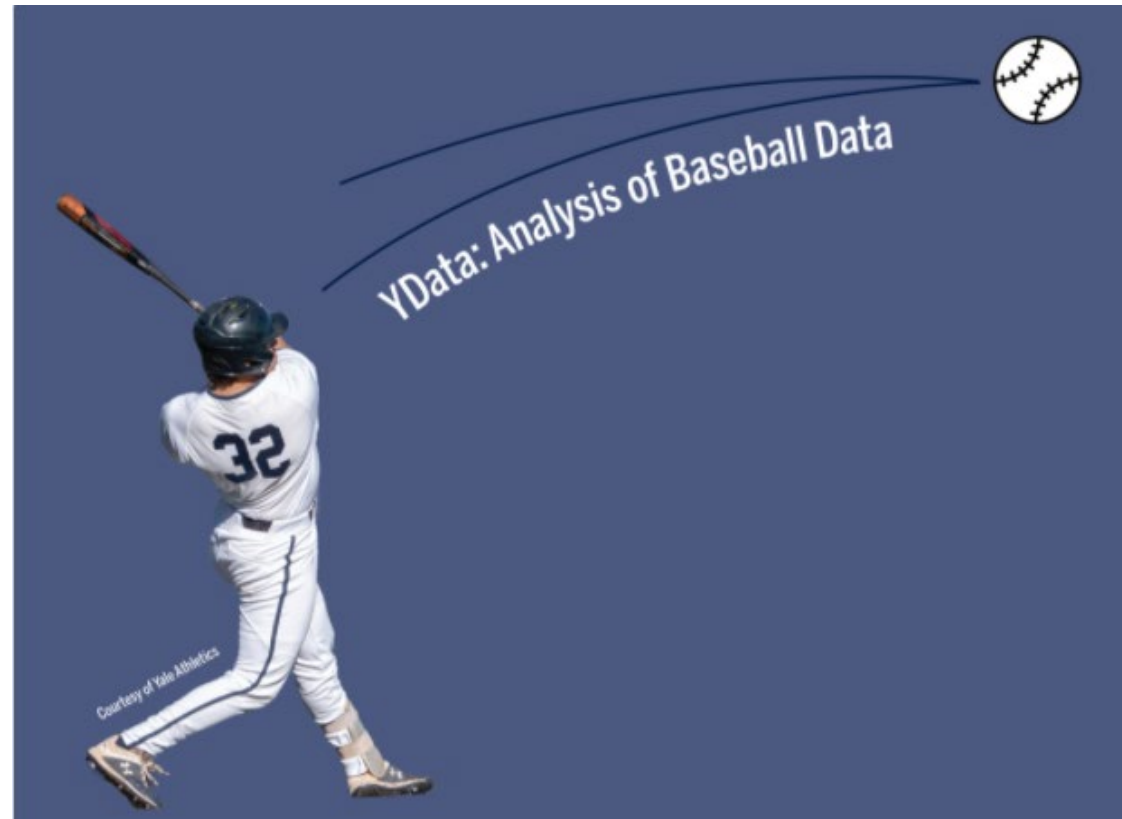


# Probability and simulations using games part II



# Overview

Lab 4 discussion

Discussion of chapter 4 of Astroball

Discuss All-Star baseball and simulations in Python

Play Strat-O-Matic

Quick review or probability rules and Tree Diagrams

# Lab 4: questions?

How did it go?

If you have not done so yet, please fill out the lab 4 reflection

You will get a little more practice with OOP on lab 5

- You will be provided with the Baseball\_Game object
- You will add a method display\_game()



