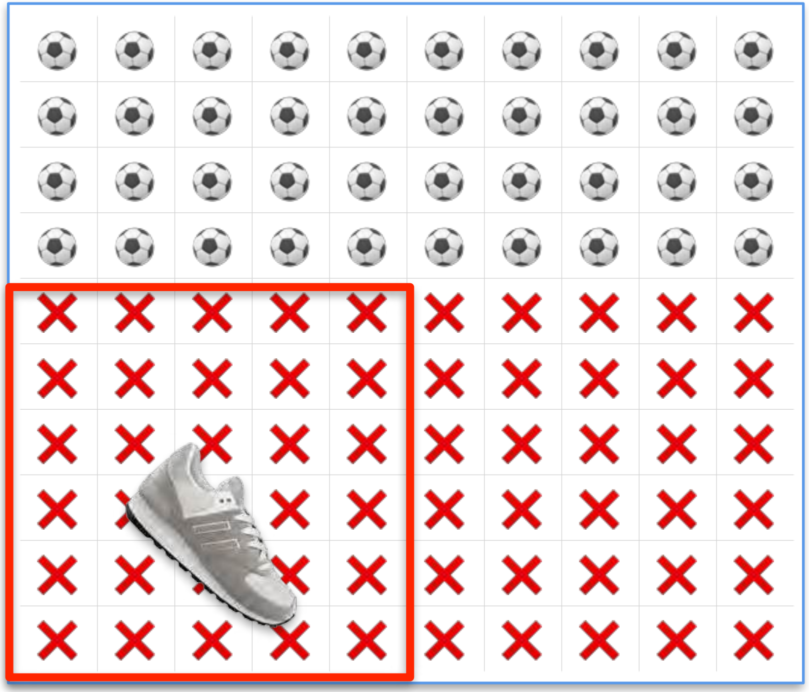
$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

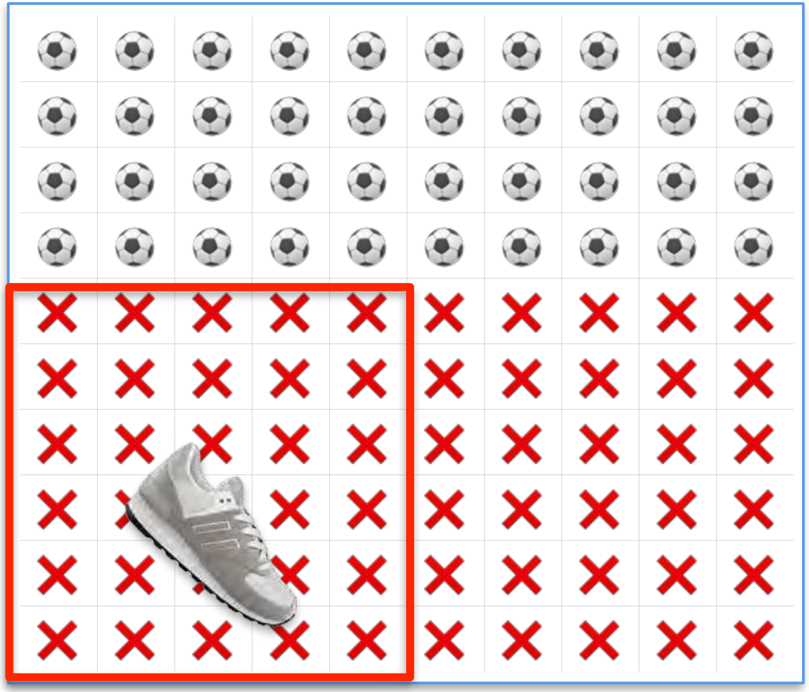
Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid \text{not } S) = 0.5$

Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

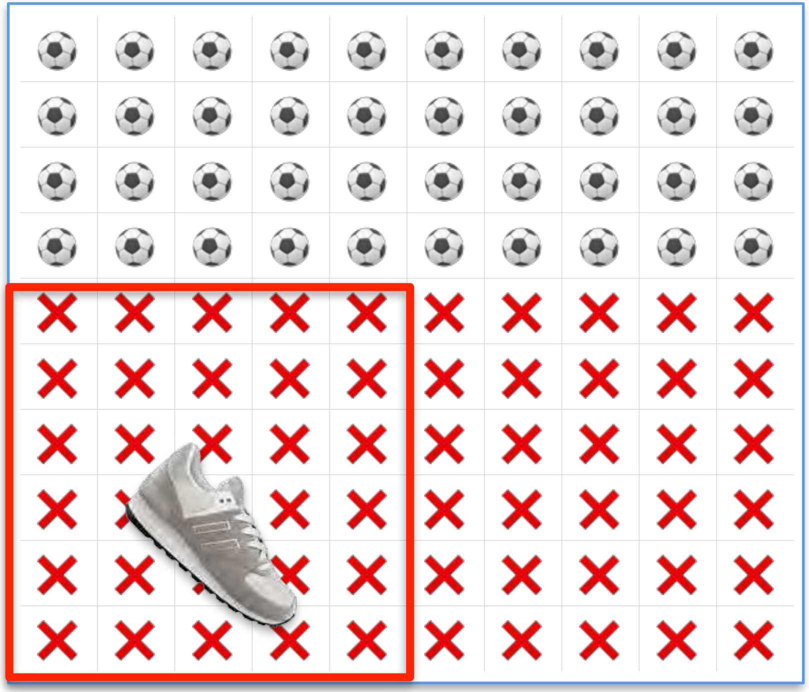
$\mathbf{P}(S) = 0.4$

$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) =$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

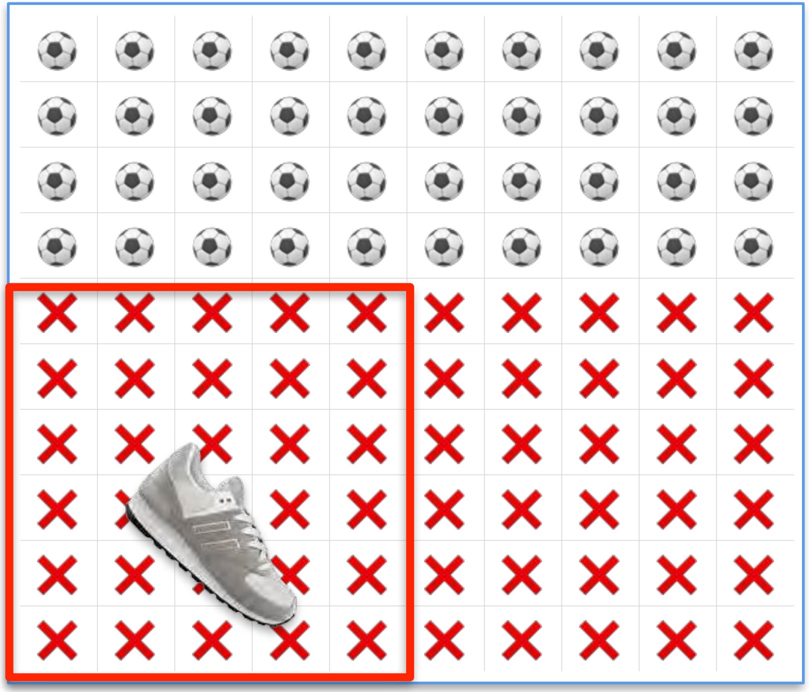
Conditional Probability

$\mathbf{P}(R \mid S) = 0.8$

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$



$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \quad \mathbf{P}(\text{not } S)$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid \text{not } S) = 0.5$

Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

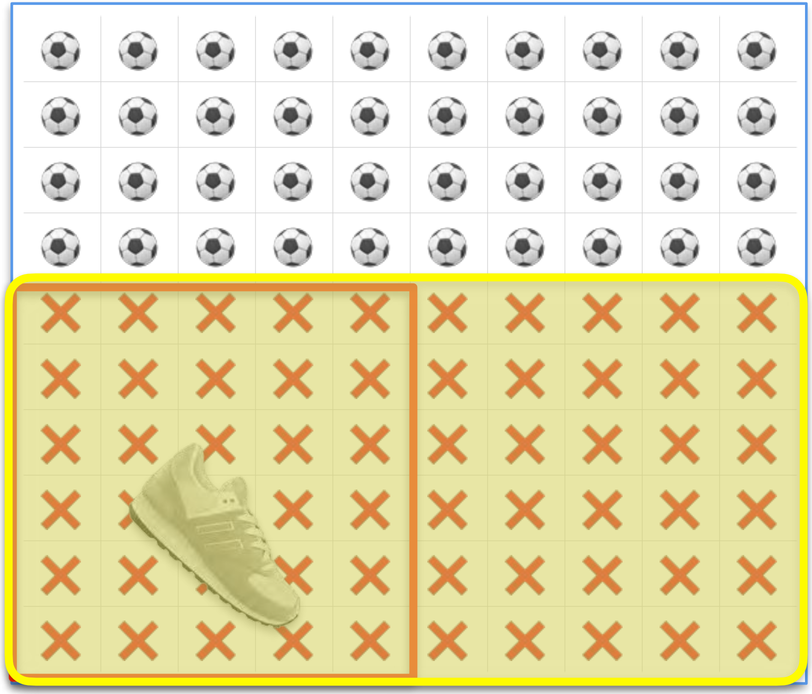
$\mathbf{P}(S) = 0.4$

$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \quad \mathbf{P}(\text{not } S)$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

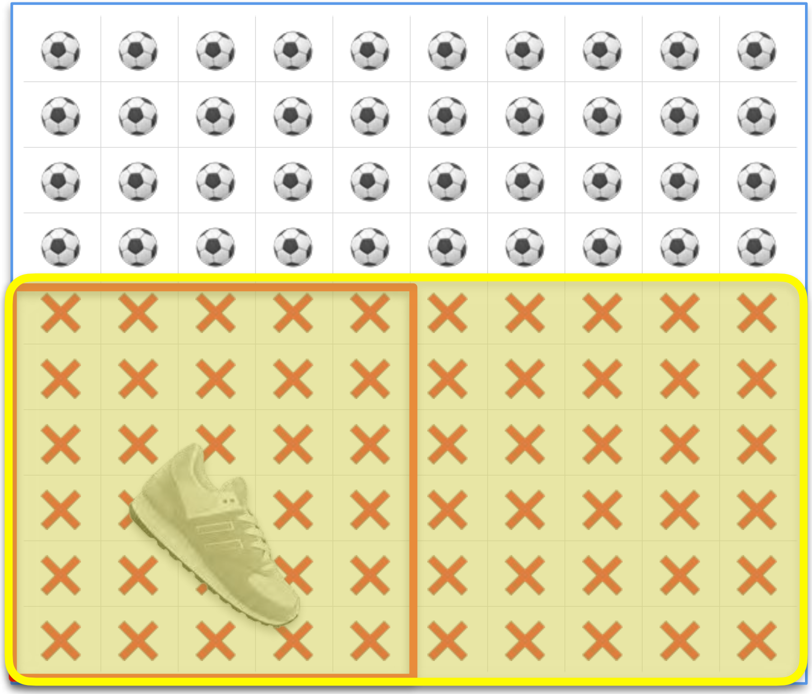
Conditional Probability

P(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

P(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet$

$\mathbf{P}(\text{not } S) = 0.6$

Conditional Probability

P(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

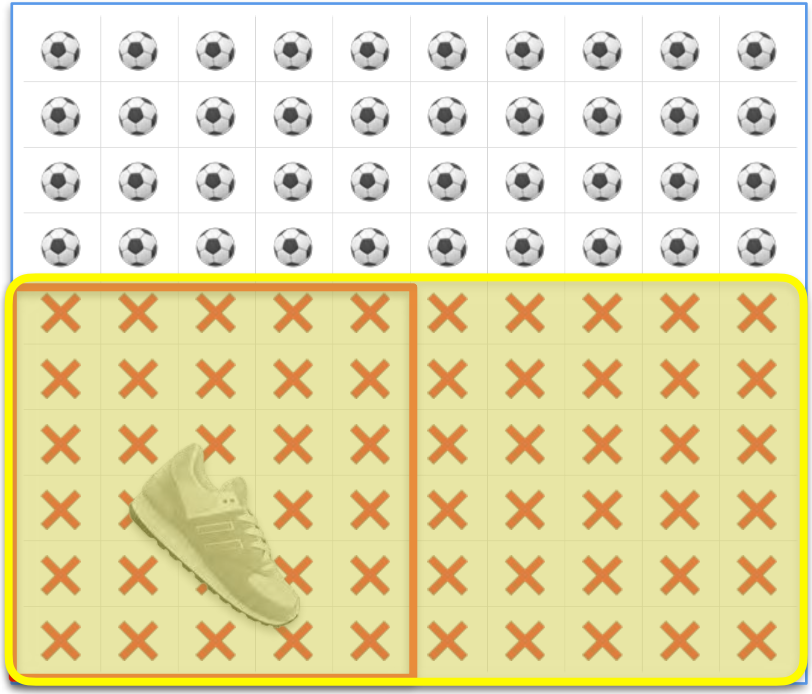
$\mathbf{P}(S) = 0.4$

P(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

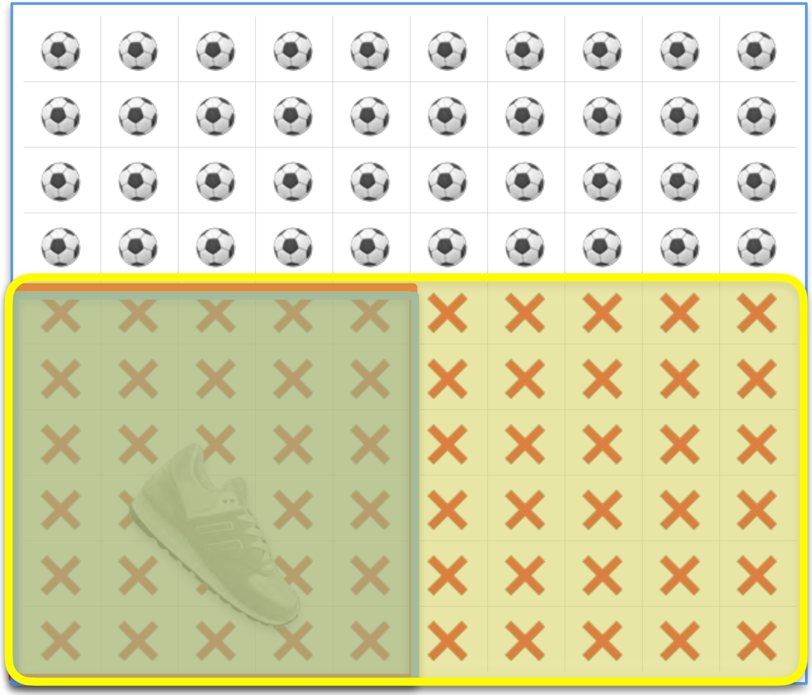
Conditional Probability

$\mathbf{P}(\text{Soccer and Running shoes})$

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(\text{not Soccer and Running shoes})$

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid \text{not } S) = 0.5$

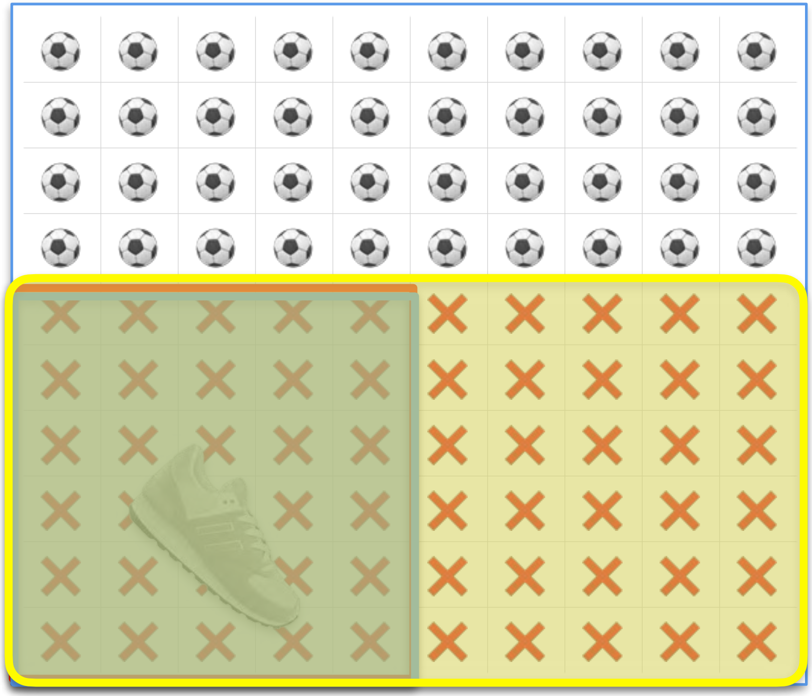
Conditional Probability

$\mathbf{P}(R \mid S) = 0.8$

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$



$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$= 0.6$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid \text{not } S) = 0.5$

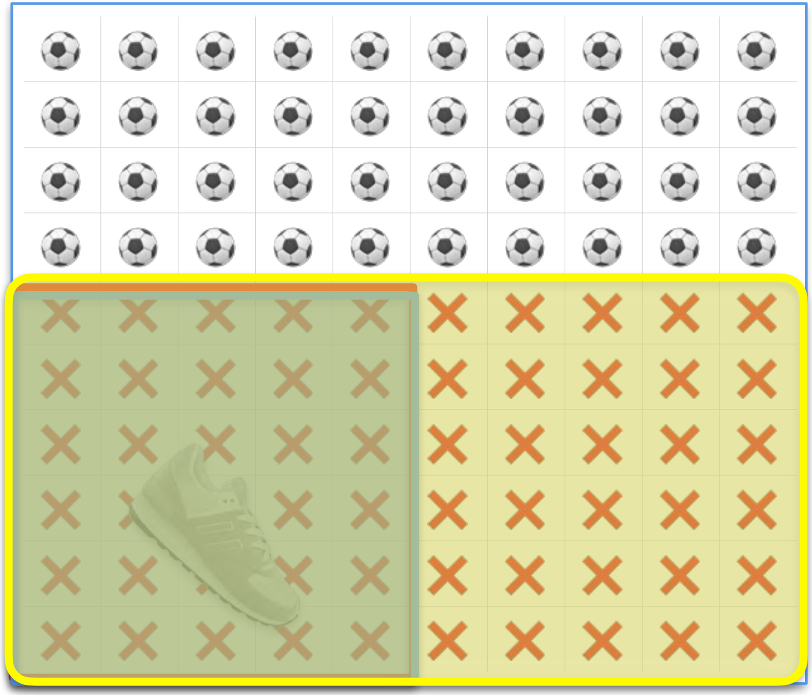
Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$= 0.6 \bullet$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid \text{not } S) = 0.5$

Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

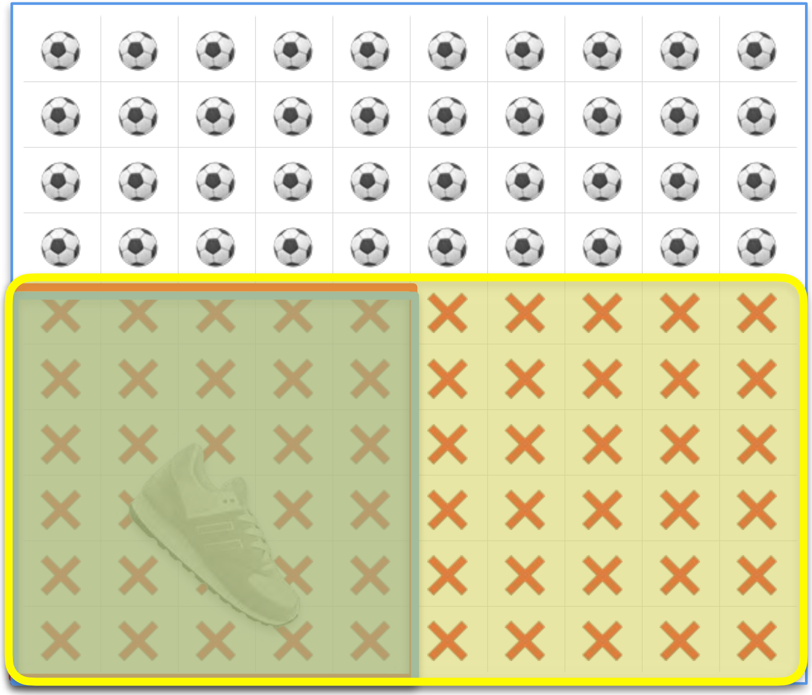
$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$= 0.6 \bullet 0.5$

$\mathbf{P}(\text{not } S) = 0.6$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

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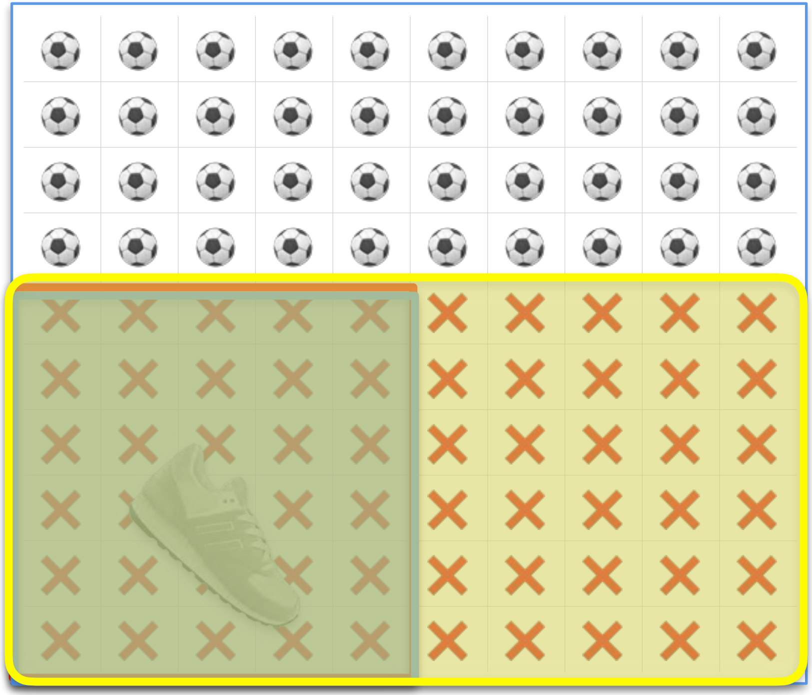
$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

$= 0.6 \bullet 0.5$

$= 0.3$

$\mathbf{P}(\text{not } S) = 0.6$

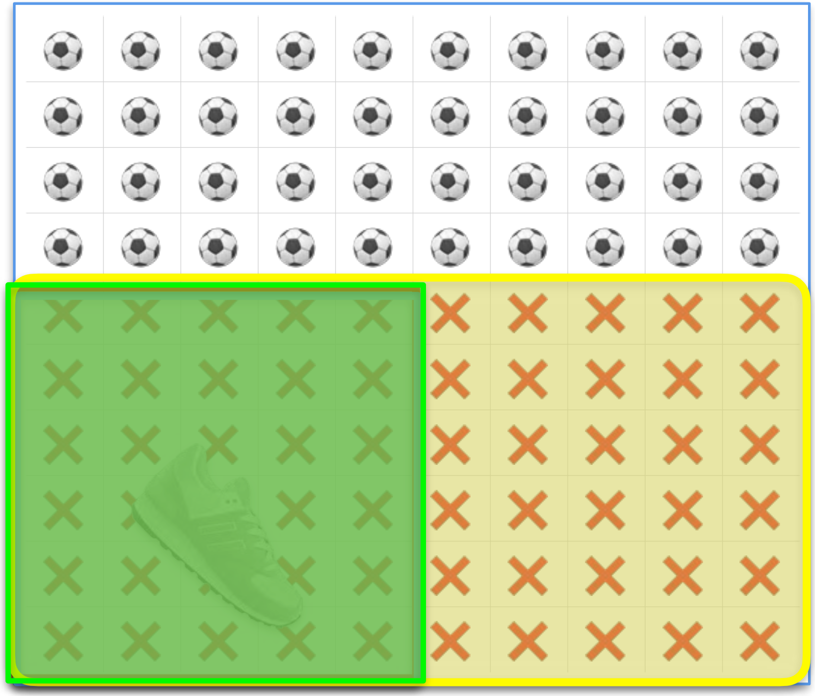
Conditional Probability

$\mathbf{P}$(Soccer and Running shoes)

$\mathbf{P}(S \cap R) = 0.32$

$\mathbf{P}(S) = 0.4$

$\mathbf{P}(R \mid S) = 0.8$



$\mathbf{P}(R \mid \text{not } S) = 0.5$

$\mathbf{P}$(not Soccer and Running shoes)

$\mathbf{P}(\text{not } S \cap R) = \mathbf{P}(\text{not } S) \bullet \mathbf{P}(R \mid \text{not } S)$

