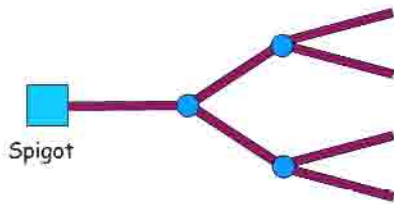


### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



ERASE



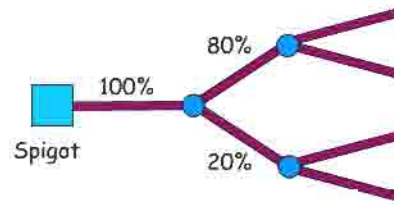
1



Lecture 11

### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Make sure that you have adjusted the first junction box so that 80% of the water goes to the "upper" line and 20% to the lower.

ERASE

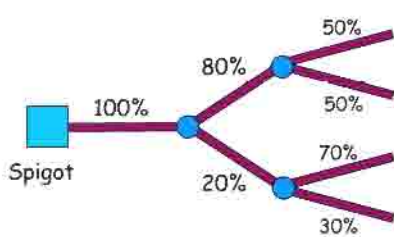


2



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Adjust the other junction boxes as shown. And, turn on the water.

ERASE

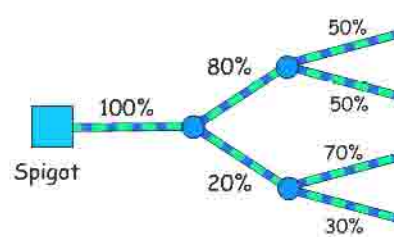


3



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



ERASE

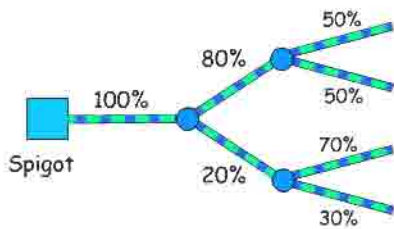


4



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Question: How much water comes out right here:

ERASE

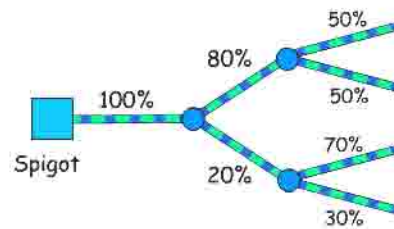


5



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Answer: 70% of 20%

ERASE

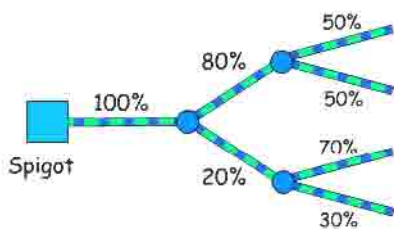


6



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Answer: 70% of 20%  
 $.7 \times .2 = .14$   
14%