# Astroball discussion

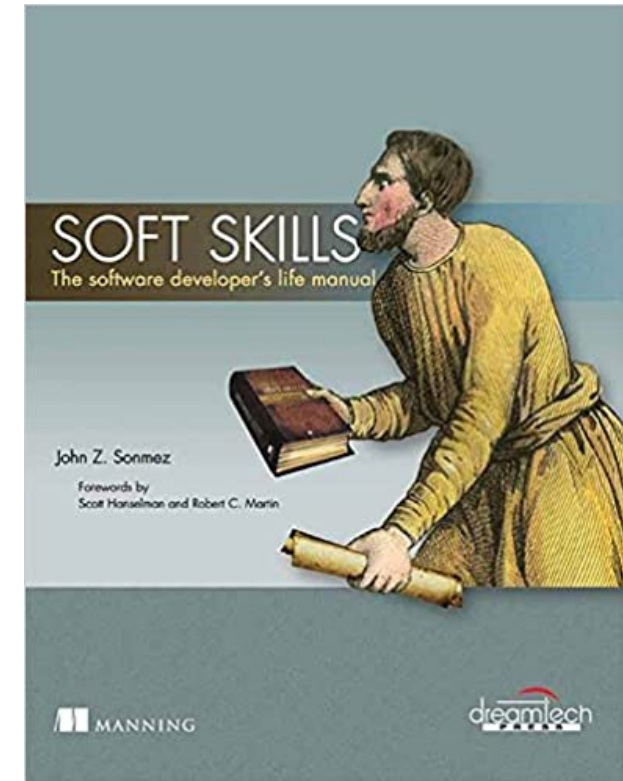
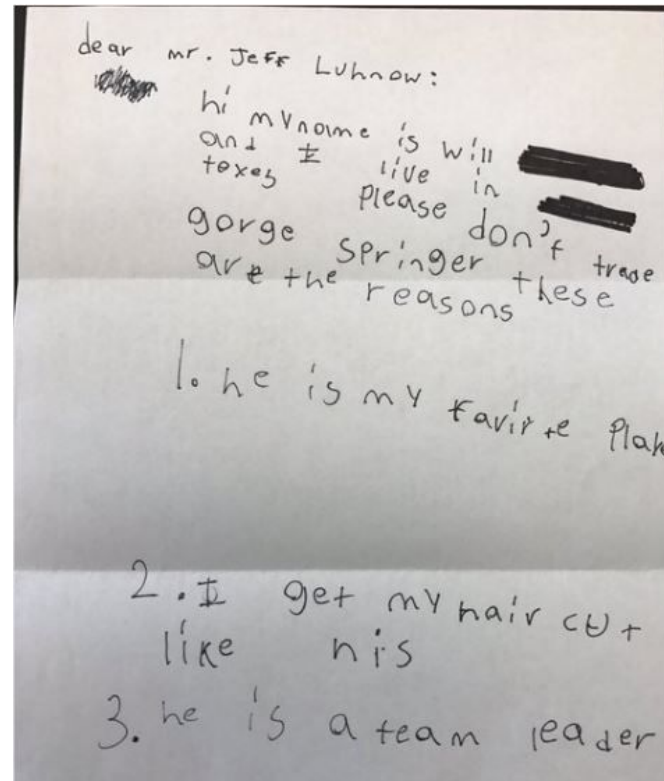
Let's discuss the chapter for 7 minutes in breakout rooms and then have a larger conversation as a group

- Discuss your quote and reaction to chapter 4

# Thoughts on the chapter 4 of Astrobball?

## Roster ruthlessness:

"It is purely statistical analysis, " Lowrie told Evan Drellich, the *Houston Chronicle's* beat writer, of the way Luhnow and the Astros operated. "I think you can't have that approach and expect to have good personal relations." pg 90