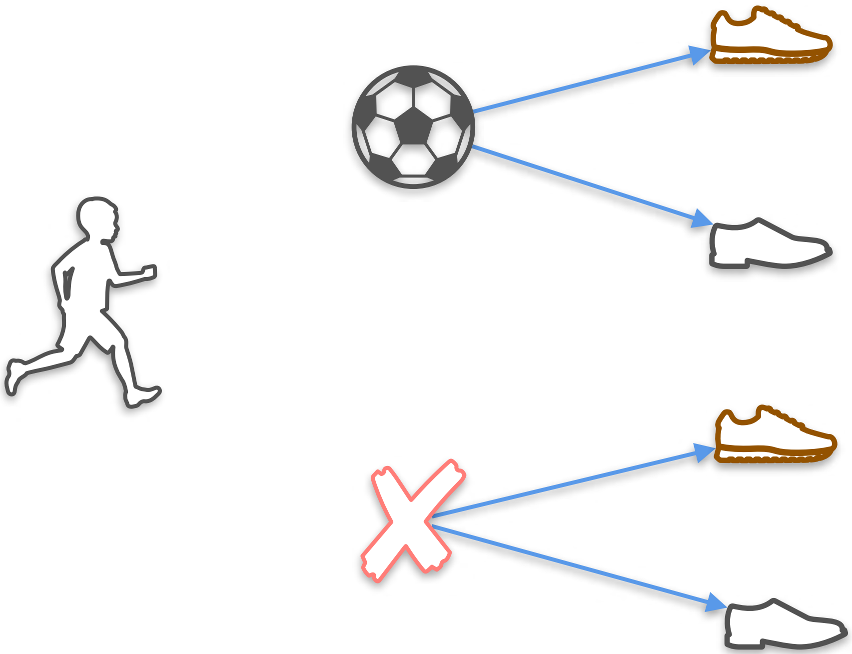
$= 0.6 \bullet 0.5$

$= 0.3$

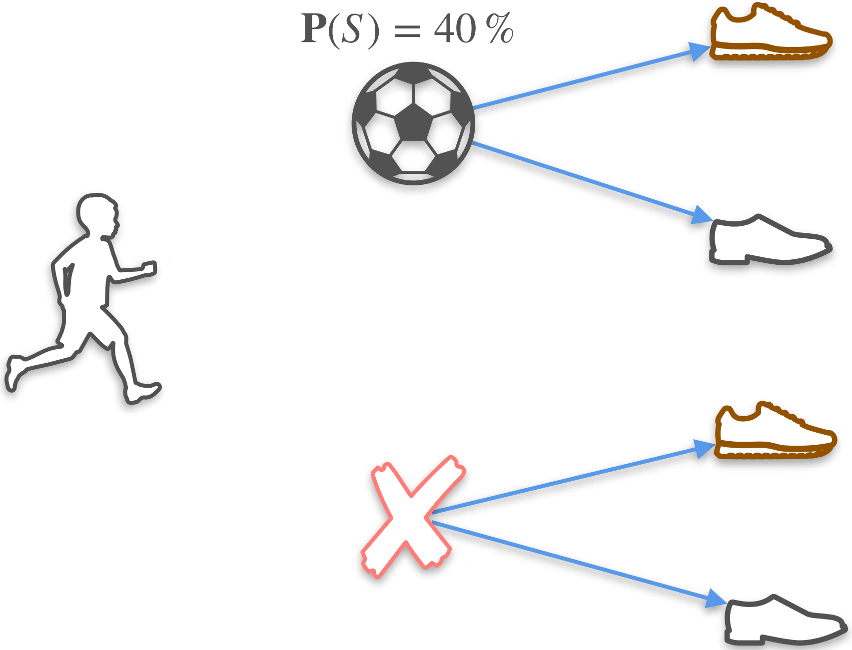
$\mathbf{P}(\text{not } S) = 0.6$

Conditional Probability

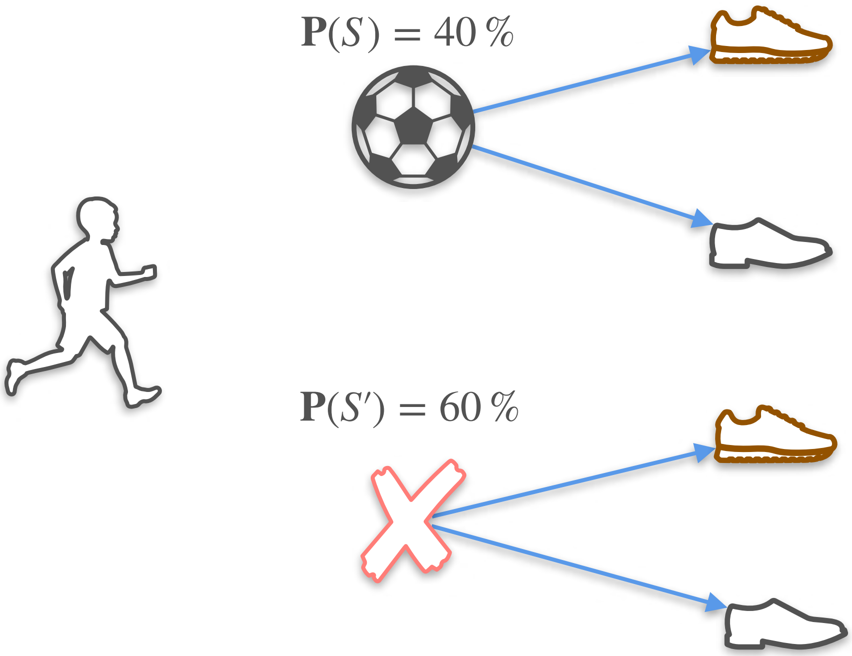
Conditional Probability



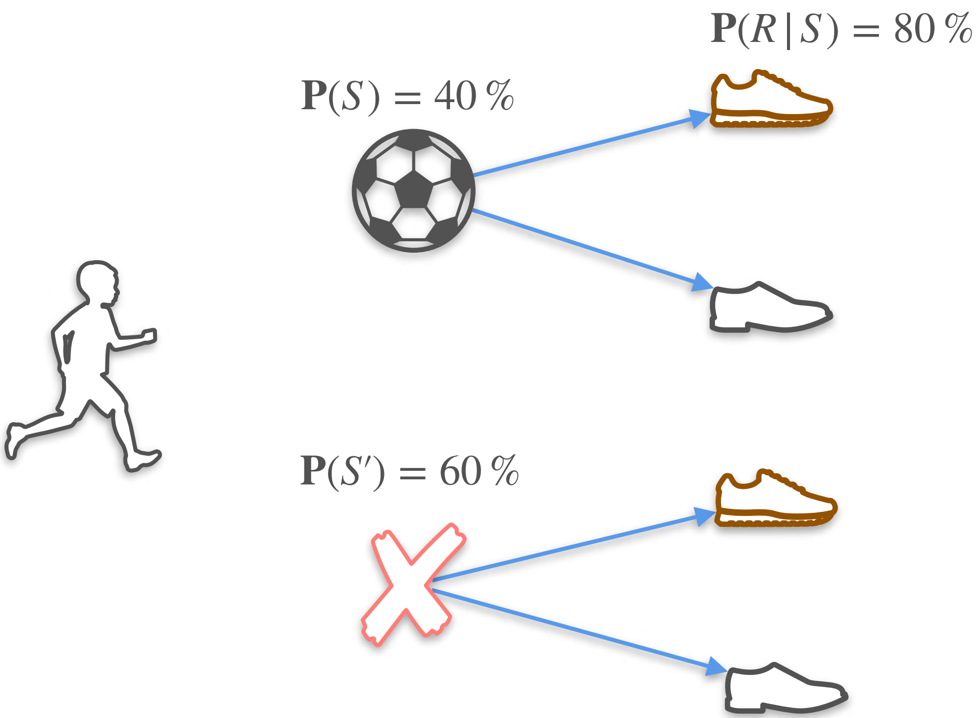
Conditional Probability



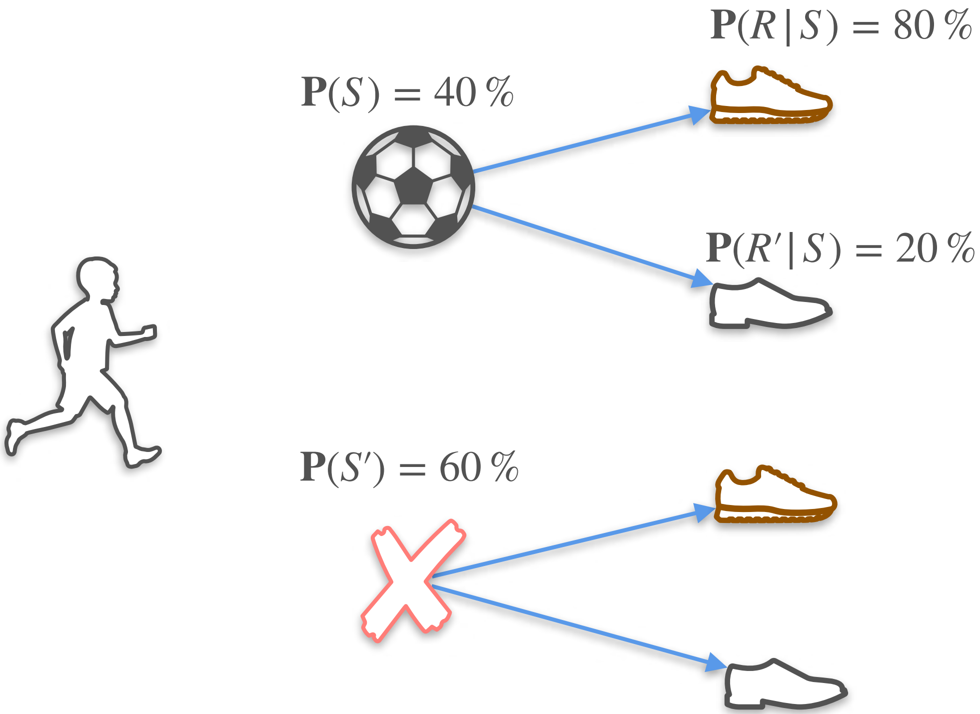
Conditional Probability



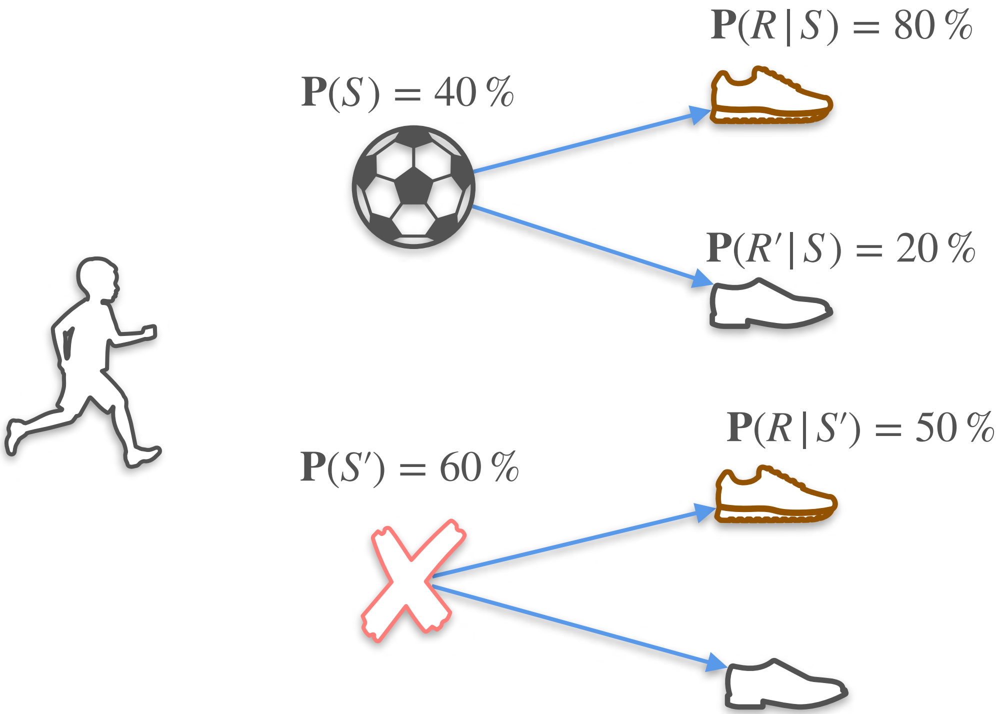
Conditional Probability



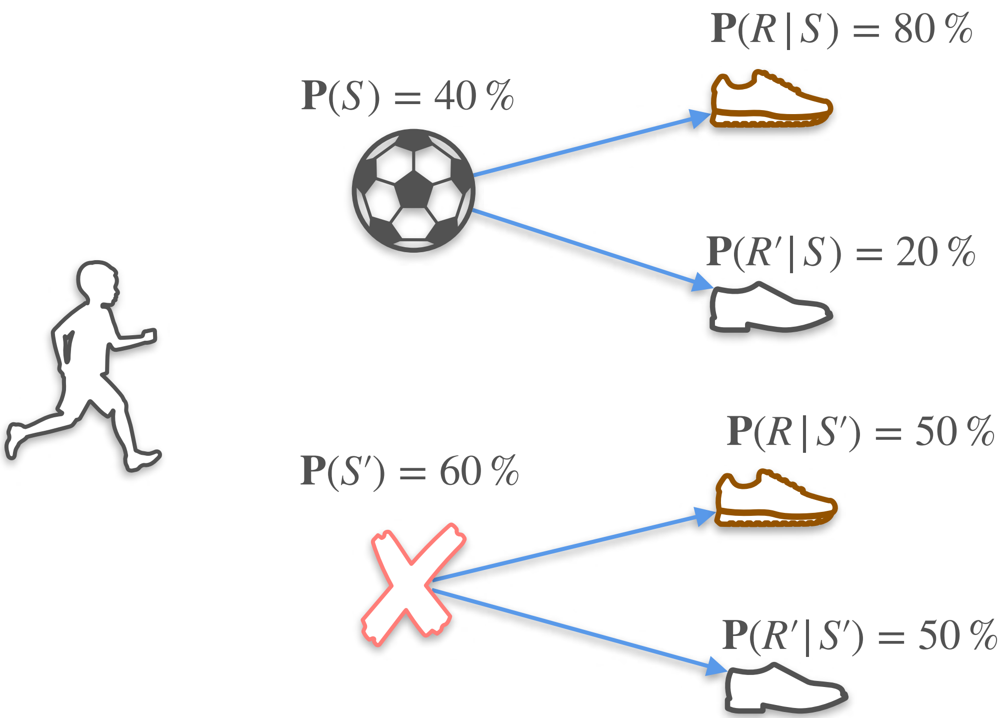
Conditional Probability



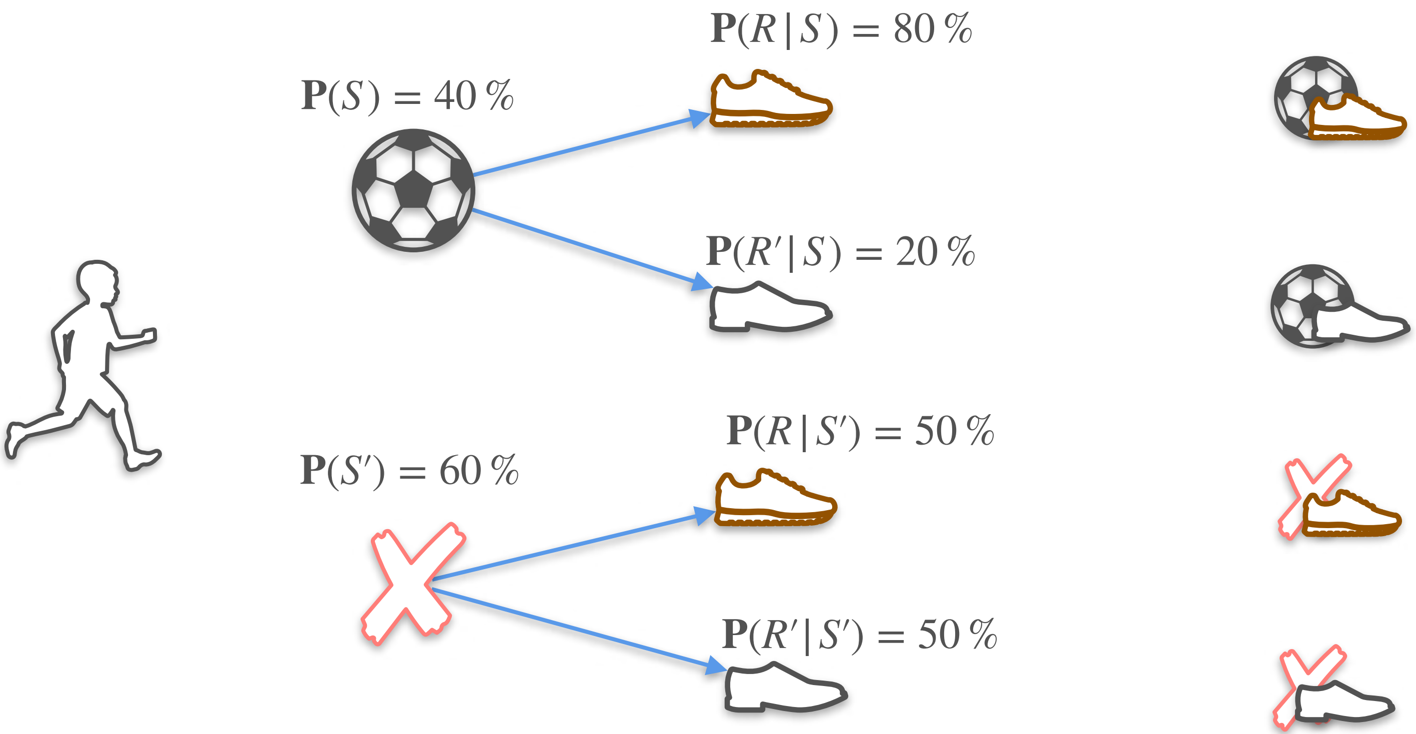
Conditional Probability



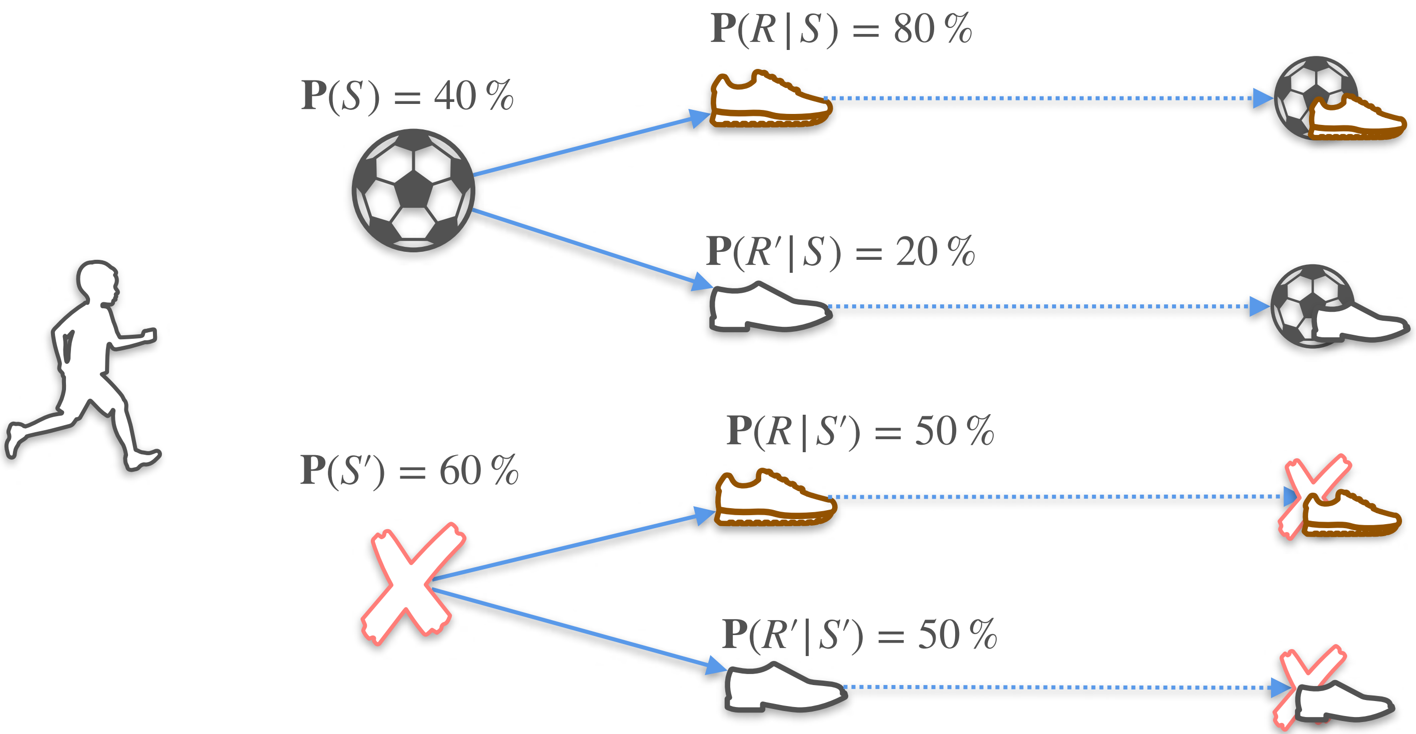
Conditional Probability



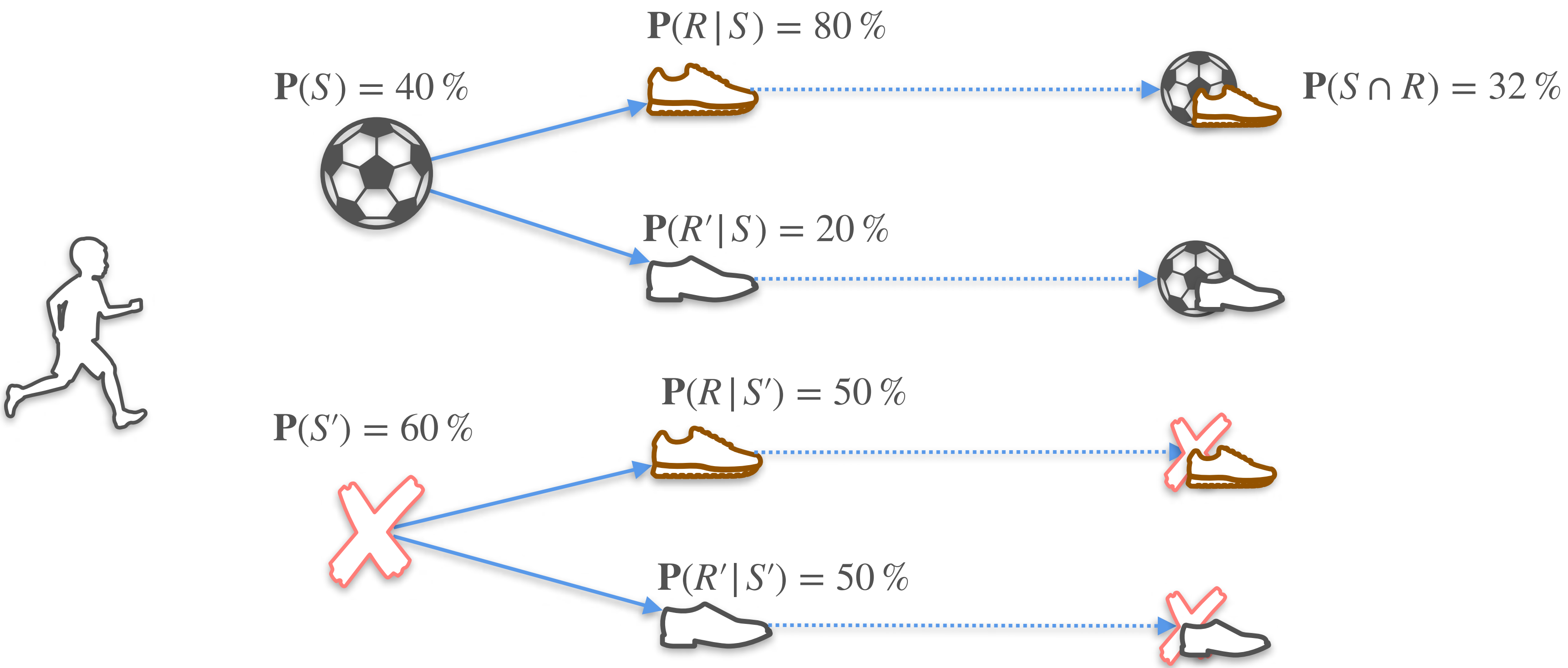
Conditional Probability



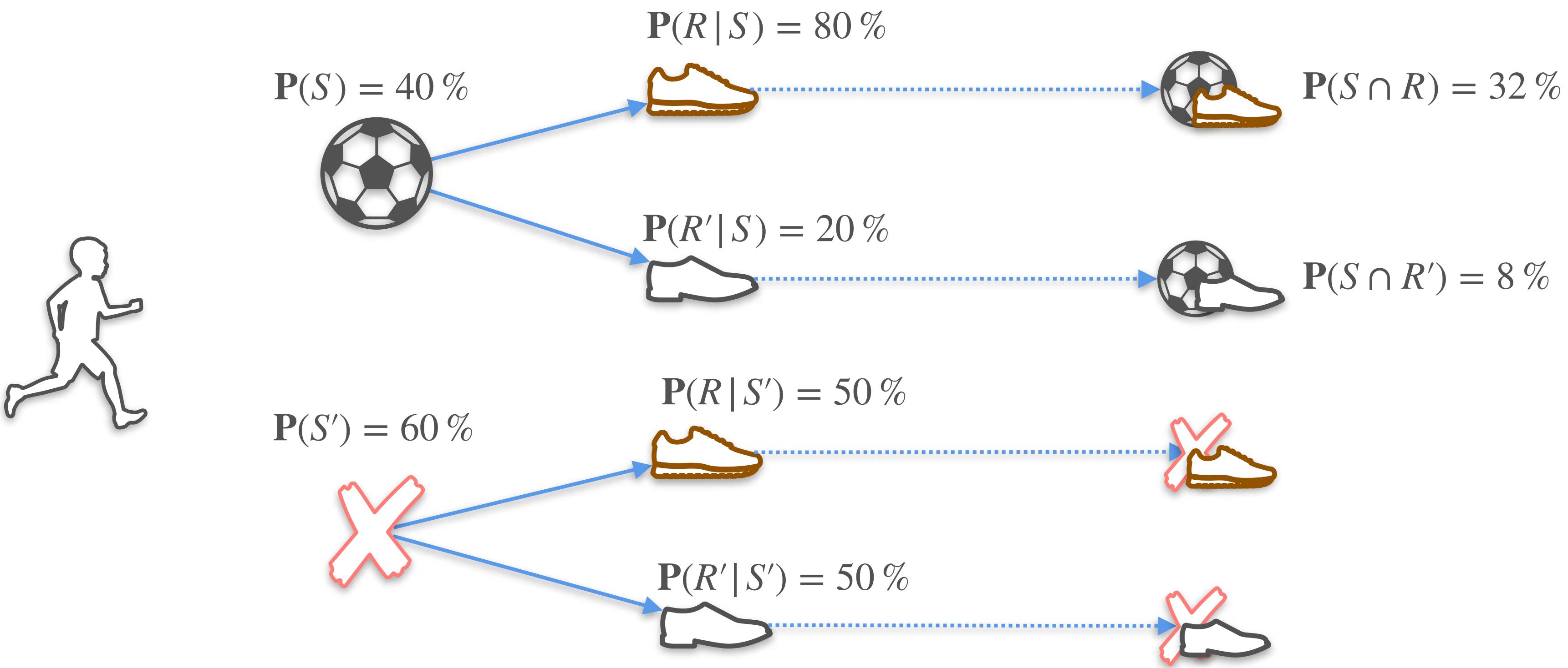
Conditional Probability



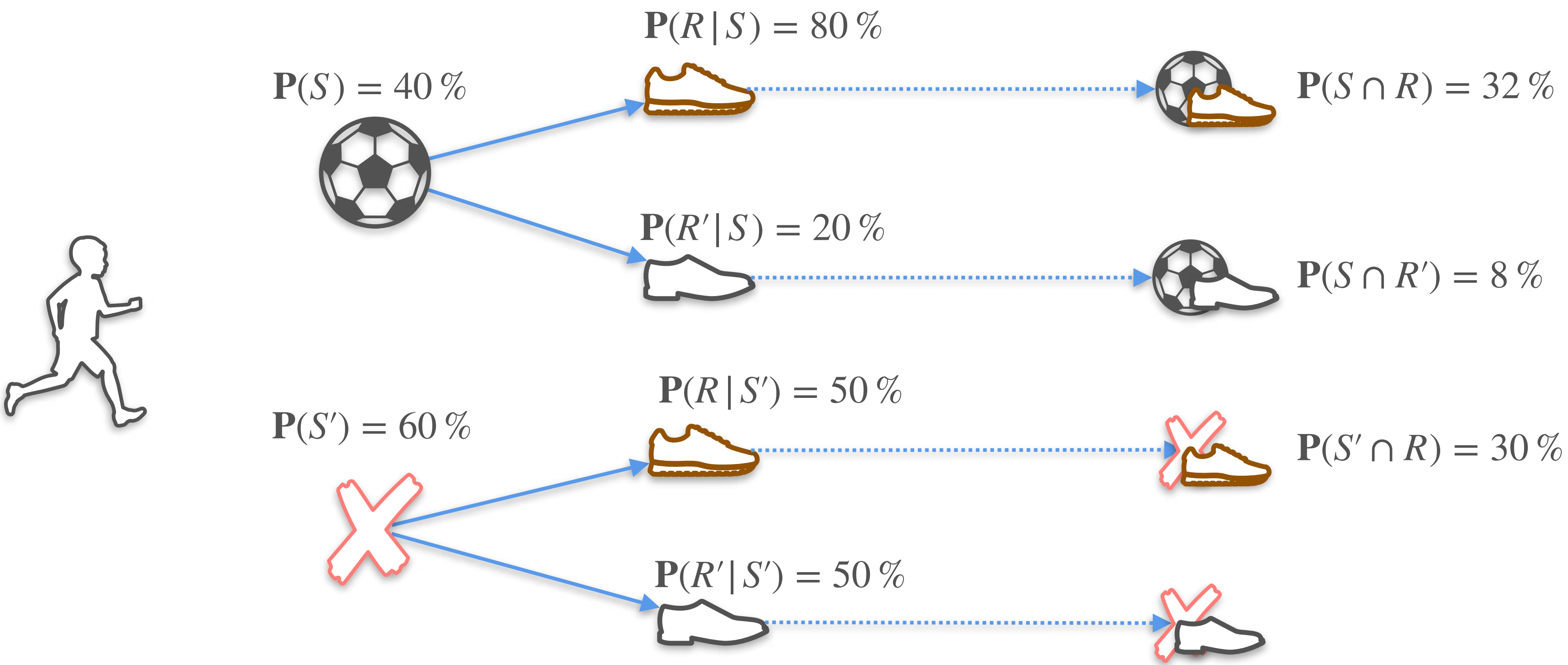
Conditional Probability



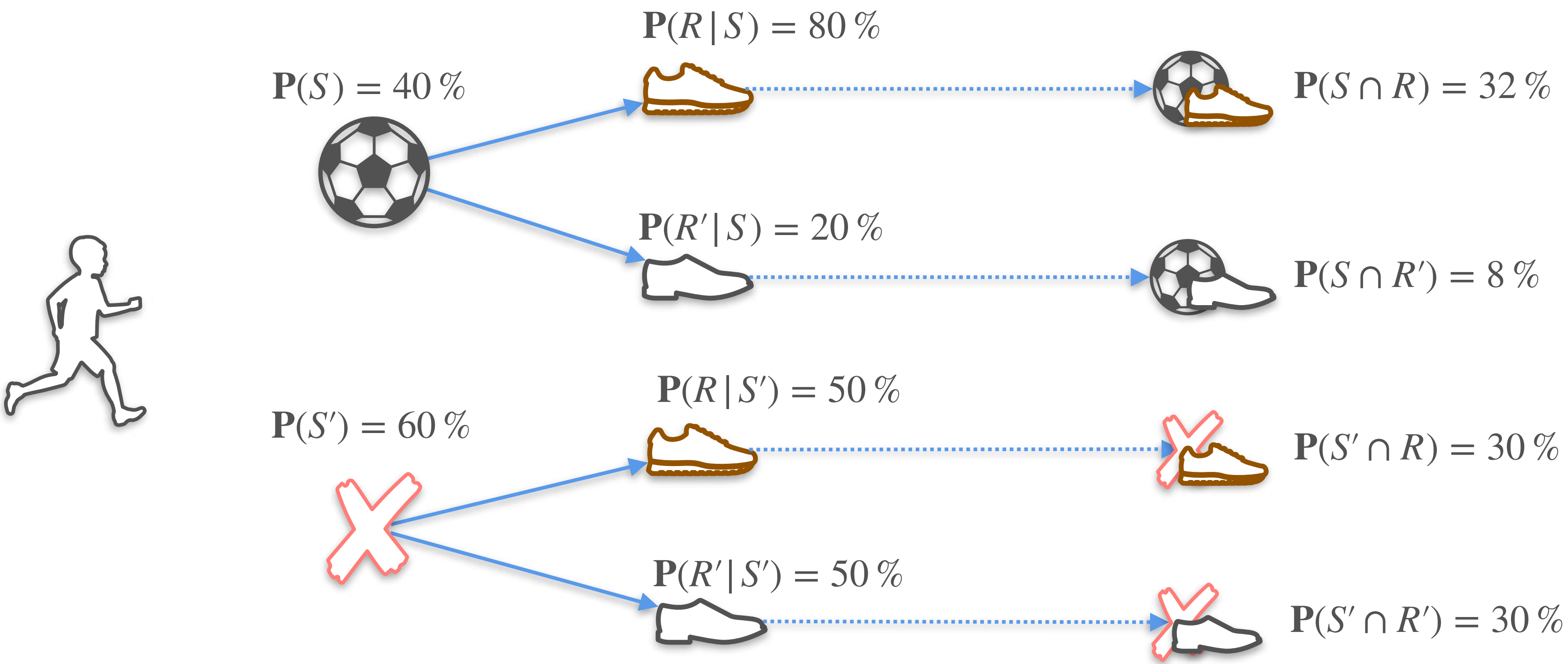
Conditional Probability



Conditional Probability

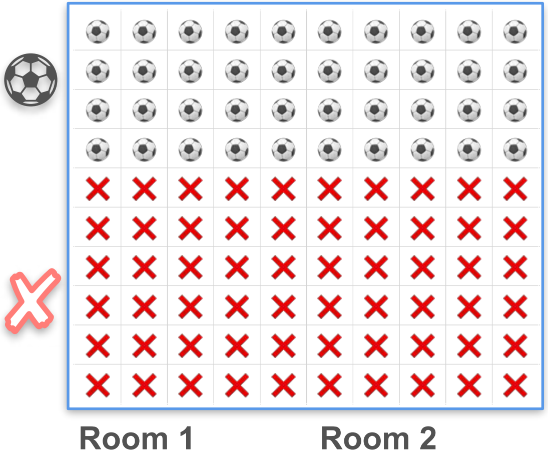


Conditional Probability

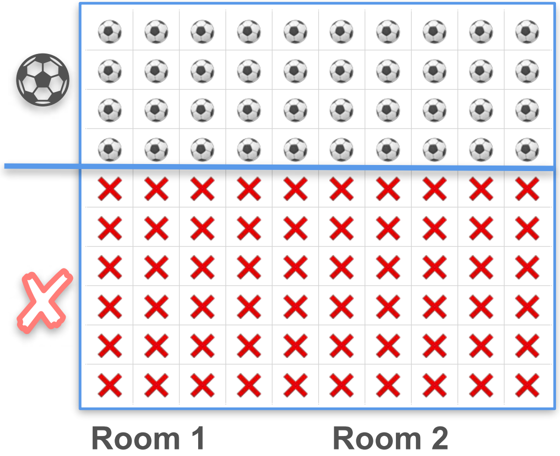


Independent vs Dependent Events

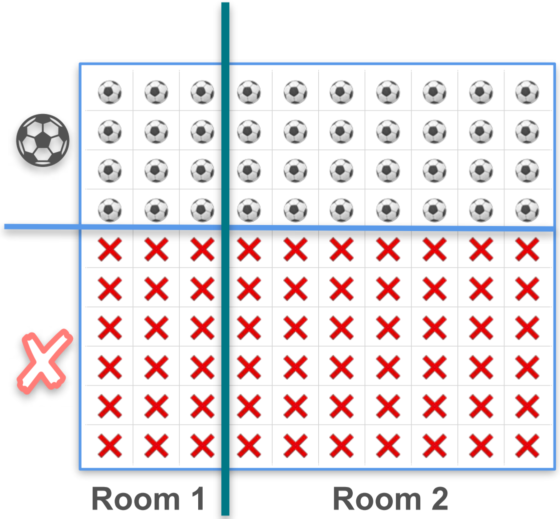
Independent vs Dependent Events



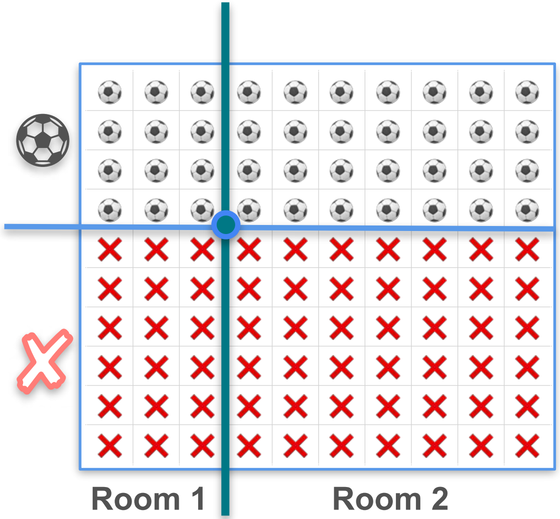
Independent vs Dependent Events



Independent vs Dependent Events

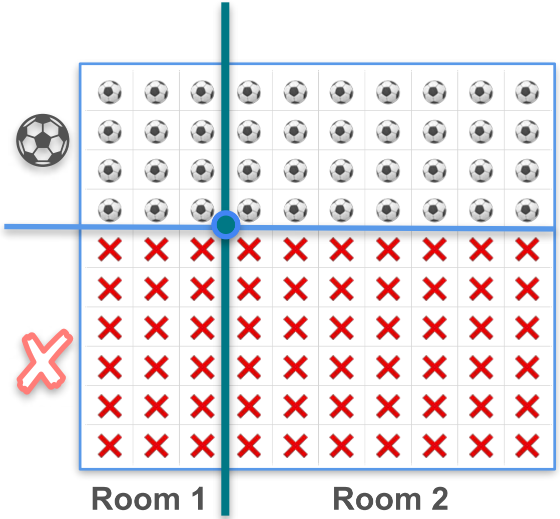


Independent vs Dependent Events



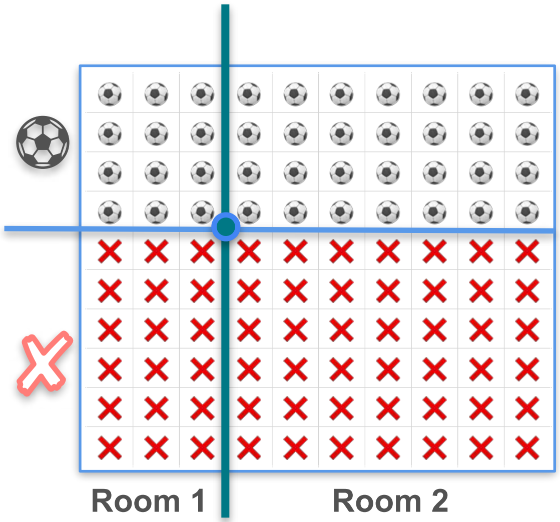
Independent vs Dependent Events

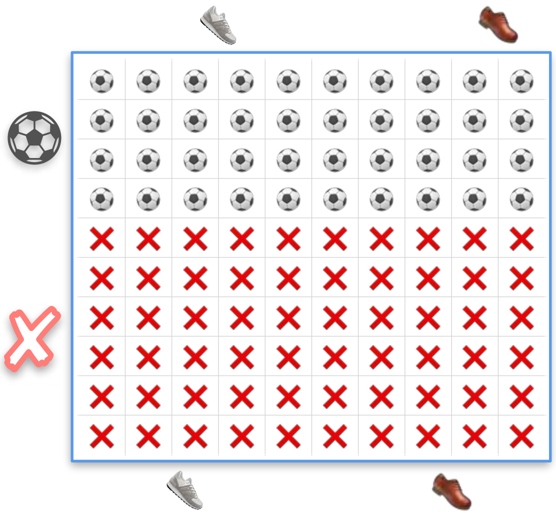
Independent



Independent vs Dependent Events

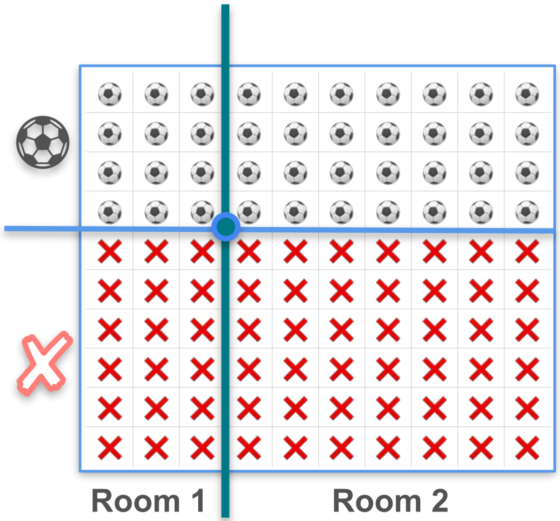
Independent

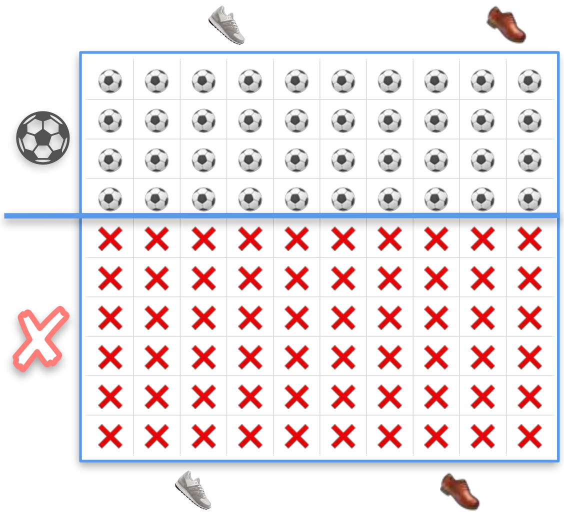




Independent vs Dependent Events

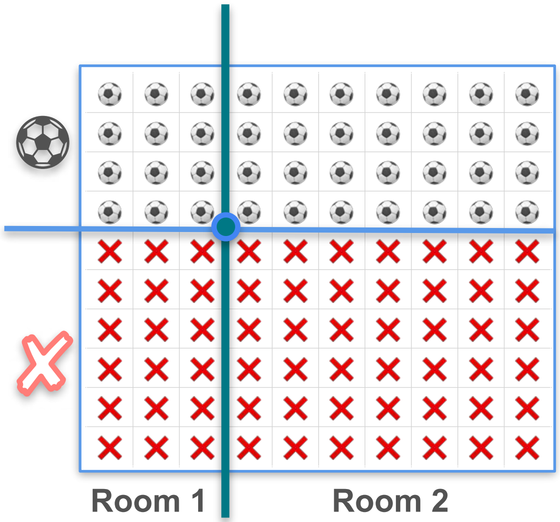
Independent

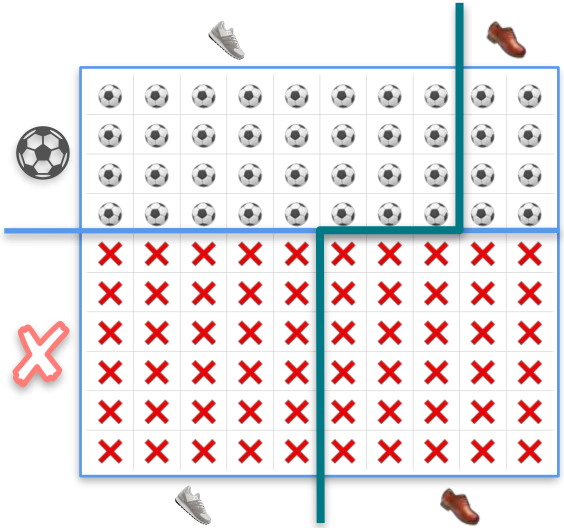




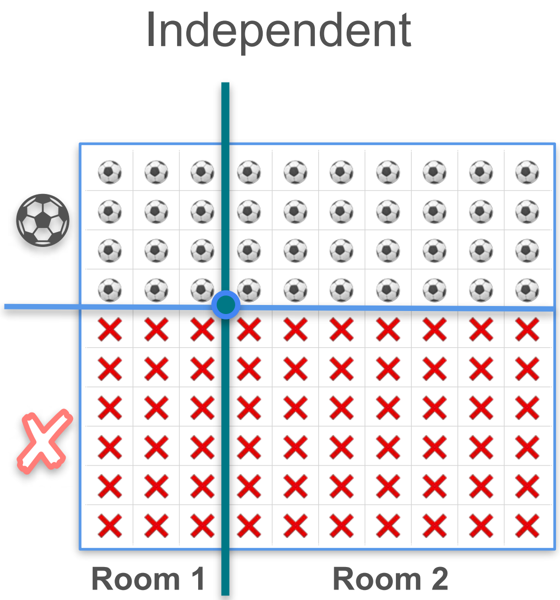
Independent vs Dependent Events

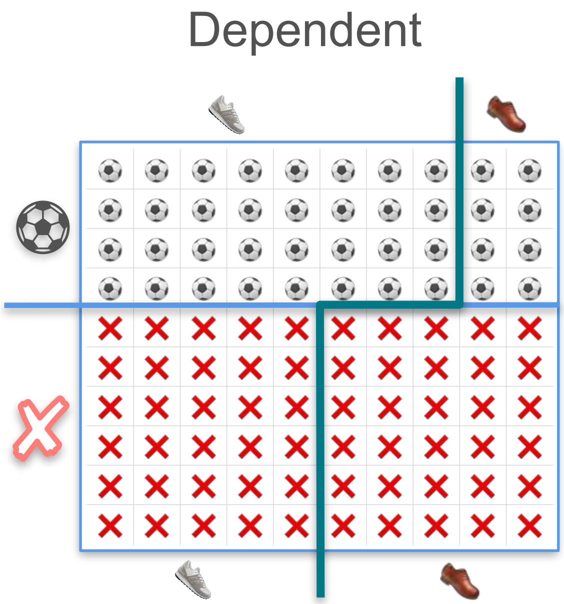
Independent





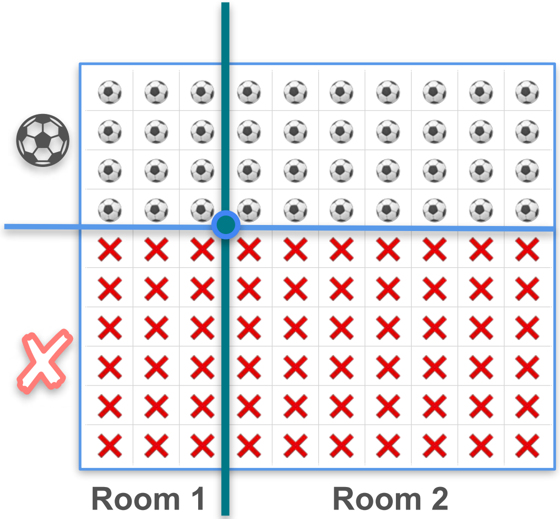
Independent vs Dependent Events



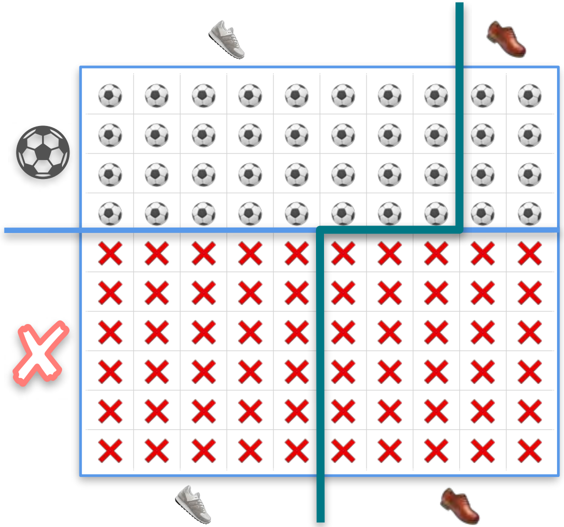


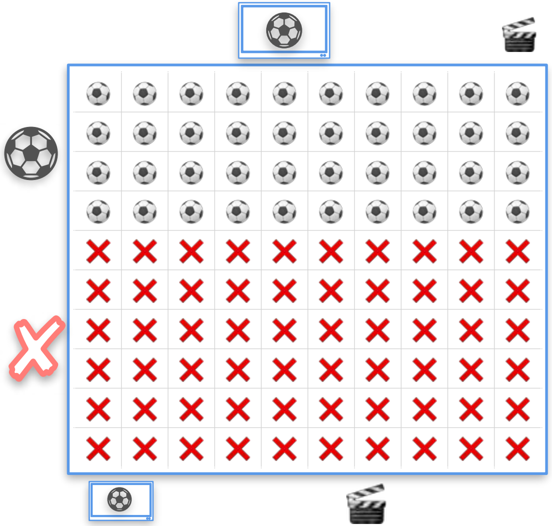
Independent vs Dependent Events

Independent



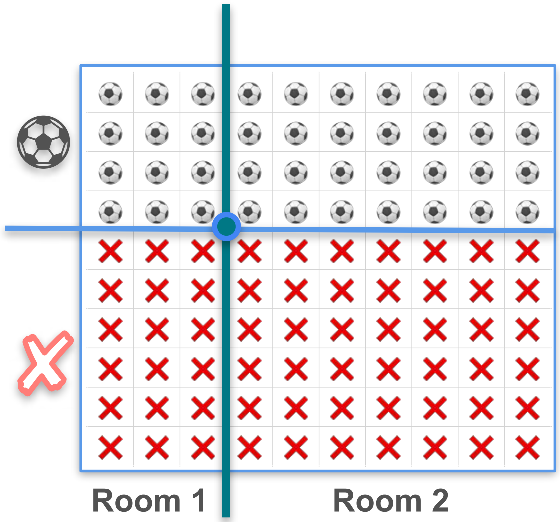
Dependent



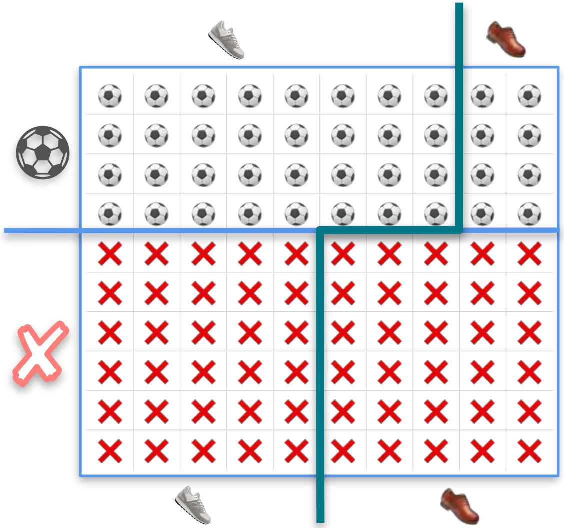


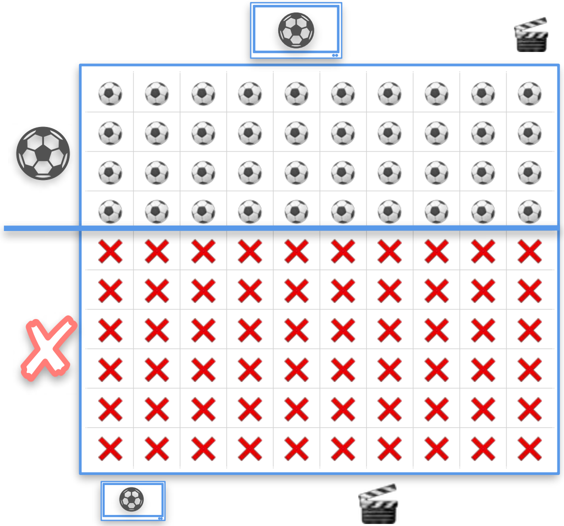
Independent vs Dependent Events

Independent

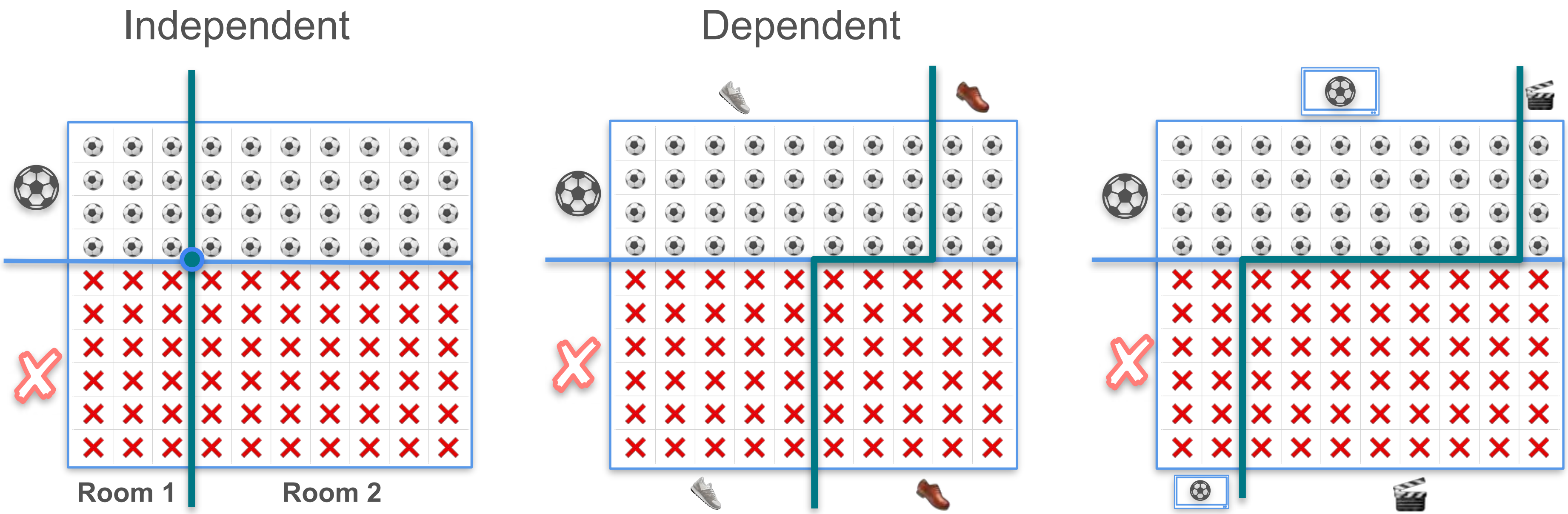


Dependent

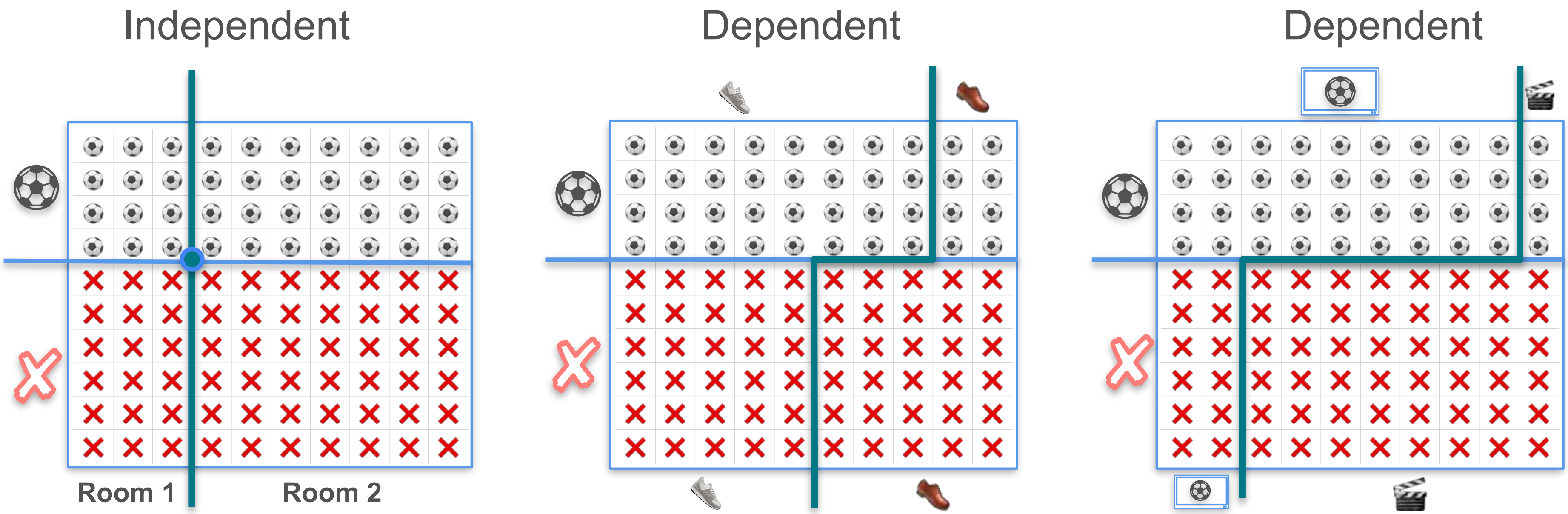




Independent vs Dependent Events



Independent vs Dependent Events



Conditional Probability

Conditional Probability

Independent

Conditional Probability

Independent

$\mathbf{P}(S) = 40\,\%$

$\mathbf{P}(R\,|\,S) = 50\,\%$

Room 1

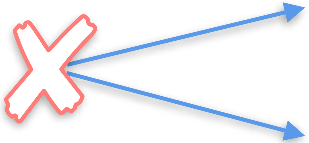
$\mathbf{P}(R'\,|\,S) = 50\,\%$

Room 2

$\mathbf{P}(S') = 60\,\%$

$\mathbf{P}(R\,|\,S') = 50\,\%$

Room 1



$\mathbf{P}(R'\,|\,S) = 50\,\%$

Room 2

Conditional Probability

Independent

Dependent

$\mathbf{P}(R \mid S) = 50\,\%$

$\mathbf{P}(S) = 40\,\%$

Room 1

$\mathbf{P}(R' \mid S) = 50\,\%$

Room 2

$\mathbf{P}(R \mid S') = 50\,\%$

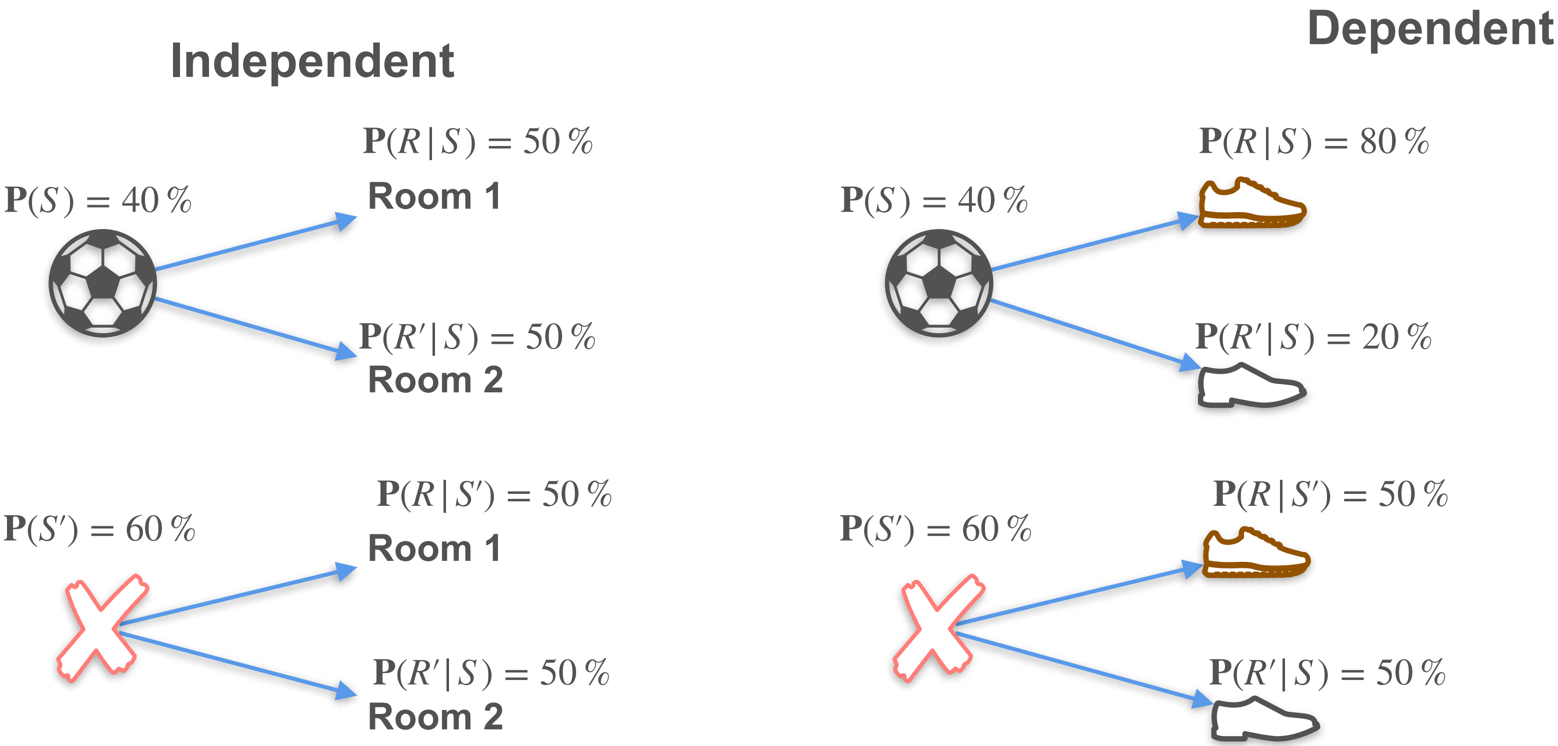
$\mathbf{P}(S') = 60\,\%$

Room 1

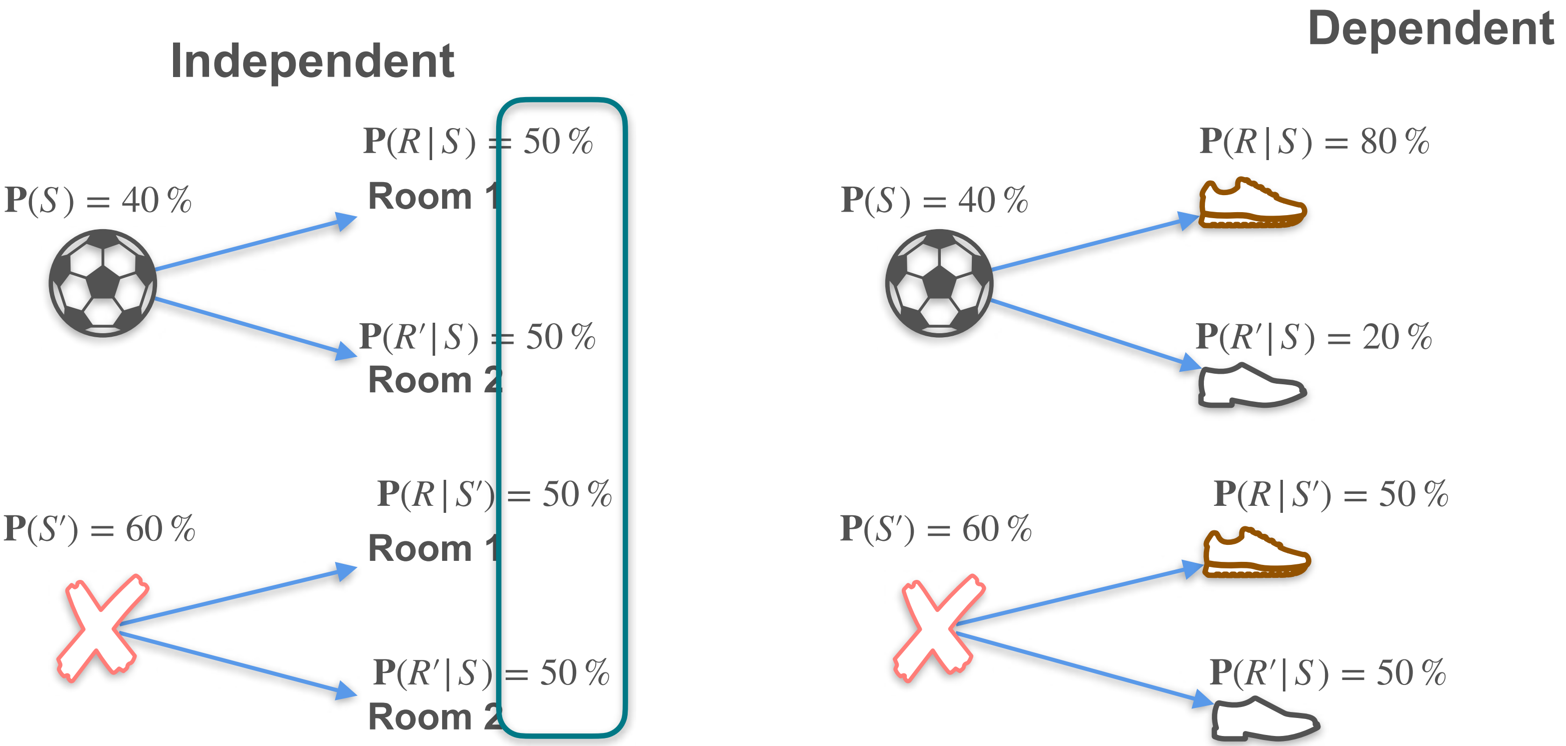
$\mathbf{P}(R' \mid S) = 50\,\%$

Room 2

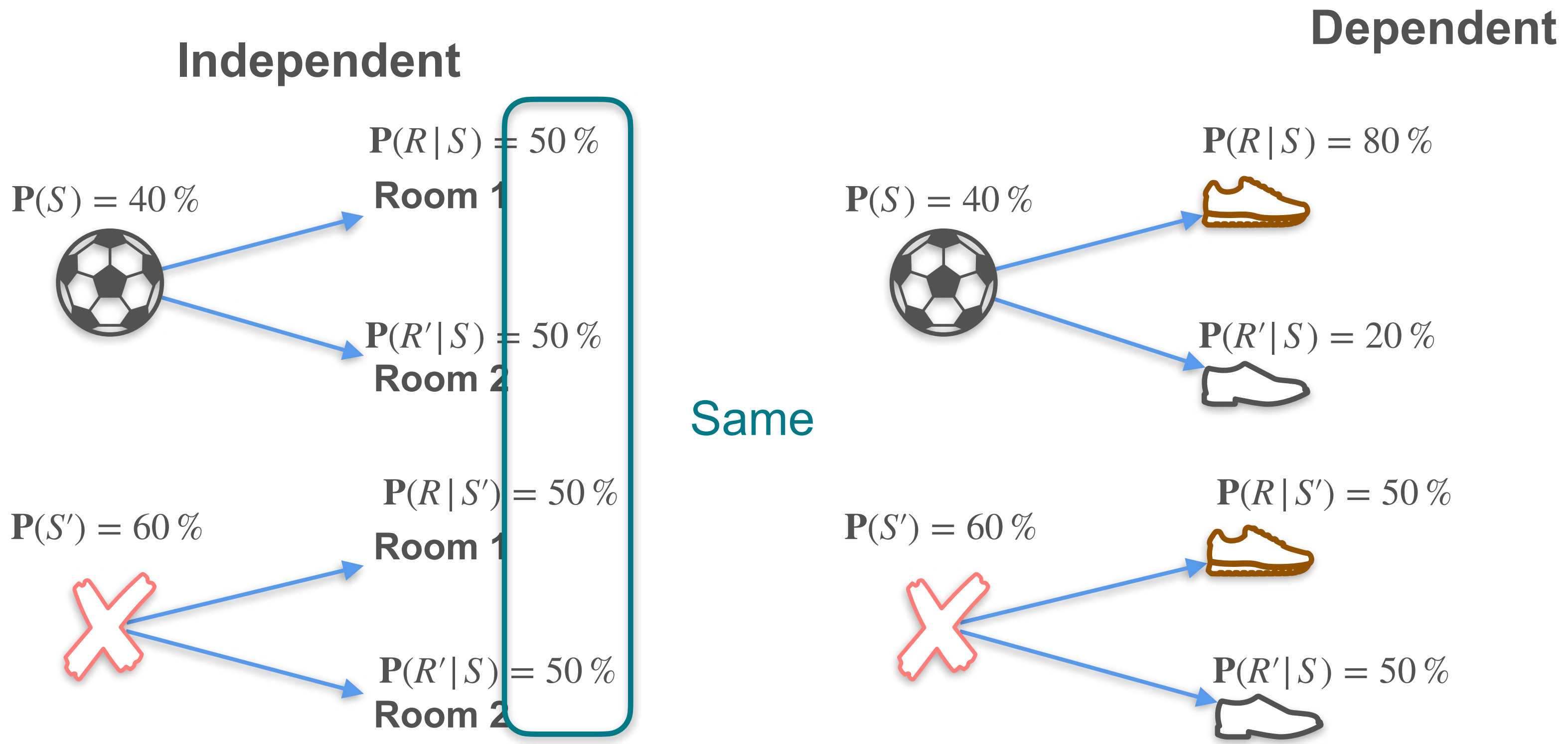