ERASE

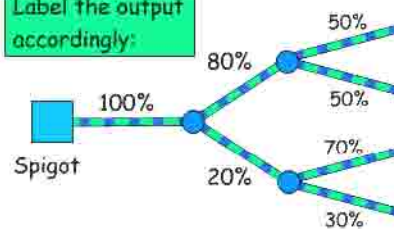


7



### CONDITIONAL PROBABILITY AND TREES:

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



$.7 \times .2 = .14$  14%

ERASE

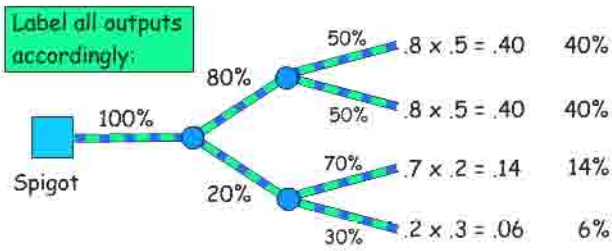


8



## CONDITIONAL PROBABILITY AND TREES:

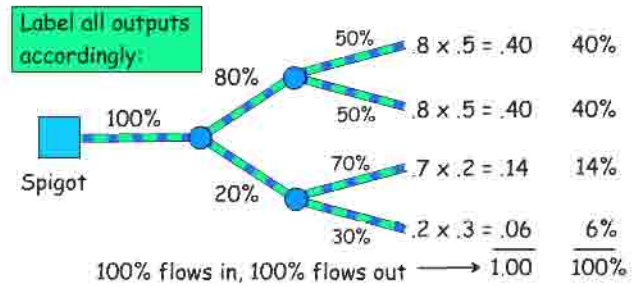
HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



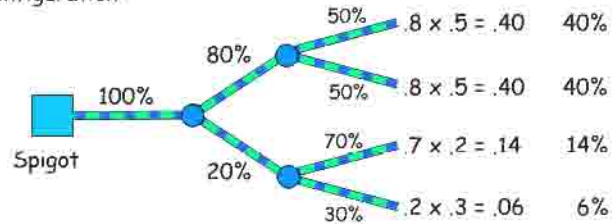
Lecture 11

## CONDITIONAL PROBABILITY AND TREES:

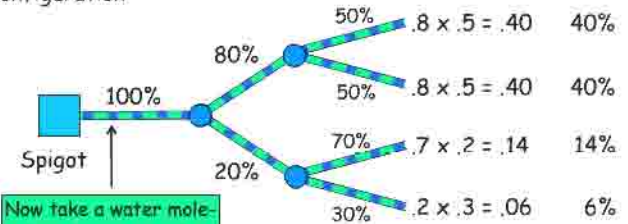
HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



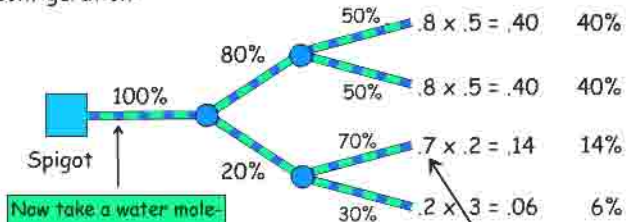
HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:

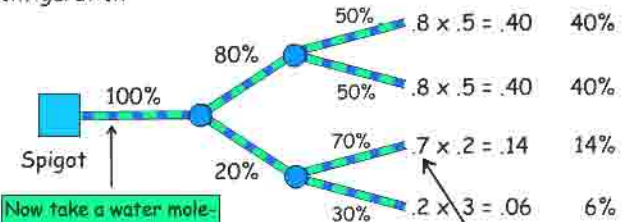


HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



QUESTION: What is the probability that it came out right here?

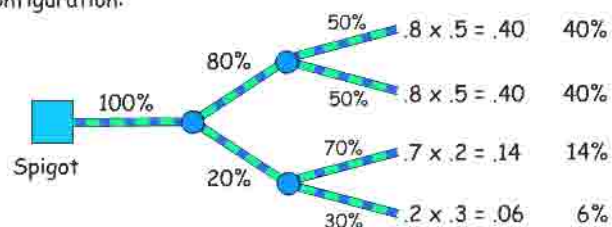
HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



QUESTION: What is the probability that it came out right here?

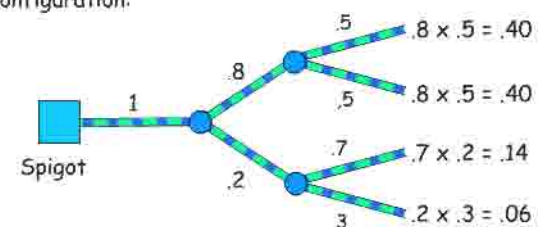
ANSWER: .14 (14% of H<sub>2</sub>O exits here)

HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



Percentages translate directly into probabilities:

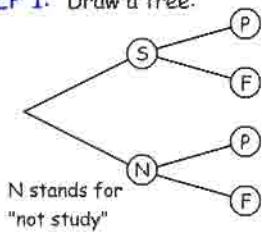
HOME PROJECT: Go out to your front yard and cut up your garden hose, and tape it and glue it together in the following configuration:



If the route of a particle is determined probabilistically as indicated above, then the numbers at the right indicate the probabilities for the outcome at the given locations.