# Thoughts on the chapter 4 of Astroball?

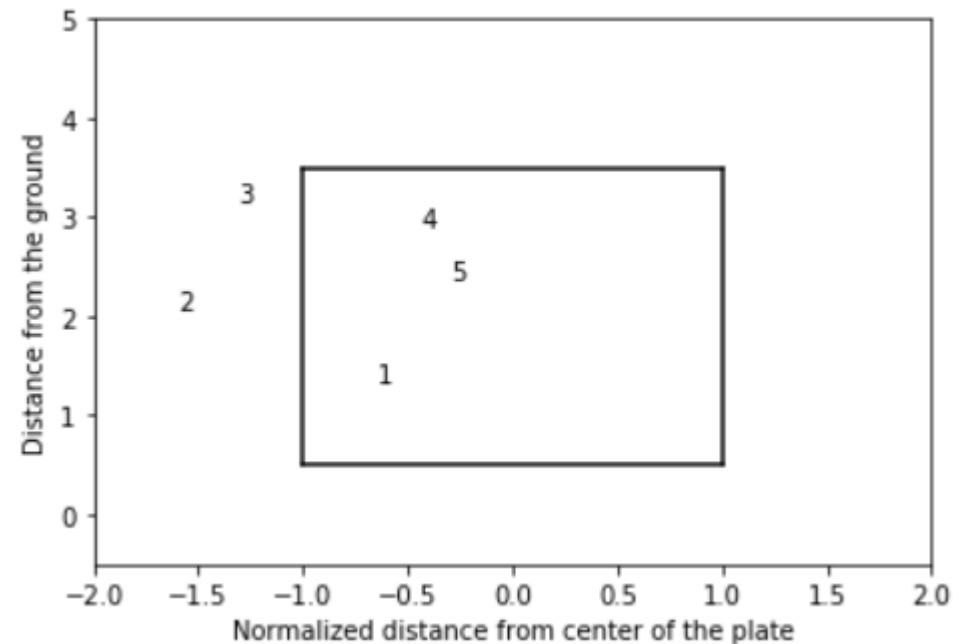
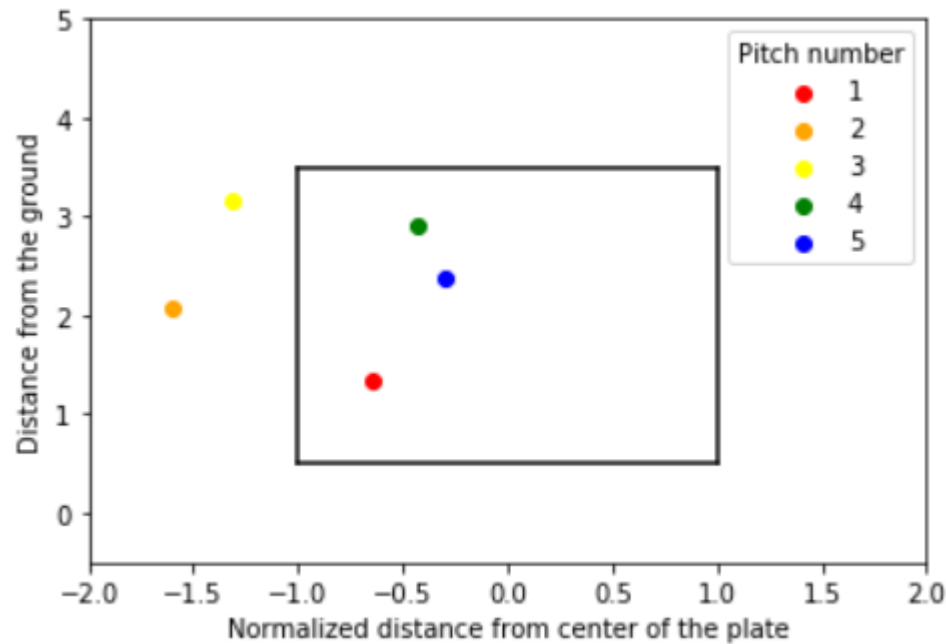
Keuchel and the [evolution of baseball video games](#)

- Page 92



# Thoughts on the chapter 4 of Astroball?

Keuchel vs. Fielder pitch locations using Statcast data:



# Probability

Probability models assigns a number between 0 and 1 to the outcome of an event occurring

$\Pr(\text{event}) = 0$  if there is no chance of an event occurring

$\Pr(\text{event}) = 1$  if the event will definitely occur

$\Pr(\text{event}) \in [0, 1]$  if there is some possibility that an event will occur