Conditional Probability



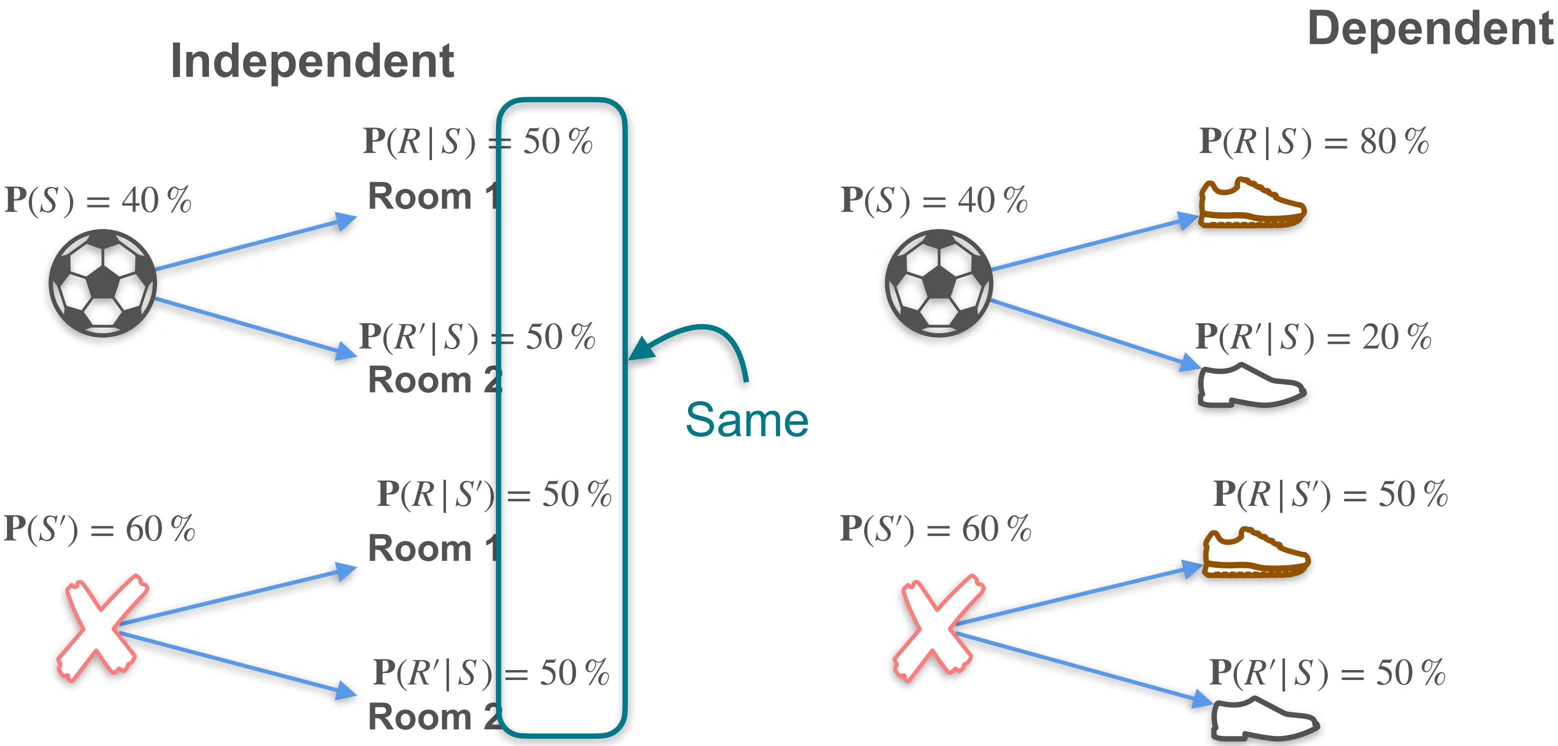
Conditional Probability



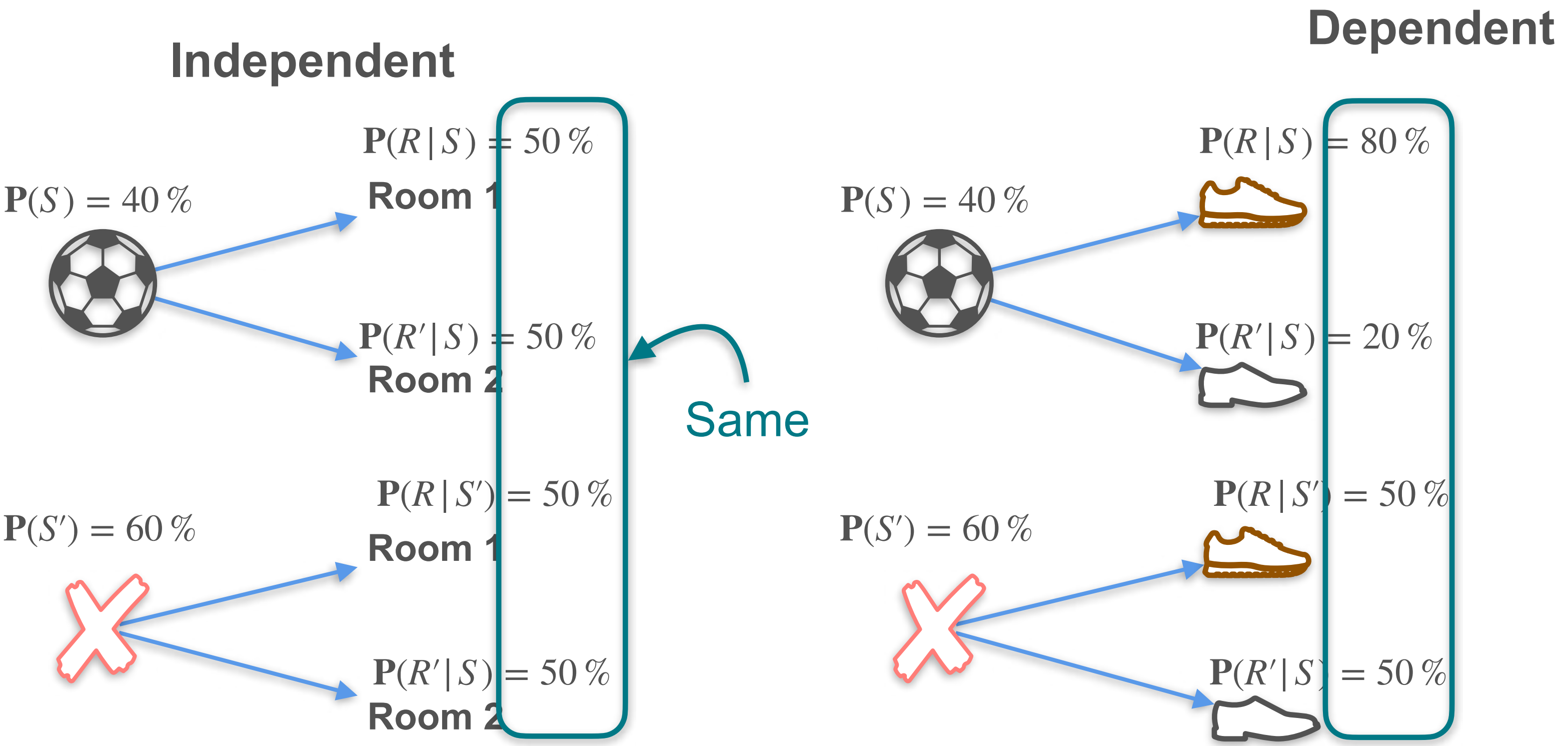
Conditional Probability



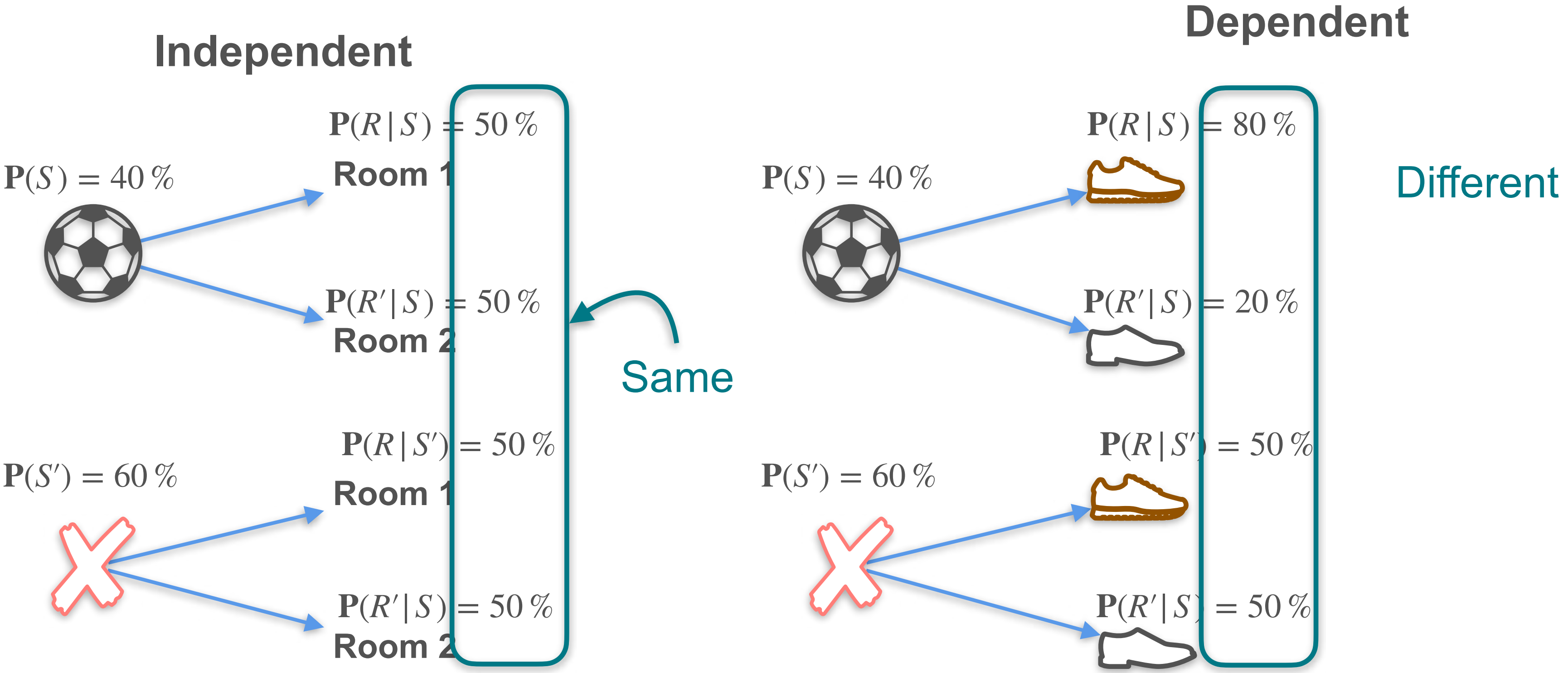
Conditional Probability



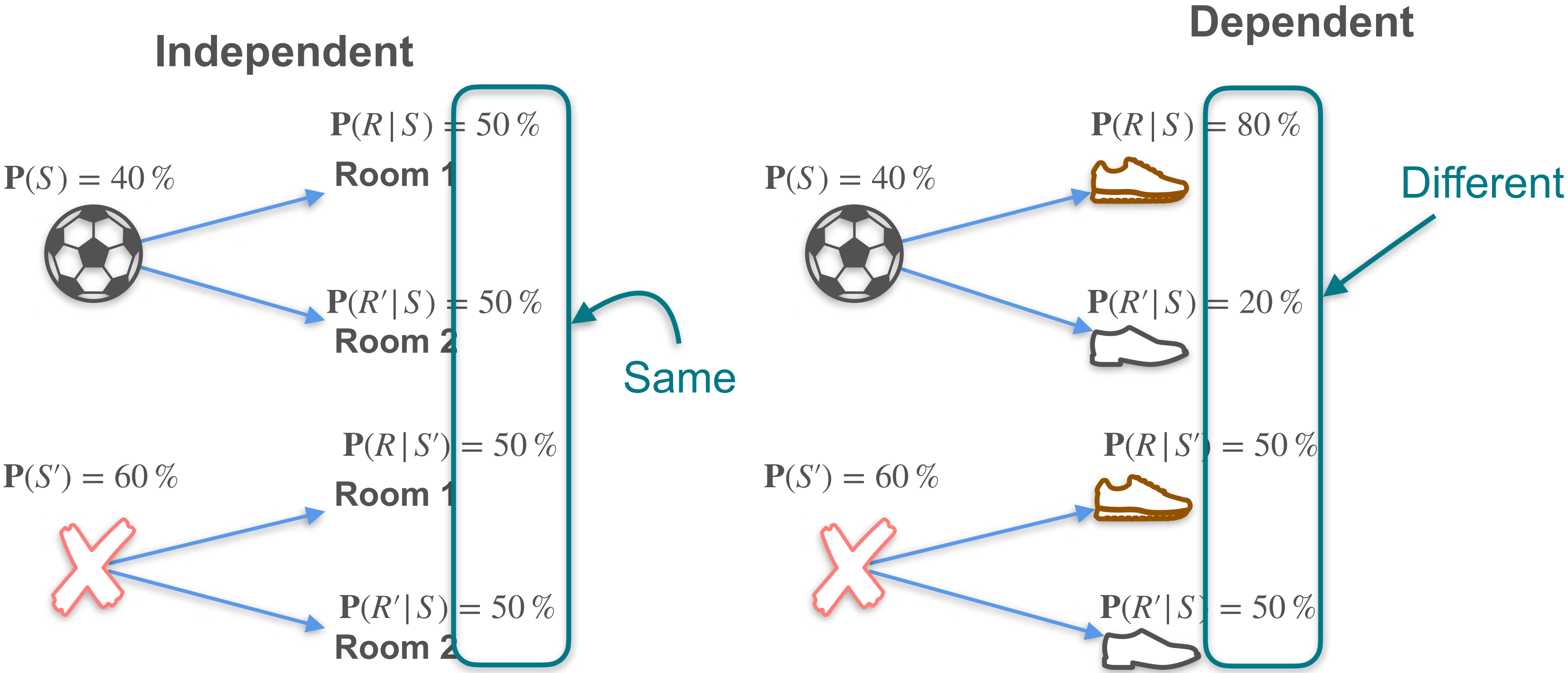
Conditional Probability



Conditional Probability



Conditional Probability



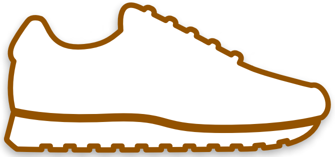
DeepLearning.AI

Introduction to probability

Bayes theorem

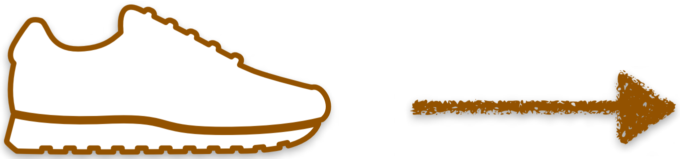
Bayes Theorem - Motivation

Bayes Theorem - Motivation



60%

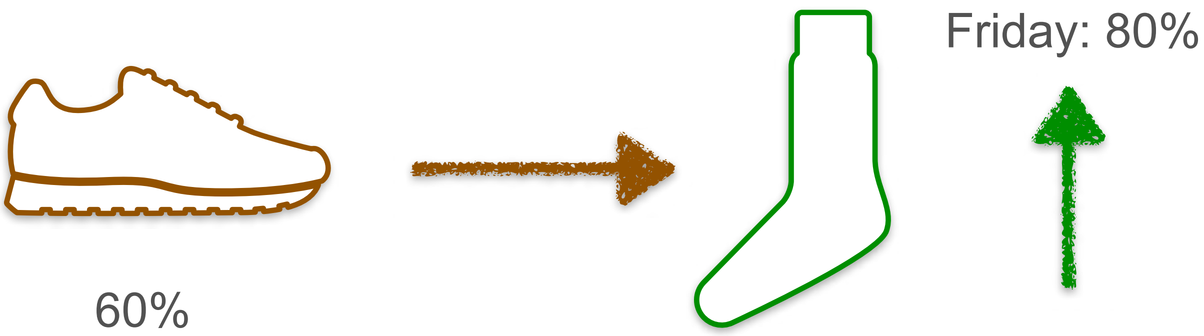
Bayes Theorem - Motivation



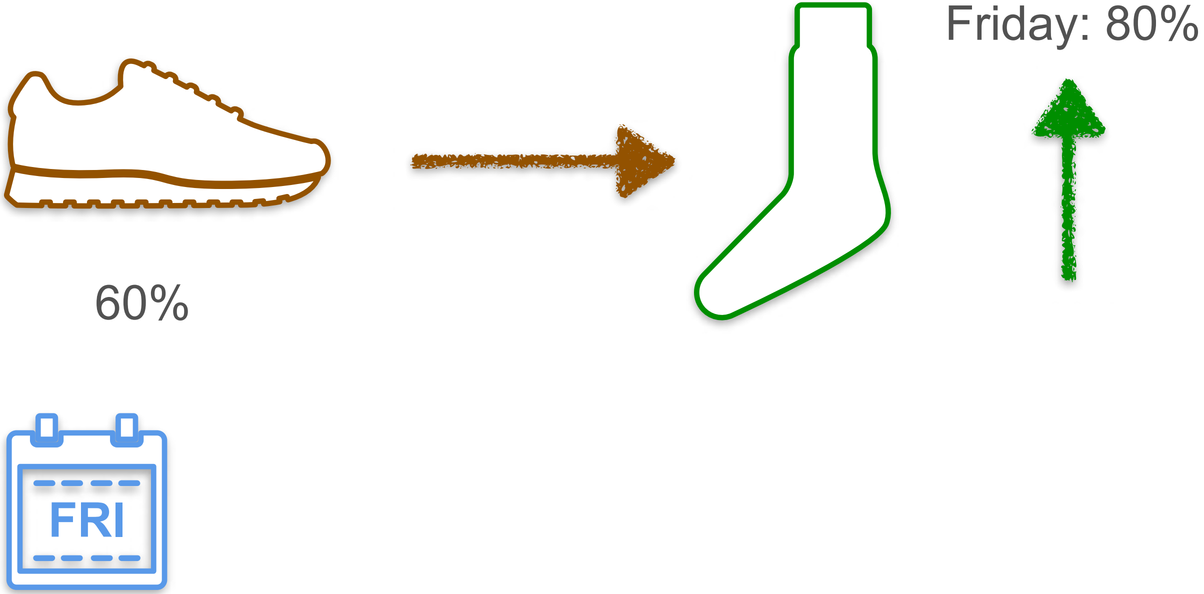
60%

Bayes Theorem - Motivation

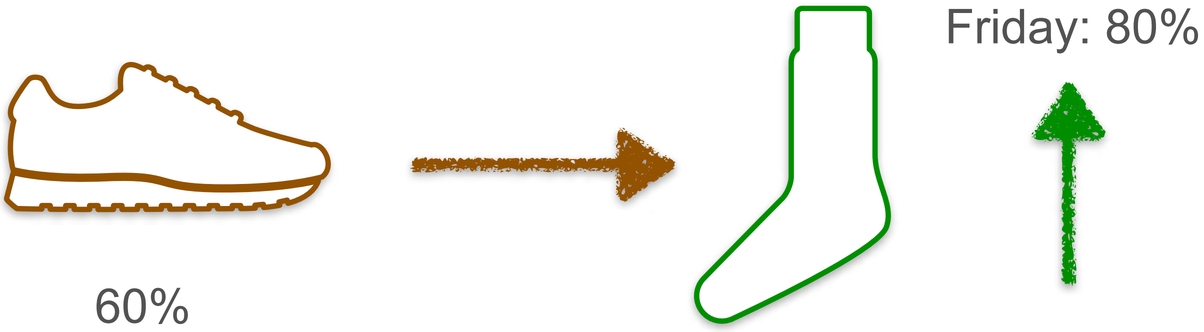
Bayes Theorem - Motivation



Bayes Theorem - Motivation



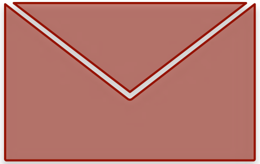
Bayes Theorem - Motivation



What is the probability that a customer will purchase a pair of socks given that they purchased shoes?

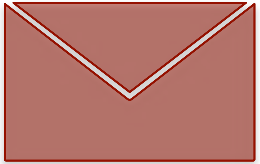
Bayes Theorem: Motivation

Bayes Theorem: Motivation



spam

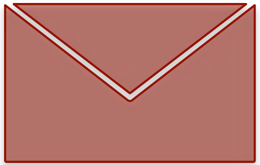
Bayes Theorem: Motivation



spam

contains
“lottery”

Bayes Theorem: Motivation

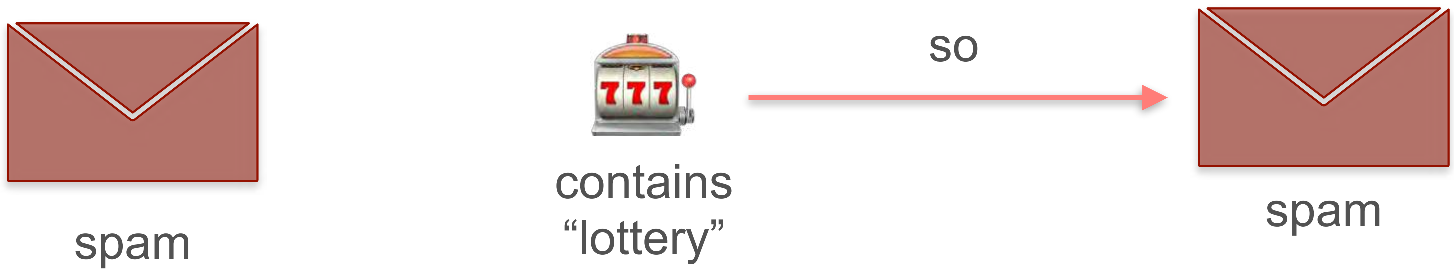


spam

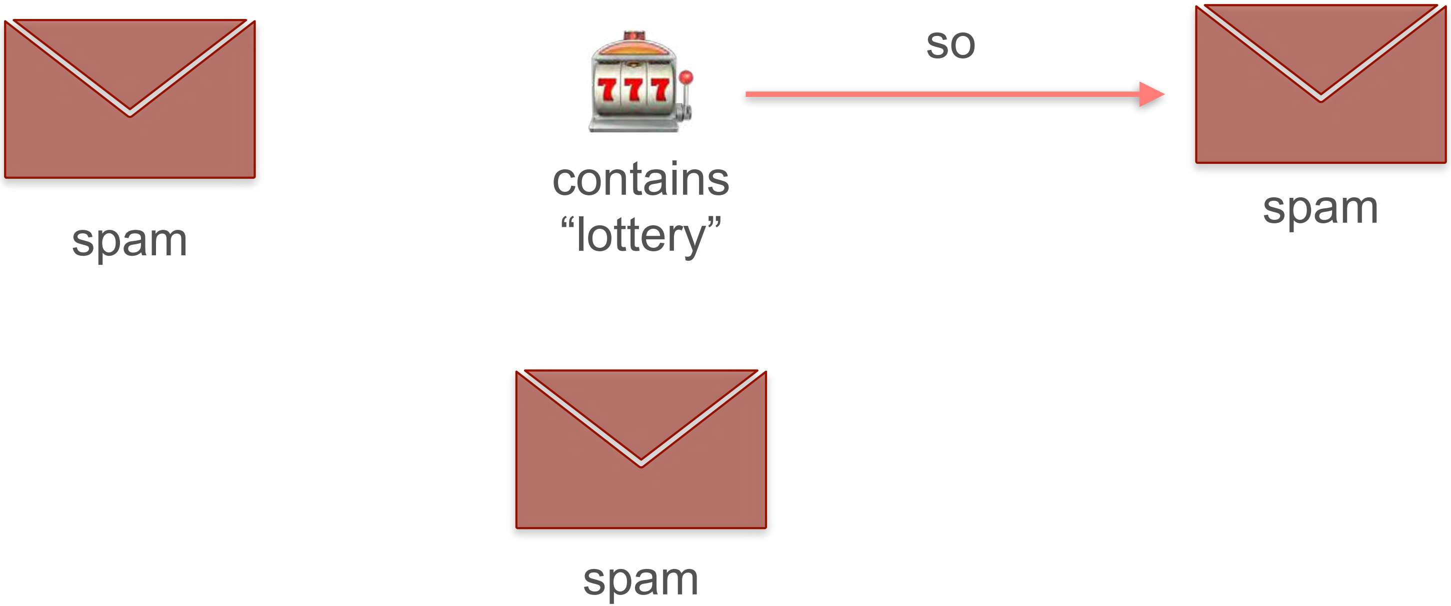
contains
“lottery”

so

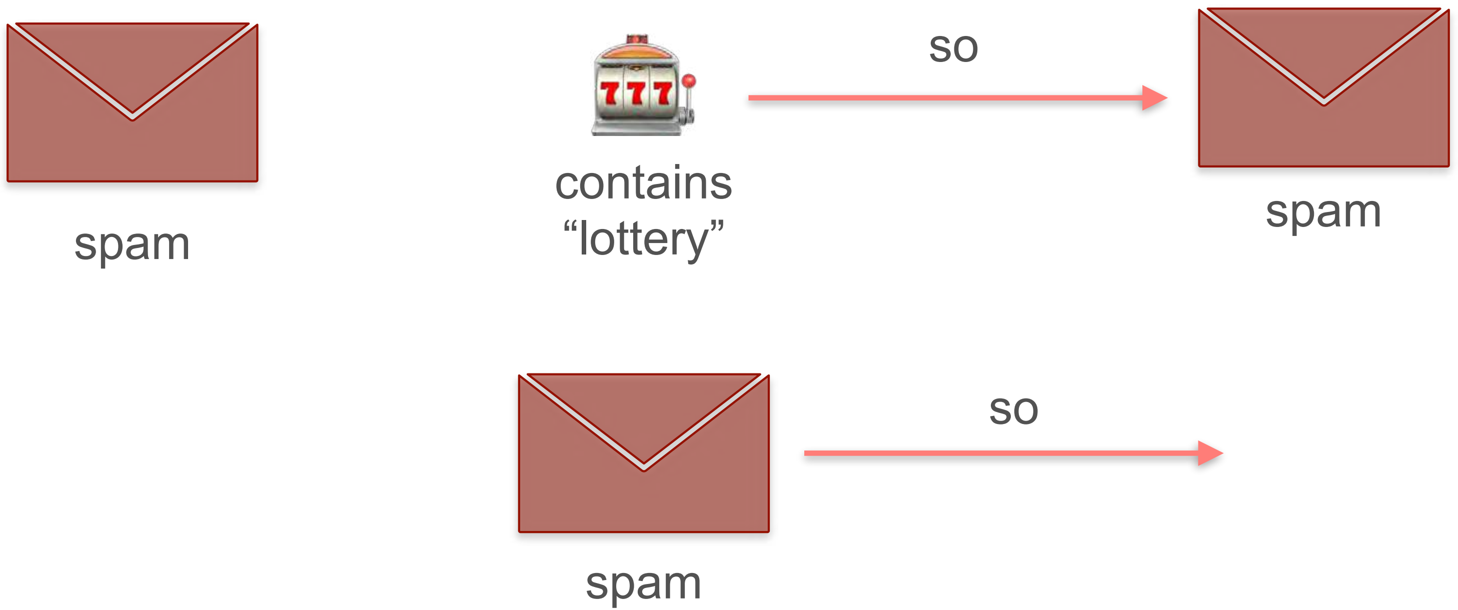
Bayes Theorem: Motivation



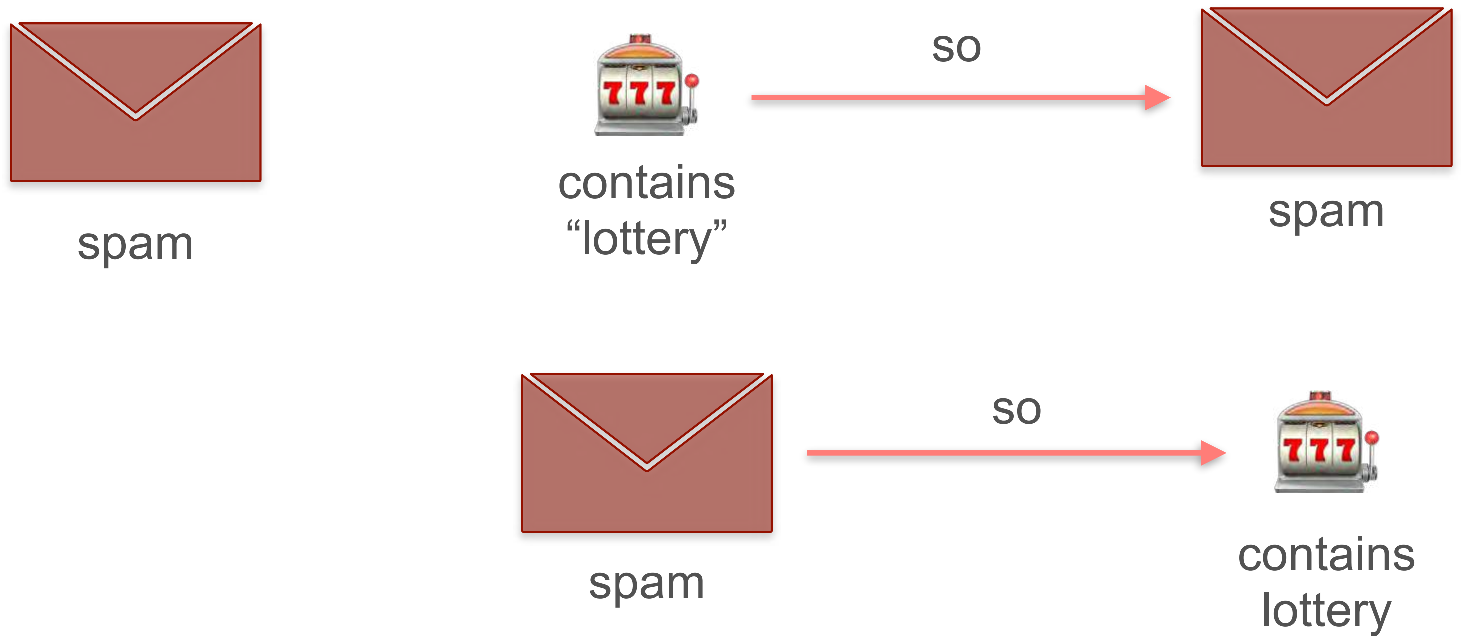
Bayes Theorem: Motivation



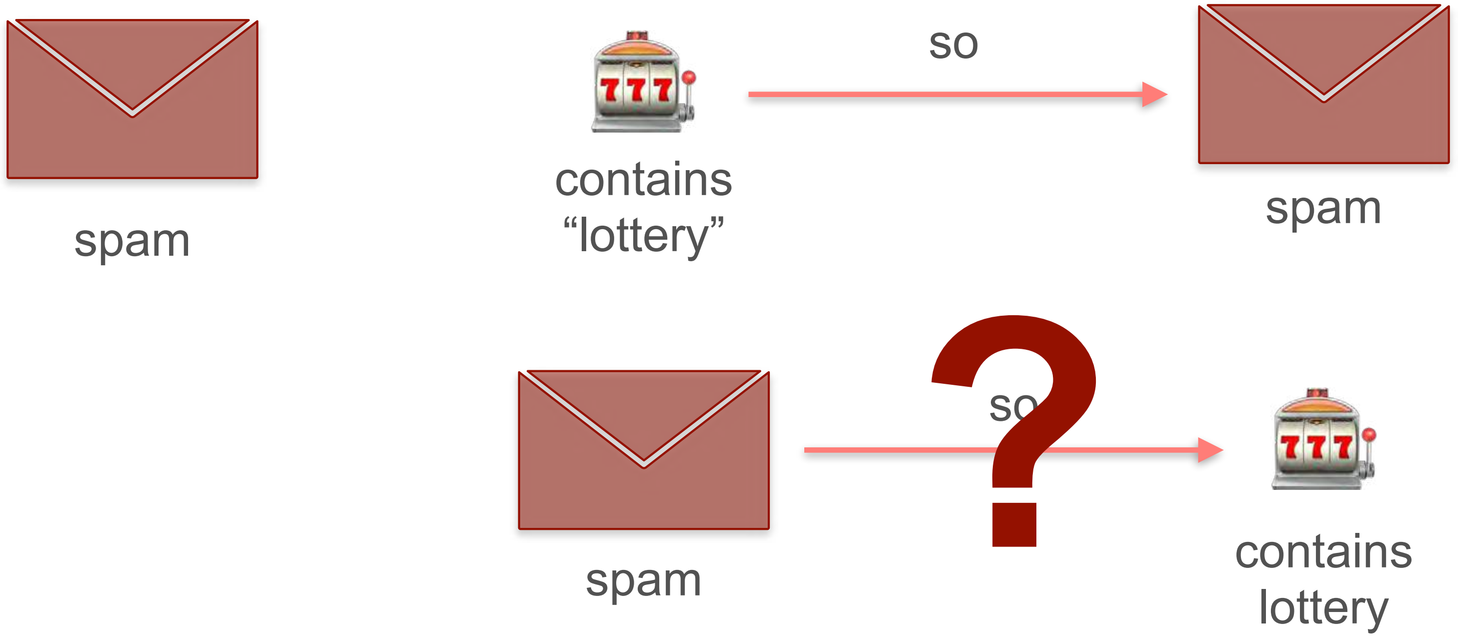
Bayes Theorem: Motivation



Bayes Theorem: Motivation

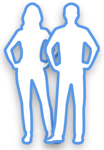


Bayes Theorem: Motivation

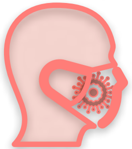


Bayes Theorem: Intuition

Bayes Theorem: Intuition

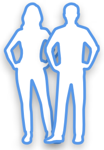


1,000,000 people

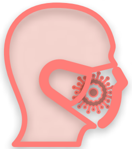


1 / 10,000 people

Bayes Theorem: Intuition



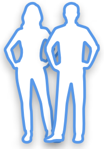
1,000,000 people



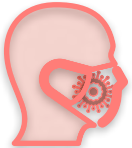
1 / 10,000 people

99% Effective

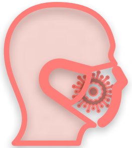
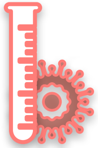
Bayes Theorem: Intuition



1,000,000 people

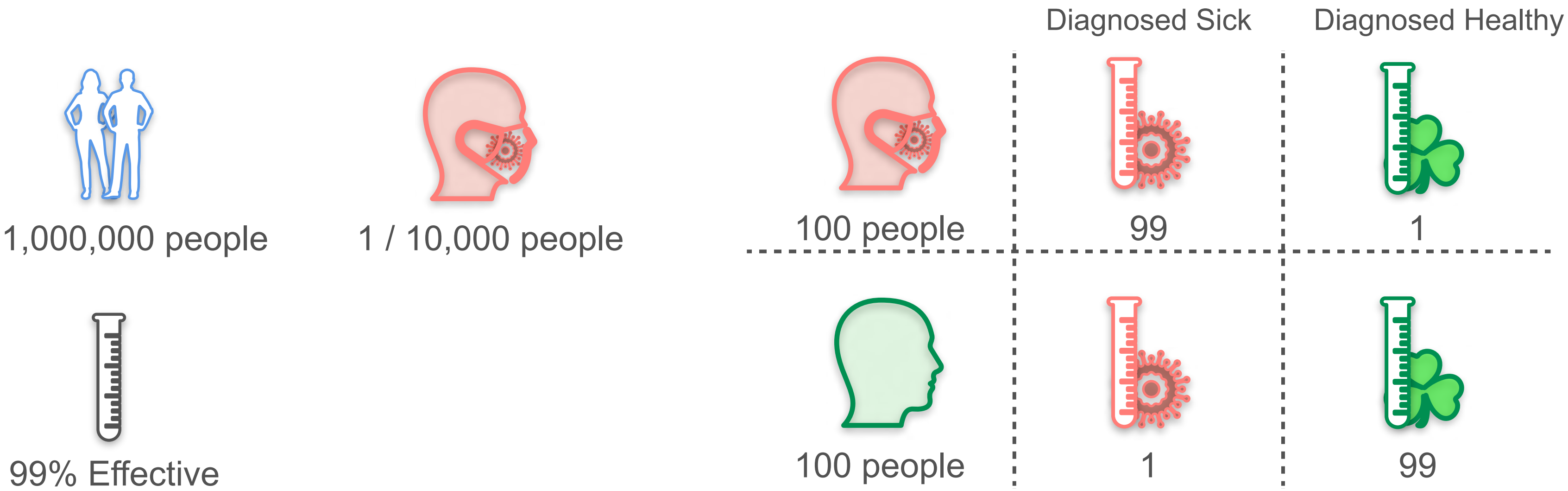


1 / 10,000 people

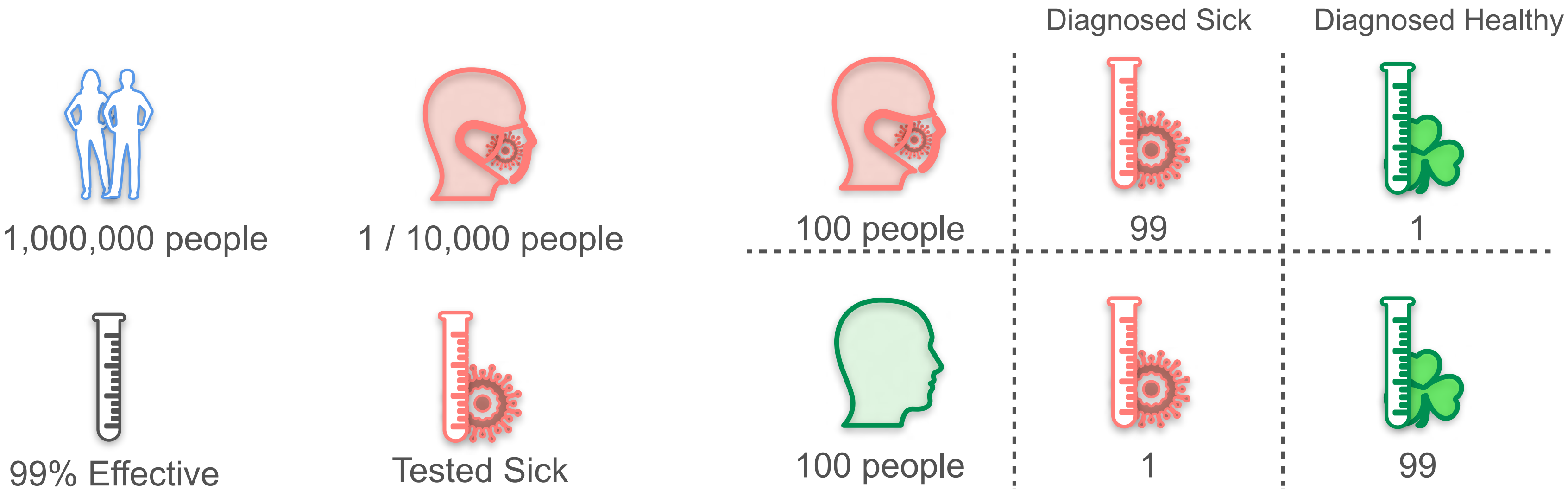
	Diagnosed Sick	Diagnosed Healthy
 100 people	 99	 1

99% Effective

Bayes Theorem: Intuition



Bayes Theorem: Intuition



Bayes Theorem: Intuition

1,000,000 people

1 / 10,000 people

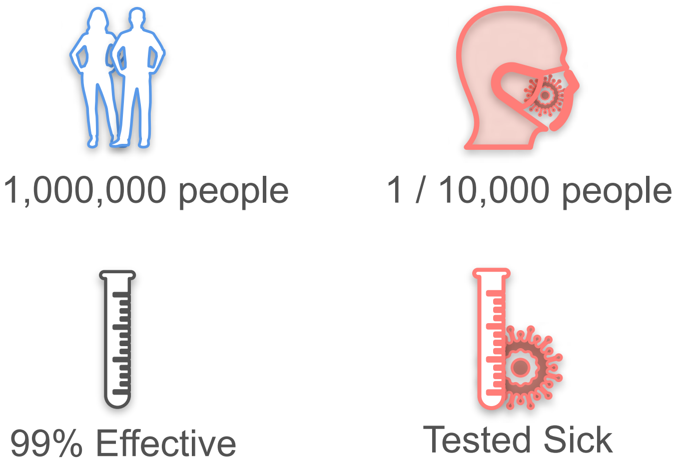
99% Effective

Tested Sick

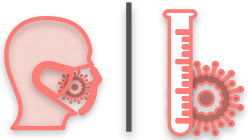
	Diagnosed Sick	Diagnosed Healthy
100 people	99	1
100 people	1	99

What's the probability that **you are sick**

Bayes Theorem: Intuition



	Diagnosed Sick	Diagnosed Healthy
100 people	99	1
100 people	1	99



What's the probability that **you are sick GIVEN that you tested sick**?

Bayes Theorem: Intuition

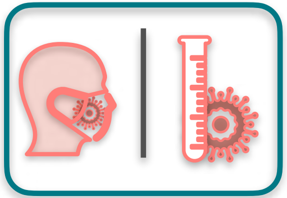
1,000,000 people

1 / 10,000 people

99% Effective

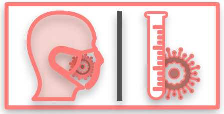
Tested Sick

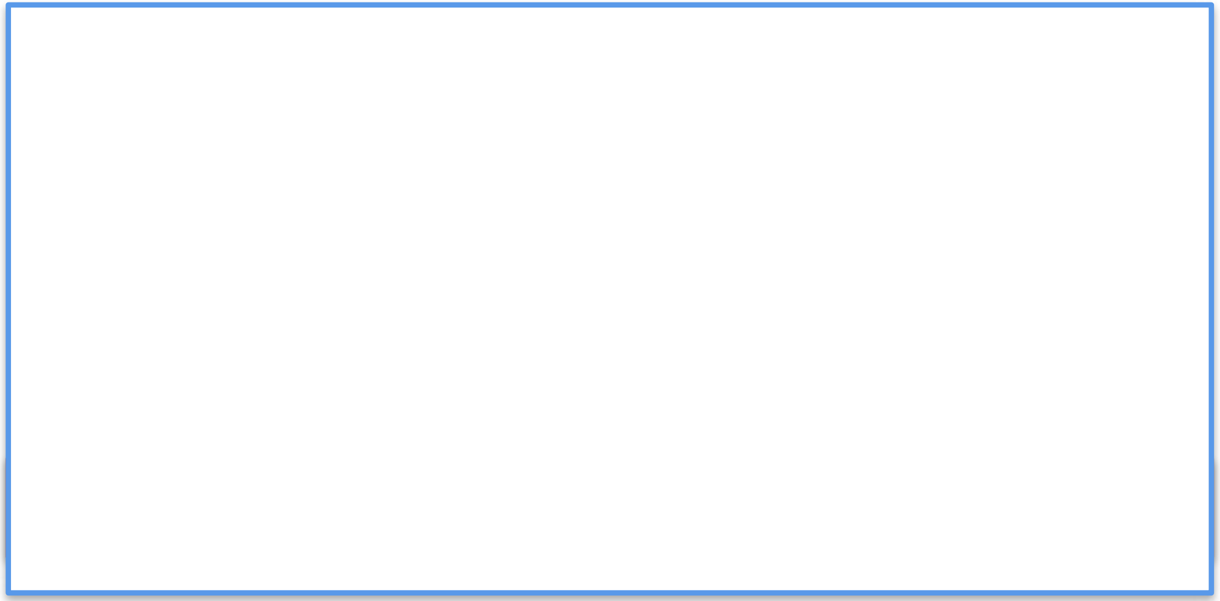
	Diagnosed Sick	Diagnosed Healthy
100 people	99	1
100 people	1	99



What's the probability that **you are sick GIVEN that you tested sick**?