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?

**STEP 1:** Draw a tree:



N stands for "not study"

ERASE



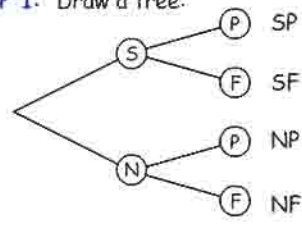
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Lecture 11

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?

**STEP 1:** Draw a tree:



Officially, these are the outcomes. We'll never mention them again using this notation.

ERASE

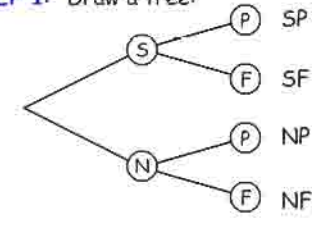


18



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?

**STEP 1:** Draw a tree:



Officially, these are the outcomes. We'll never mention them again using this notation. However, S will be used to denote {SP, SF} an event in the sample space (i.e anything with an S in it).

ERASE

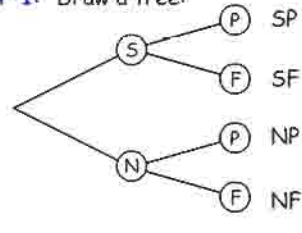


19



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?

**STEP 1:** Draw a tree:



Likewise, F will denote {SF, NF}. It represents the event that he failed. So the notation makes sense. There is also the event N, the event that he does not study.

ERASE



20



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?  $Pr[P] = ?$

The problem asks, what is  $Pr[P]$ ?

ERASE

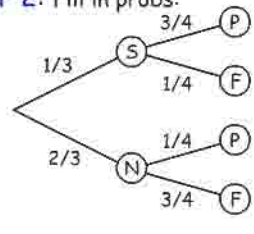


21



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?  $Pr[P] = ?$

**STEP 2:** Fill in probs:



ERASE

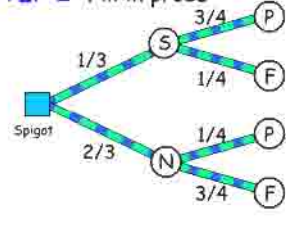


22



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?  $Pr[P] = ?$

**STEP 2:** Fill in probs:



At this point you could build a garden hose model of this. A red molecule released at the spigot would follow these probs. The probability that it would come out here would be the same as the probability that Clyde would not study and would pass.

ERASE

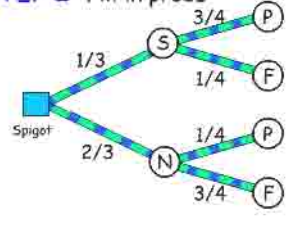


23



**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is his probability of passing?  $Pr[P] = ?$

**STEP 2:** Fill in probs:



Clyde's life is pretty much modeled by this red water molecule. There is a 1/3 chance the water molecule will reach S, and there is a 1/3 chance Clyde will study. If the molecule makes it to S, there is a 3/4 it will make it to P, and if Clyde studies there is a 3/4 he will pass. The garden hose model should work.