# Probability

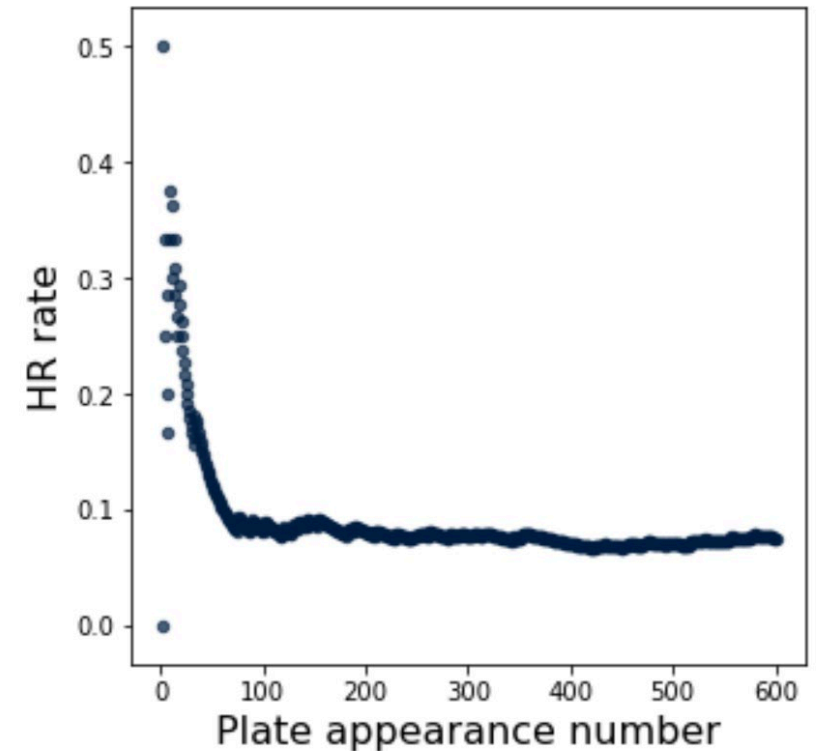
One way to interpret probability is in terms of the **relative frequency** of an event

If we repeat an experiment  $N$  times, we get:

$$Pr(event) \approx \frac{\text{number of times an event occurs}}{N}$$

If we repeated this infinitely many times, we would get the true probability of the event

- i.e.,  $N \rightarrow \infty$



# Probability through estimating the relative frequency of events

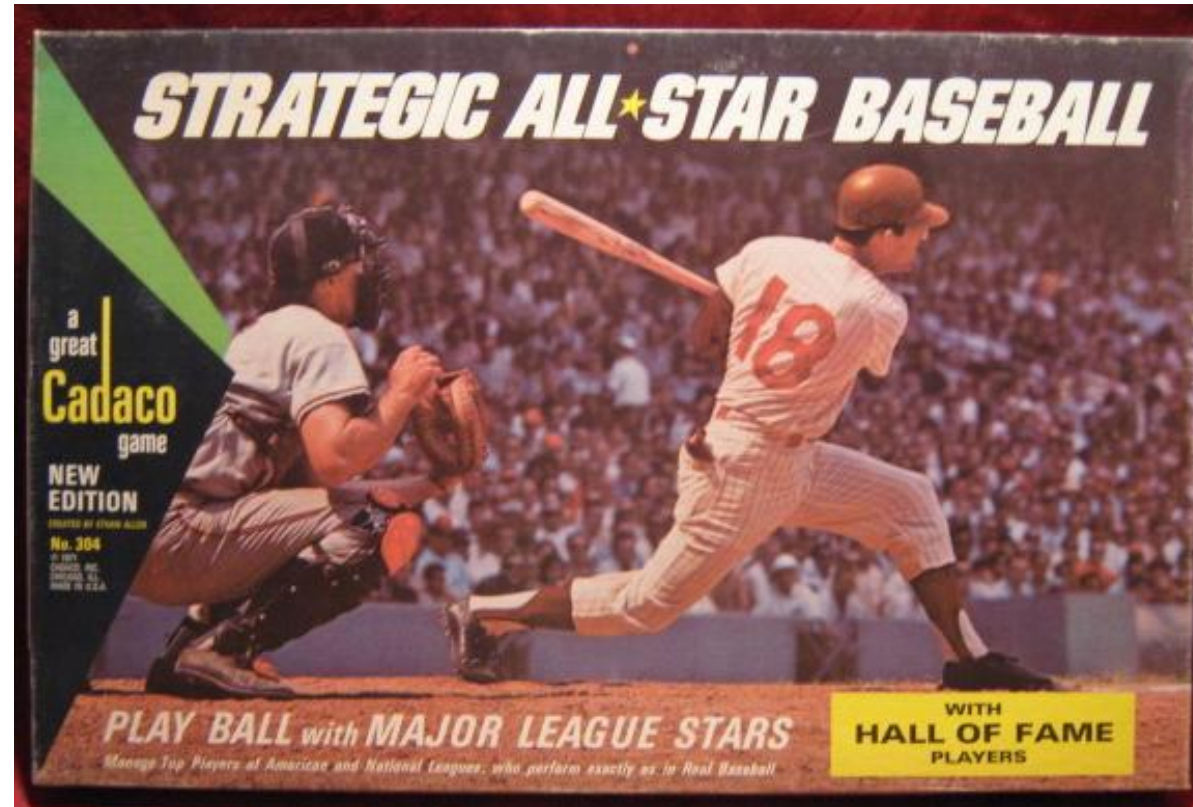
Last class we discussed calculating probabilities using the additive and multiplicative probability rules