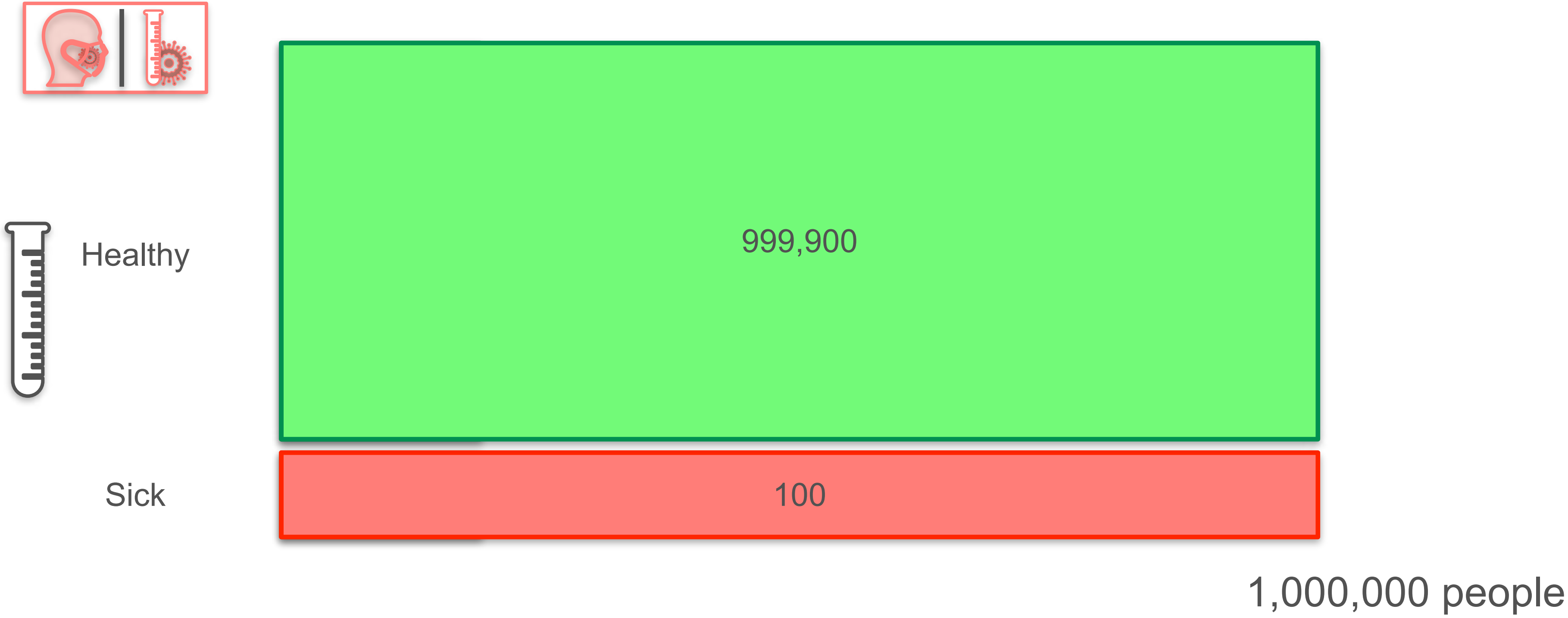
Bayes Theorem: Intuition



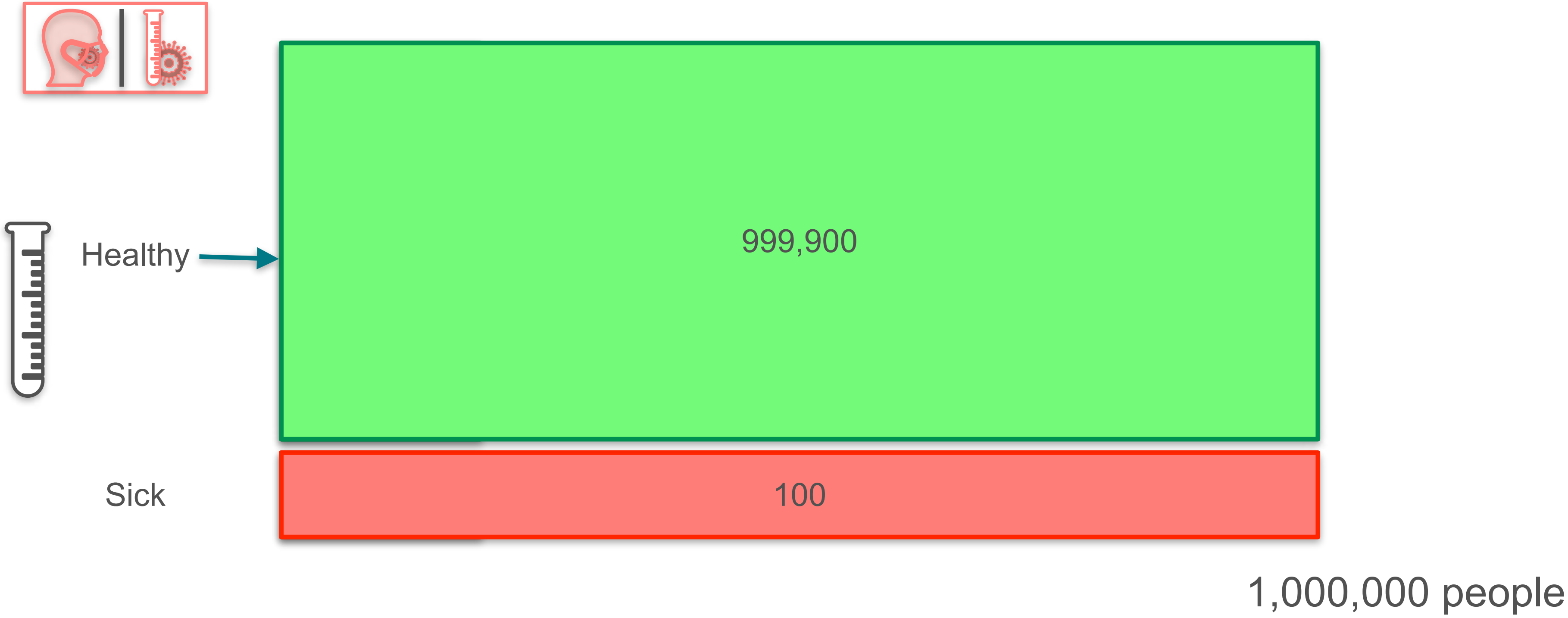


1,000,000 people

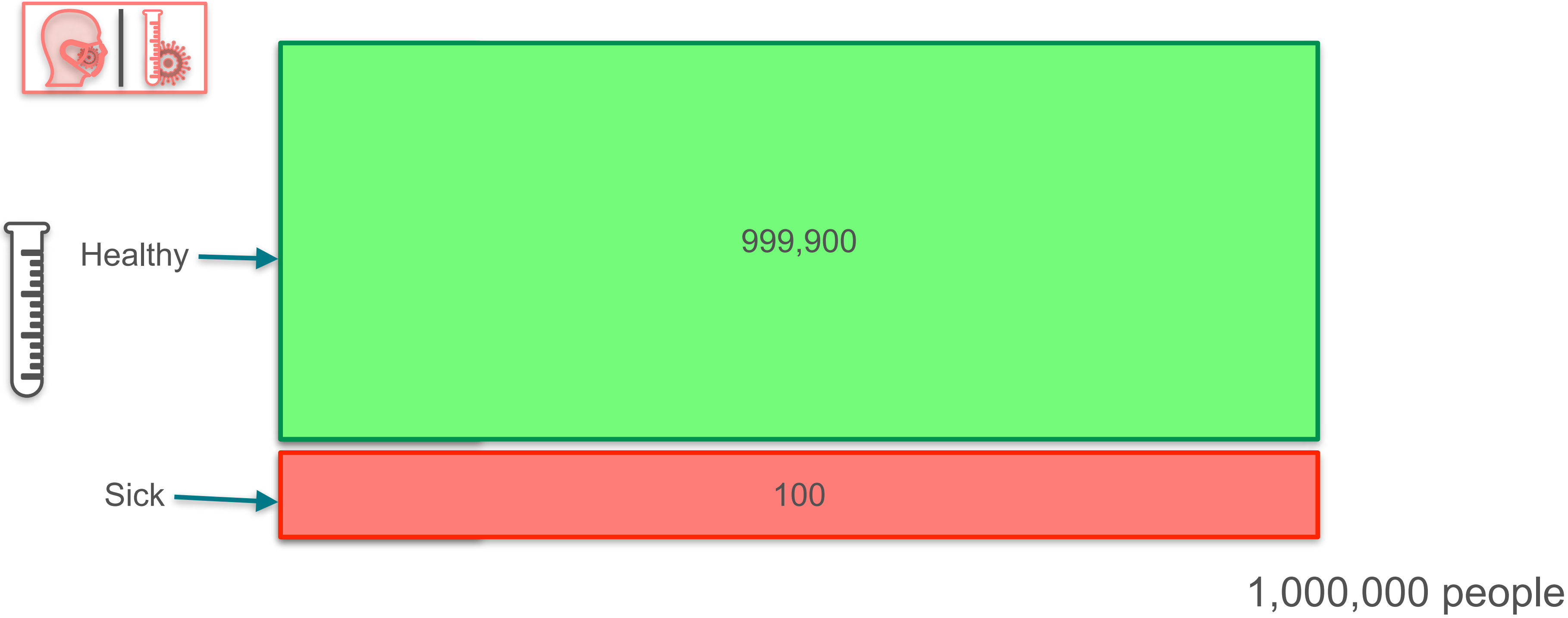
Bayes Theorem: Intuition



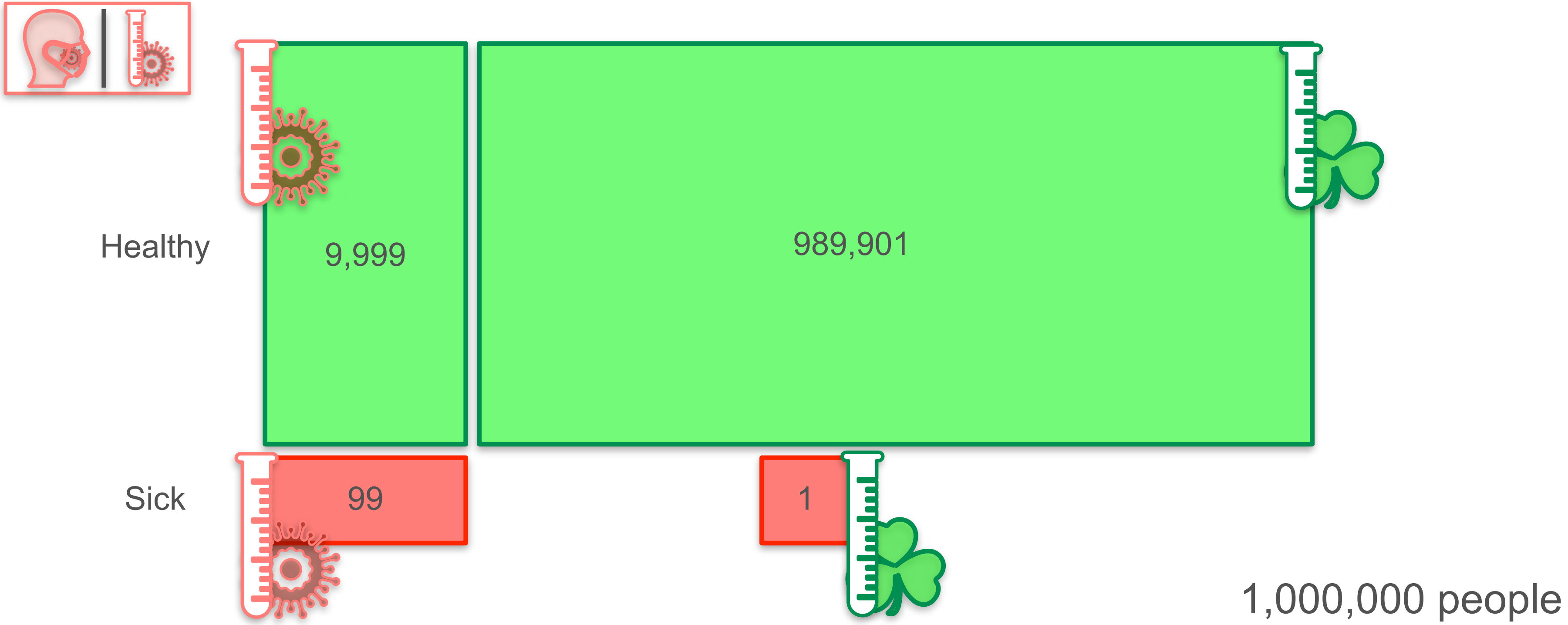
Bayes Theorem: Intuition



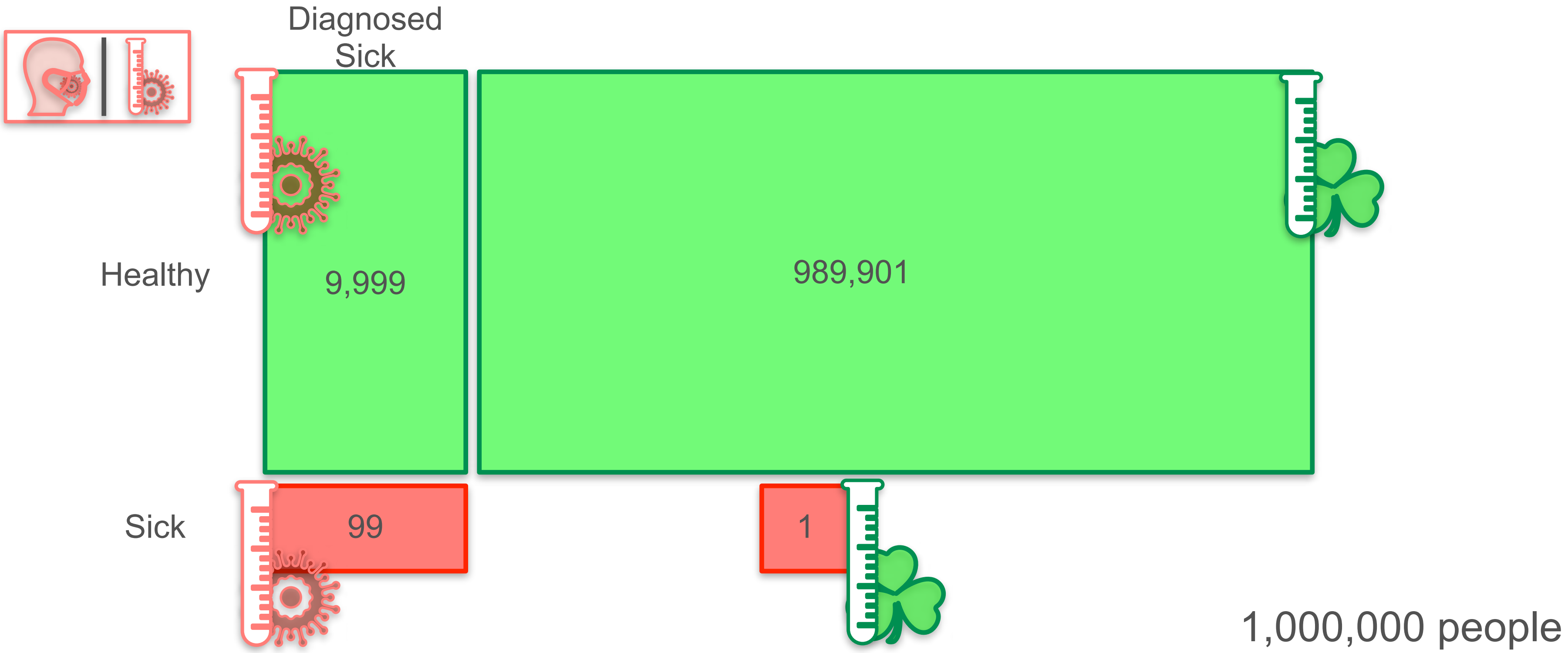
Bayes Theorem: Intuition



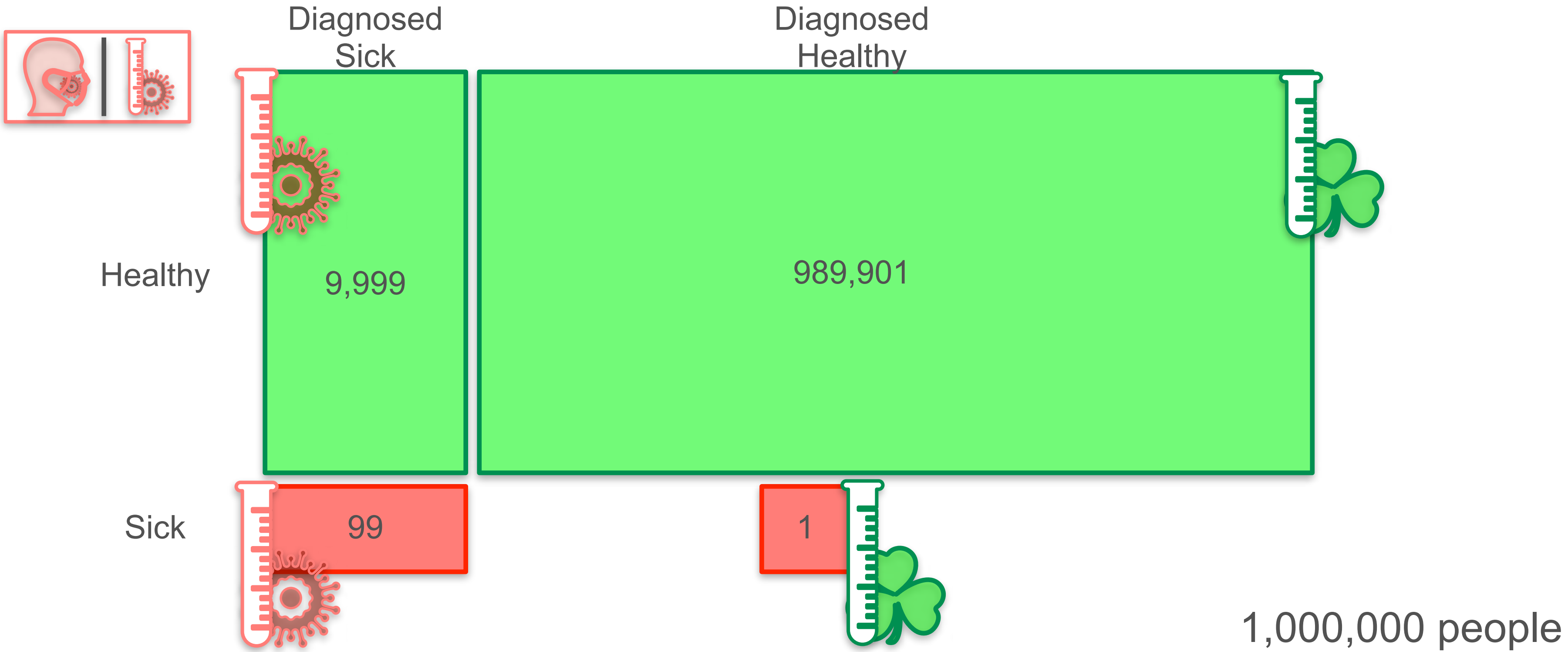
Bayes Theorem: Intuition



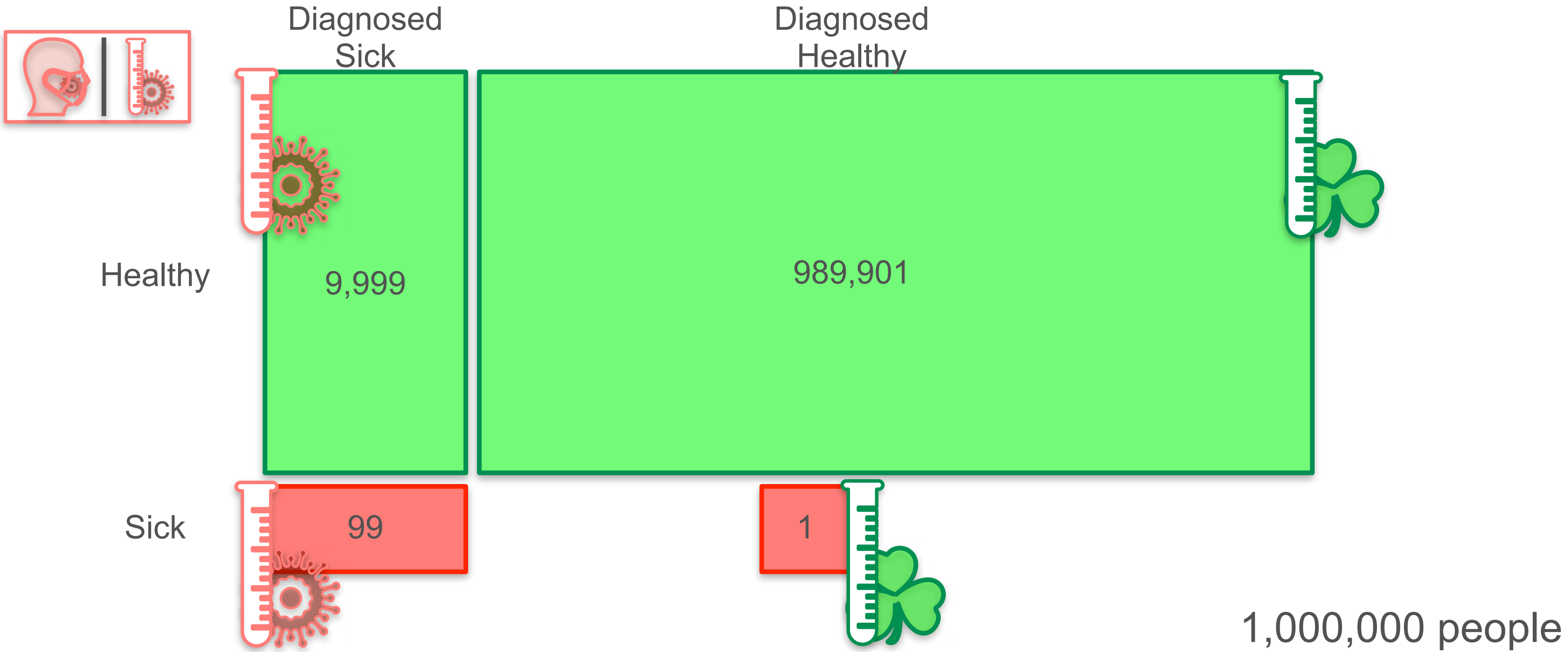
Bayes Theorem: Intuition



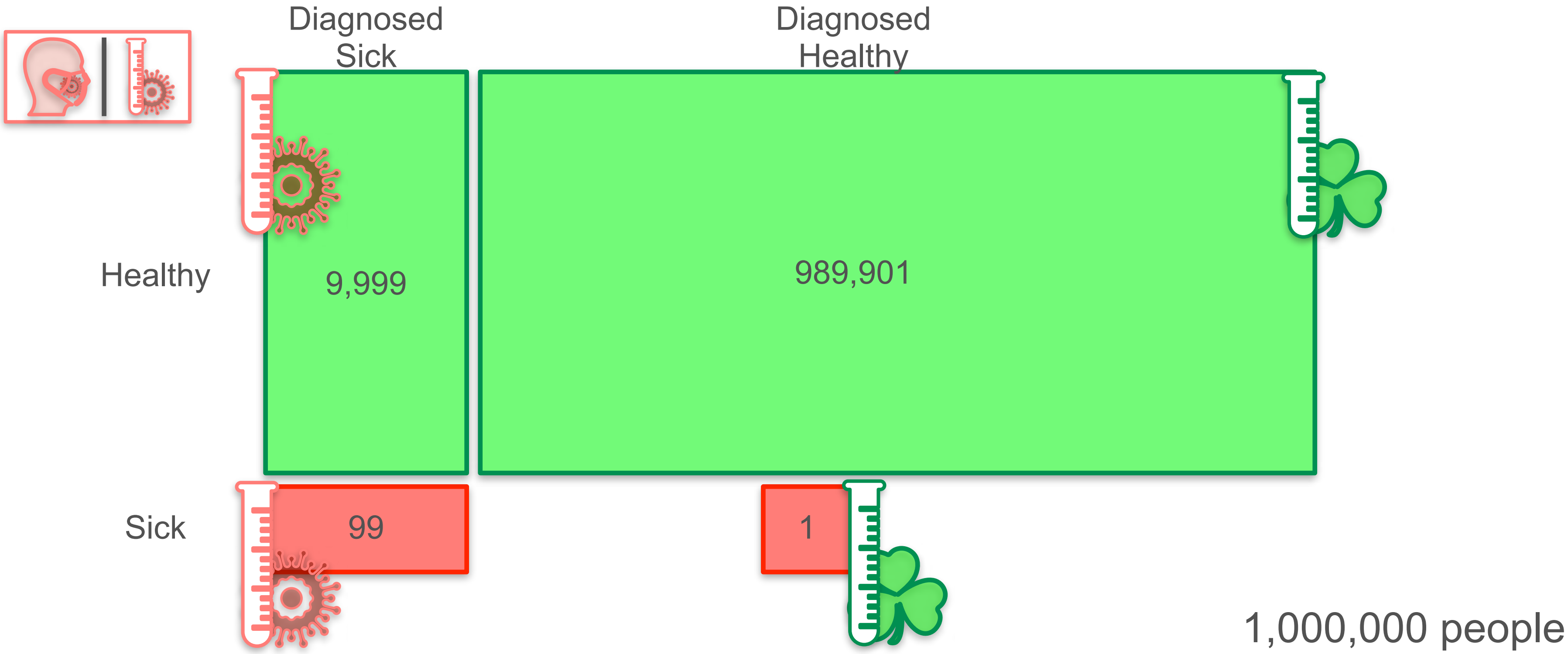
Bayes Theorem: Intuition



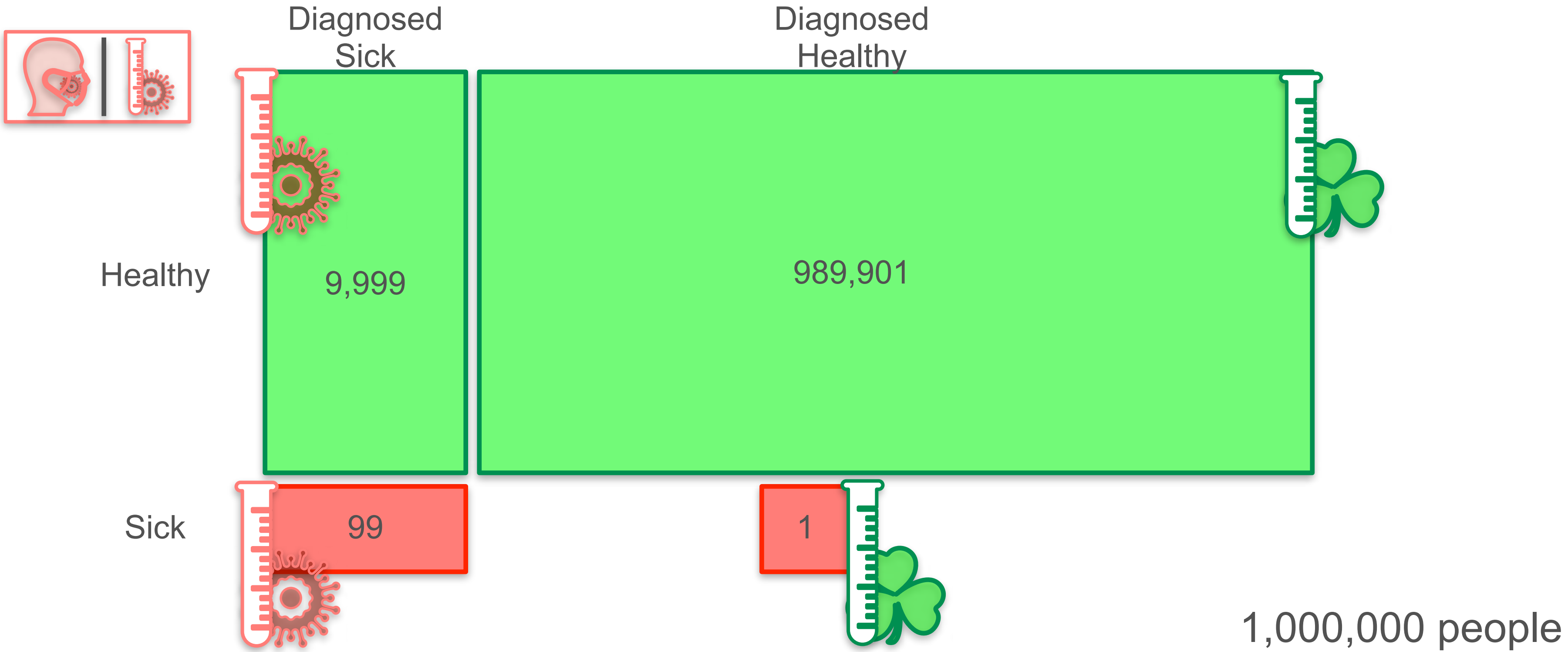
Bayes Theorem: Intuition



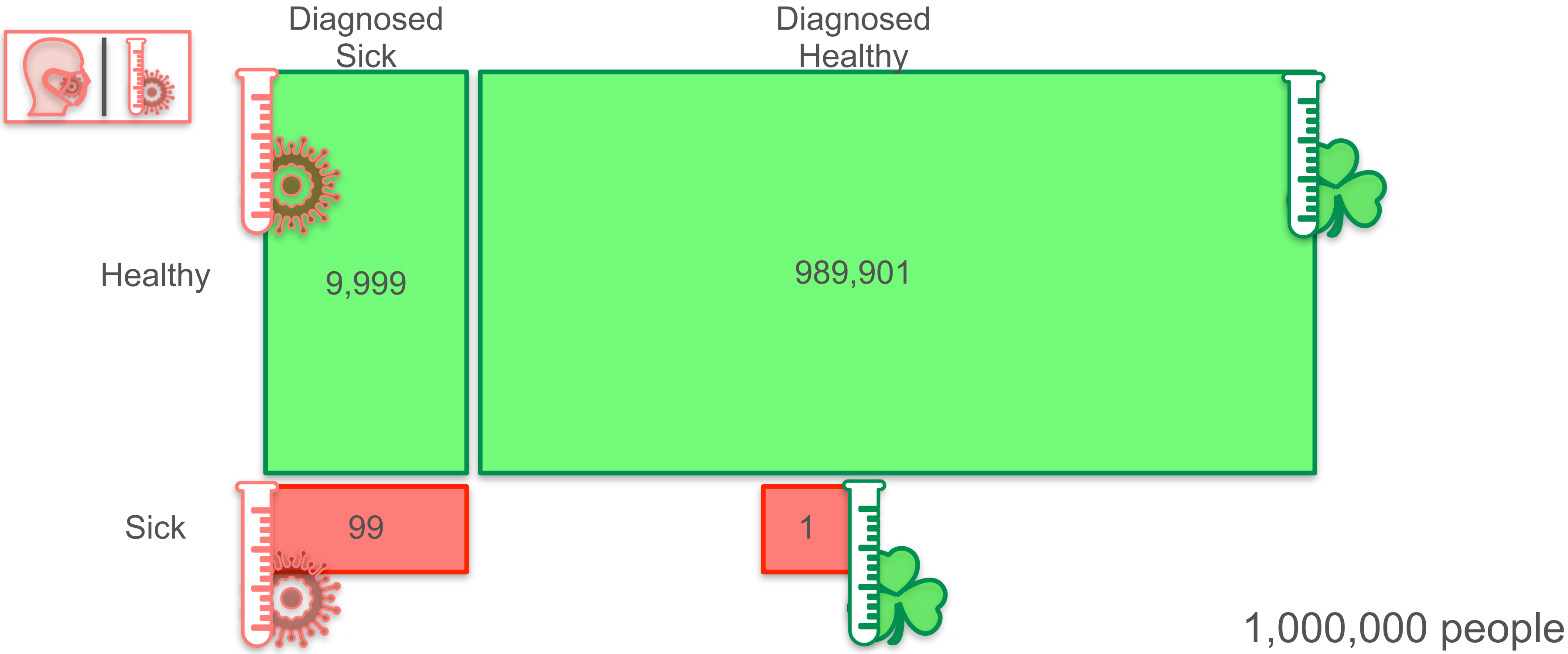
Bayes Theorem: Intuition



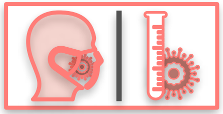
Bayes Theorem: Intuition

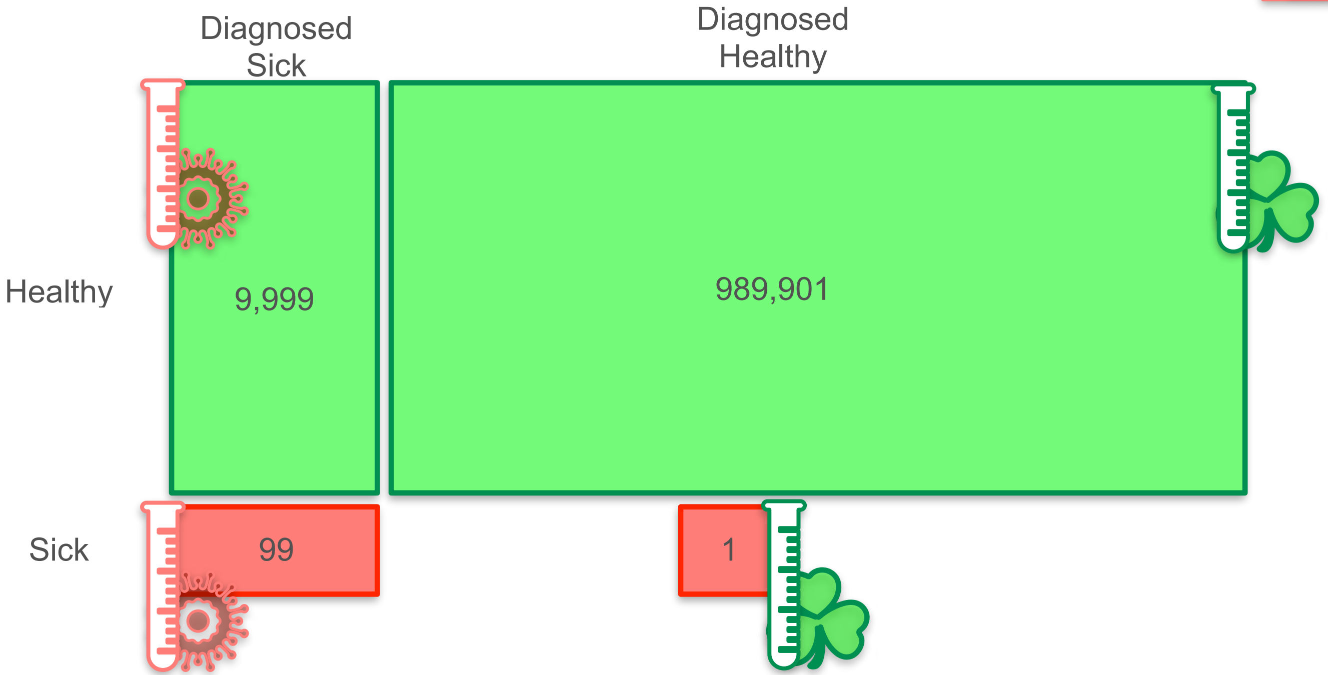


Bayes Theorem: Intuition



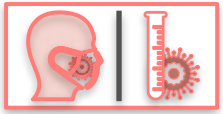
Bayes Theorem: Intuition



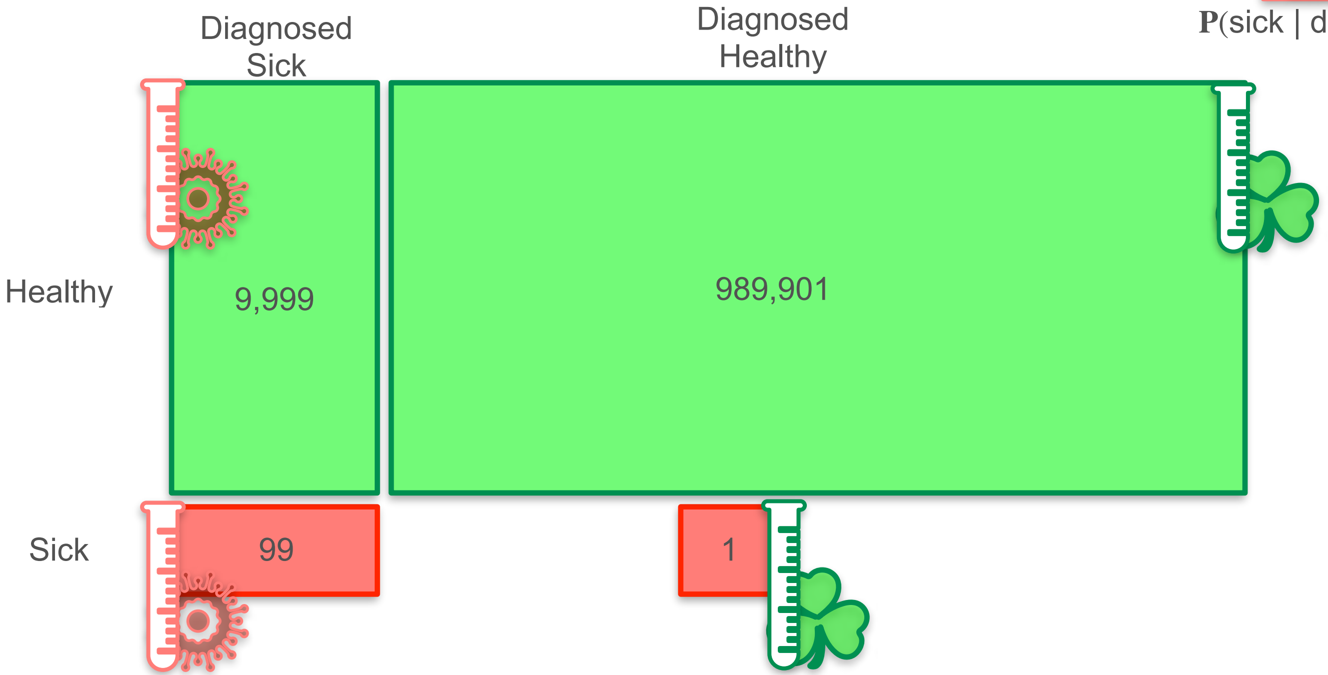


1,000,000 people

Bayes Theorem: Intuition

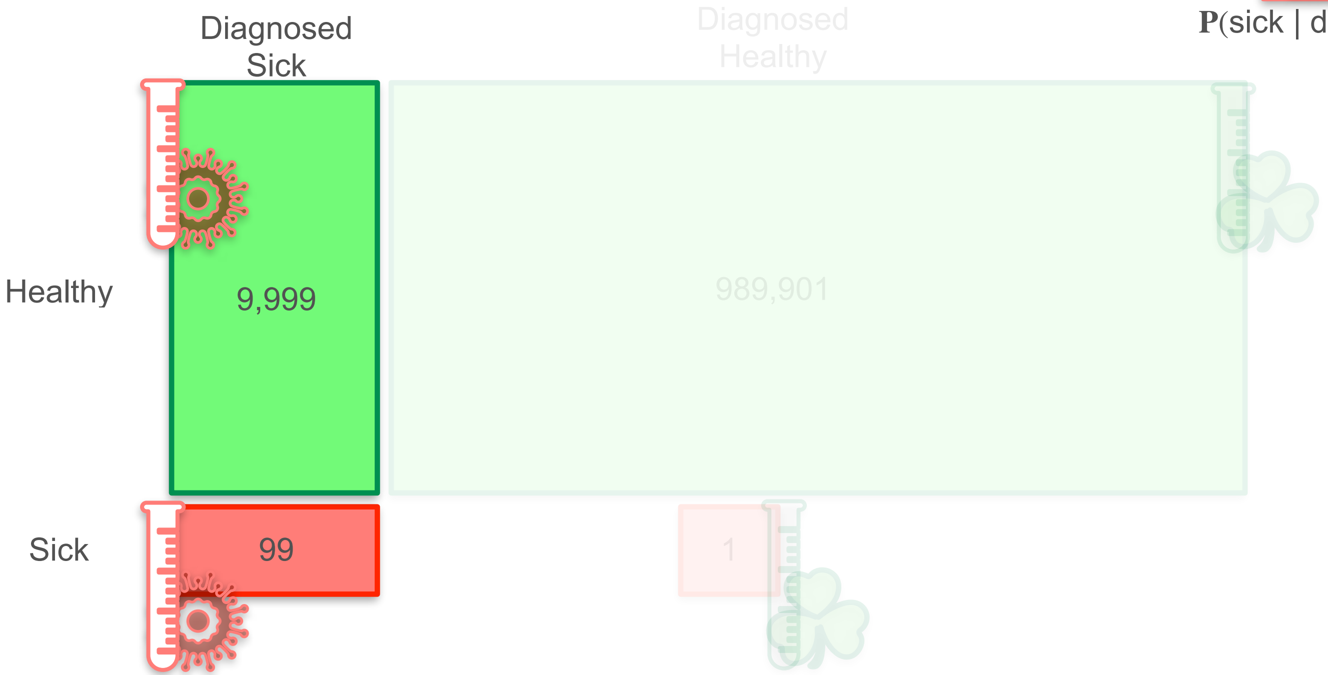


$\mathbf{P}$(sick | diagnosed sick) = ————



1,000,000 people

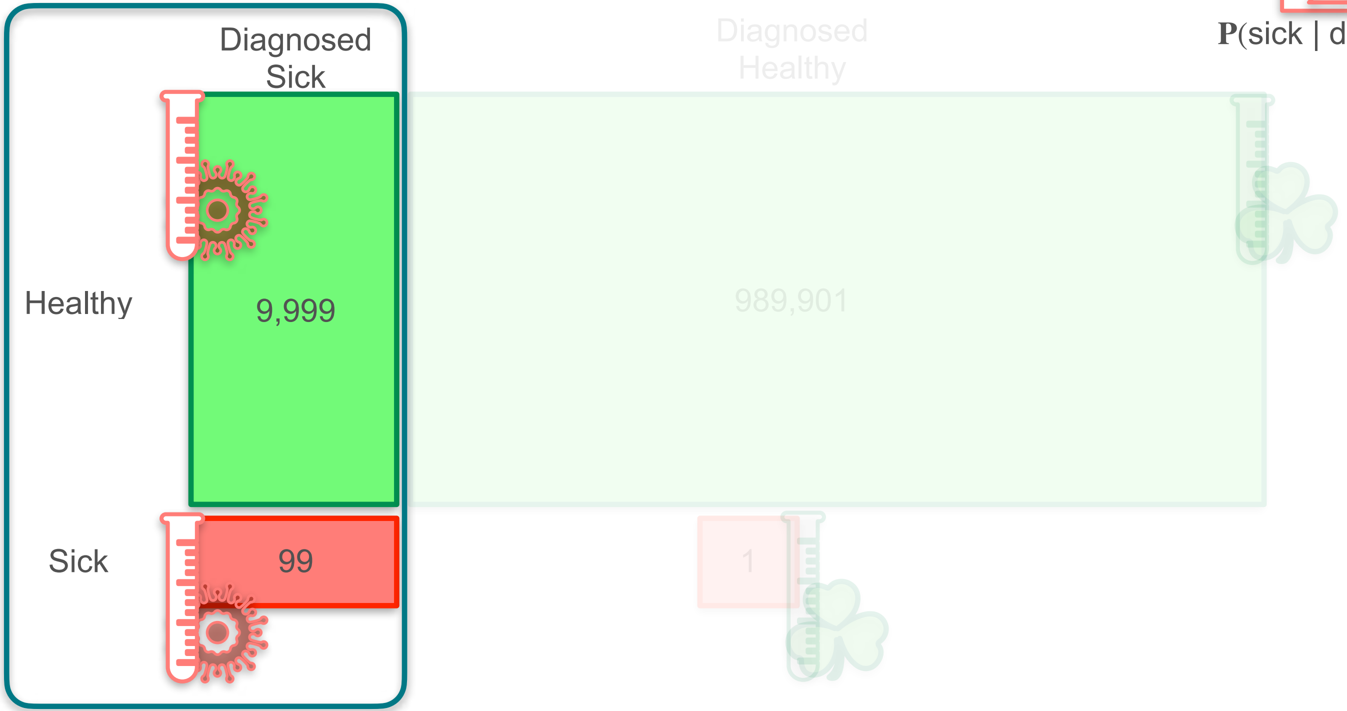
Bayes Theorem: Intuition



$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \underline{\hspace{4cm}}$

1,000,000 people

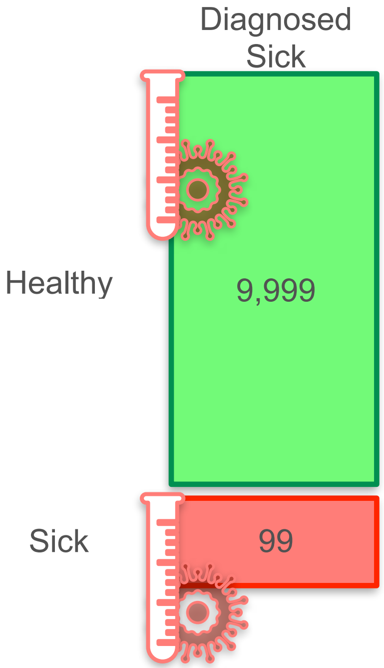
Bayes Theorem: Intuition

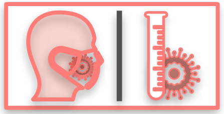


$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \text{—————}$

1,000,000 people

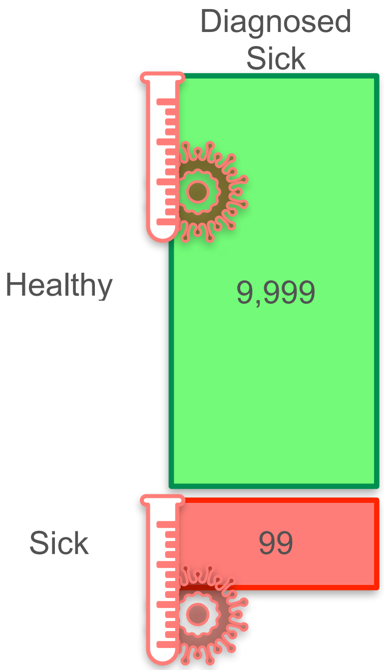
Bayes Theorem: Intuition

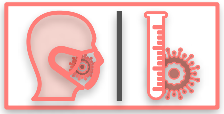


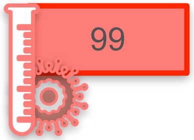


$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \underline{\hspace{4cm}}$$

Bayes Theorem: Intuition

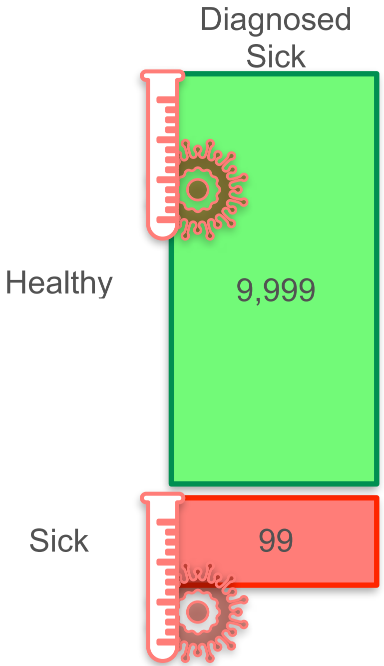


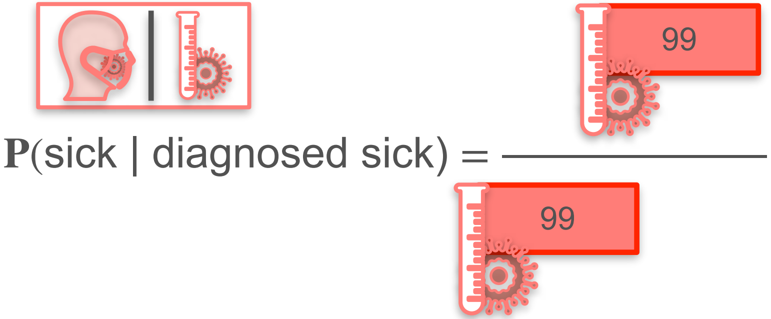




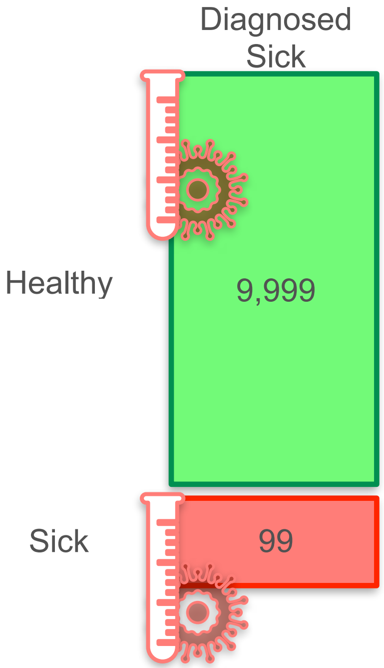
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \overline{\qquad\qquad}$

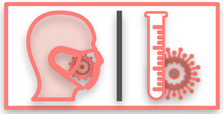
Bayes Theorem: Intuition



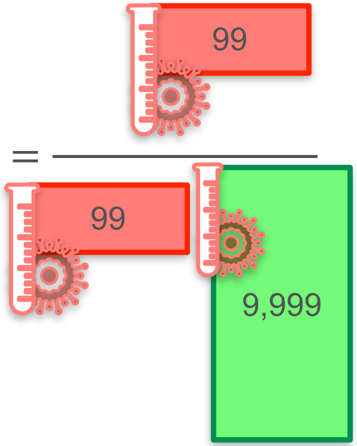


Bayes Theorem: Intuition

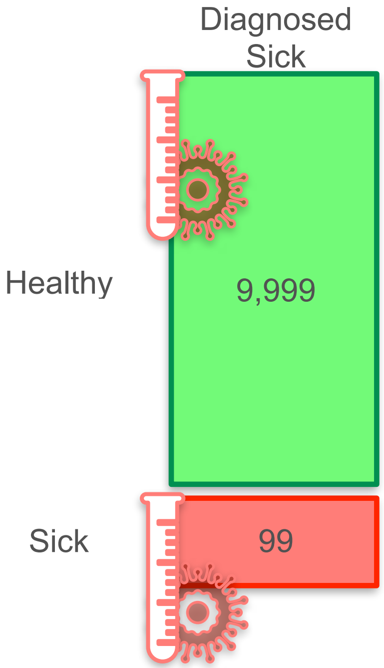


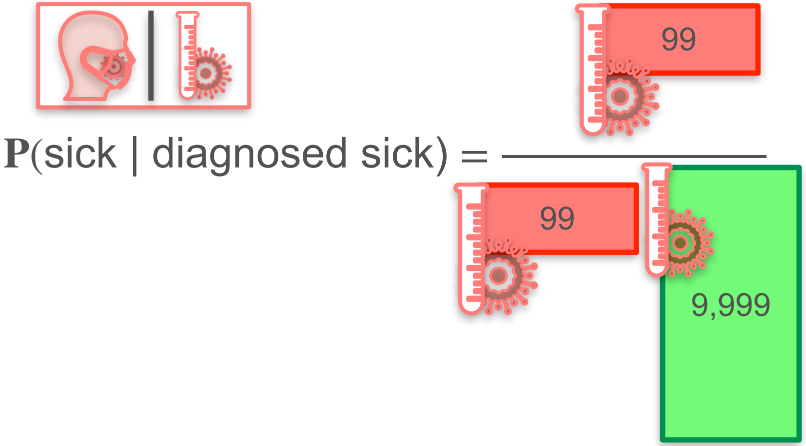


P(sick | diagnosed sick) =



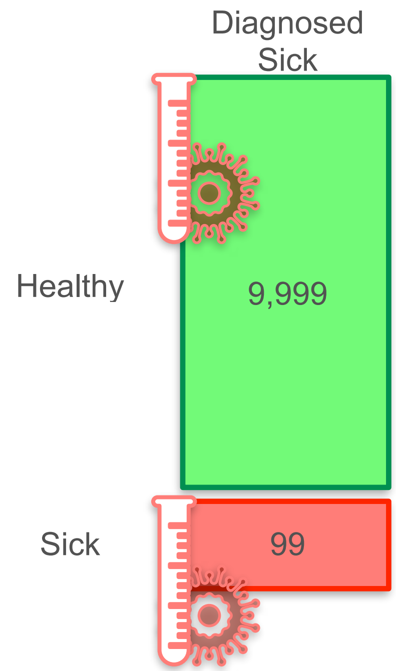
Bayes Theorem: Intuition

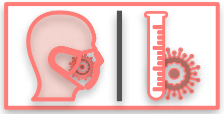




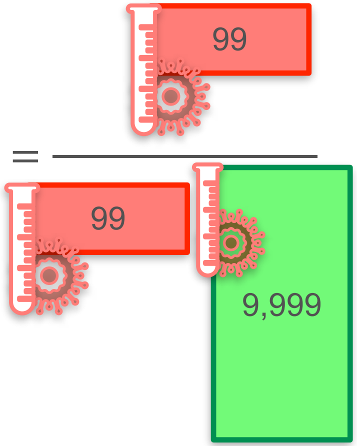
$$= \frac{\text{sick and diagnosed sick}}{\text{sick and diagnosed sick} + \text{healthy and diagnosed sick}}$$

Bayes Theorem: Intuition





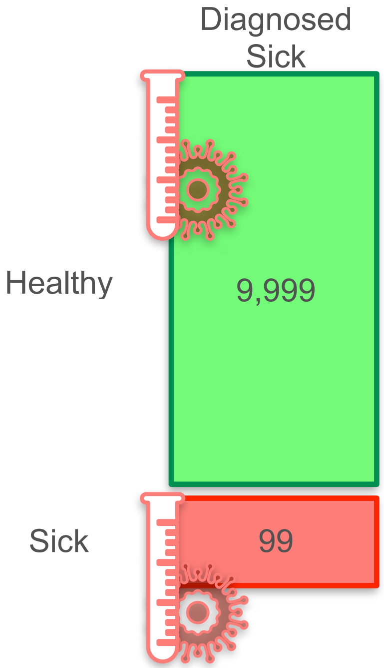
P(sick | diagnosed sick) =

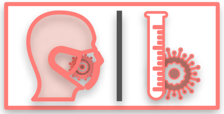


$$= \frac{99}{99 + 9999}$$

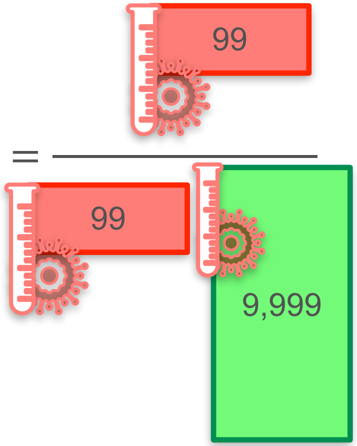
$$= \frac{\text{sick and diagnosed sick}}{\text{sick and diagnosed sick + healthy and diagnosed sick}}$$