ERASE

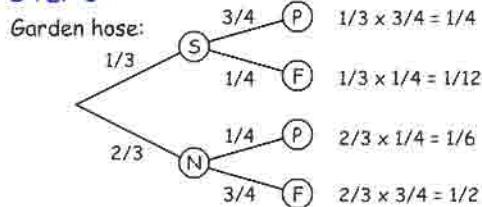


24



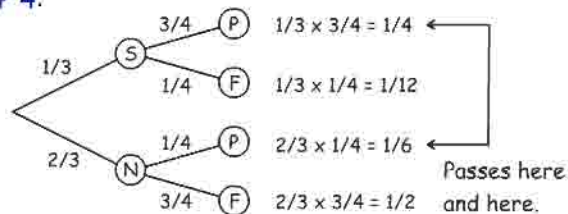
**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[P] = ?$

**STEP 3:**



**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[P] = ?$

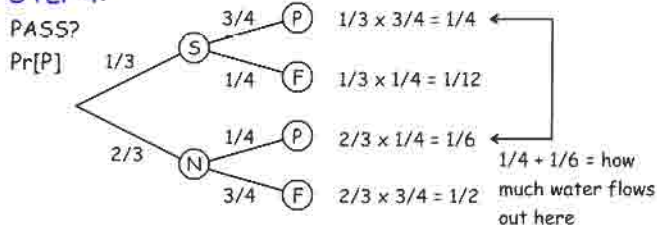
**STEP 4:**



Lecture 11

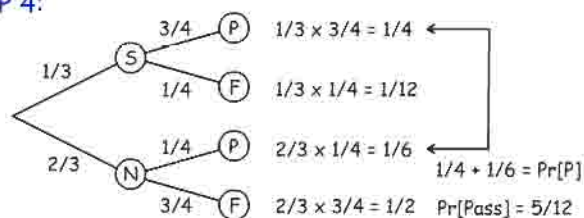
**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[P] = ?$

**STEP 4:**



**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[P] = ?$

**STEP 4:**



**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[P] = ?$

	P	S	$S \cap P$
$1/3 \times 3/4 = 1/4$	X		
$1/3 \times 1/4 = 1/12$			
$2/3 \times 1/4 = 1/6$	X		
$2/3 \times 3/4 = 1/2$			
<b>5/12</b>			

**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[S \cap P] = ?$

**STUDY & PASS?**

	P	S	$S \cap P$
$1/3 \times 3/4 = 1/4$	X		
$1/3 \times 1/4 = 1/12$			
$2/3 \times 1/4 = 1/6$	X		
$2/3 \times 3/4 = 1/2$			
<b>5/12</b>			

**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[S \cap P] = ?$

**STUDY & PASS?**

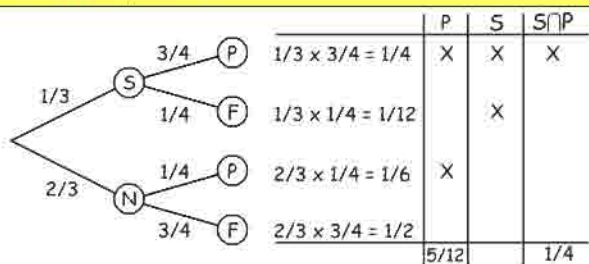
	P	S	$S \cap P$
$1/3 \times 3/4 = 1/4$	X	X	X
$1/3 \times 1/4 = 1/12$		X	
$2/3 \times 1/4 = 1/6$	X		
$2/3 \times 3/4 = 1/2$			
<b>5/12</b>			

**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is his probability of passing?  $\Pr[S \cap P] = ?$

**STUDY & PASS?**

	P	S	$S \cap P$
$1/3 \times 3/4 = 1/4$	X	X	X
$1/3 \times 1/4 = 1/12$		X	
$2/3 \times 1/4 = 1/6$	X		
$2/3 \times 3/4 = 1/2$			
<b>5/12</b>			<b>1/4</b>

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?



ERASE

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Lecture 11

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?

**COMMENT:** This is a conditional probability problem. You are being given additional information.

Given that he passed, what is the probability that he studied?

ERASE

34

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?

**COMMENT:** This is a conditional probability problem. You are being given additional information.

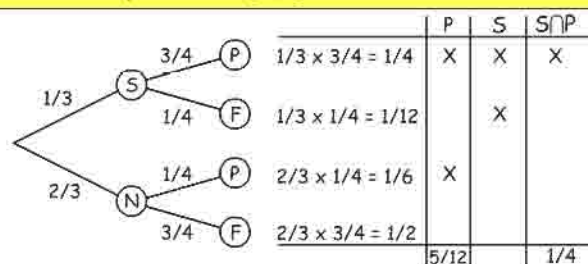
Given that he passed, what is the probability that he studied?