- We will review and extend this later in the class

However sometimes it is not possible to mathematically calculate the probability distribution

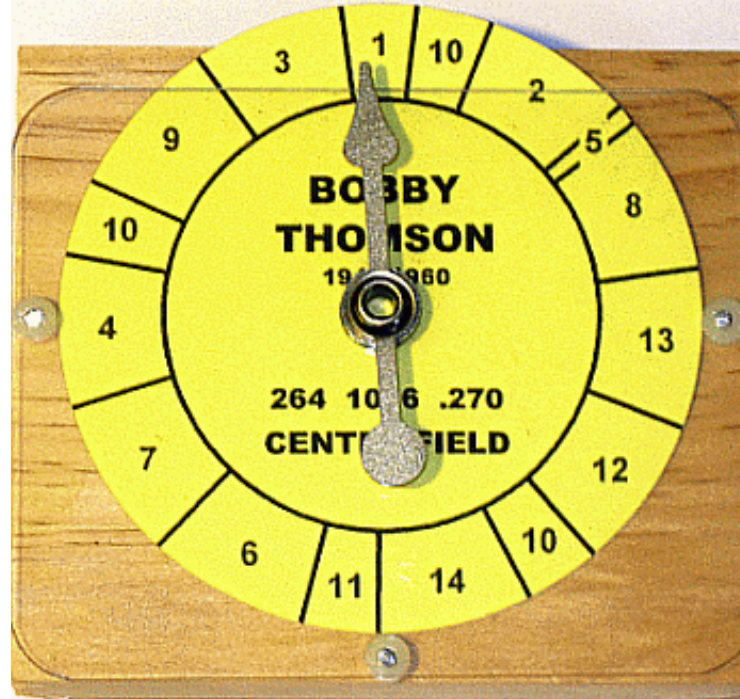
In such cases, we can estimate the probability of events by counting their relative frequencies

# All-Star Baseball



Game that was popular in the 1960's and 70's

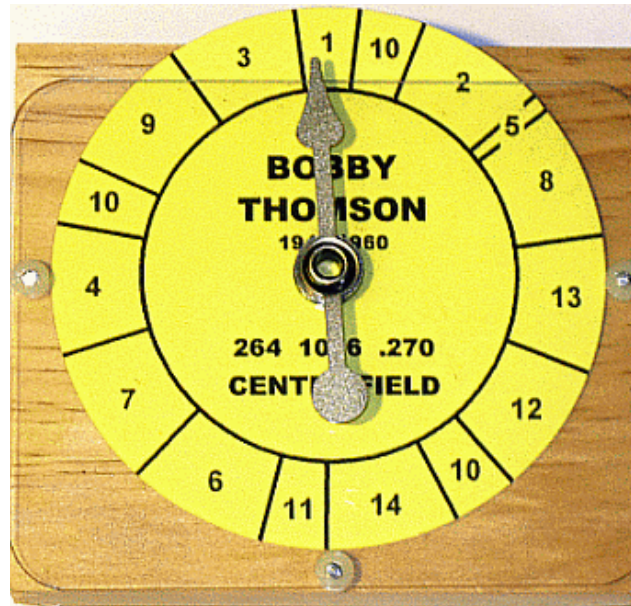
# All-Star Baseball



Each player represented by a spinner

- 1 = HR; 2, 13 = 1B, 11 = 2B, etc.