Bayes Theorem: Intuition





P(sick | diagnosed sick) =

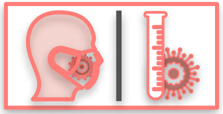


$$= \frac{99}{99 + 9999}$$

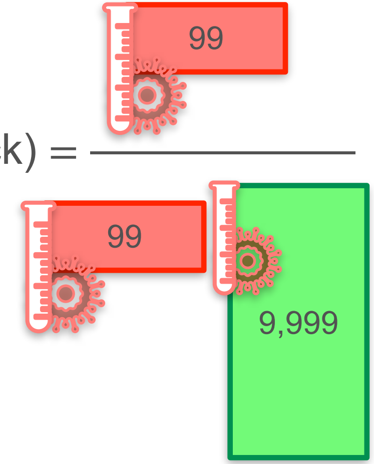
$$= \frac{99}{10098} = 0.0098$$

$$= \frac{\text{sick and diagnosed sick}}{\text{sick and diagnosed sick + healthy and diagnosed sick}}$$

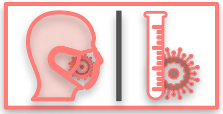
Bayes Theorem: Intuition



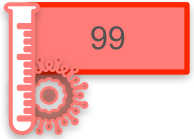
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) =$

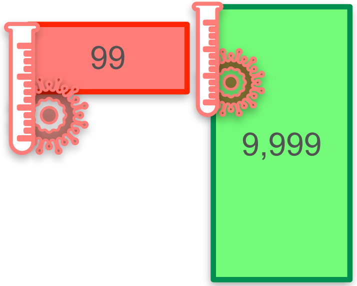


Bayes Theorem: Intuition



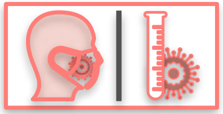
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = $



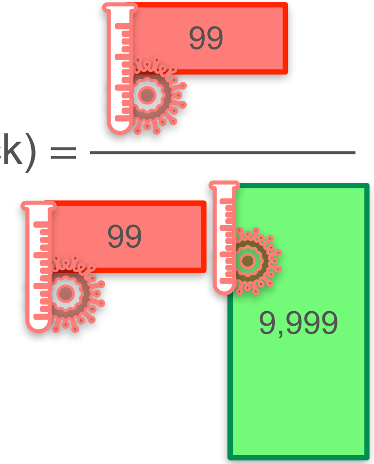


$$= \frac{\text{sick and diagnosed sick}}{\text{everyone diagnosed sick}}$$

Bayes Theorem: Intuition



$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) =$



$$= \frac{\text{sick and diagnosed sick}}{\text{sick and diagnosed sick + healthy and diagnosed sick}}$$

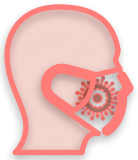
$$= \frac{\text{sick and diagnosed sick}}{\text{everyone diagnosed sick}}$$

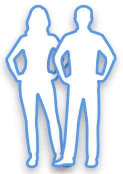
Bayes Theorem: Intuition

1,000,000
people

Bayes Theorem: Intuition

sick = 100

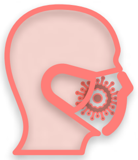


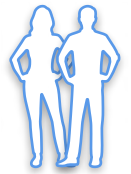


1,000,000
people

Bayes Theorem: Intuition

sick = 100

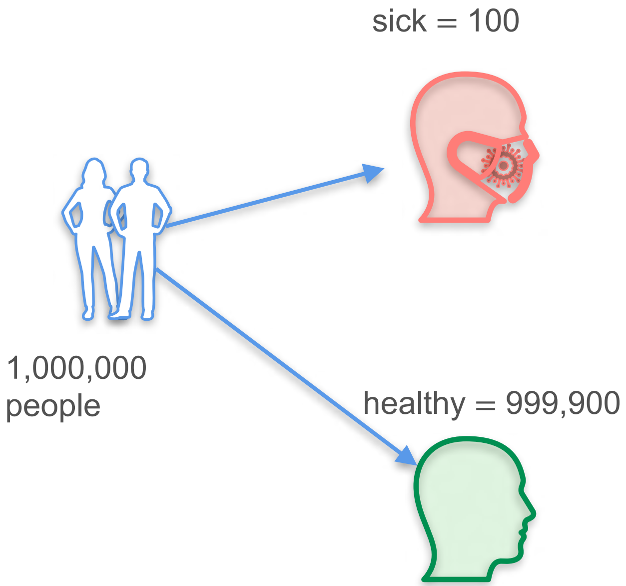




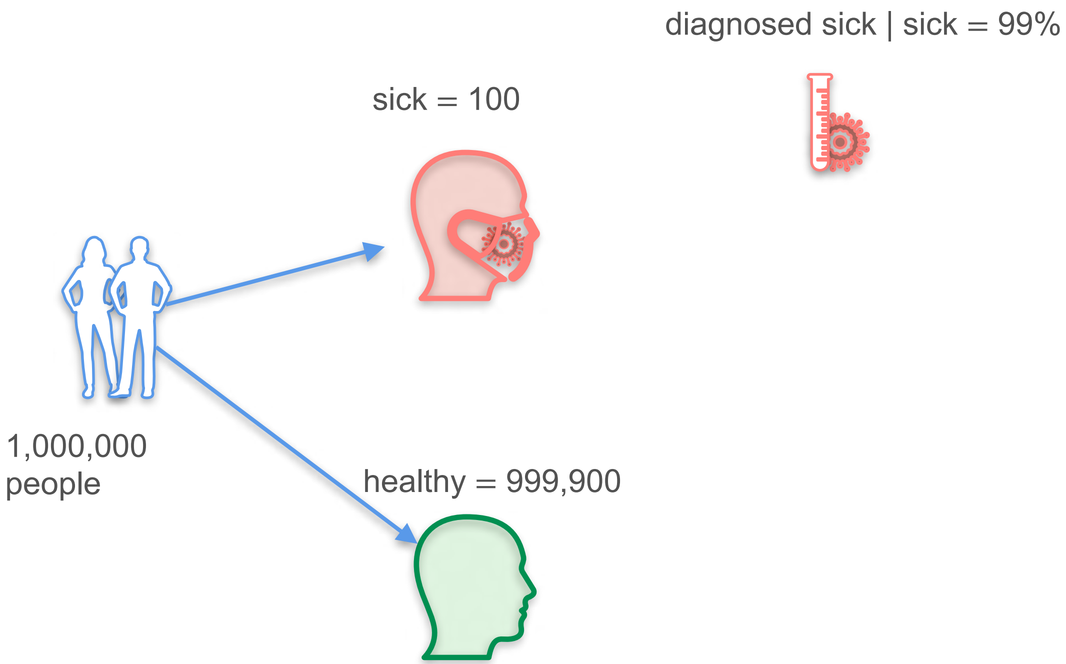
1,000,000
people

healthy = 999,900

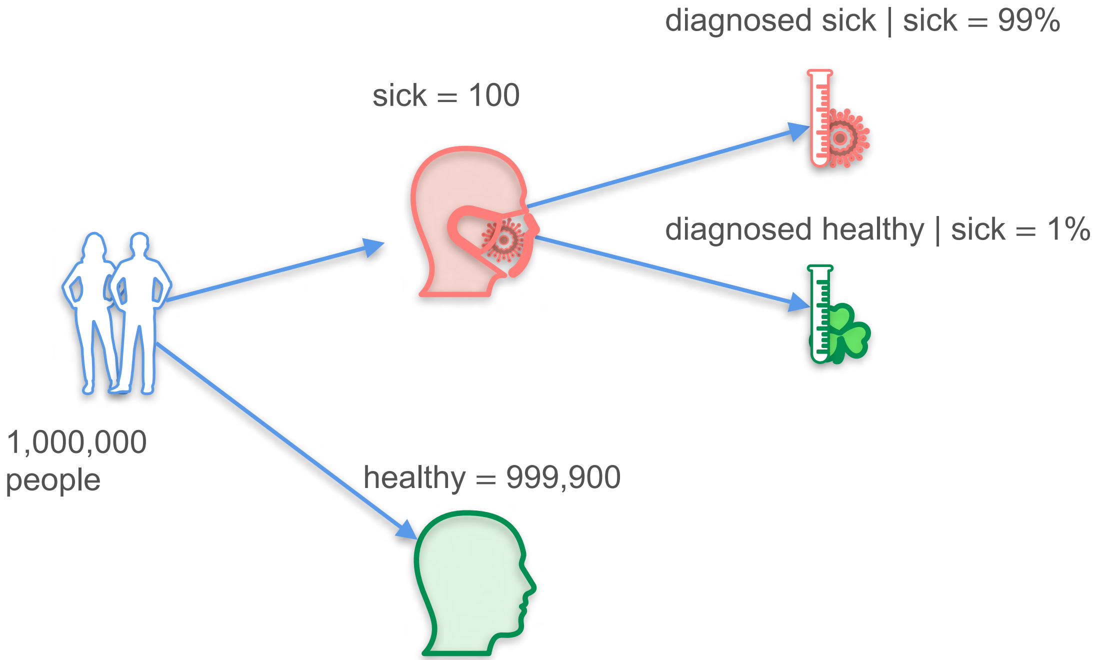
Bayes Theorem: Intuition



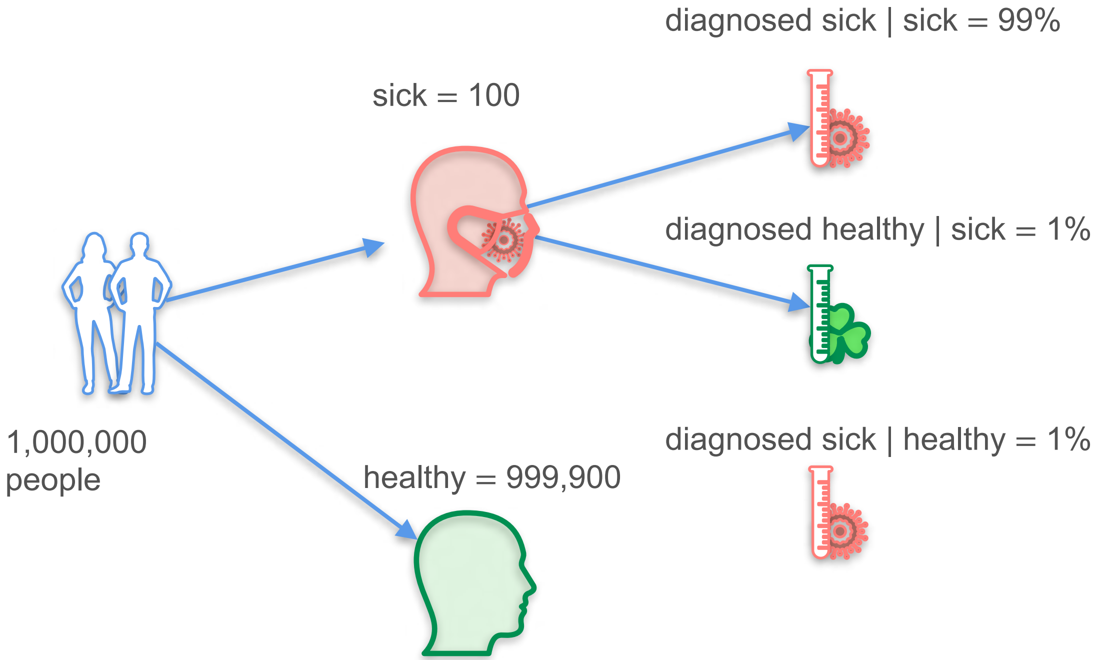
Bayes Theorem: Intuition



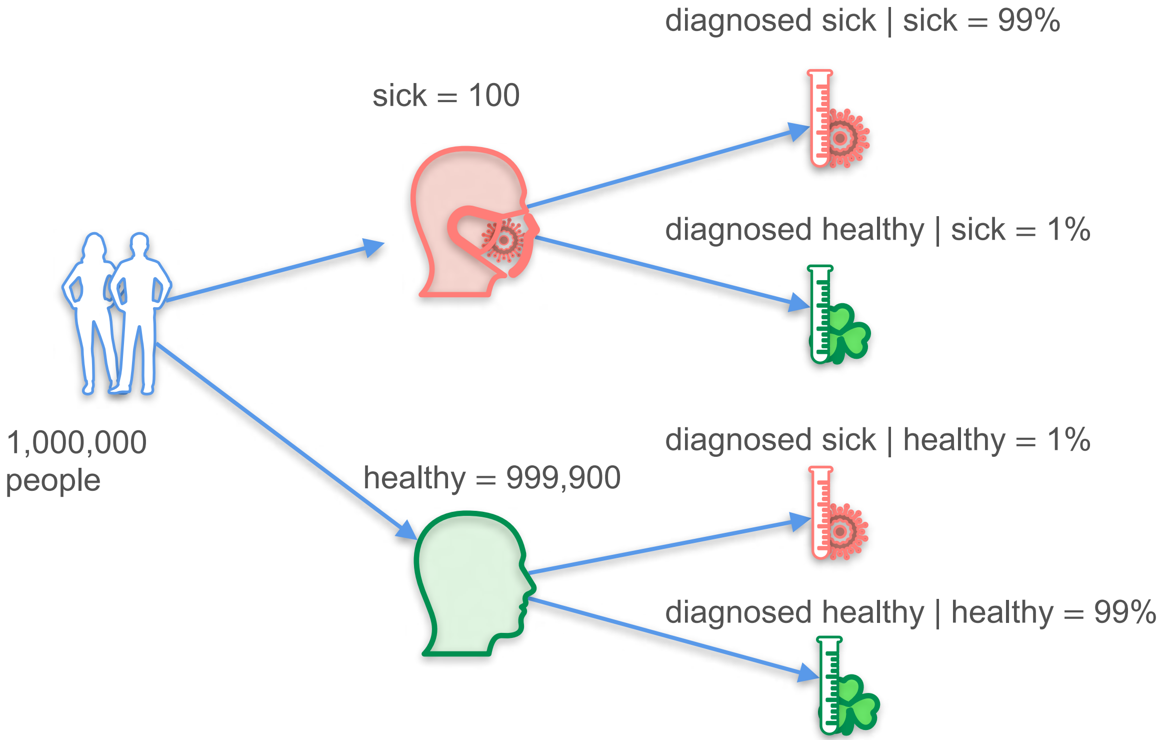
Bayes Theorem: Intuition



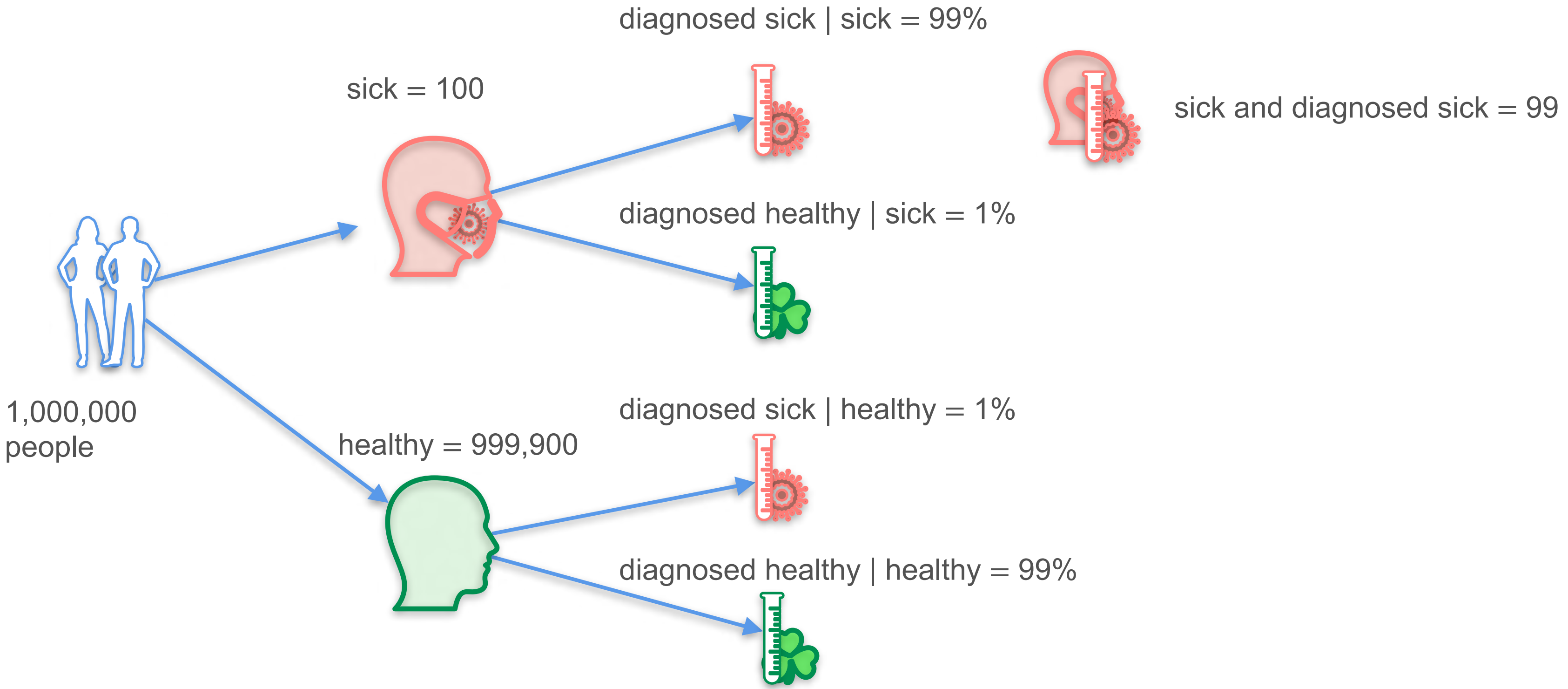
Bayes Theorem: Intuition



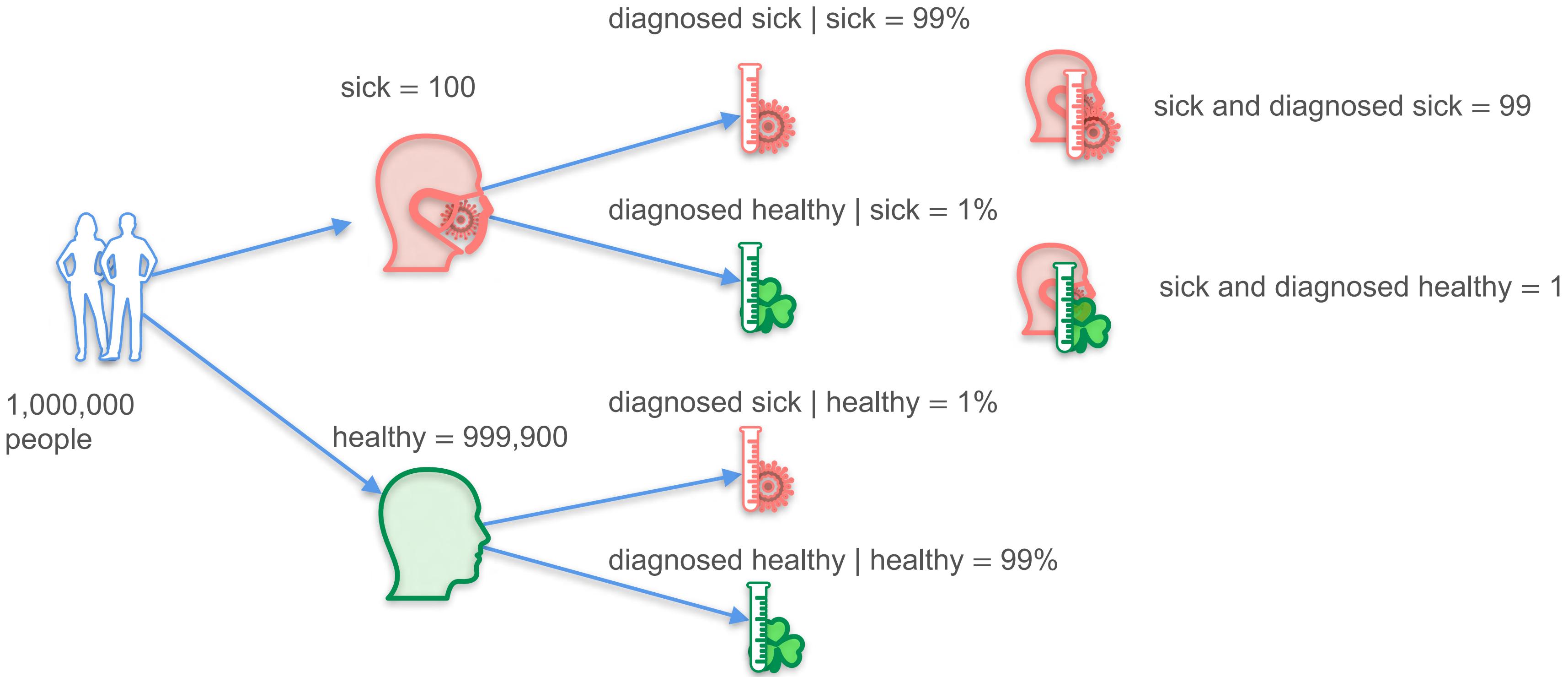
Bayes Theorem: Intuition



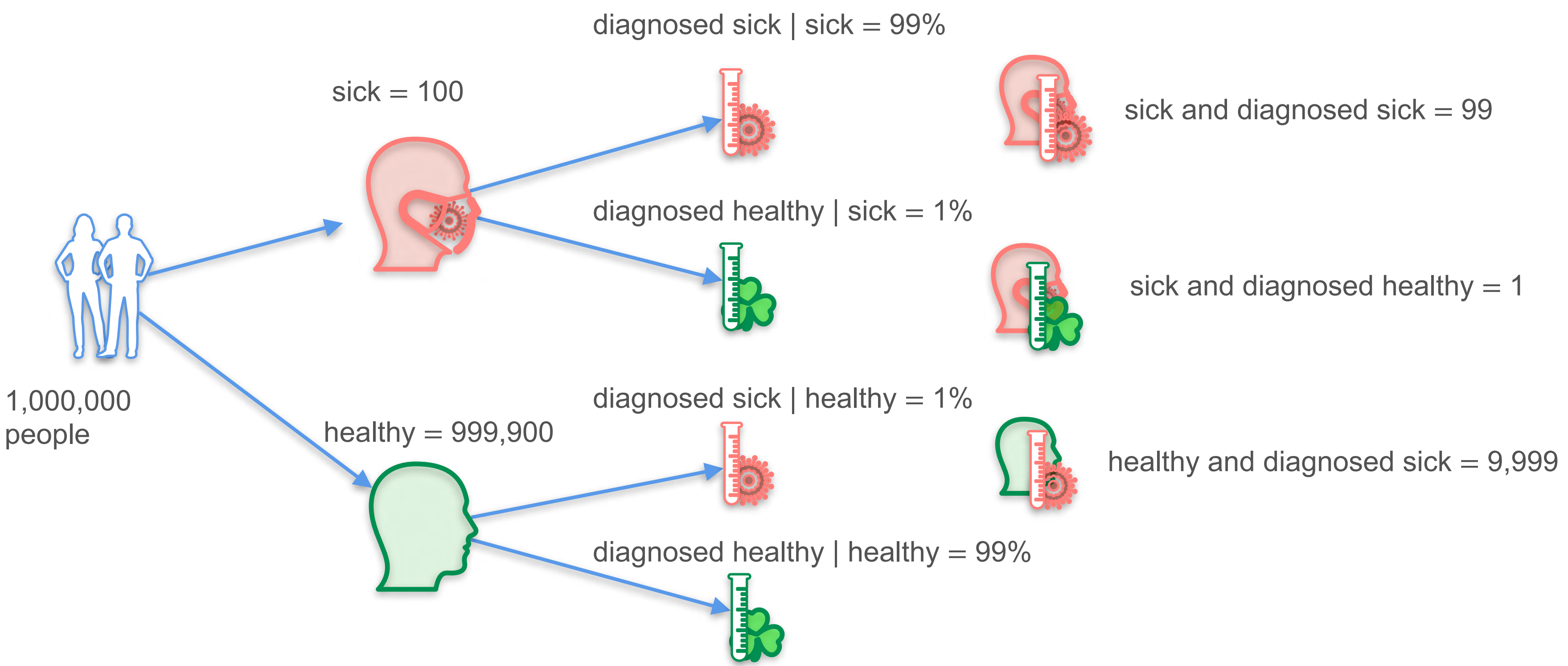
Bayes Theorem: Intuition



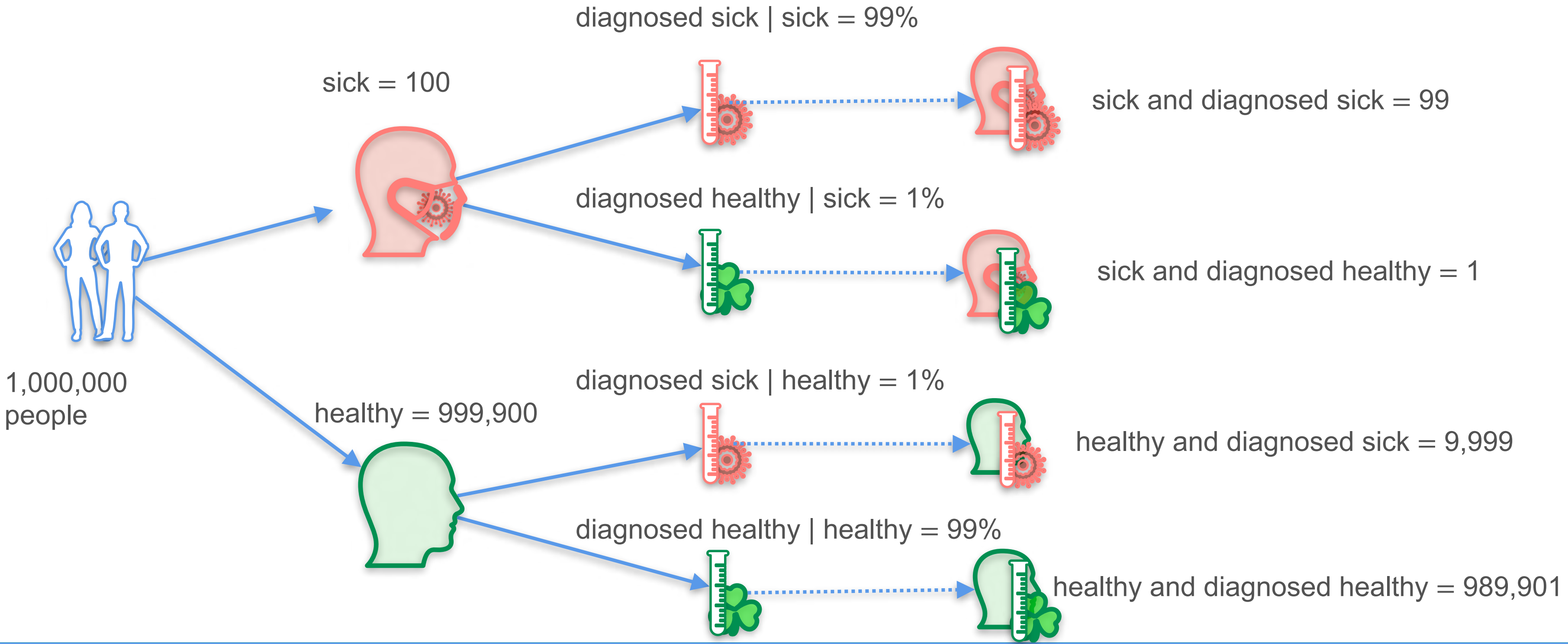
Bayes Theorem: Intuition



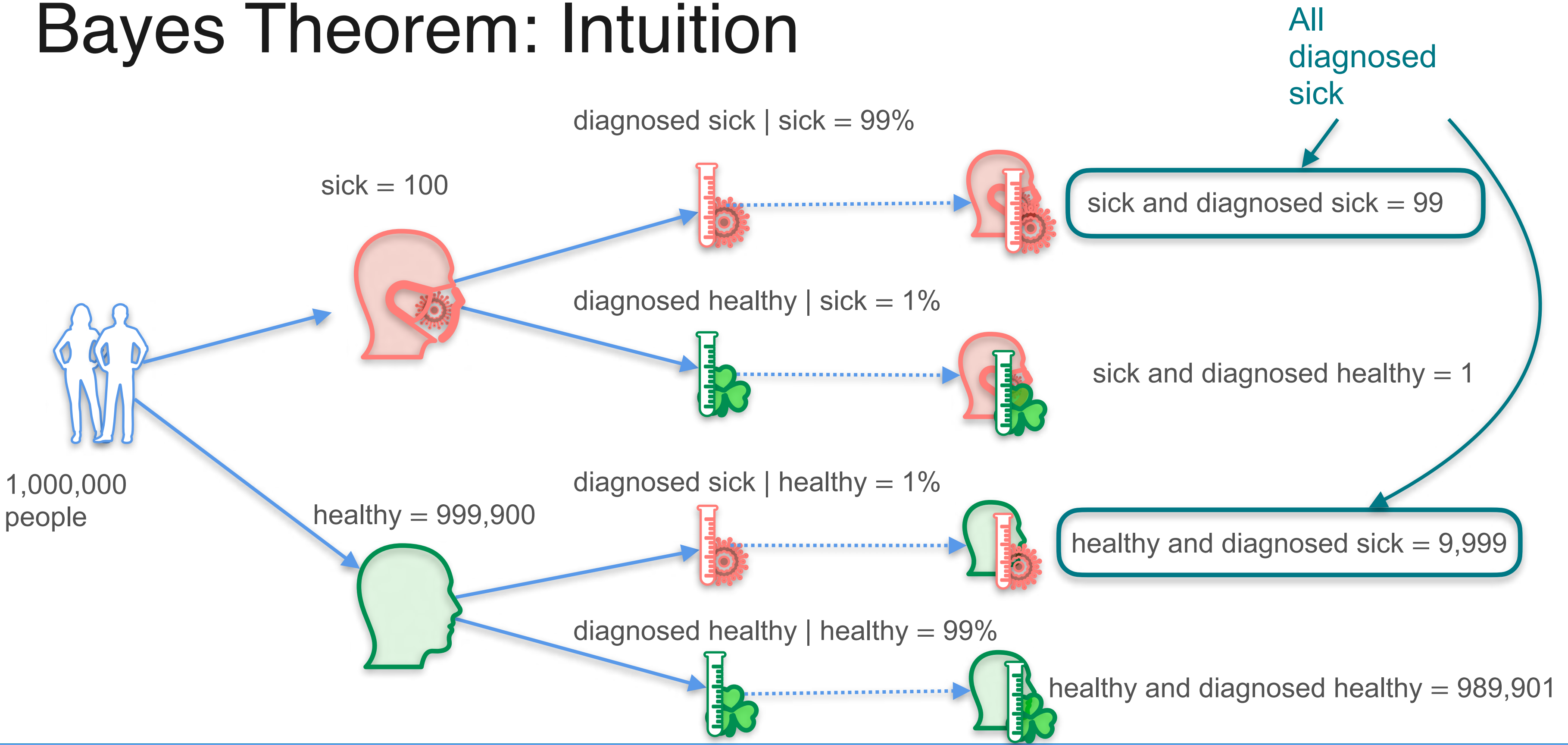
Bayes Theorem: Intuition



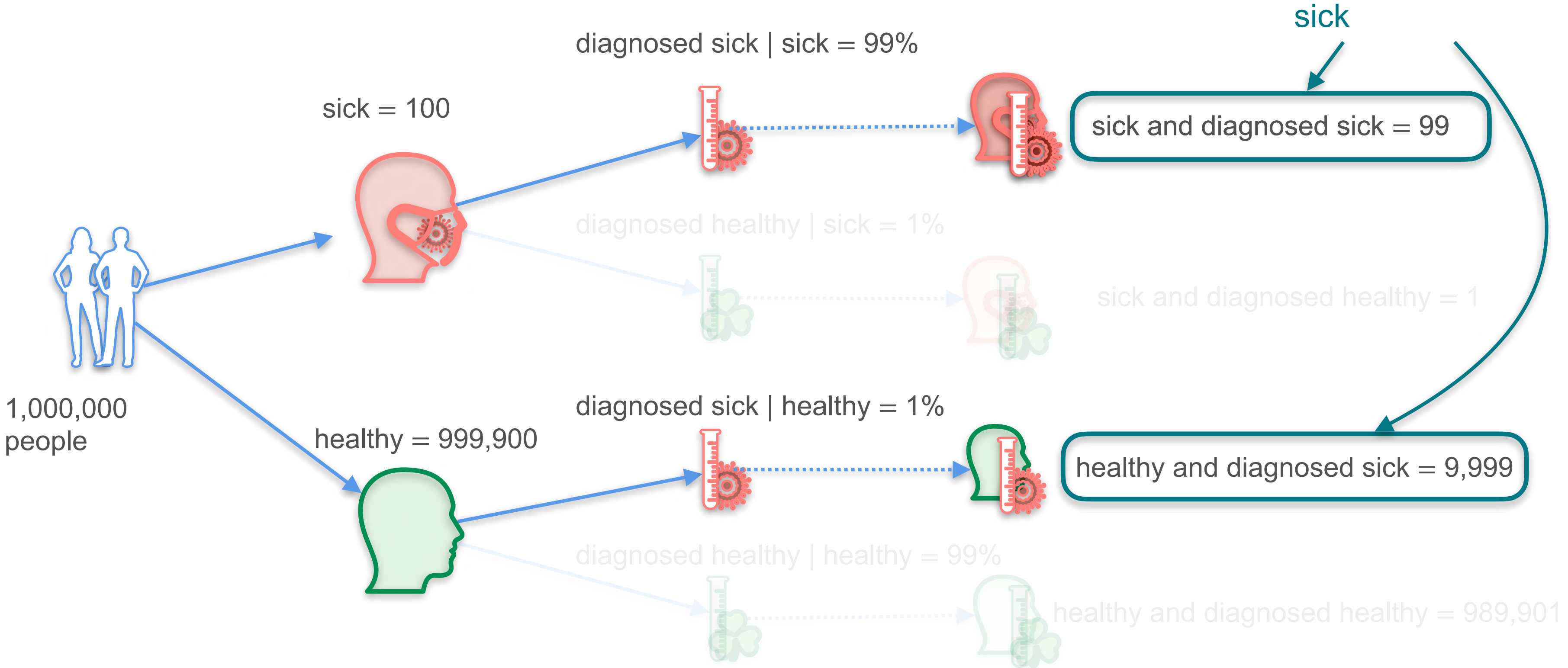
Bayes Theorem: Intuition



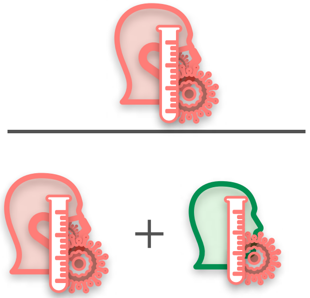
Bayes Theorem: Intuition



Bayes Theorem: Intuition

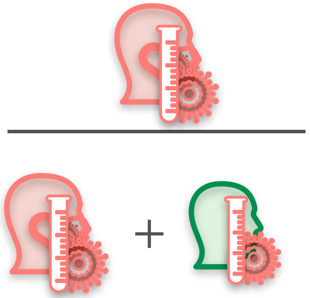


Bayes Theorem: Intuition

$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) =$ 

$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \frac{\text{sick and diagnosed sick} = 99}{\text{healthy and diagnosed sick} = 9{,}999 + \text{sick and diagnosed sick} = 99}$$

Bayes Theorem: Intuition

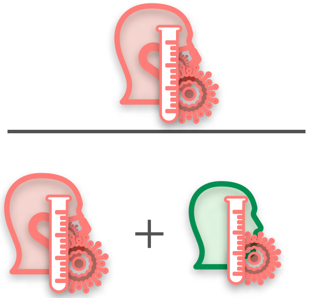
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) =$ 

$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \frac{\text{sick and diagnosed sick} = 99}{\text{healthy and diagnosed sick} = 9{,}999 + \text{sick and diagnosed sick} = 99}$$

$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \frac{99}{10098}$$

Bayes Theorem: Intuition

$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) =$



$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \frac{\text{sick and diagnosed sick} = 99}{\text{healthy and diagnosed sick} = 9{,}999 + \text{sick and diagnosed sick} = 99}$$

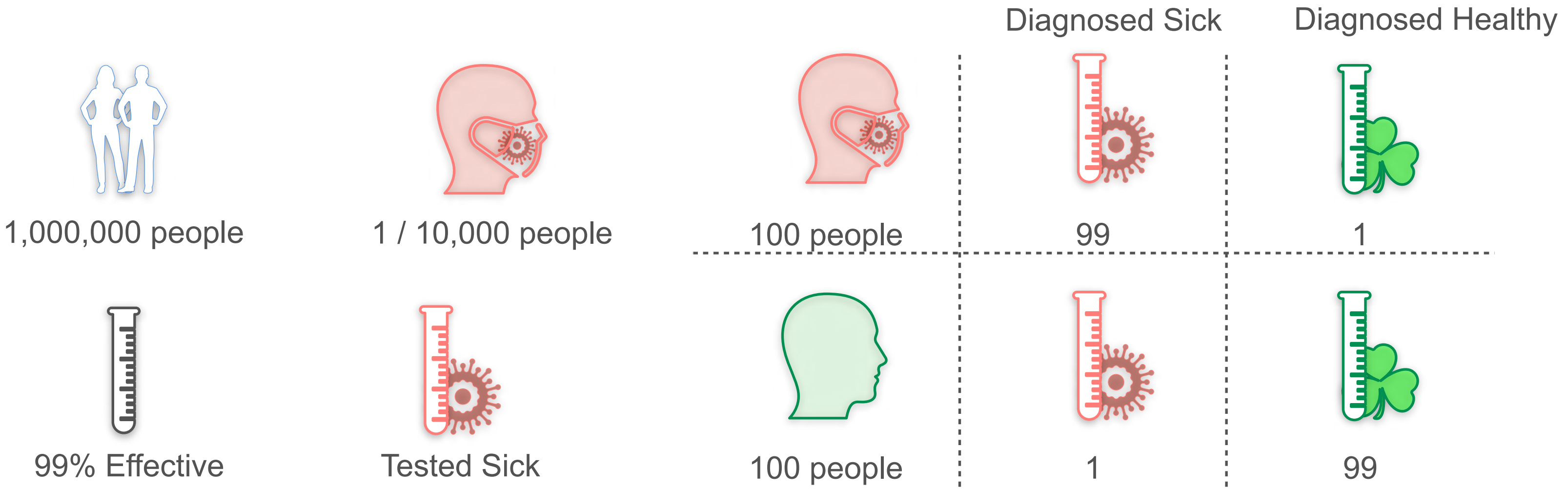
$$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = \frac{99}{10098} = 0.0098$$

Bayes Theorem: Formula

Bayes Theorem: Formula

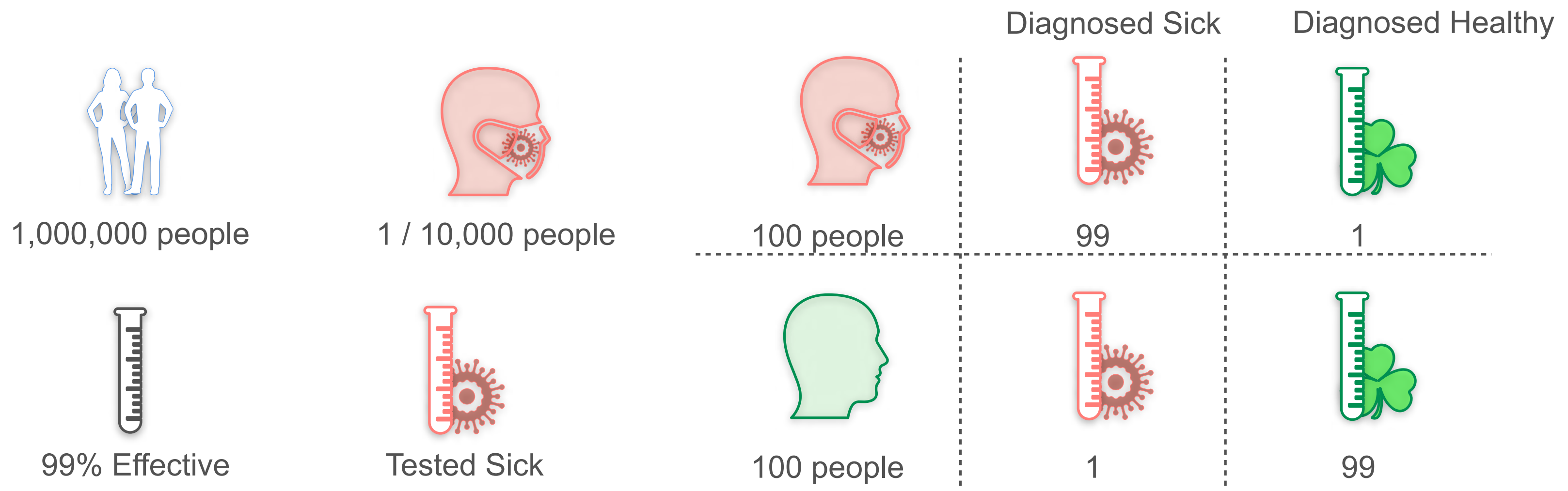
The probability that **you are sick GIVEN that you tested sick**

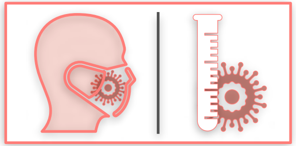
Bayes Theorem: Formula



The probability that **you are sick GIVEN that you tested sick**

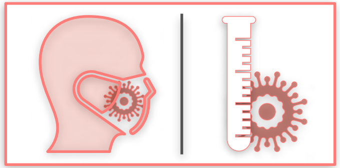
Bayes Theorem: Formula





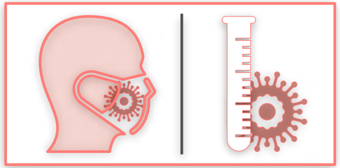
The probability that **you are sick GIVEN that you tested sick**

Bayes Theorem: Formula



The probability that **you are sick GIVEN that you tested sick**

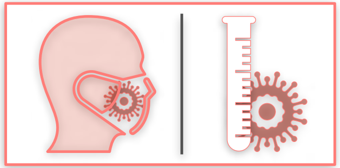
Bayes Theorem: Formula



The probability that **you are sick GIVEN that you tested sick**

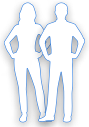
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

Bayes Theorem: Formula



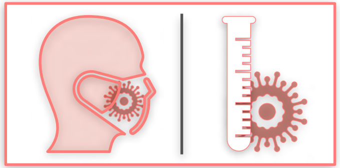
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

The probability that **you are sick GIVEN that you tested sick**



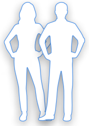
1,000,000

Bayes Theorem: Formula

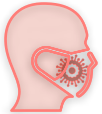


$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

The probability that **you are sick GIVEN that you tested sick**

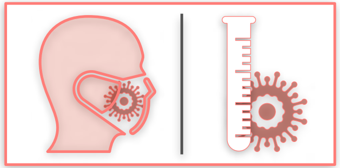


1,000,000



1 / 10,000

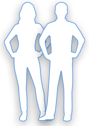
Bayes Theorem: Formula



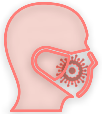
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

$\mathbf{P}(\text{sick}) = 0.01\%$

The probability that **you are sick GIVEN that you tested sick**

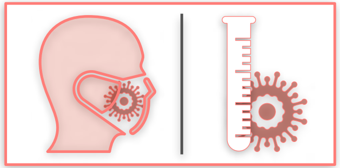


1,000,000



1 / 10,000

Bayes Theorem: Formula

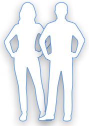


$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

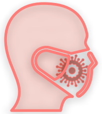
$\mathbf{P}(\text{sick}) = 0.01\%$

$\mathbf{P}(\text{not sick}) = 99.99\%$

The probability that **you are sick GIVEN that you tested sick**

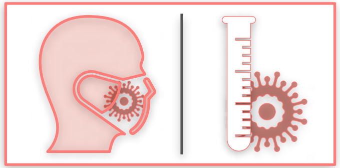


1,000,000



1 / 10,000

Bayes Theorem: Formula

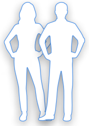


$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

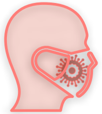
$\mathbf{P}(\text{sick}) = 0.01\%$

$\mathbf{P}(\text{not sick}) = 99.99\%$

The probability that **you are sick GIVEN that you tested sick**



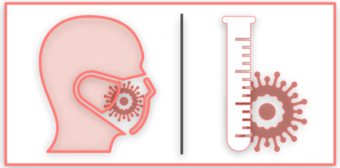
1,000,000



1 / 10,000

99% Effective

Bayes Theorem: Formula



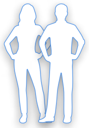
$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

$\mathbf{P}(\text{sick}) = 0.01\%$

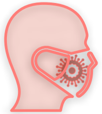
$\mathbf{P}(\text{not sick}) = 99.99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

The probability that **you are sick GIVEN that you tested sick**



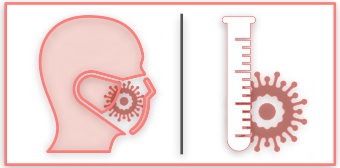
1,000,000



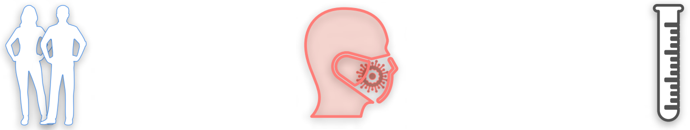
1 / 10,000

99% Effective

Bayes Theorem: Formula



The probability that **you are sick GIVEN that you tested sick**



$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

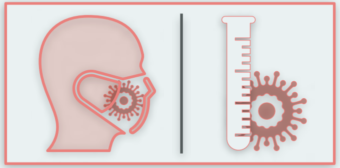
$\mathbf{P}(\text{sick}) = 0.01\%$

$\mathbf{P}(\text{not sick}) = 99.99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{not sick}) = 1\%$

Bayes Theorem: Formula



$P(\text{sick} \mid \text{diagnosed sick}) = ?$

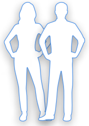
$P(\text{sick}) = 0.01\%$

$P(\text{not sick}) = 99.99\%$

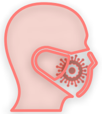
$P(\text{diagnosed sick} \mid \text{sick}) = 99\%$

$P(\text{diagnosed sick} \mid \text{not sick}) = 1\%$

The probability that **you are sick GIVEN that you tested sick**



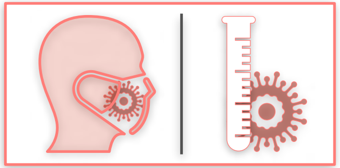
1,000,000



1 / 10,000

99% Effective

Bayes Theorem: Formula



$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

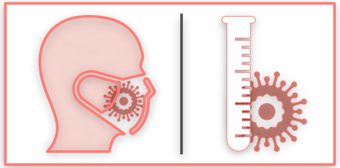
$\mathbf{P}(\text{sick}) = 0.01\%$

$\mathbf{P}(\text{not sick}) = 99.99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{not sick}) = 1\%$

Bayes Theorem: Formula



A: sick

B: diagnosed sick

$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

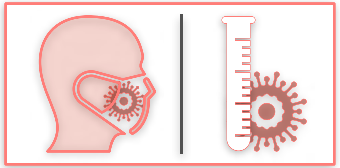
$\mathbf{P}(\text{sick}) = 0.01\%$

$\mathbf{P}(\text{not sick}) = 99.99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{not sick}) = 1\%$

Bayes Theorem: Formula



A: sick

B: diagnosed sick

$\mathbf{P}(\text{sick} \mid \text{diagnosed sick}) = ?$

$\mathbf{P}(A \mid B) = ?$

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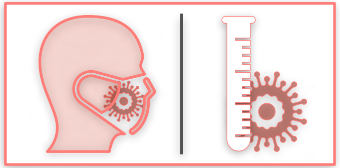