$Pr[S|P] = ?$

ERASE

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**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $Pr[S|P] = ?$



ERASE

36

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $Pr[S|P] = ?$

$Pr[S|P] = \frac{Pr[S \cap P]}{Pr[P]}$

	P	S	S∩P
1/3 × 3/4 = 1/4	X	X	X
1/3 × 1/4 = 1/12		X	
2/3 × 1/4 = 1/6	X		
2/3 × 3/4 = 1/2			
5/12			1/4

ERASE

37

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $Pr[S|P] = ?$

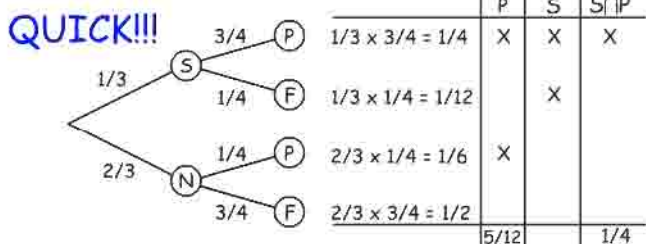
$Pr[S|P] = \frac{Pr[S \cap P]}{Pr[P]} = \frac{1/4}{5/12} = 3/5$

	P	S	S∩P
1/3 × 3/4 = 1/4	X	X	X
1/3 × 1/4 = 1/12		X	
2/3 × 1/4 = 1/6	X		
2/3 × 3/4 = 1/2			
5/12			1/4

ERASE

38

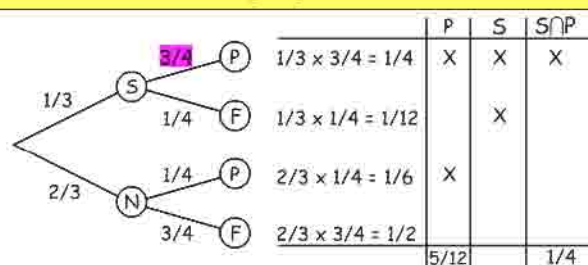
**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he passed **IF** he studied?  $Pr[P|S] = ?$



ERASE

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**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he passed **IF** he studied?  $Pr[P|S] = 3/4$



ERASE

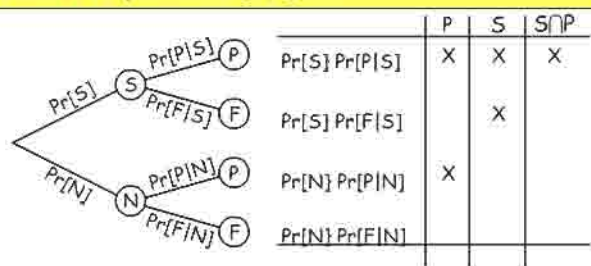
40

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed? GO BACK TO EARLIER PROBLEM

Return to:  $\Pr[S|P] = ?$

Now we'll look at the problem using symbols rather than numbers.

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$



Lecture 11

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

	P	S	S∩P
$\Pr[S] \Pr[P S]$	X	X	X
$\Pr[S] \Pr[F S]$		X	
$\Pr[N] \Pr[P N]$	X		
$\Pr[N] \Pr[F N]$			

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

	P	S	S∩P
$\Pr[S] \Pr[P S]$	X	X	X
$\Pr[S] \Pr[F S]$		X	
$\Pr[N] \Pr[P N]$	X		
$\Pr[N] \Pr[F N]$			

$$= \frac{\Pr[S] \cdot \Pr[P|S]}{\Pr[S] \Pr[P|S] + \Pr[N] \Pr[P|N]}$$

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

**BAYE'S FORMULA**

prob of passing by studying

On the dart board of passing, how large is studying?