# All-Star Baseball



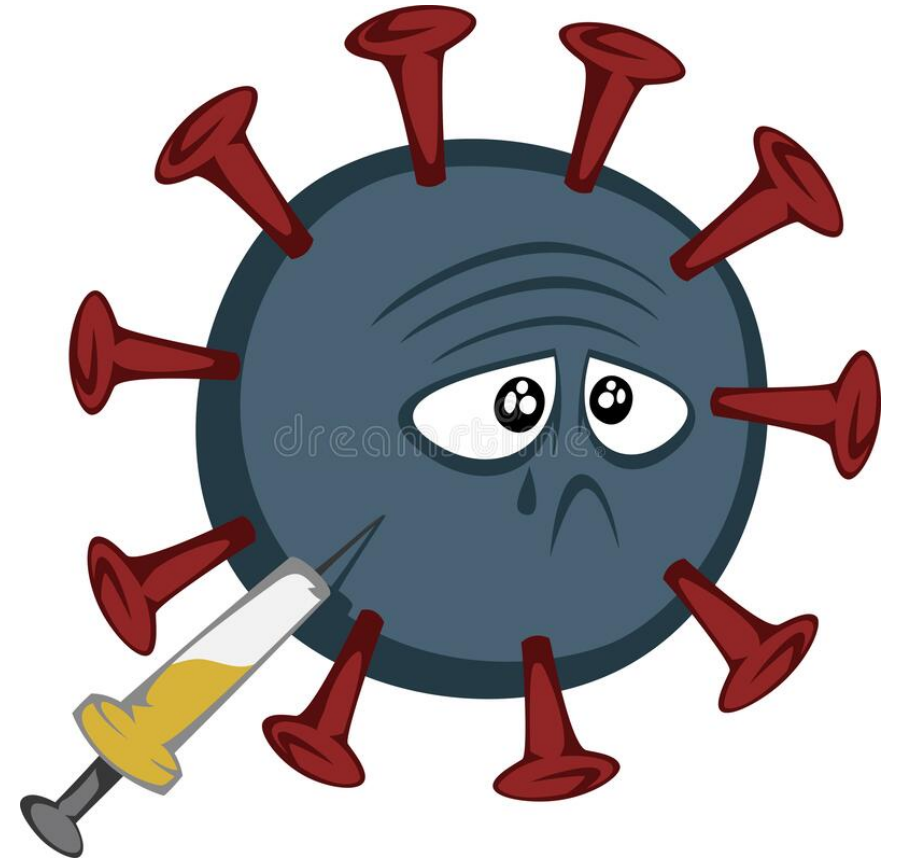
For all-star baseball is it not possible to analytically calculate the probability of different events

- Instead we would just have to repeat the event many times can calculate the relative frequencies

# All-Star Baseball

Unfortunately due to COVID-19 we are not going to play All-Star Baseball

But you will simulate it in Python on lab 5!



# Simulating All-Star Baseball in Python

Steps to simulate a game of All-Star Baseball in Python?

1. `get_spinner_probabilities(retro_id)`
2. `get_lineups(game_id)`
3. `get_all_spinners(away_lineup, home_lineup)`
4. `simulate_game(game_id)`

# Simulating All-Star Baseball in Python

1. `get_spinner_probabilities(retro_id)`

EVENT_GROUP_NAME	count	EVENT_PROPORTIONS
Double	31	0.0469697
Error	9	0.0136364
Home run	24	0.0363636
Out	241	0.365152
Single	92	0.139394
Strikeout	165	0.25
Triple	2	0.0030303
Walk	96	0.145455

[illegible]



# Simulating All-Star Baseball in Python

## 2. get\_lineups(game\_id)

- For a given game\_id, find the retro\_ids for first home and away batters
- Returns a tuple (away\_lineup, home\_lineup)

BAT_ID
calhk001
troum001
bourj002
simma001
pujoa001
lastt001
lucrj001
goodb001
cozaz001

# Simulating All-Star Baseball in Python

## 3. `get_all_spinners(away_lineup, home_lineup)`

- Returns a two lists as a tuple: `(away_lineup, home_lineup)`
- Each list, contains the spinner tables for the 9 players in the line up

```
home_spinners = []
```

```
for i in range(0,9):
```

```
    # stuff
```

```
    home_spinners.append( ...)
```

# Simulating All-Star Baseball in Python

## 4. `simulate_game(game_id)`

- Uses a `Baseball_Game()` object to keep track of the game and loops until the end of the game
- Keep track of the current batter (for both the home and away team)
- Gets the spinner table for the current batter
- Generates a random play based on the spinner probabilities
- Have a series of *if statements* to tell how to update the `Baseball_Game` state

# Simulating All-Star Baseball in Python

Questions?