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From Conditional Probability

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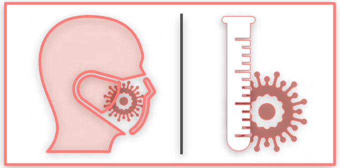

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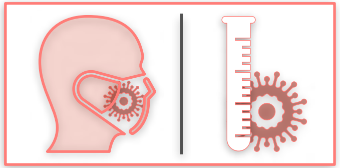

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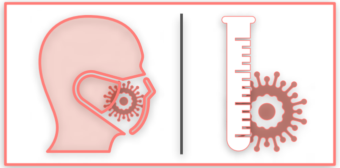

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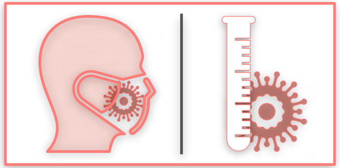

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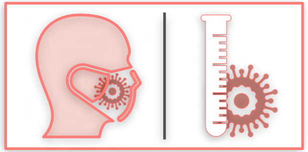

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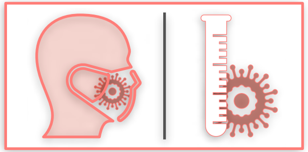

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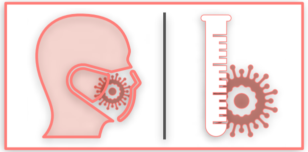

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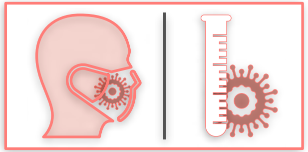

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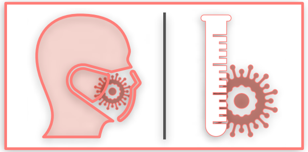

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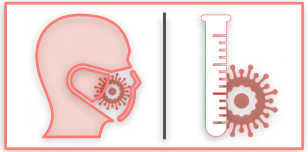
BAYES THEOREM FORMULA CAN HELP

Bayes Theorem: Formula



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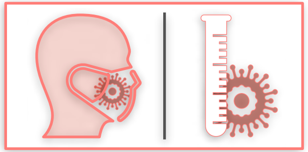

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From Conditional Probability

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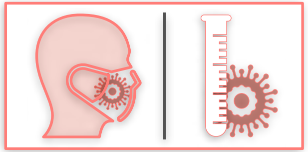

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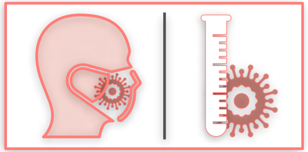

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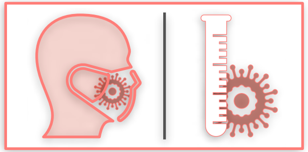

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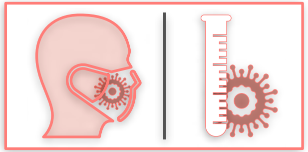

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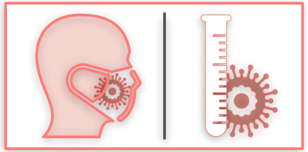

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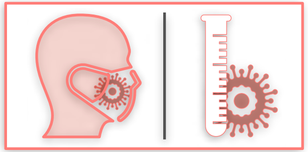

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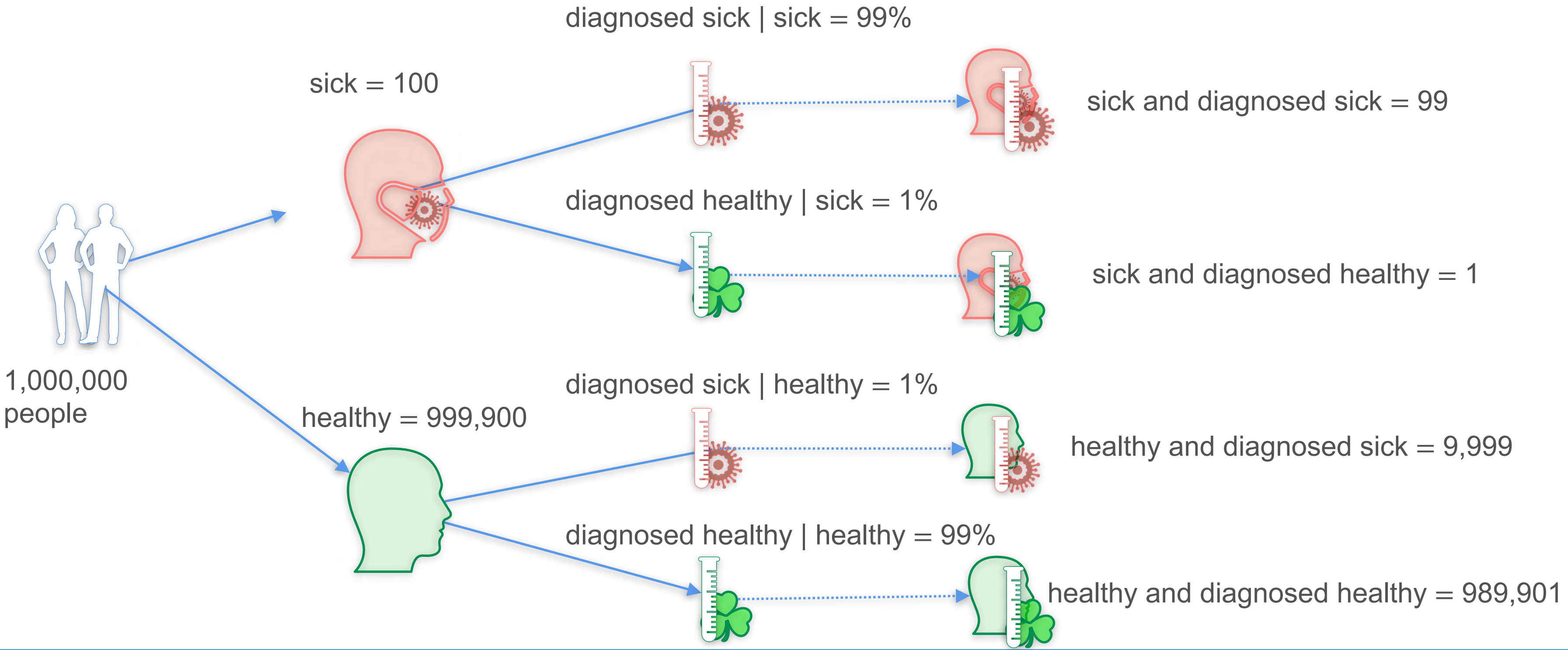

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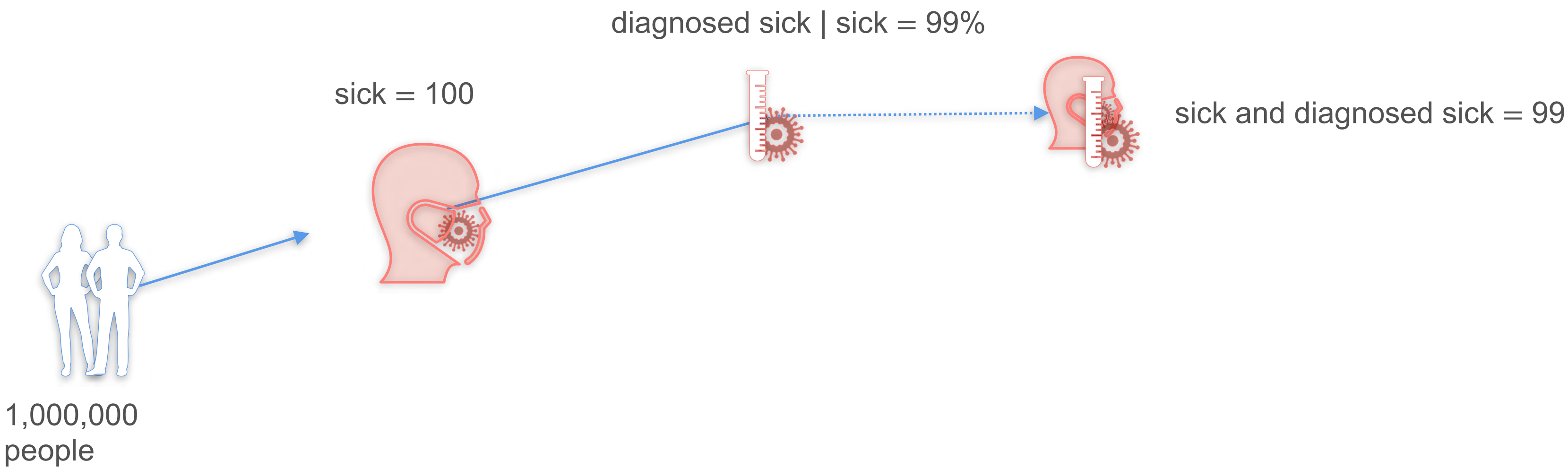

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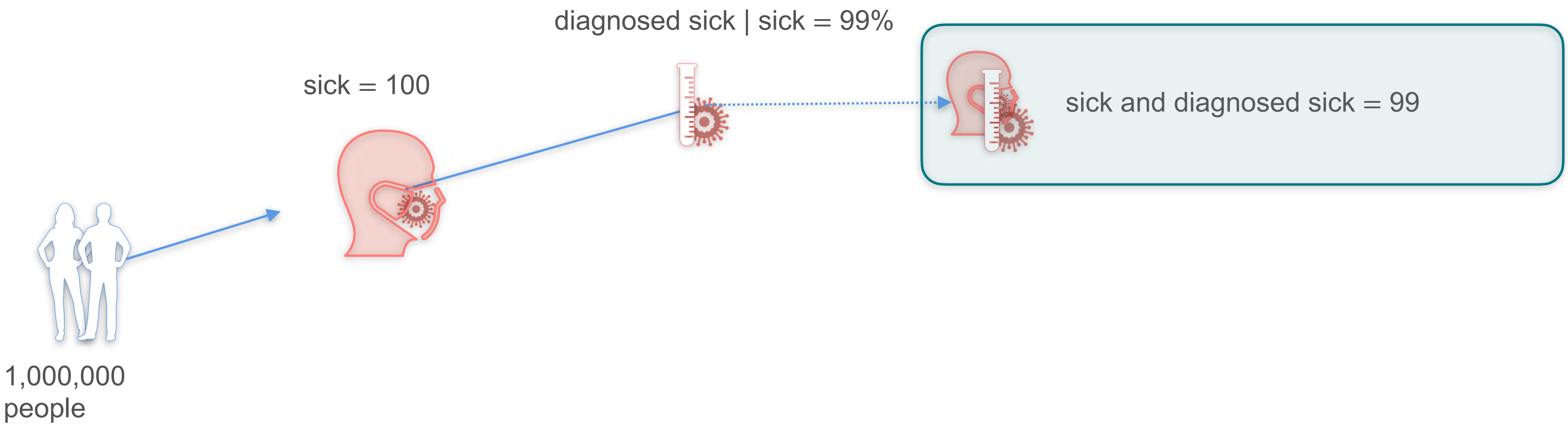

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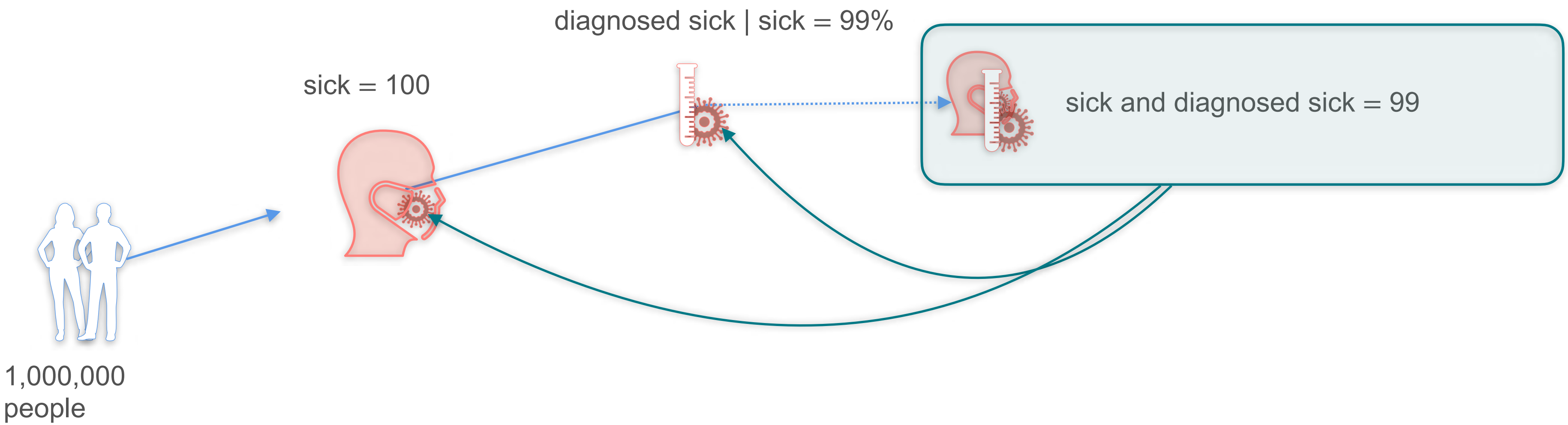

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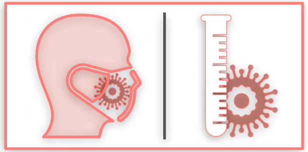

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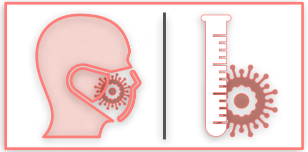

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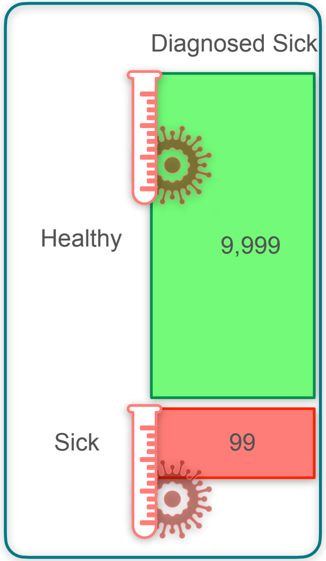

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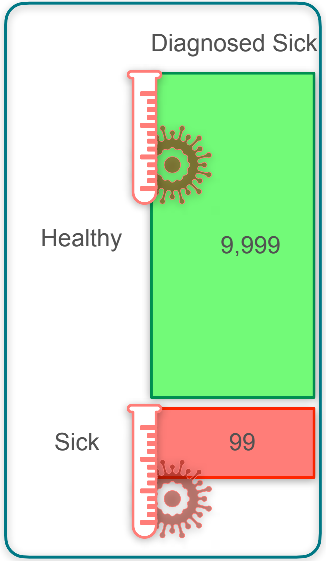

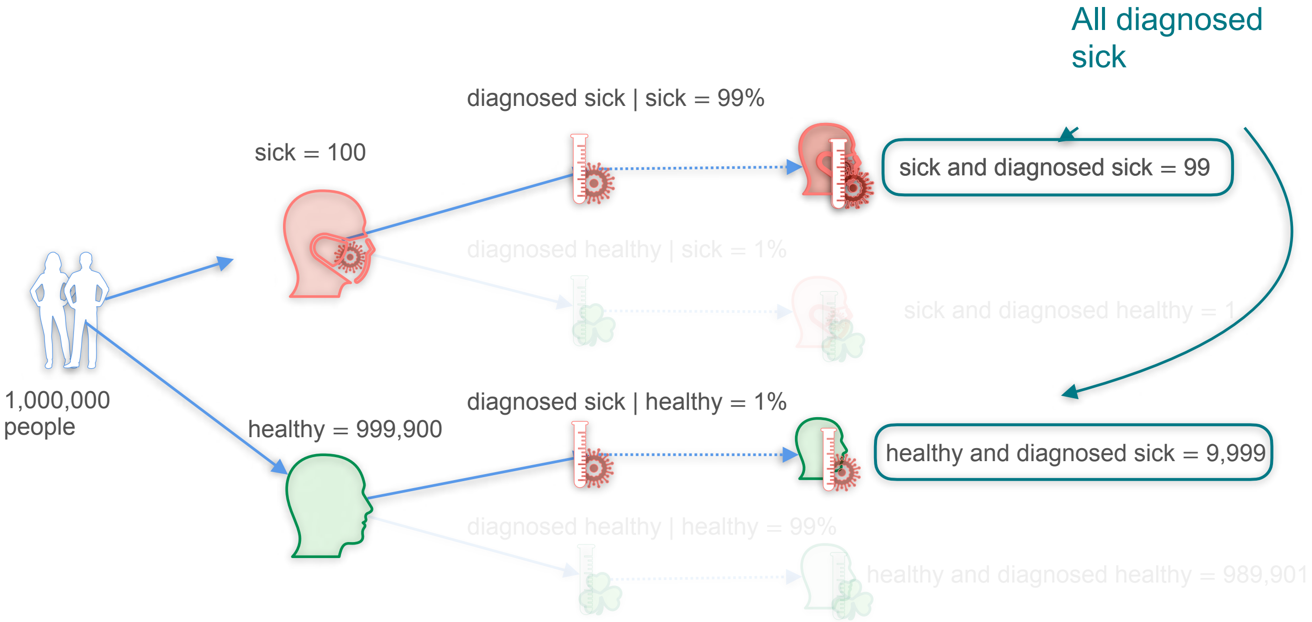

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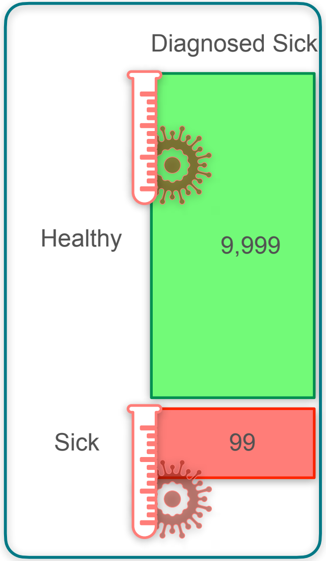

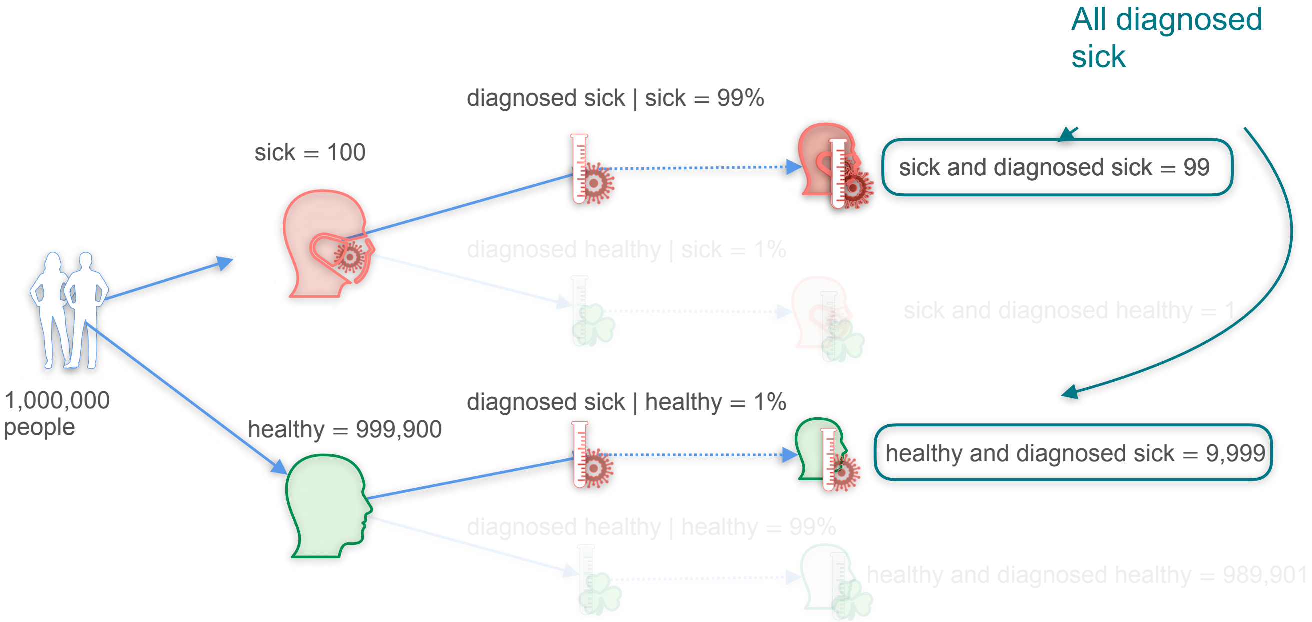

$\mathbf{P}(\text{sick} \cap \text{diagnosed sick})$

Bayes Theorem: Formula

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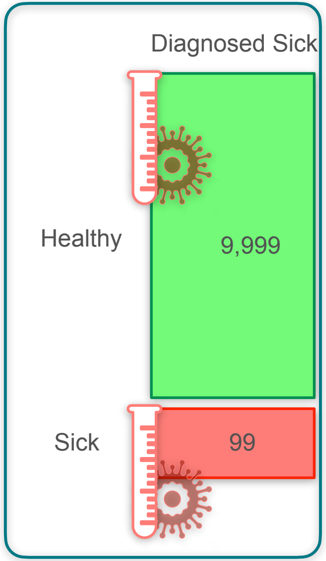

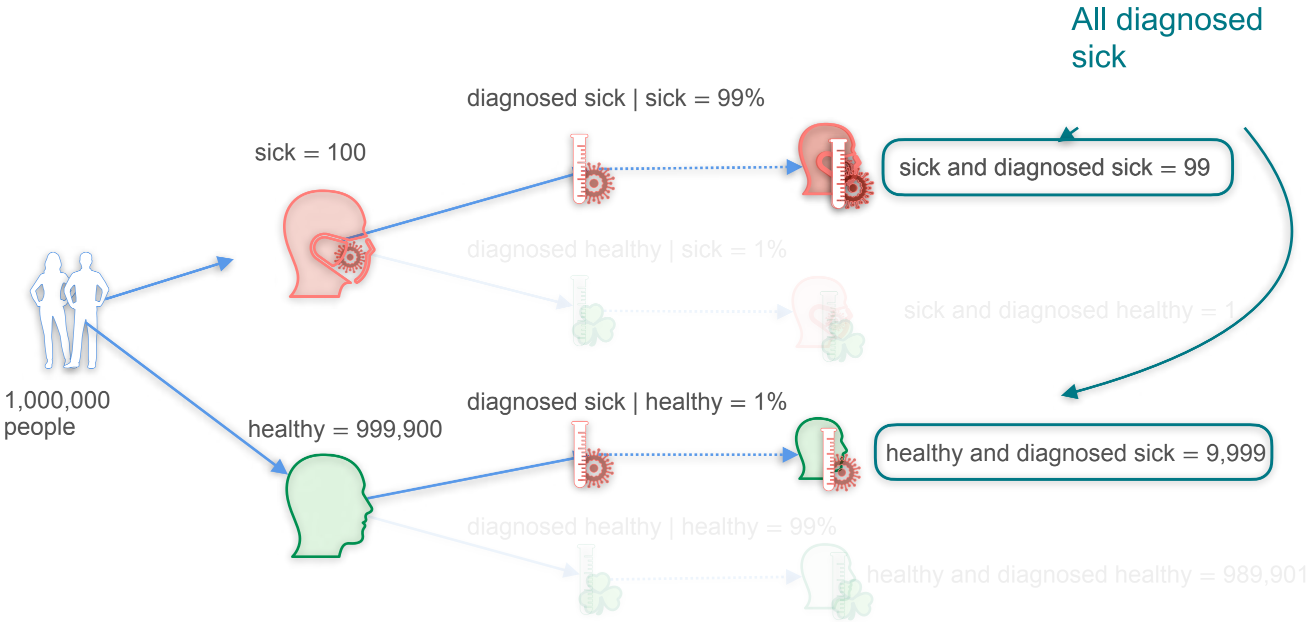

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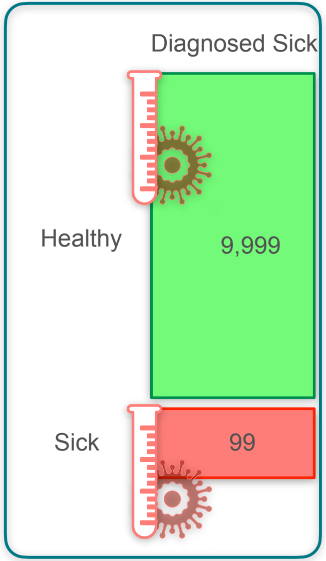
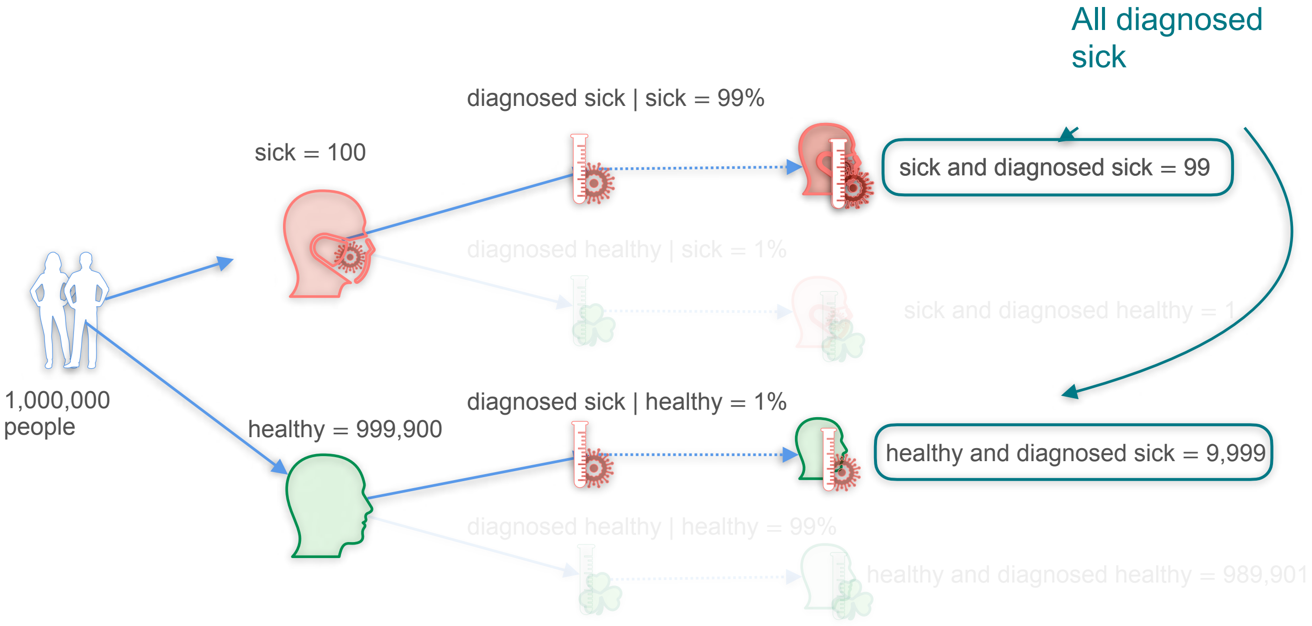
Bayes Theorem: Formula

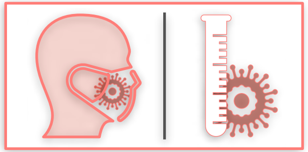
$\mathbf{P}(\text{diagnosed sick}) =$





$$\mathbf{P}(\text{sick} \cap \text{diagnosed sick}) + \mathbf{P}(\text{not sick} \cap \text{diagnosed sick})$$

Bayes Theorem: Formula



A: sick

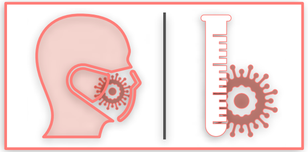
B: diagnosed sick

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

$$\mathbf{P}(A \mid B) = \frac{\mathbf{P}(\text{sick}) \bullet \mathbf{P}(\text{diagnosed sick} \mid \text{sick})}{\mathbf{P}(\text{diagnosed sick}) = ?}$$

$$\mathbf{P}(\text{diagnosed sick}) = \mathbf{P}(\text{sick} \cap \text{diagnosed sick}) + \mathbf{P}(\text{not sick} \cap \text{diagnosed sick})$$

Bayes Theorem: Formula



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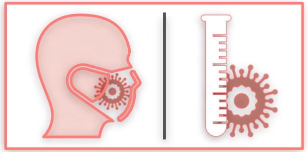

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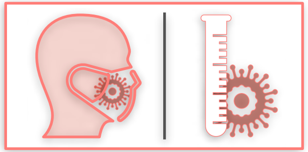

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$$\mathbf{P}(\text{sick} \cap \text{diagnosed sick})$$

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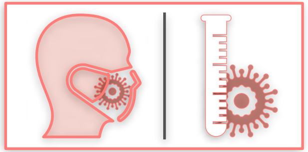

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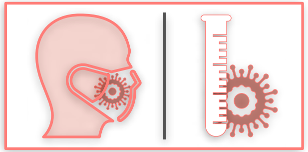

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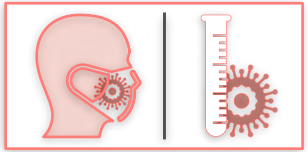

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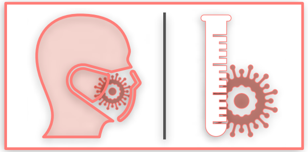

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$$\begin{aligned}\mathbf{P}(\text{sick} \cap \text{diagnosed sick}) &= \mathbf{P}(A \cap B) \\ &= \mathbf{P}(\text{sick}) \bullet \mathbf{P}(\text{diagnosed sick} \mid \text{sick})\end{aligned}$$

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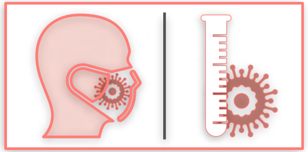

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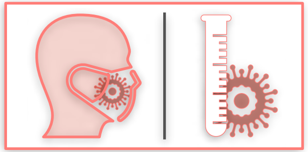

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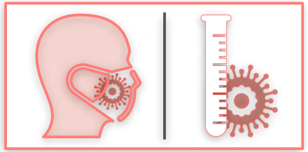
Bayes Theorem: Formula



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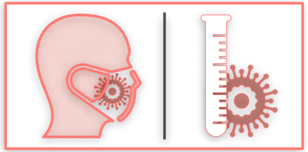

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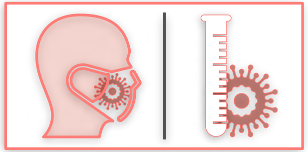

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BAYES THEOREM FORMULA

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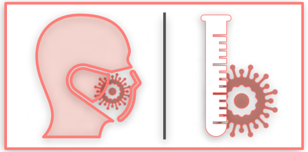

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$\mathbf{P}(\text{sick}) = 0.01\%$

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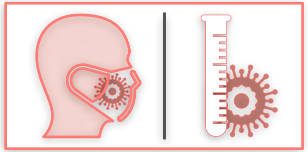

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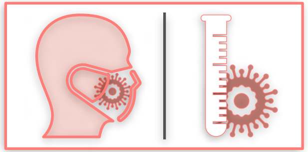

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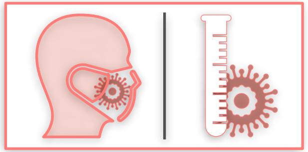

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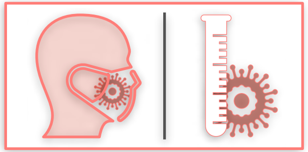

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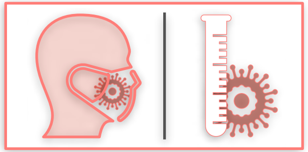

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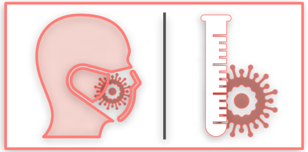

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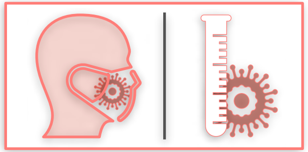

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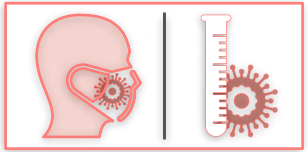

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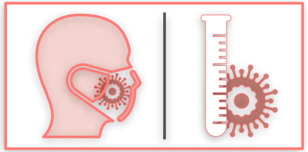

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$\mathbf{P}(\text{sick}) = 1\%$

$\mathbf{P}(\text{not sick}) = 99\%$

$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

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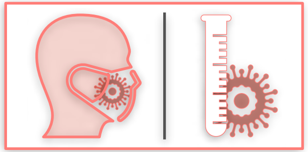

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BAYES THEOREM
FORMULA

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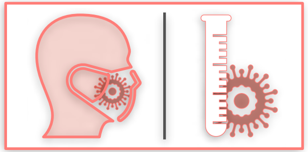

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$\mathbf{P}(\text{diagnosed sick} \mid \text{sick}) = 99\%$

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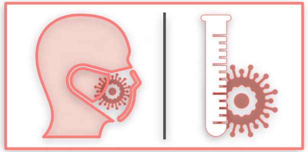
BAYES THEOREM FORMULA

Bayes Theorem: Formula



A: sick

B: diagnosed sick

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

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$\mathbf{P}(A)$ = 0.01%

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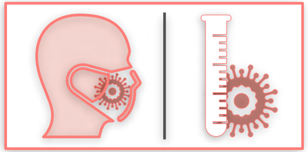

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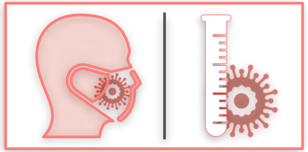

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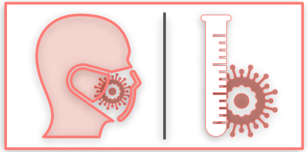

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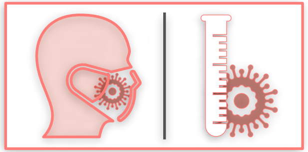

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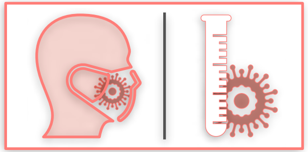

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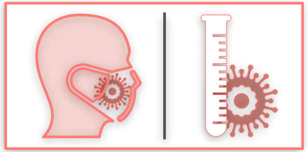

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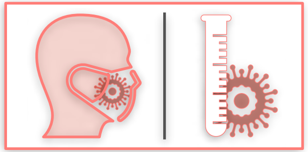

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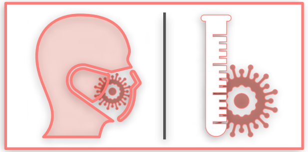

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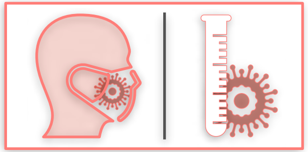

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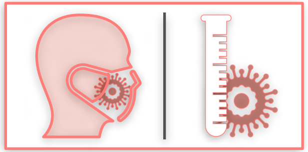

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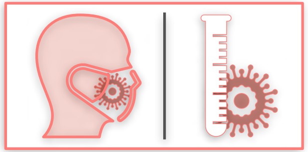

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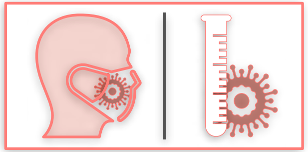

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$$\mathbf{P}(A \mid B) = \frac{0.0001 \times 0.99}{(0.0001 \times 0.99) + (0.9999 \times 0.01)}$$

$$\mathbf{P}(A \mid B) = 0.0098$$

BAYES THEOREM FORMULA

Bayes Theorem: Spam Example

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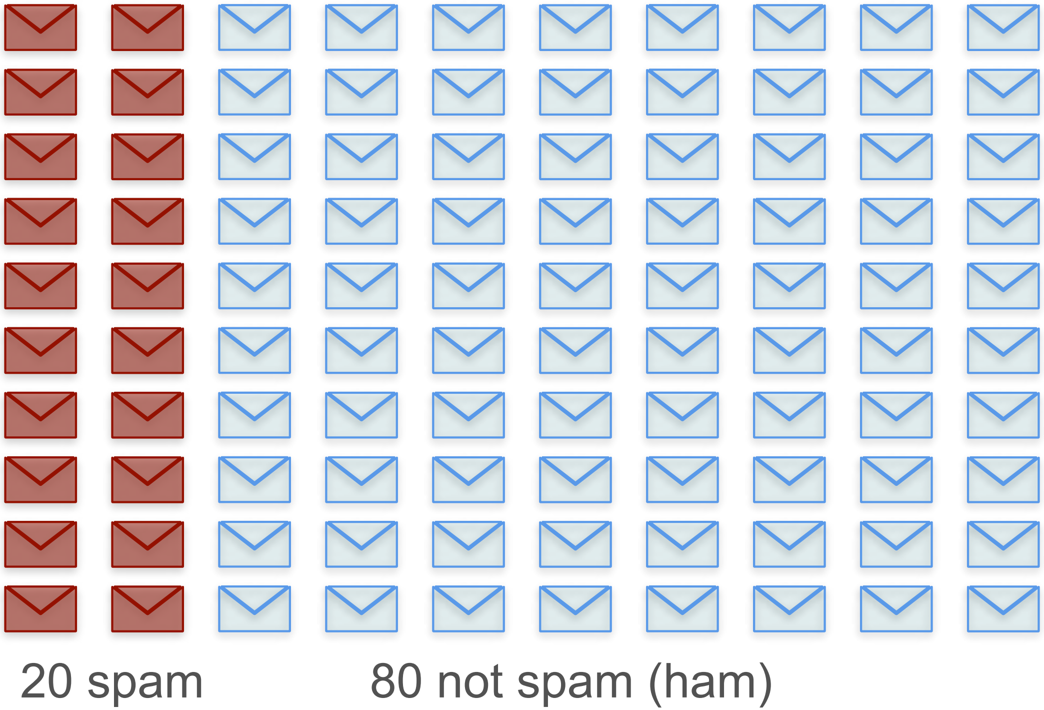
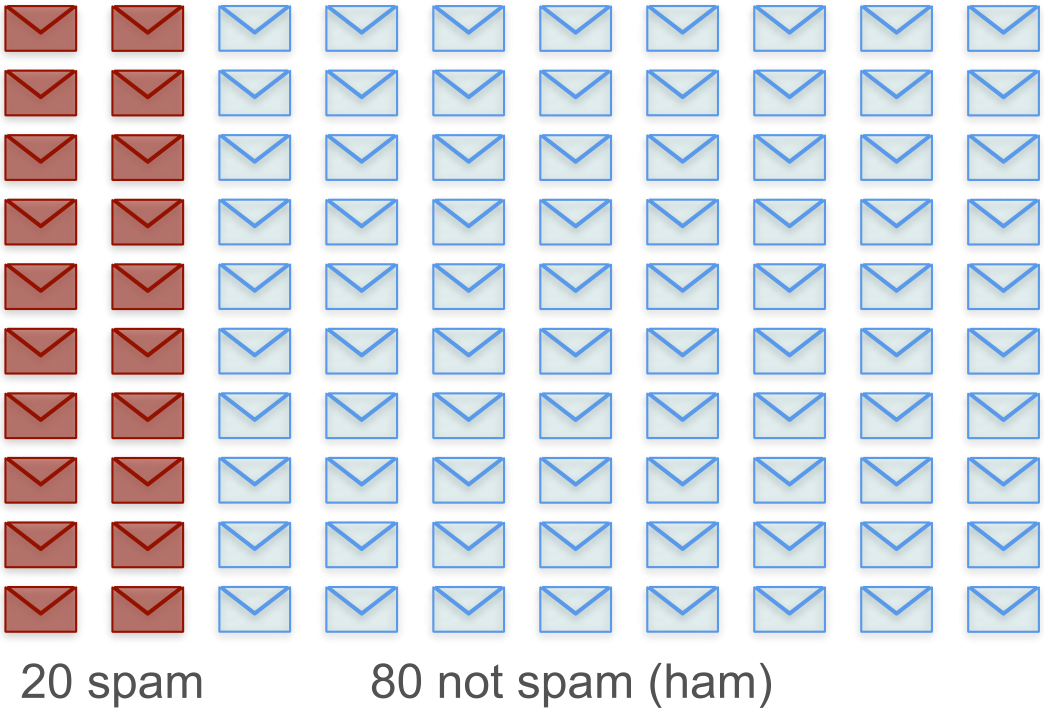


Bayes Theorem: Spam Example

20 spam   80 not spam (ham)

“lottery”

Bayes Theorem: Spam Example



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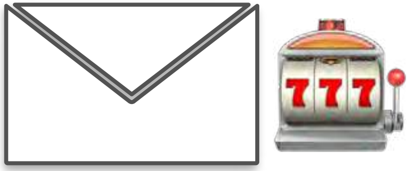

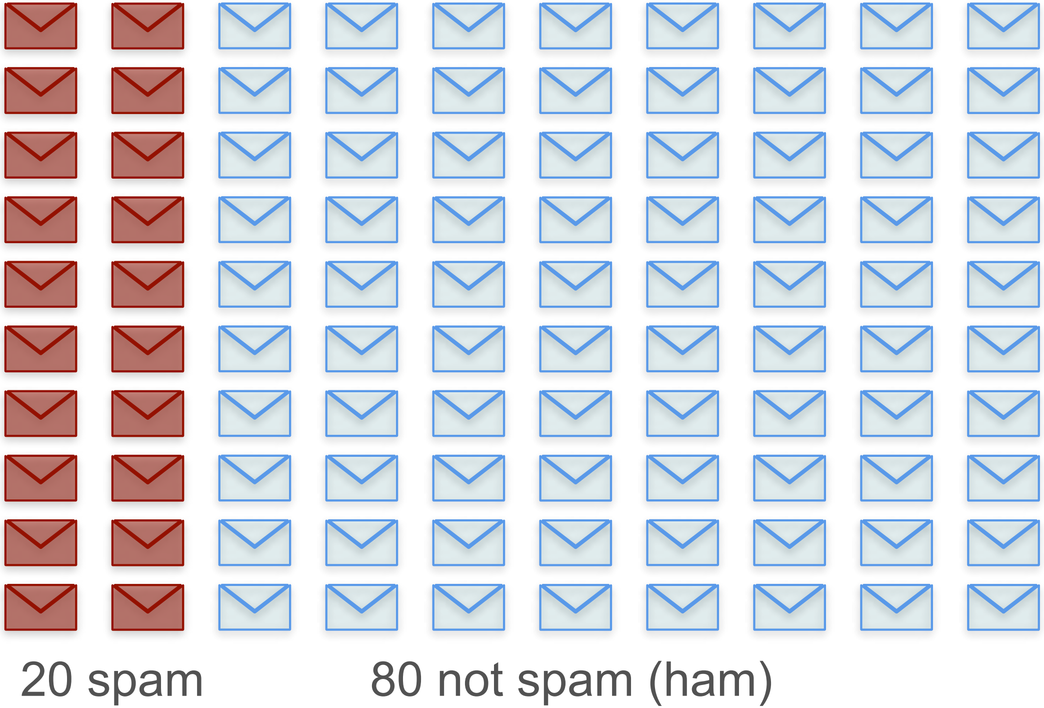

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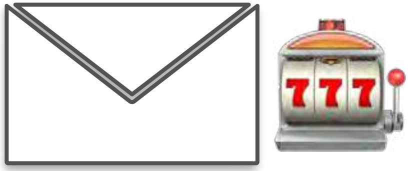

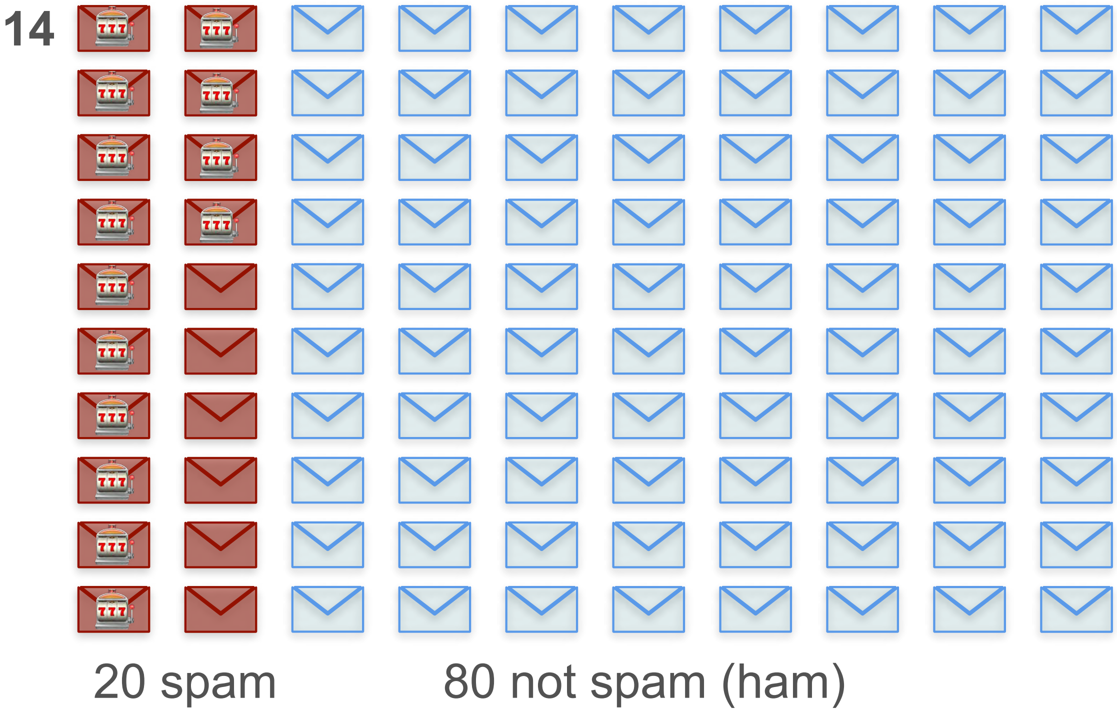

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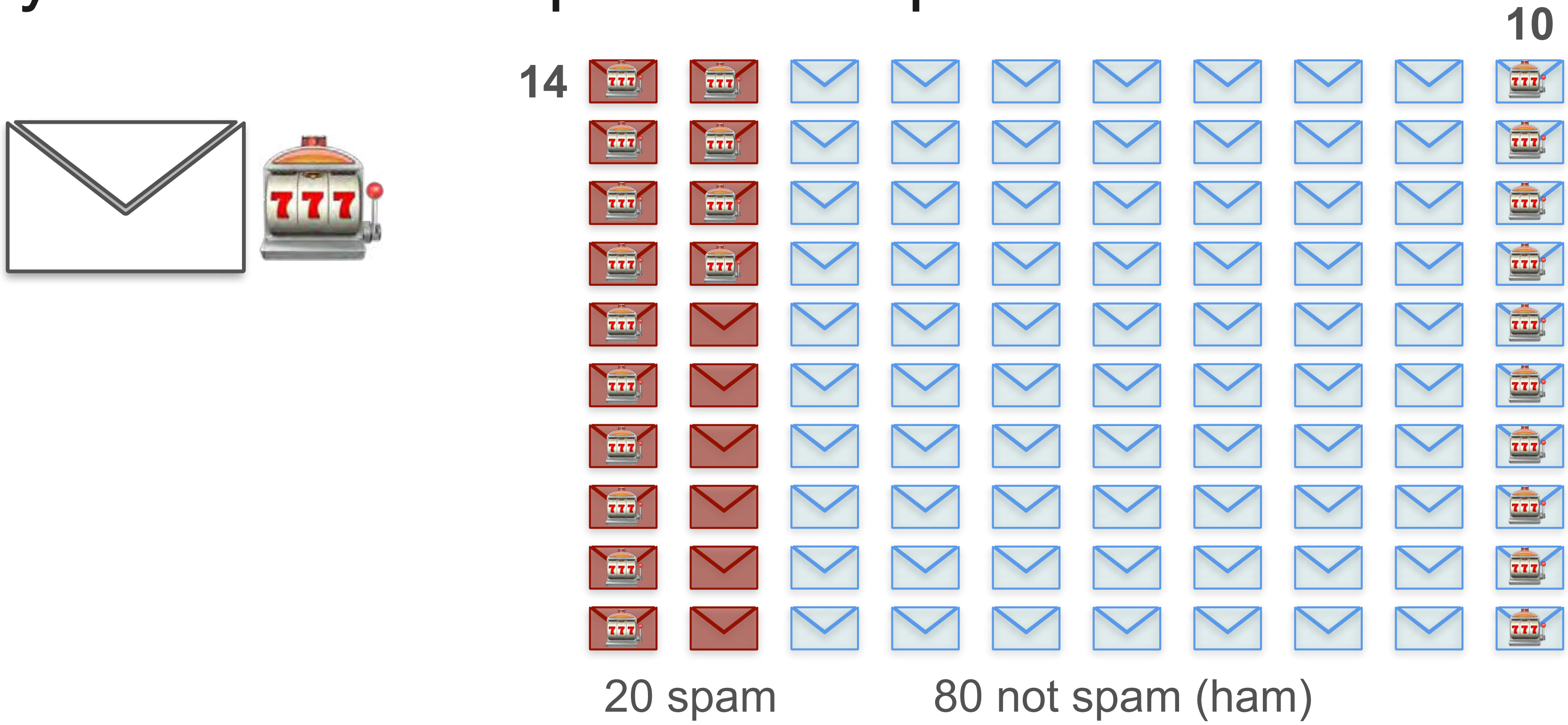

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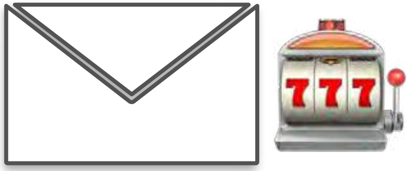
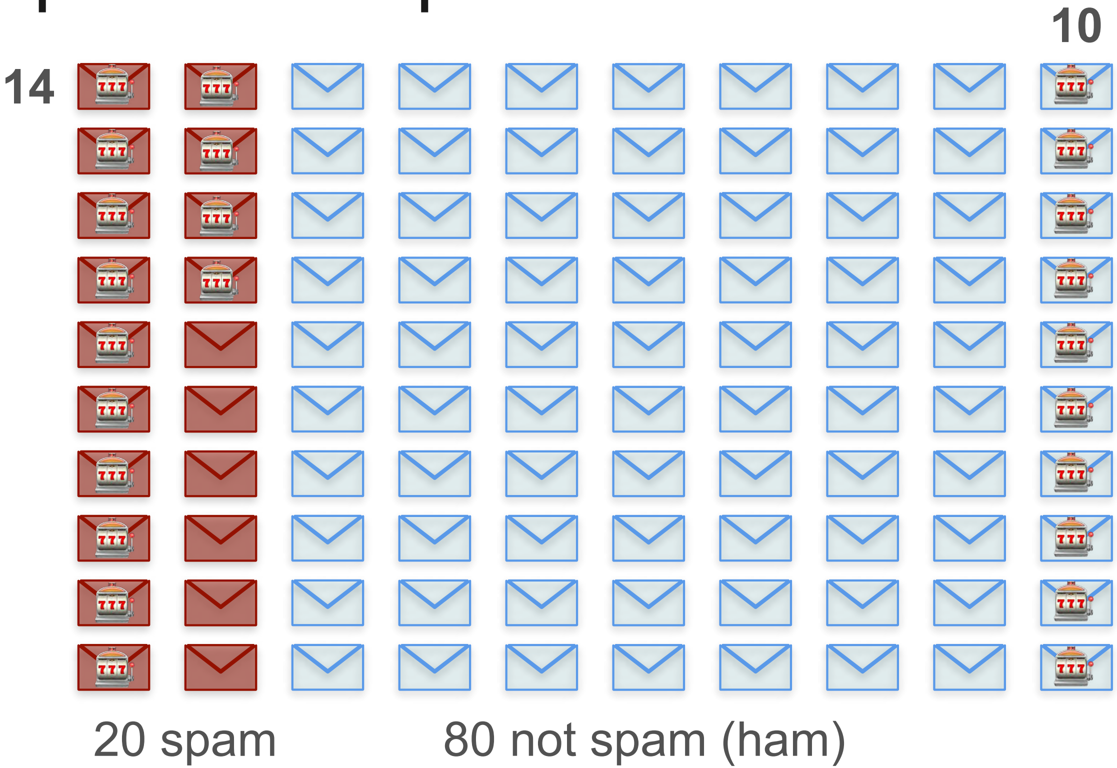


What is the probability that an email containing lottery is a spam?