prob of passing by studying or not studying (either way)

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

$\Pr[S] = 1/3 \quad \Pr[N] = 2/3$   
 $\Pr[P|S] = 3/4 \quad \Pr[P|N] = 1/4$   
 $\Pr[S|P] = ?$

$$= \frac{\Pr[S] \cdot \Pr[P|S]}{\Pr[S] \Pr[P|S] + \Pr[N] \Pr[P|N]}$$

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

$\Pr[S] = 1/3 \quad \Pr[N] = 2/3$   
 $\Pr[P|S] = 3/4 \quad \Pr[P|N] = 1/4$   
 $\Pr[S|P] = ?$

$$= \frac{1/3 \cdot 3/4}{1/3 \cdot 3/4 + 2/3 \cdot 1/4}$$

**EXAMPLE:** Clyde studies for 1/3 of his exams (chosen at random). If he studies, he has a probability 3/4 of passing an exam. If he doesn't study, he has a probability of 1/4 of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]} =$$

$\Pr[S] = 1/3 \quad \Pr[N] = 2/3$   
 $\Pr[P|S] = 3/4 \quad \Pr[P|N] = 1/4$   
 $\Pr[S|P] = ?$

$$= \frac{1/3 \cdot 3/4}{1/3 \cdot 3/4 + 2/3 \cdot 1/4}$$

**EXAMPLE:** Clyde studies for  $1/3$  of his exams (chosen at random). If he studies, he has a probability  $3/4$  of passing an exam. If he doesn't study, he has a probability of  $1/4$  of passing. On a randomly selected test, what is probability that he studied **IF** he passed?  $\Pr[S|P] = ?$

$$\Pr[S|P] = \frac{\Pr[S \cap P]}{\Pr[P]}$$

$$= \frac{1/3 \cdot 3/4}{1/3 \cdot 3/4 + 2/3 \cdot 1/4}$$

$$= 3/5$$

$$\Pr[S] = 1/3 \quad \Pr[N] = 2/3$$

$$\Pr[P|S] = 3/4 \quad \Pr[P|N] = 1/4$$

$$\Pr[S|P] = ?$$

ERASE



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Lecture 11

**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?

ERASE



50



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**

$W_1$  is the event of getting a white on the first draw.

$W_2$  is the event of getting a white on the second draw.

ERASE

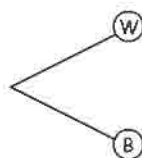


51



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**



ERASE

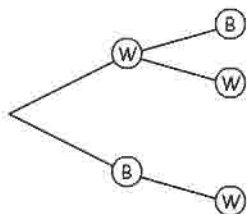


52



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**



ERASE

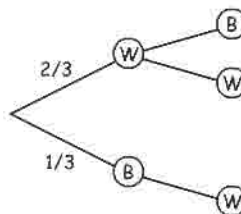


53



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**



ERASE

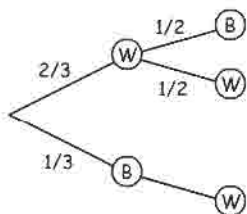


54



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**



ERASE

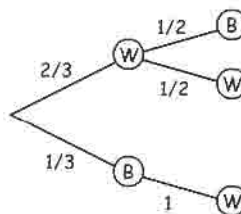


55



**EXAMPLE:** A hat contains 2 white slips of paper and one black. Two slips of paper are drawn out at random, without replacement. What is the probability that the first slip drawn is white given that the second slip drawn is white?  $\Pr[W_1|W_2]$