# Strat-o-matic



Much more complex board games

- Takes into account Hitters and Pitchers
- Advanced version accounts for additional factors (e.g., ball parks etc.)

# Strat-o-matic

<b>NELSON CRUZ</b>			<b>BRANDON McCARTHY</b>		
rightfield-2 leftfield-3			pitcher-3 batting # 1		
stealing-A running 1-12			starter		
<b>TEXAS</b>			<b>PITCHING CARD TEXAS</b>		
<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
2-flyball (cf)B 3-groundball (3b)A 4-groundball (3b)B 5-strikeout 6-strikeout 7-WALK 8-groundball (ss)A 9-strikeout 10-groundball (p)B 11-groundball (ss)A++ 12-lineout (2b) into as many outs as possible	2-flyball (cf)A 3-groundball (ss)A++ 4-groundball (ss)A 5-strikeout 6-strikeout 7-flyball (lf)B 8-strikeout 9-strikeout 10-flyball (cf)B 11-groundball (ss)A++ plus injury 12-WALK	2-SINGLE* 1-2 lineout (3b) 3-20 3-WALK 4-groundball (3b)B 5-SINGLE 6-HOMERUN 7-HOMERUN 1-10 DOUBLE 11-20 8-groundball (3b)A 9-DOUBLE** 1 SINGLE** 2-20 10-HOMERUN 11-SINGLE 12-flyball (rf)B	2-groundball (p)B 3-FLYBALL (lf)X 4-flyball (cf)B 5-groundball (2b)C 6-SINGLE* 1-10 lineout (3b) 11-20 7-flyball (rf)B 8-DOUBLE** 1-12 SINGLE** 13-20 9-flyball (lf)C 10-popout (1b) 11-FLYBALL (rf)X 12-flyball (lf)B	2-lineout (ss) 3-TRIPLE 1 DOUBLE 2-20 4-CATCHER'S CARD X 5-HOMERUN 1-19 DOUBLE 20 6-strikeout 7-GROUND-BALL(2b)X 8-flyball (cf)B 9-strikeout 10-GROUND-BALL(ss)X 11-strikeout 12-groundball (1b)C	2-groundball (1b)C 3-GROUND-BALL(p)X 4-GROUND-BALL(3b)X 5-strikeout 6-WALK 7-SINGLE 8-WALK 9-GROUND-BALL(ss)X 10-FLYBALL (cf)X 11-GROUND-BALL(1b)X 12-groundball (p)B
<b>2009 BATTING RECORD</b>			<b>2009 PITCHING RECORD</b>		
AVG	AB	2B	3B	HR	RBI
.260	462	21	1	33	76
BB	SO	SB	CS	SLG%	ONBASE%
49	118	20	.4	.524	.332
W	L	ERA	STARTS	SAVES	
7	4	4.62	17	0	
IP	HITS ALLOWED	BB	SO	HOMERUNS ALLOWED	
97	96	36	65	13	

Each player is represented by a card

A single white die is rolled to determine whether to use hitter or pitcher's card:



- 1-3 -> hitters card
- 4-6 -> pitcher's card

# Strat-o-matic

NELSON CRUZ			rightfield-2 leftfield-3	stealing-A running 1-12	
TEXAS					
1		2		3	
2-flyball (cf)B 3-groundball (3b)A 4-groundball (3b)B 5-strikeout 6-strikeout 7-WALK 8-groundball (ss)A 9-strikeout 10-groundball (p)B 11-groundball (ss)A++ 12-lineout (2b) into as many outs as possible		2-flyball (cf)A 3-groundball (ss)A++ 4-groundball (ss)A 5-strikeout 6-strikeout 7-flyball (lf)B 8-strikeout 9-strikeout 10-flyball (cf)B 11-groundball (ss)A++ plus injury 12-WALK		2-SINGLE* 1-2 lineout (3b) 3-20 3-WALK 4-groundball (3b)B 5-SINGLE 6-HOMERUN 7-HOMERUN 1-10 DOUBLE 11-20 8-groundball (3b)A 9-DOUBLE** 1 SINGLE** 2-20 10-HOMERUN 11-SINGLE 12-flyball (rf)B	
2009 BATTING RECORD					
AVG	AB	2B	3B	HR	RBI
.260	462	21	1	33	76
BB	SO	SB	CS	SLG%	ONBASE%
49	118	20	.4	.524	.332

Then, two red dice are rolled and their sum determines which play in the card should be used



For some plays additionally a 20 sided die is rolled to determine the final outcome

- and other tables/rules often need to be consulted



# Strat-o-matic

Let's play!