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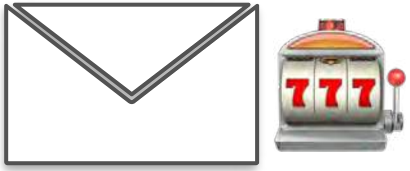
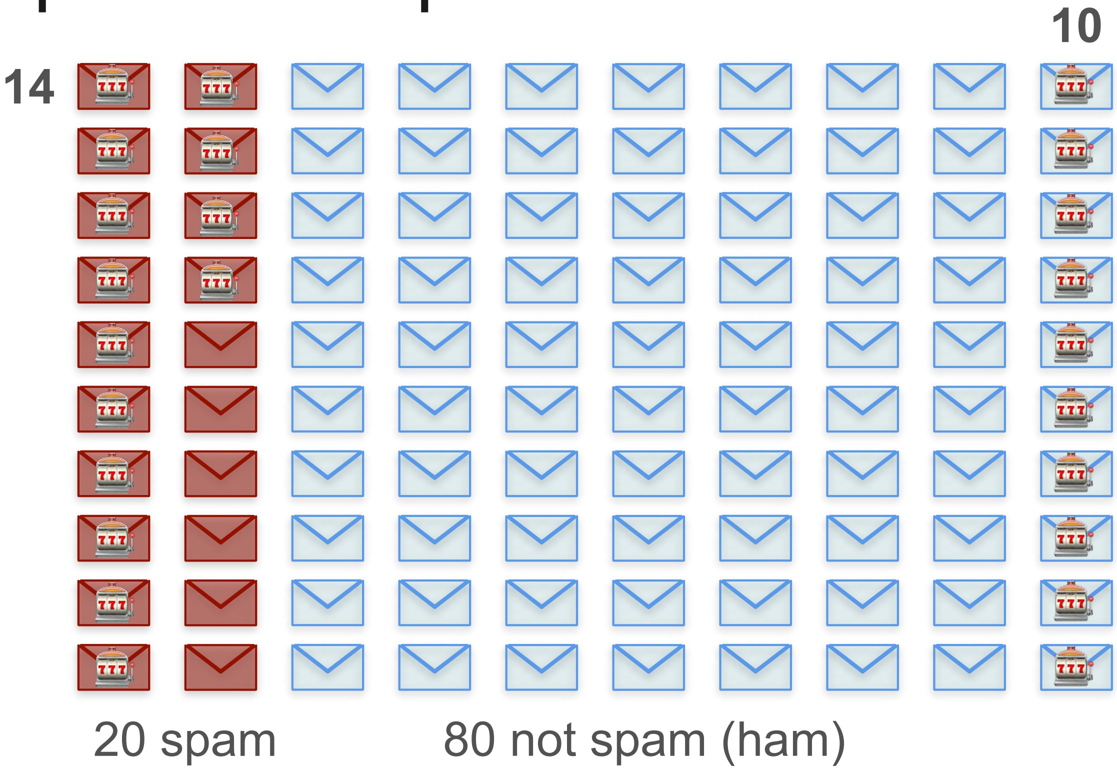
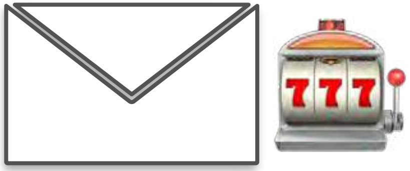


What is the probability that an email containing lottery is a spam?

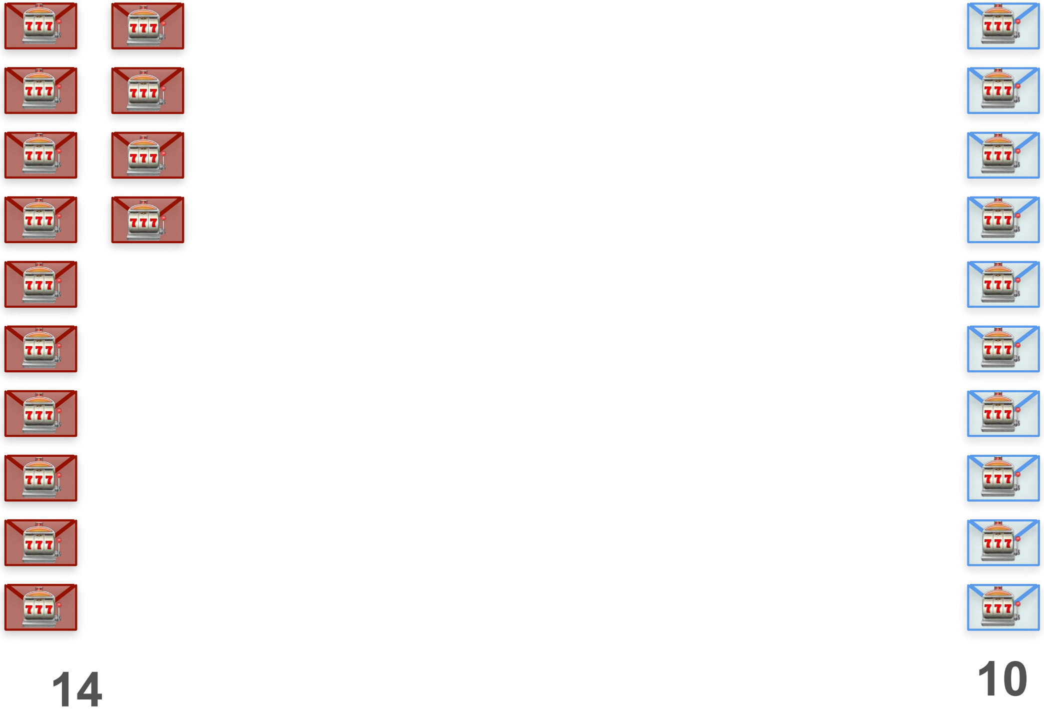
$\mathbf{P}(\text{spam} \mid \text{lottery})$



Bayes Theorem: Spam Example (Intuition Solution)



$\mathbf{P}$(spam | lottery)



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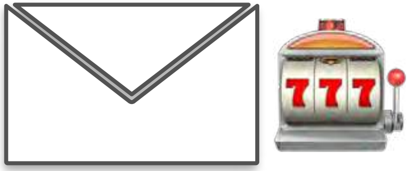

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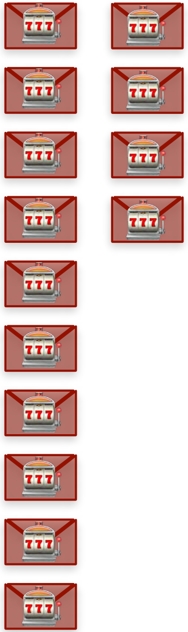

14

24 emails

containing lottery

10

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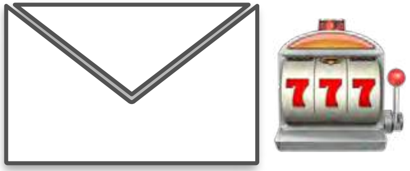

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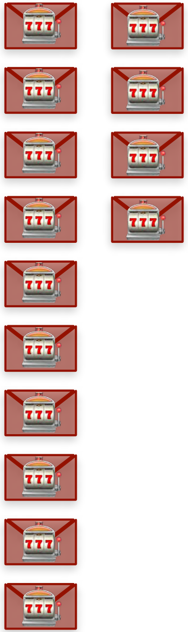

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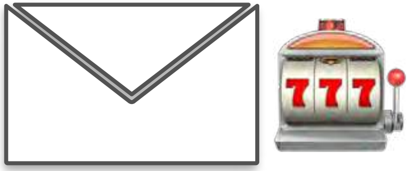

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24 emails

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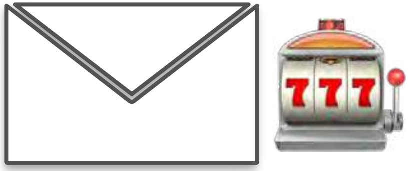

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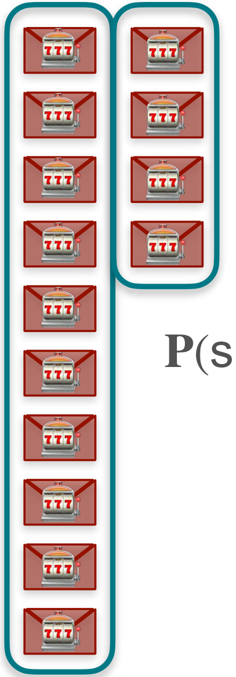

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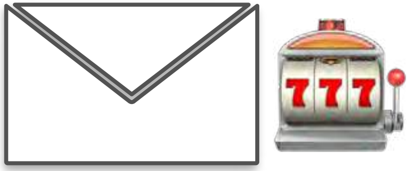

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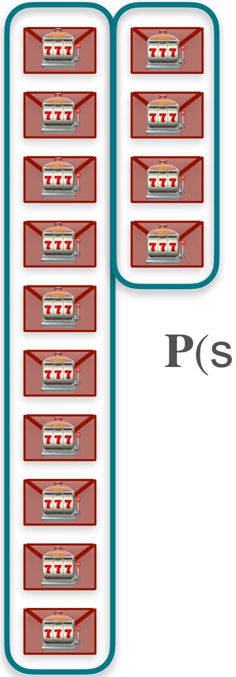

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10

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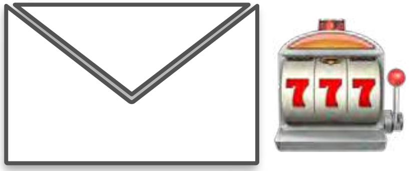

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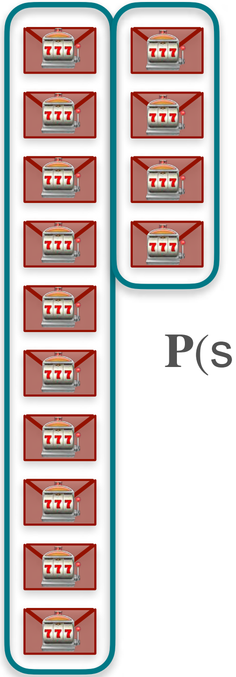

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24 emails

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$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\text{spam and lottery}}{\text{all lottery}}$$

$$= \frac{14}{24}$$

$$= \frac{7}{12} = 0.583$$

10

Bayes Theorem: Spam Example (Formula Solution)

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$$\mathbf{P}(\text{spam} \mid \text{lottery})$$

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A: Email is spam

Bayes Theorem: Spam Example (Formula Solution)

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A: Email is spam B: Email contains lottery

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A: Email is spam $\quad$ B: Email contains lottery

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) + \mathbf{P}(\text{not spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{not spam})}$$

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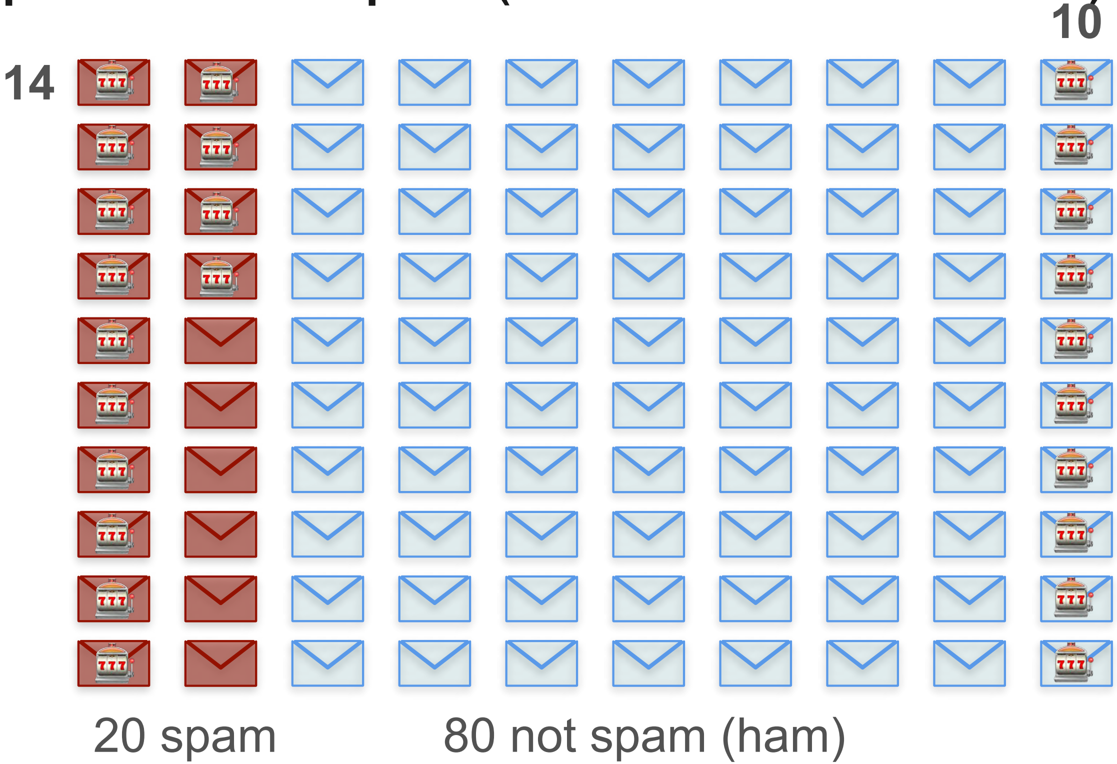

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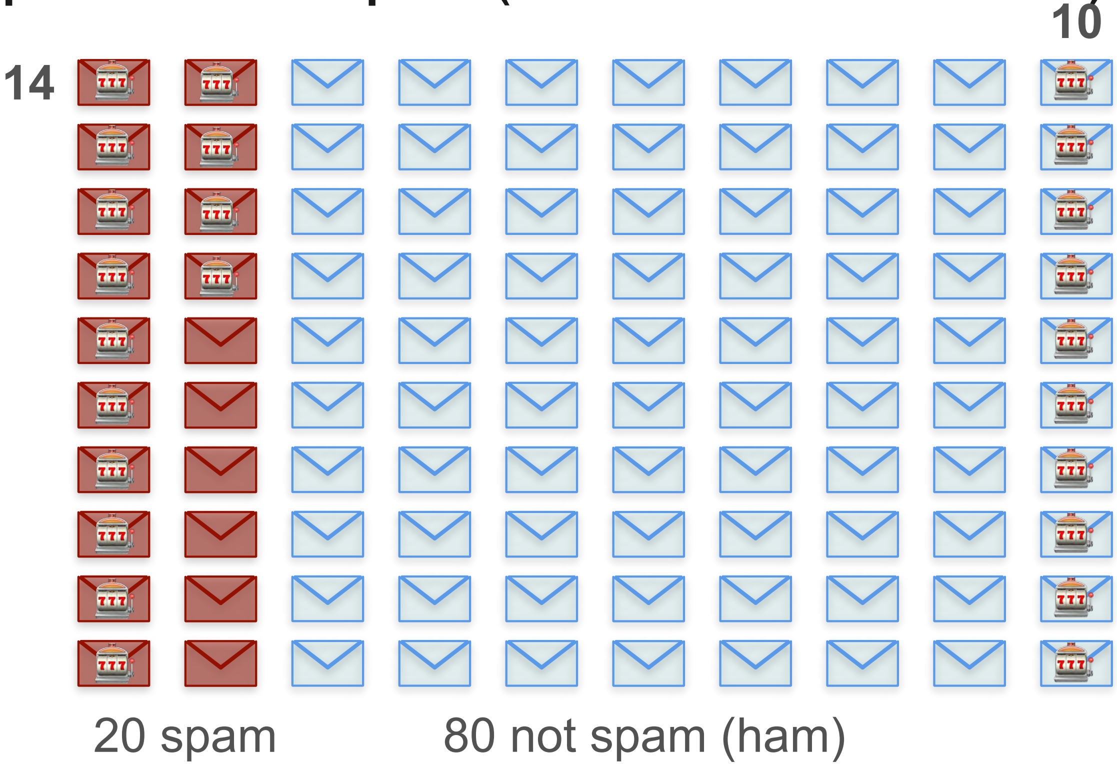
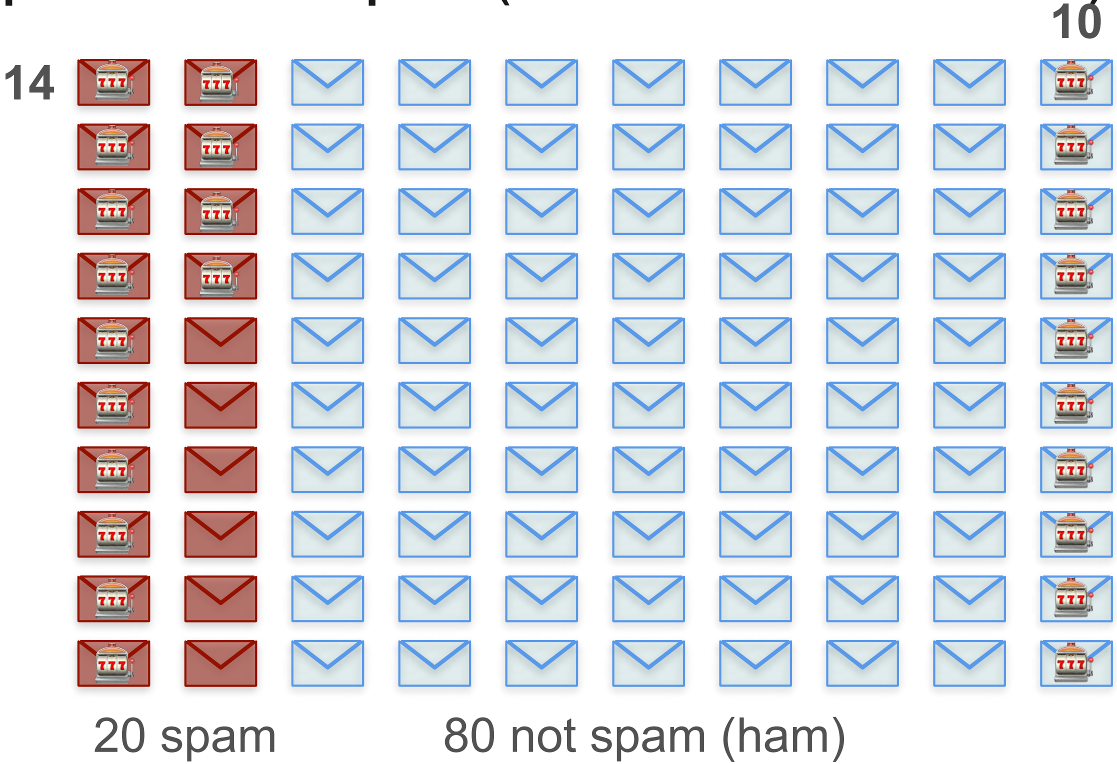
$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$



Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{not spam}) = \frac{80}{100} = 0.8$$

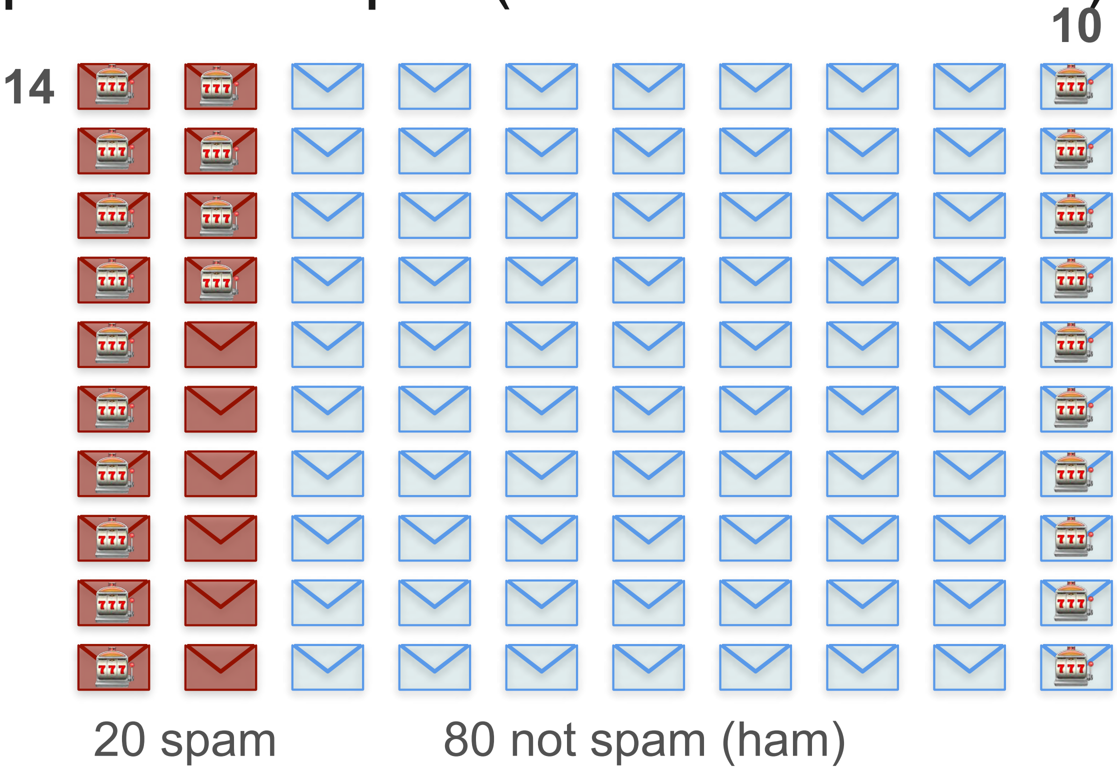


Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{not spam}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{lottery} \mid \text{spam}) = \frac{14}{20} = 0.7$$



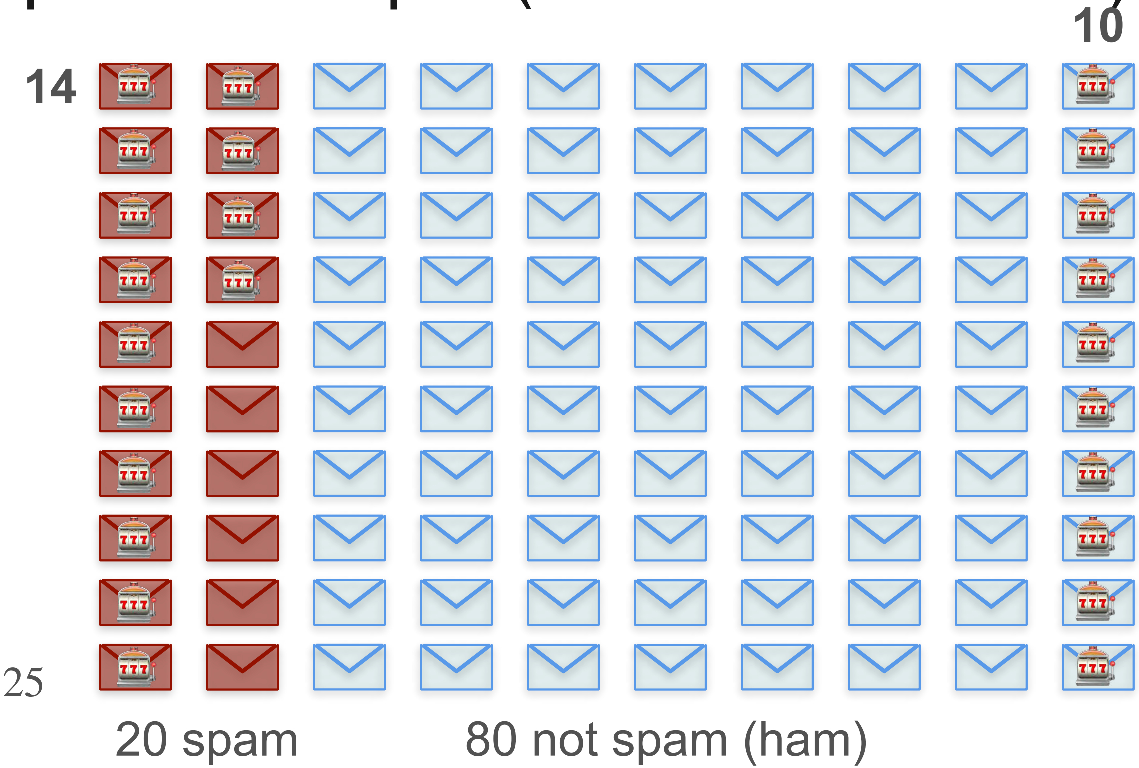
Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{not spam}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{lottery} \mid \text{spam}) = \frac{14}{20} = 0.7$$

$$\mathbf{P}(\text{lottery} \mid \text{not spam}) = \frac{10}{80} = 0.125$$



Bayes Theorem: Spam Example (Formula Solution)

Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = 0.2$$

Bayes Theorem: Spam Example (Formula Solution)

$\mathbf{P}(\text{spam}) = 0.2$ $\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

Bayes Theorem: Spam Example (Formula Solution)

$\mathbf{P}(\text{spam}) = 0.2$

$\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

$\mathbf{P}(\text{not spam}) = 0.8$

Bayes Theorem: Spam Example (Formula Solution)

$\mathbf{P}(\text{spam}) = 0.2$

$\mathbf{P}(\text{not spam}) = 0.8$

$\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

$\mathbf{P}(\text{lottery} \mid \text{not spam}) = 0.125$

Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = 0.2 \qquad \mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$$

$$\mathbf{P}(\text{not spam}) = 0.8 \qquad \mathbf{P}(\text{lottery} \mid \text{not spam}) = 0.125$$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) + \mathbf{P}(\text{not spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{not spam})}$$

Bayes Theorem: Spam Example (Formula Solution)

$$\mathbf{P}(\text{spam}) = 0.2 \qquad \mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$$

$$\mathbf{P}(\text{not spam}) = 0.8 \qquad \mathbf{P}(\text{lottery} \mid \text{not spam}) = 0.125$$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) + \mathbf{P}(\text{not spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{not spam})}$$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{0.2 \times 0.7}{(0.2 \times 0.7) + (0.8 \times 0.125)}$$

Bayes Theorem: Spam Example (Formula Solution)

$\mathbf{P}(\text{spam}) = 0.2$

$\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

$\mathbf{P}(\text{not spam}) = 0.8$

$\mathbf{P}(\text{lottery} \mid \text{not spam}) = 0.125$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) + \mathbf{P}(\text{not spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{not spam})}$$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{0.2 \times 0.7}{(0.2 \times 0.7) + (0.8 \times 0.125)} = 0.583$$

Bayes Theorem

Bayes Theorem

PRIOR

Bayes Theorem

PRIOR

EVENT

Bayes Theorem

PRIOR	EVENT	POSTERIOR

Bayes Theorem

PRIOR | **EVENT** | **POSTERIOR**

$\mathbf{P}(A)$

Bayes Theorem

PRIOR	EVENT	POSTERIOR
$\mathbf{P}(A)$	E	

Bayes Theorem

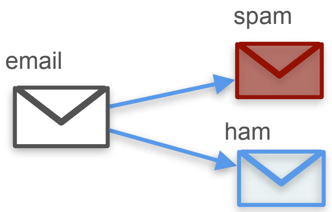
PRIOR	EVENT	POSTERIOR
$\mathbf{P}(A)$	E	$\mathbf{P}(A \mid E)$

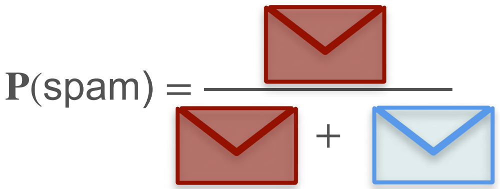
Prior and Posterior

PRIOR EVENT POSTERIOR

Prior and Posterior

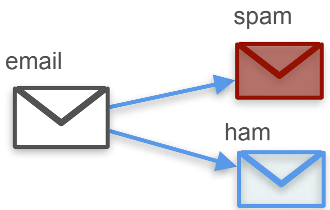
PRIOR | **EVENT** | **POSTERIOR**

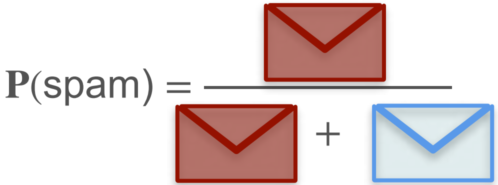




Prior and Posterior

PRIOR





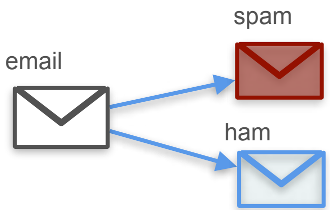
EVENT

Email contains lottery

POSTERIOR

Prior and Posterior

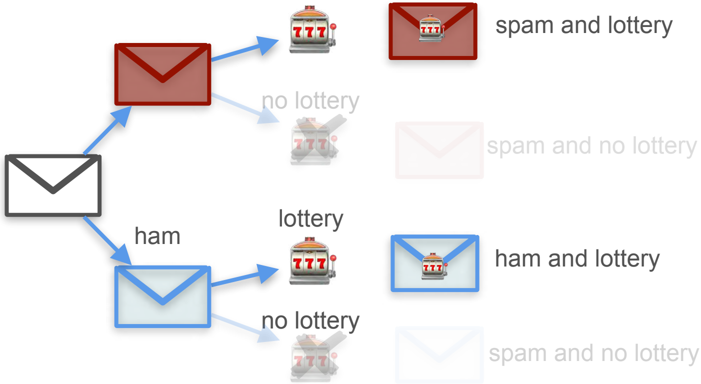
PRIOR



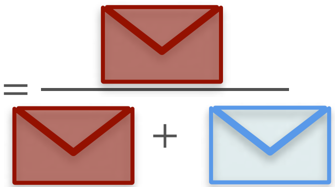
EVENT

Email contains lottery

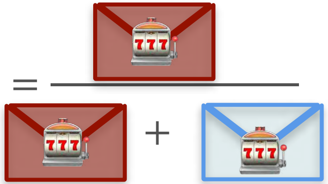
POSTERIOR



$\mathrm{P}(\text{spam}) =$



$\mathrm{P}(\text{spam} \mid \text{lottery}) =$



Prior and Posterior

PRIOR	EVENT	POSTERIOR

Prior and Posterior

PRIOR **EVENT** **POSTERIOR**

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Prior and Posterior

PRIOR | **EVENT** | **POSTERIOR**

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Prior and Posterior

PRIOR **EVENT** **POSTERIOR**

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10) = \frac{3}{36}$$

Prior and Posterior

PRIOR | **EVENT** | **POSTERIOR**

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10) = \frac{3}{36}$$

?

1st dice is 6

Prior and Posterior

PRIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10) = \frac{3}{36}$$

EVENT

?

1st dice is 6

POSTERIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Prior and Posterior

PRIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10) = \frac{3}{36}$$

EVENT

?

1st dice is 6

POSTERIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

Prior and Posterior

PRIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10) = \frac{3}{36}$$

EVENT

?

1st dice is 6

POSTERIOR

1,1	1,2	1,3	1,4	1,5	1,6
2,1	2,2	2,3	2,4	2,5	2,6
3,1	3,2	3,3	3,4	3,5	3,6
4,1	4,2	4,3	4,4	4,5	4,6
5,1	5,2	5,3	5,4	5,5	5,6
6,1	6,2	6,3	6,4	6,5	6,6

$$\mathbf{P}(\text{sum} = 10 \mid \text{1st is 6}) = \frac{1}{6}$$

Prior and Posterior

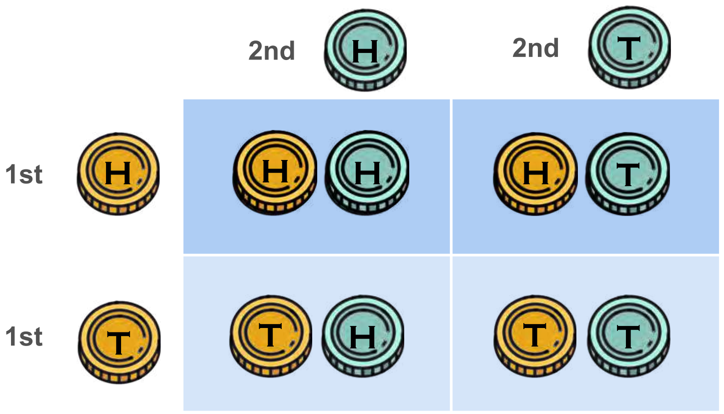
PRIOR

EVENT

POSTERIOR

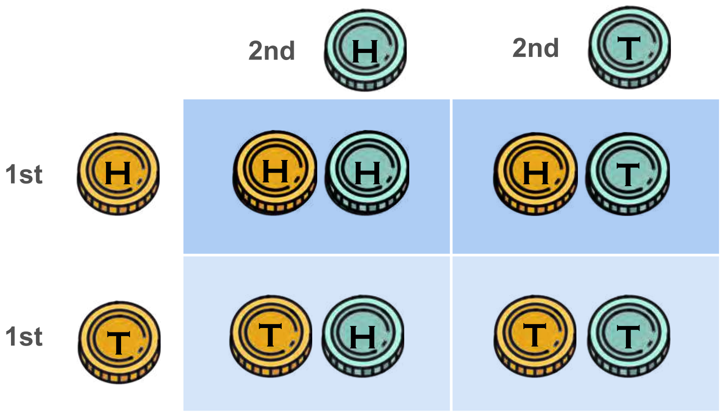
Prior and Posterior

PRIOR EVENT POSTERIOR



Prior and Posterior

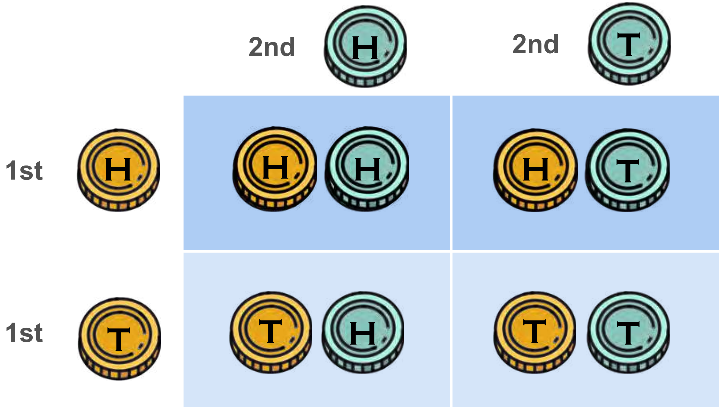
PRIOR **EVENT** **POSTERIOR**



$$\mathbf{P}(HH) = \frac{1}{4}$$

Prior and Posterior

PRIOR | **EVENT** | **POSTERIOR**

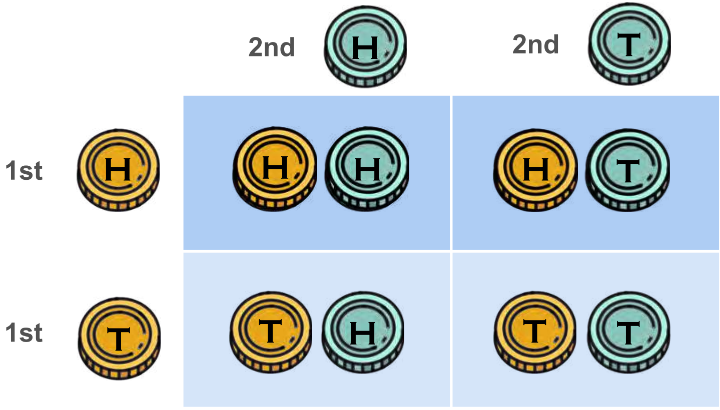


$$\mathbf{P}(HH) = \frac{1}{4}$$

1st coin is H

Prior and Posterior

PRIOR **EVENT** **POSTERIOR**

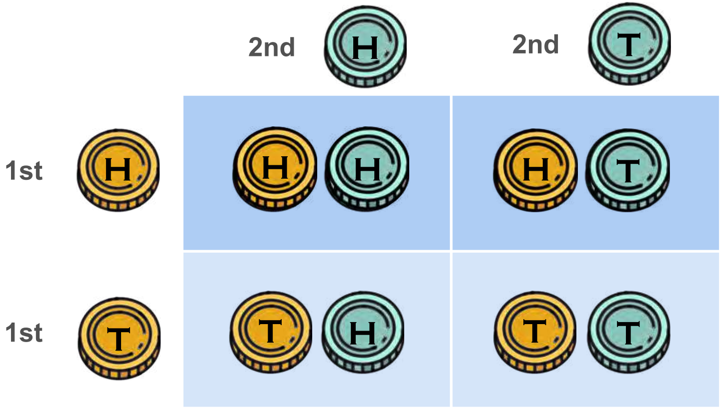


$$\mathbf{P}(HH) = \frac{1}{4}$$

1st coin is H

Prior and Posterior

PRIOR



$$\mathbf{P}(HH) = \frac{1}{4}$$

EVENT

1st coin is H

POSTERIOR

$$\mathbf{P}(HH \mid \text{1st is } H) = \frac{1}{2}$$

Video 8e: the Naive Bayes Model

What About 2 Events?

PRIOR

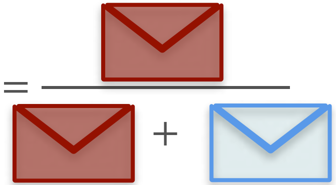
EVENT

POSTERIOR

What About 2 Events?

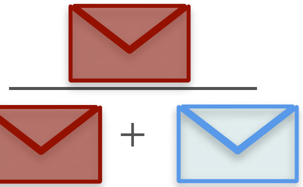
PRIOR **EVENT** **POSTERIOR**

P(spam) =



What About 2 Events?

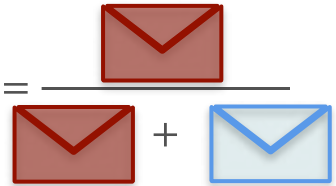
PRIOR | **EVENT** | **POSTERIOR**

P(spam) = 

Email contains ‘lottery’

What About 2 Events?

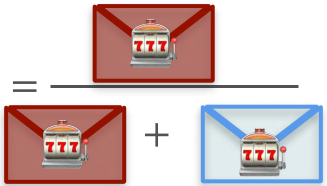
PRIOR

P(spam) = 

EVENT

Email contains ‘lottery’

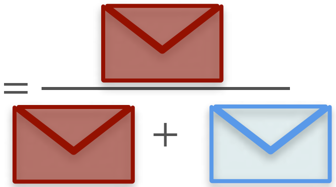
POSTERIOR

P(spam | lottery) = 

What About 2 Events?

PRIOR

$P(\text{spam}) =$



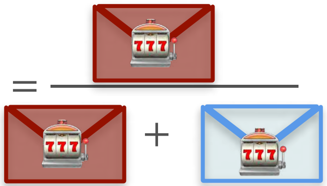
EVENT

Email contains ‘lottery’

Email contains ‘winning'

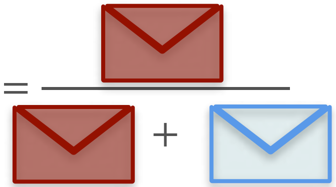
POSTERIOR

$P(\text{spam} \mid \text{lottery}) =$



What About 2 Events?

PRIOR

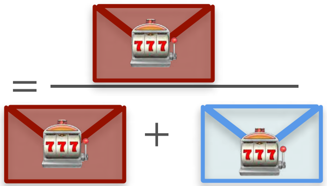
$\mathbf{P}(\text{spam}) =$ 

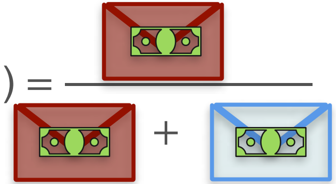
EVENT

Email contains ‘lottery’

Email contains ‘winning'

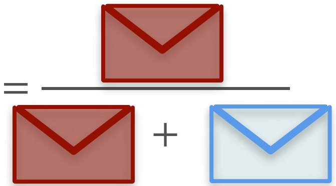
POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery}) =$ 

$\mathbf{P}(\text{spam} \mid \text{winning}) =$ 

What About 2 Events?

PRIOR

$\mathbf{P}(\text{spam}) =$ 

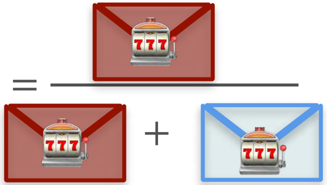
EVENT

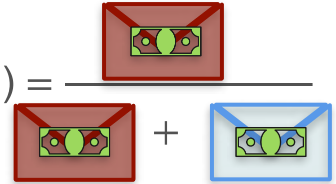
Email contains ‘lottery’

Email contains ‘winning'

Email contains ‘lottery’ and ‘winning’

POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery}) =$ 

$\mathbf{P}(\text{spam} \mid \text{winning}) =$ 

What About 2 Events?

PRIOR

P(spam) =

EVENT

Email contains ‘lottery’

Email contains ‘winning'

Email contains ‘lottery’ and ‘winning’

POSTERIOR

P(spam | lottery) =

P(spam | winning) =

?

What About 2 Events?

EVENT

POSTERIOR

🎰 💵

Email contains ‘lottery’ and ‘winning’

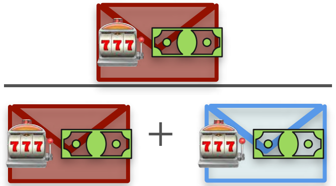
What About 2 Events?

EVENT

Email contains ‘lottery’ and ‘winning’

POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) =$

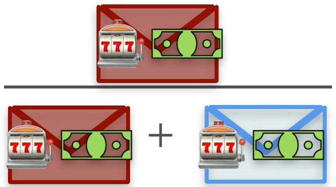


What About 2 Events?

EVENT

Email contains ‘lottery’ and ‘winning’

POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) =$ 

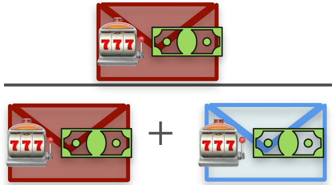
$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

What About 2 Events?

EVENT

Email contains ‘lottery’ and ‘winning’

POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) =$ 

?

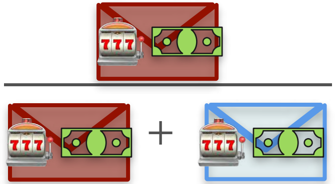
$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

What About 2 Events?

EVENT

Email contains ‘lottery’ and ‘winning’

POSTERIOR

$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) =$ 

$$\frac{\text{\# Spam emails with 'lottery' and 'winning'}}{\text{\# Emails with 'lottery' and 'winning'}}$$

?

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

What About More Than 2 Events?

EVENT	POSTERIOR

What About More Than 2 Events?

EVENT

POSTERIOR

Email contains $w_1, w_2, \ldots, w_{100}$

DeepLearning.AI

What About More Than 2 Events?

EVENT

POSTERIOR

Email contains $w_1, w_2, \ldots, w_{100}$

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_{100}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{ham})}$$

What About More Than 2 Events?

EVENT | **POSTERIOR**

Email contains $w_1, w_2, \ldots, w_{100}$

?

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_{100}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{ham})}$$

What About More Than 2 Events?

EVENT | **POSTERIOR**

Email contains $w_1, w_2, \ldots, w_{100}$

$$\frac{\text{\# Spam emails with } w_1, \ldots, w_{100}}{\text{\# Emails with } w_1, \ldots, w_{100}}$$

?

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_{100}) = \frac{\mathbf{P}(\text{spam})\ \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{ham})}$$

What About More Than 2 Events?

EVENT **POSTERIOR**

Email contains $w_1, w_2, \ldots, w_{100}$

$$\frac{\cancel{\#\text{ Spam emails with } w_1, \ldots, w_{100}}\ 0}{\#\text{ Emails with } w_1, \ldots, w_{100}}$$

?

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_{100}) = \frac{\mathbf{P}(\text{spam})\ \boxed{\mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam})}}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_{100} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

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$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

The appearances of ‘lottery’ and ‘winning’ are independent

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

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$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \overbrace{\mathbf{P}(\text{lottery \& winning} \mid \text{spam})}^{\mathbf{P}(A \cap B)}}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

The appearances of ‘lottery’ and ‘winning’ are independent

$$\mathbf{P}(A \cap B) = \mathbf{P}(A) \cdot \mathbf{P}(B)$$

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery \& winning} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

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$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery} \mid \text{ham}) \cdot \mathbf{P}(\text{winning} \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_n) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{ham})}$$

Is There a Quicker Way To Estimate the Probability?