**SOLUTION:**



ERASE

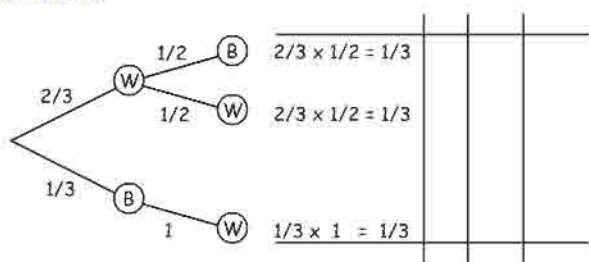


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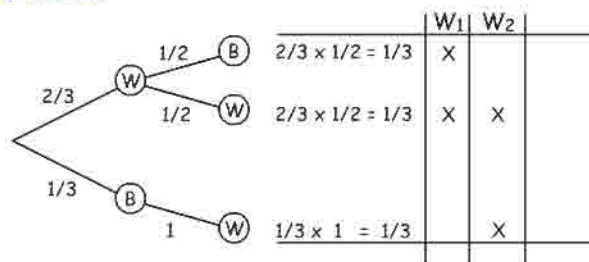
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**SOLUTION:**



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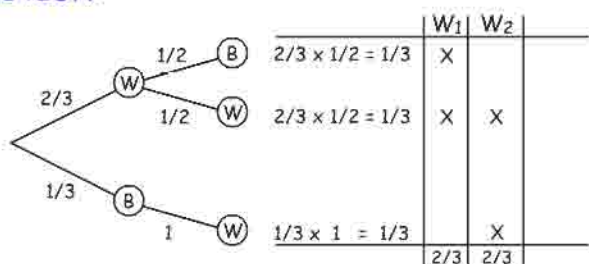
**SOLUTION:**



Lecture 11

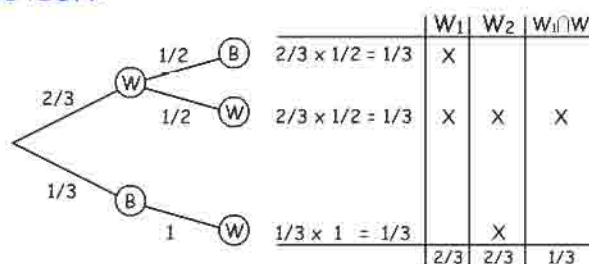
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**SOLUTION:**



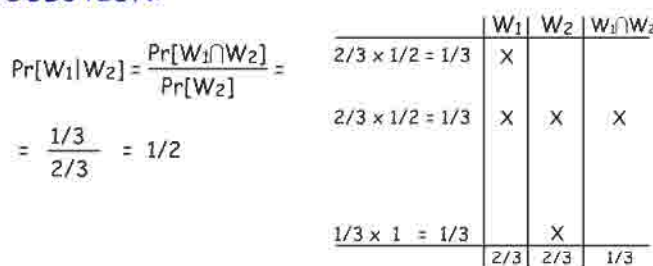
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**SOLUTION:**



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**SOLUTION:**



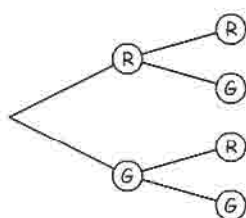
**EXAMPLE:** A space ship holds 3 red martians and 2 green martians. Two of the martians are selected at random, without replacement. What is the probability of getting 2 red martians given that you got at least one red martian?

**SOLUTION:**



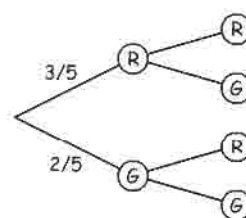
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TREE:



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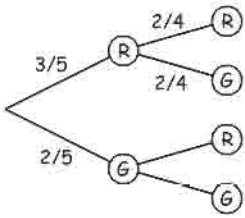
TREE:





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TREE:



ERASE



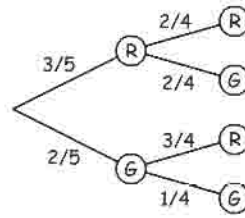
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Lecture 11

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TREE:



ERASE

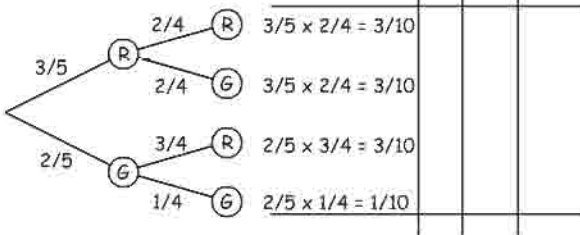


66



**EXAMPLE:** A space ship holds 3 red martians and 2 green martians. Two of the martians are selected at random, without replacement. What is the probability of getting 2 red martians given that you got at least one red martian?

TREE:



ERASE

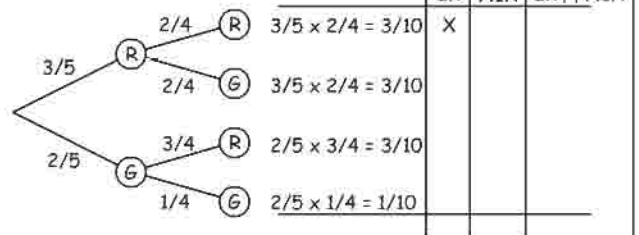


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**EXAMPLE:** A space ship holds 3 red martians and 2 green martians. Two of the martians are selected at random, without replacement. What is the probability of getting 2 red martians given that you got at least one red martian?

TREE:



ERASE

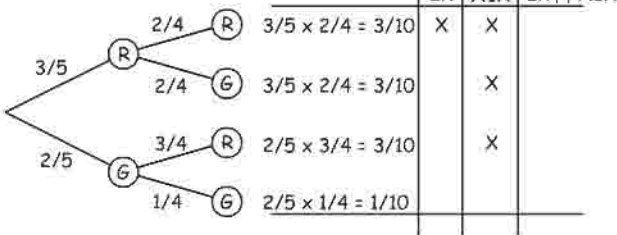


68



**EXAMPLE:** A space ship holds 3 red martians and 2 green martians. Two of the martians are selected at random, without replacement. What is the probability of getting 2 red martians given that you got at least one red martian?

TREE:



ERASE

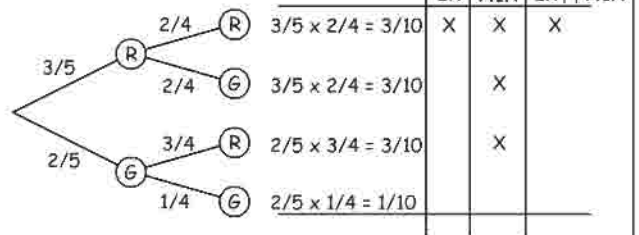


69



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TREE:



ERASE

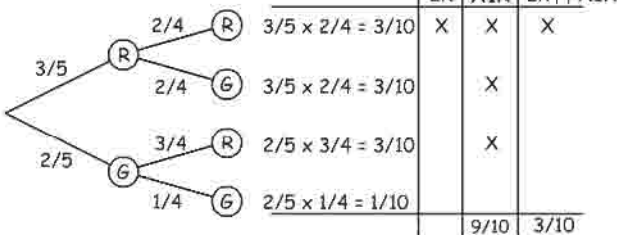


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TREE:



ERASE



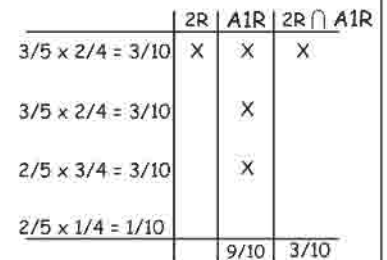
71



**EXAMPLE:** A space ship holds 3 red martians and 2 green martians. Two of the martians are selected at random, without replacement. What is the probability of getting 2 red martians given that you got at least one red martian?

$$\Pr[2R|A1R] = \frac{\Pr[2R \cap A1R]}{\Pr[A1R]}$$

$$= \frac{3/10}{9/10} = 1/3$$



ERASE



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