Naive assumption

The appearances of the words $w_1, w_2, \ldots, w_n$ are independent

$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_n) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1, \ldots, w_n \mid \text{ham})}$$

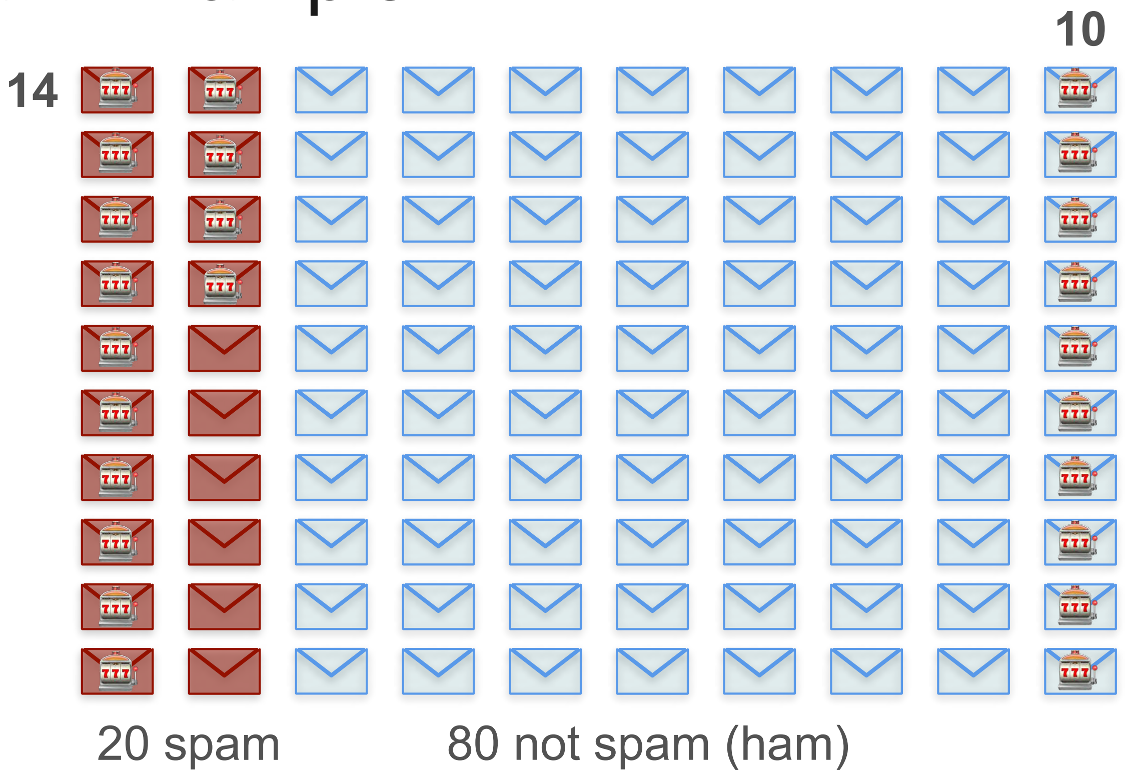
Is There a Quicker Way To Estimate the Probability?

Naive assumption

The appearances of the words $w_1, w_2, \ldots, w_n$ are independent

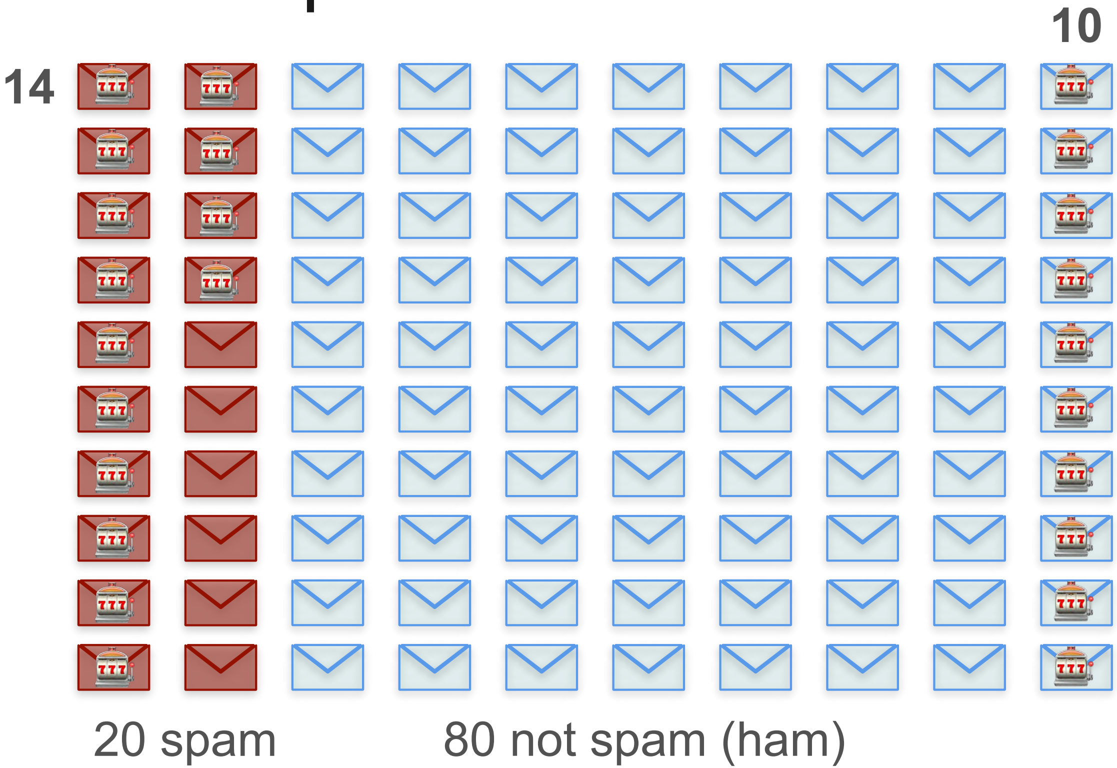
$$\mathbf{P}(\text{spam} \mid w_1, \ldots, w_n) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1 \mid \text{spam}) \cdots \mathbf{P}(w_n \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(w_1 \mid \text{spam}) \cdots \mathbf{P}(w_n \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(w_1 \mid \text{ham}) \cdots \mathbf{P}(w_n \mid \text{ham})}$$

Naive Bayes: Spam Example



Naive Bayes: Spam Example

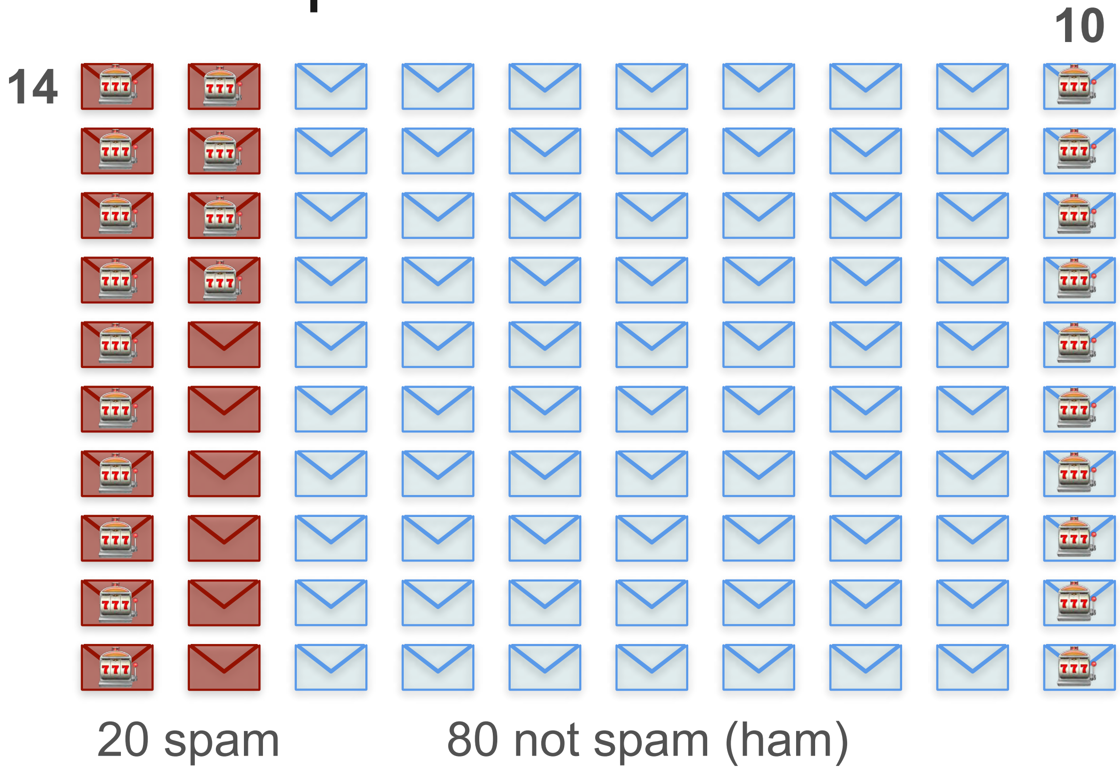
$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$



Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

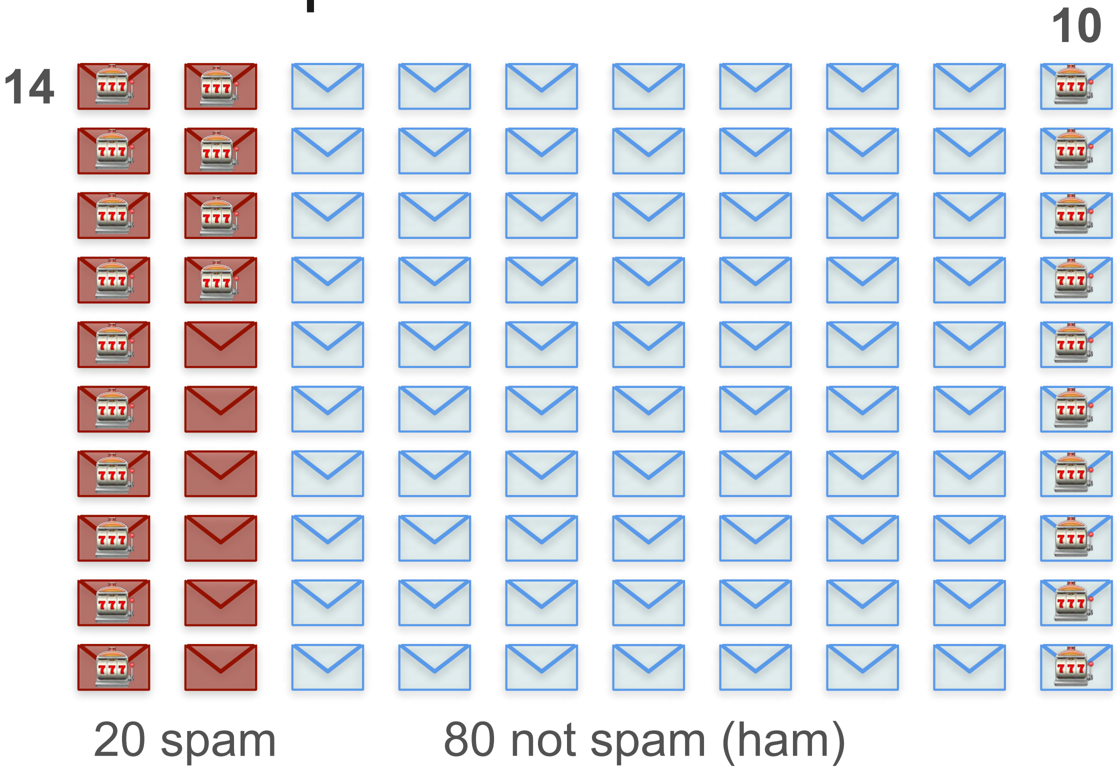


Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{lottery} \mid \text{spam}) = \frac{14}{20} = 0.7$$



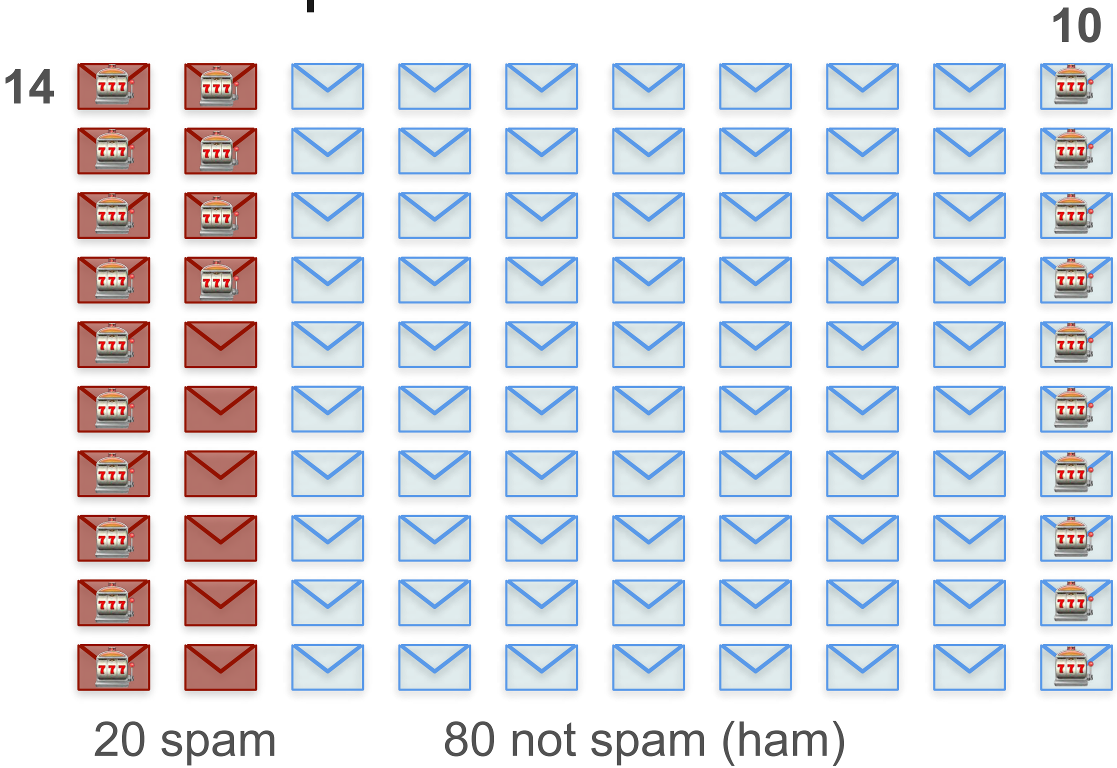
Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{lottery} \mid \text{spam}) = \frac{14}{20} = 0.7$$

$$\mathbf{P}(\text{lottery} \mid \text{ham}) = \frac{10}{80} = 0.125$$



Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

20 spam

80 not spam (ham)

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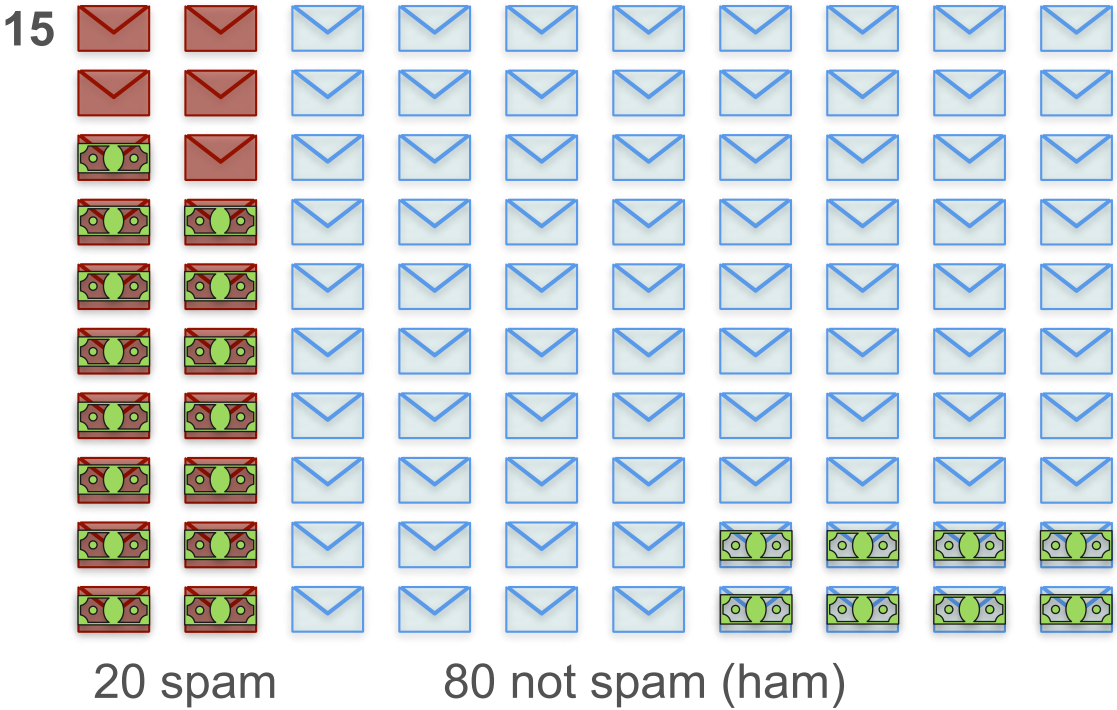
Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

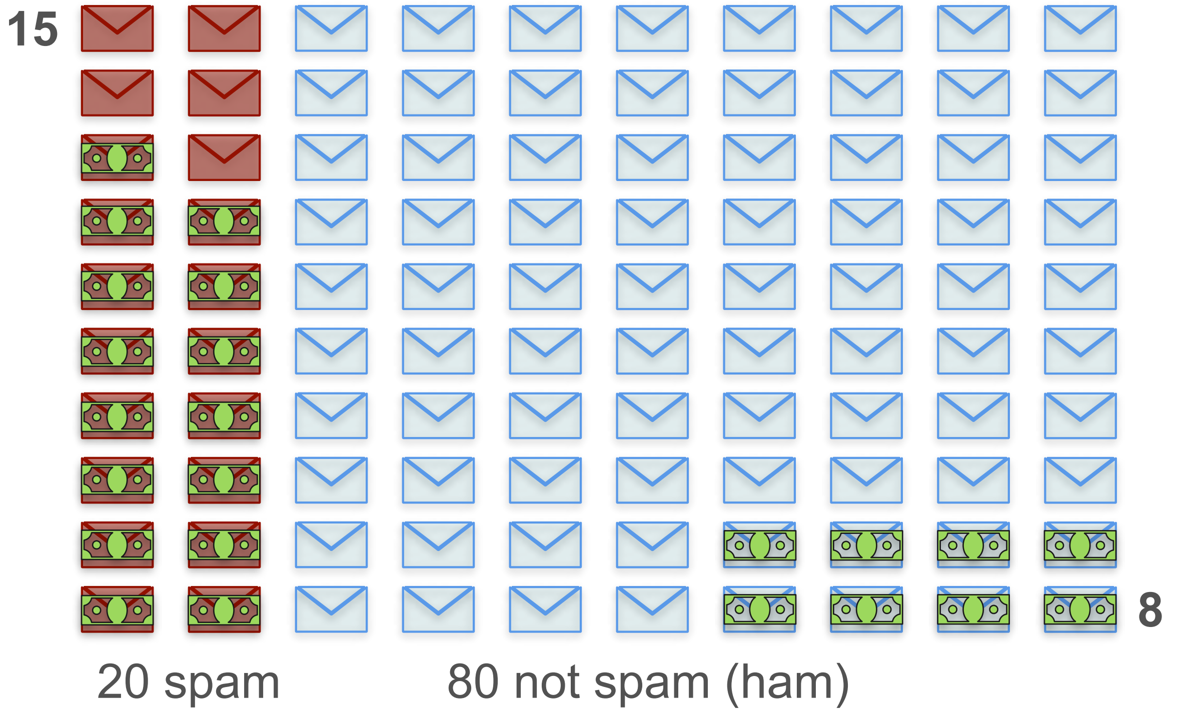
$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$



Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

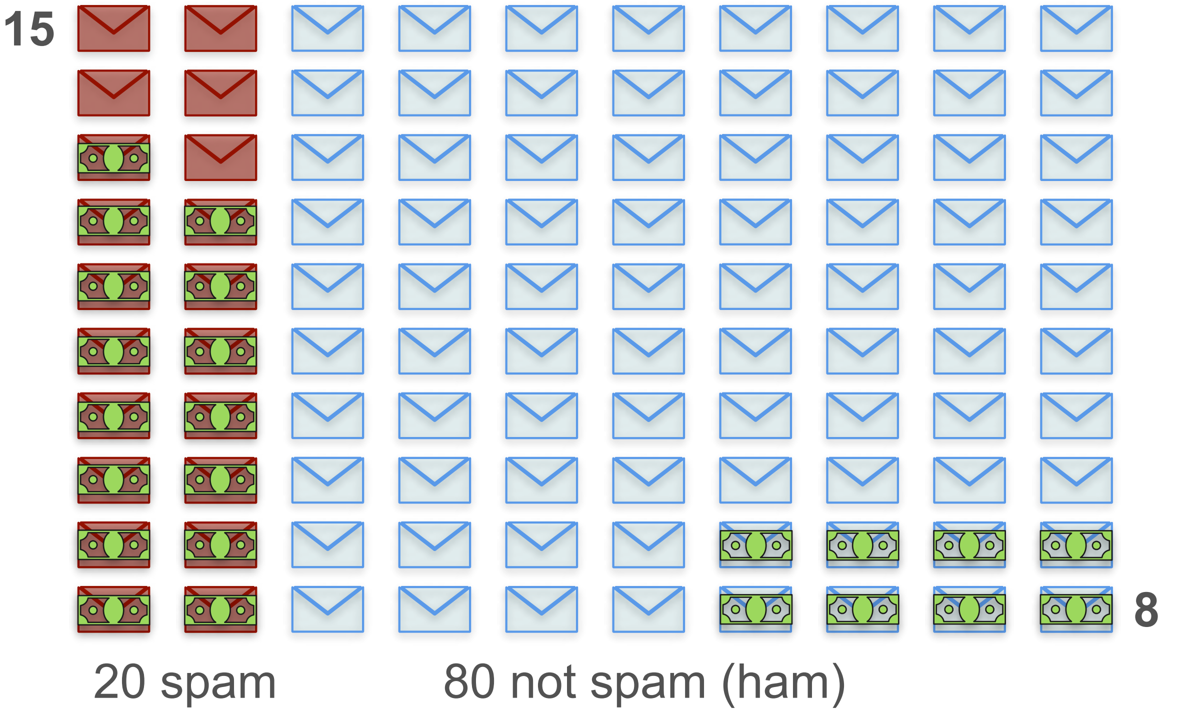


Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{winning} \mid \text{spam}) = \frac{15}{20} = 0.75$$



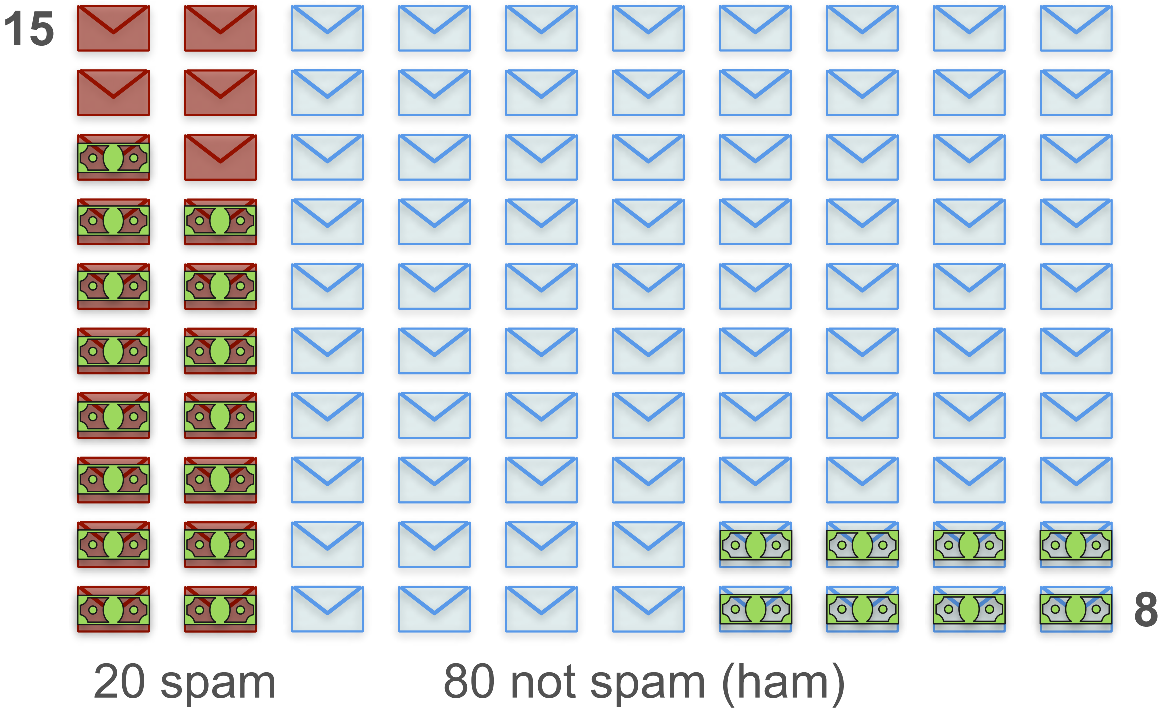
Naive Bayes: Spam Example

$$\mathbf{P}(\text{spam}) = \frac{20}{100} = 0.2$$

$$\mathbf{P}(\text{ham}) = \frac{80}{100} = 0.8$$

$$\mathbf{P}(\text{winning} \mid \text{spam}) = \frac{15}{20} = 0.75$$

$$\mathbf{P}(\text{winning} \mid \text{ham}) = \frac{8}{80} = 0.1$$



Naive Bayes: Spam Example

$\mathbf{P}(\text{spam}) = 0.2$

$\mathbf{P}(\text{not spam}) = 0.8$

$\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

$\mathbf{P}(\text{lottery} \mid \text{ham}) = 0.125$

$\mathbf{P}(\text{winning} \mid \text{spam}) = 0.75$

$\mathbf{P}(\text{winning} \mid \text{ham}) = 0.1$

Naive Bayes: Spam Example

$\mathbf{P}(\text{spam}) = 0.2$ $\quad$ $\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$ $\quad$ $\mathbf{P}(\text{winning} \mid \text{spam}) = 0.75$

$\mathbf{P}(\text{not spam}) = 0.8$ $\quad$ $\mathbf{P}(\text{lottery} \mid \text{ham}) = 0.125$ $\quad$ $\mathbf{P}(\text{winning} \mid \text{ham}) = 0.1$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery} \mid \text{ham}) \cdot \mathbf{P}(\text{winning} \mid \text{ham})}$$

Naive Bayes: Spam Example

$\mathbf{P}(\text{spam}) = 0.2$

$\mathbf{P}(\text{not spam}) = 0.8$

$\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$

$\mathbf{P}(\text{lottery} \mid \text{ham}) = 0.125$

$\mathbf{P}(\text{winning} \mid \text{spam}) = 0.75$

$\mathbf{P}(\text{winning} \mid \text{ham}) = 0.1$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery} \mid \text{ham}) \cdot \mathbf{P}(\text{winning} \mid \text{ham})}$$

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{0.2 \times 0.7 \times 0.75}{(0.2 \times 0.7 \times 0.75) + (0.8 \times 0.125 \times 0.1)}$$

Naive Bayes: Spam Example

$\mathbf{P}(\text{spam}) = 0.2$ $\mathbf{P}(\text{lottery} \mid \text{spam}) = 0.7$ $\mathbf{P}(\text{winning} \mid \text{spam}) = 0.75$

$\mathbf{P}(\text{not spam}) = 0.8$ $\mathbf{P}(\text{lottery} \mid \text{ham}) = 0.125$ $\mathbf{P}(\text{winning} \mid \text{ham}) = 0.1$

$$\mathbf{P}(\text{spam} \mid \text{lottery}) = \frac{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam})}{\mathbf{P}(\text{spam}) \cdot \mathbf{P}(\text{lottery} \mid \text{spam}) \cdot \mathbf{P}(\text{winning} \mid \text{spam}) + \mathbf{P}(\text{ham}) \cdot \mathbf{P}(\text{lottery} \mid \text{ham}) \cdot \mathbf{P}(\text{winning} \mid \text{ham})}$$

$$\mathbf{P}(\text{spam} \mid \text{lottery \& winning}) = \frac{0.2 \times 0.7 \times 0.75}{(0.2 \times 0.7 \times 0.75) + (0.8 \times 0.125 \times 0.1)} = 0.913$$

DeepLearning.AI

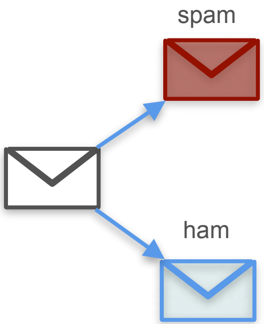
Introduction to probability

Probability in Machine Learning

Bayes Theorem

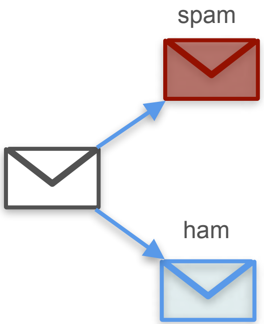
Bayes Theorem

PRIOR

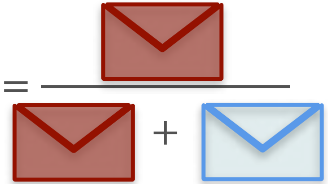


Bayes Theorem

PRIOR

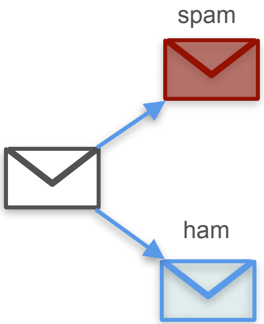


$P(\text{spam}) =$

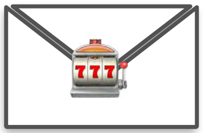


Bayes Theorem

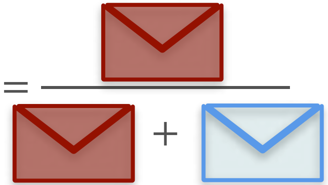
PRIOR



EVENT

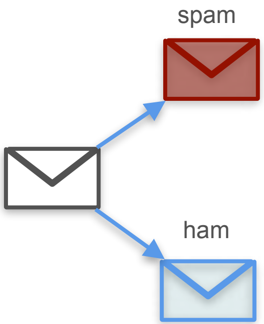


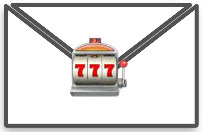
P(spam) =

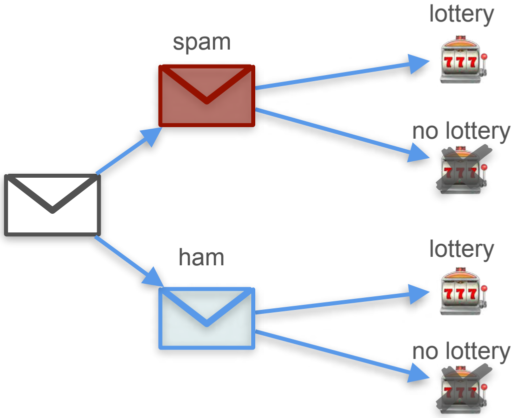


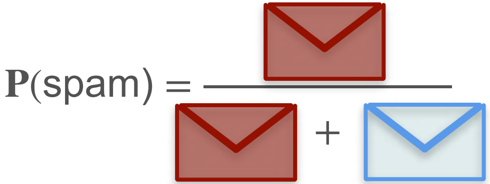
Bayes Theorem

PRIOR | **EVENT** | **POSTERIOR**



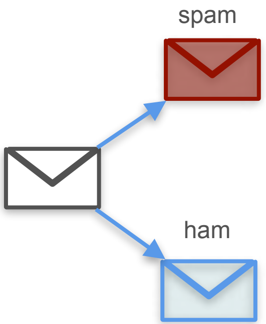






Bayes Theorem

PRIOR



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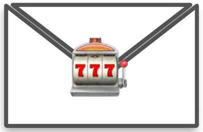

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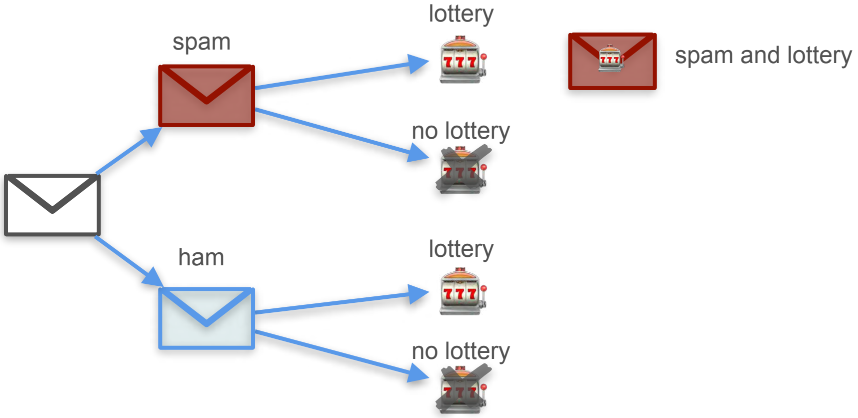
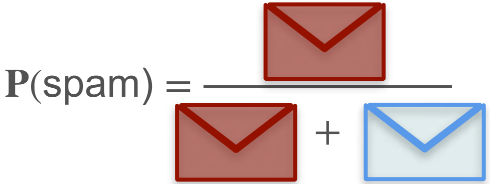
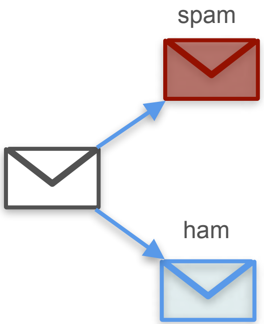




Bayes Theorem

PRIOR



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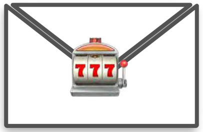

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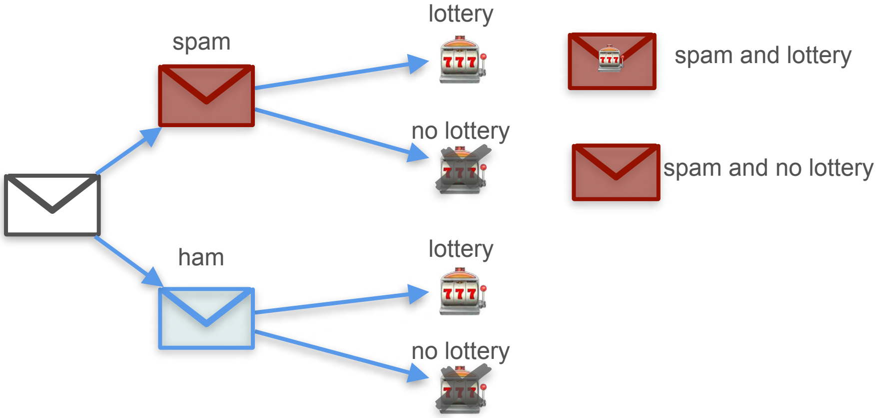
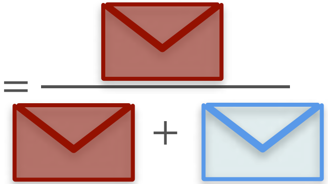
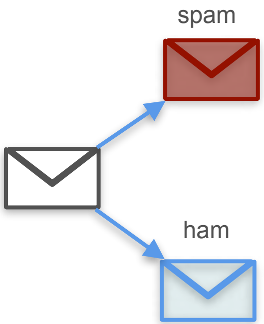


P(spam) =



Bayes Theorem

PRIOR



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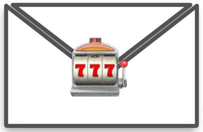

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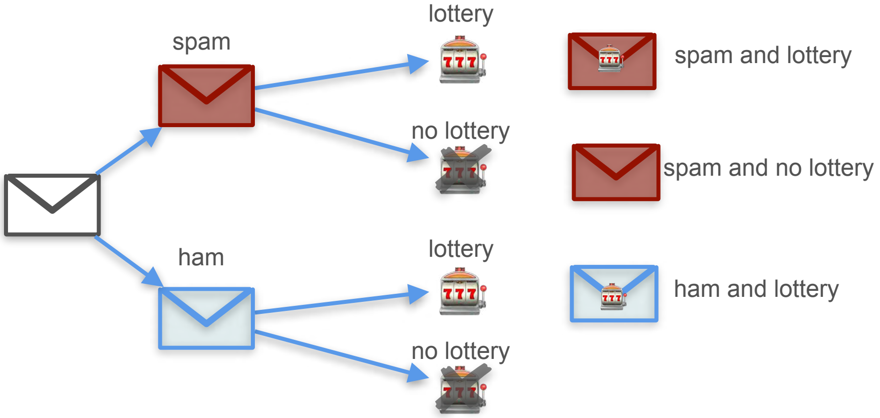
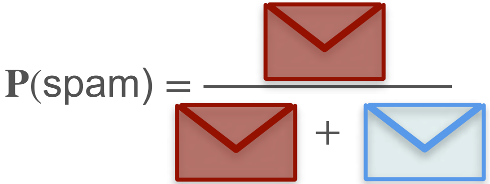
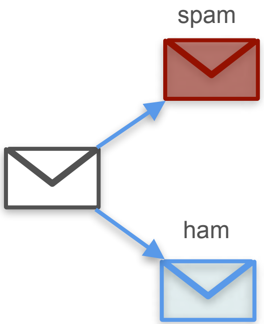




Bayes Theorem

PRIOR



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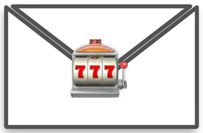
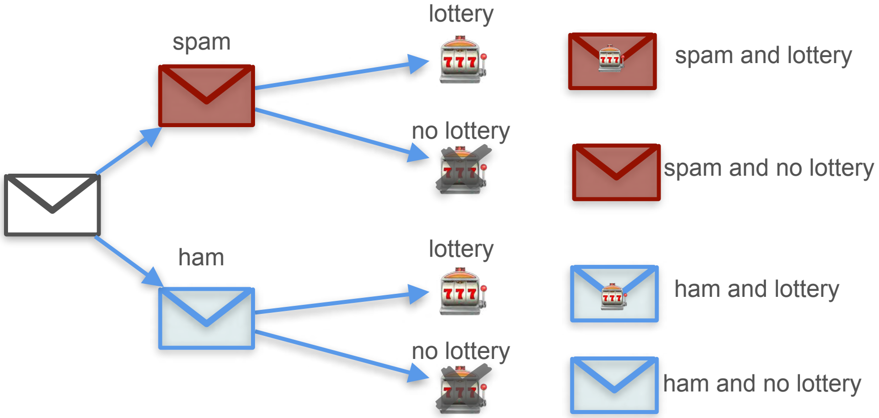
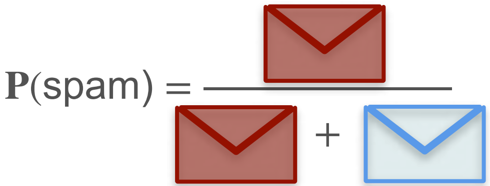


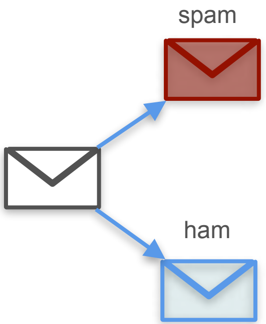
POSTERIOR



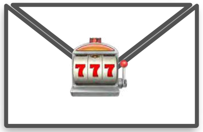


Bayes Theorem

PRIOR



EVENT



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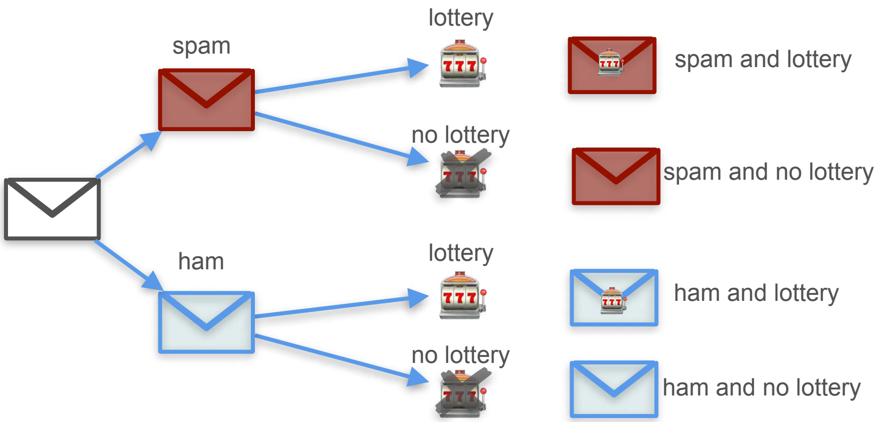
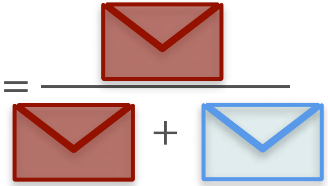


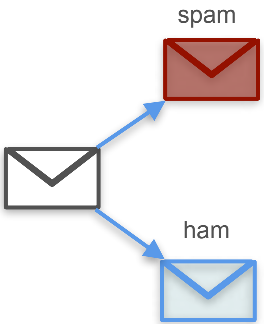
$\mathbf{P}(\text{spam}) =$

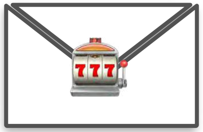


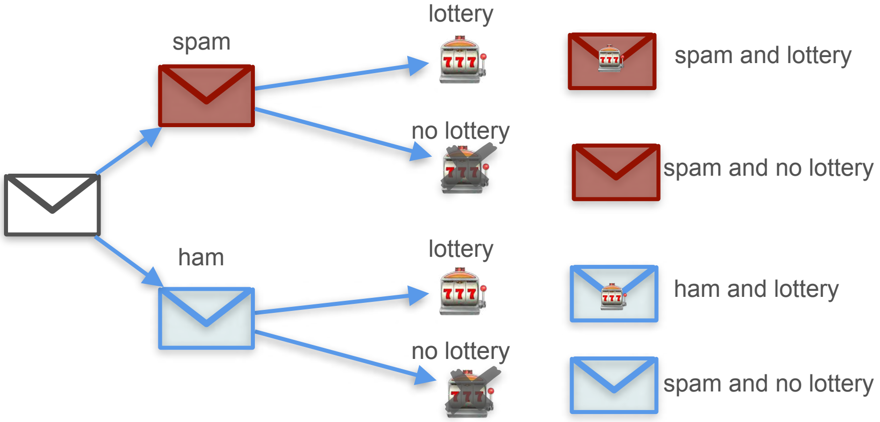
$\mathbf{P}(\text{spam} \mid \text{lottery}) =$

Bayes Theorem

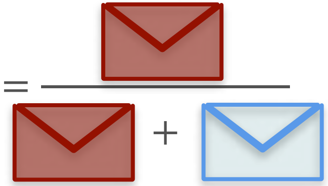
PRIOR **EVENT**







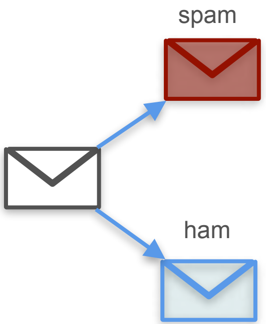
P(spam) =



P(spam | lottery) =

Bayes Theorem

PRIOR



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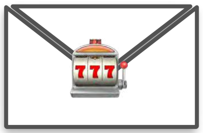
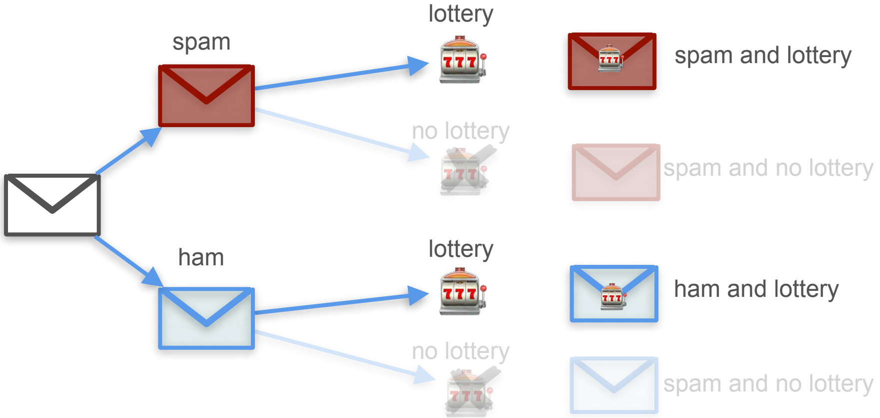
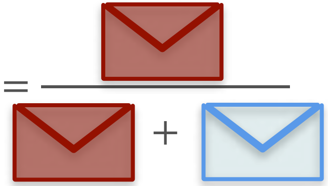


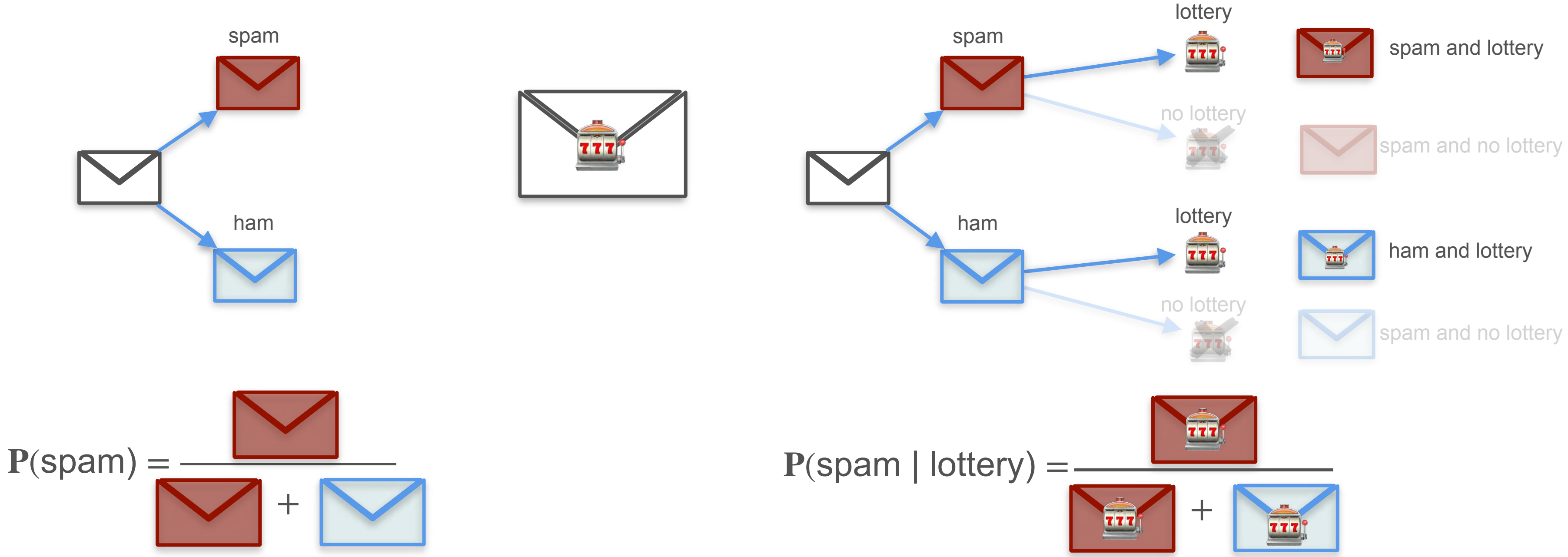


$\mathbf{P}(\text{spam}) =$ 

$\mathbf{P}(\text{spam} \mid \text{lottery}) =$

Bayes Theorem

PRIOR **EVENT** **POSTERIOR**



Example Problem

Example Problem

Image recognition

Example Problem

Image recognition

- What is the probability that there is a cat in the image

Example Problem

Image recognition

- What is the probability that there is a cat in the image
- $\mathbf{P}(\text{cat} \mid \text{image}) = \mathbf{P}(\text{cat} \mid \text{pixel}_1, \text{pixel}_2, \ldots, \text{pixel}_n)$