1. Divide into two teams: Rays and Cardinals
2. One player needs to be selected for each position:

Enter your batting order here: <http://bit.ly/strat-o-matic>

We will use the dice simulators on Canvas  
Someone keep score?



# Strat-o-matic

We are going to keep it simple so we will ignore a few rules...

- No base stealing, ignore ++,
- For batter's card, we can ignore which position the ball was hit to
  - E.g., pay attention to flyball A, ignore (rf)
- For pitcher's card, when there is an X we will use the position (card) the ball was hit to and refer to a table

Batting will roll all the dice...

- Except for fielding plays

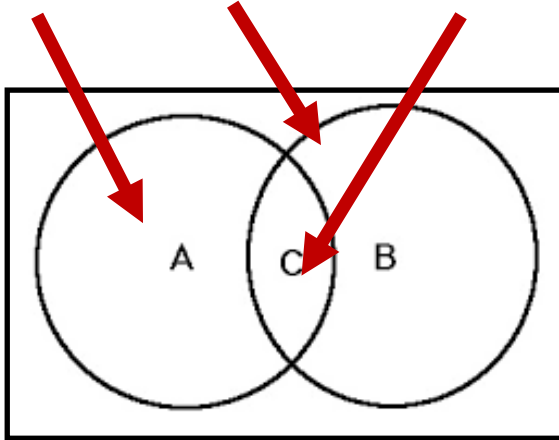
Play ball!

Probability rules...

# Probability rules - Additive rule

If there are two events A, and B, then the probability of A *or* B happening is:

$$\Pr(A \text{ or } B) = \Pr(A) + \Pr(B) - \Pr(A, B)$$



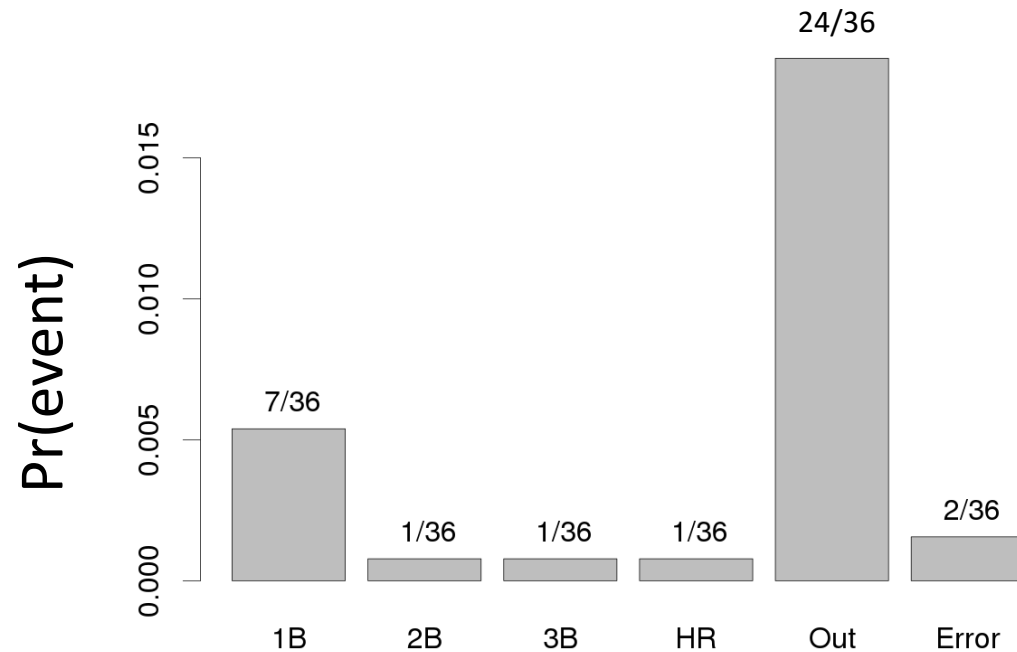
Events are called **mutually exclusive** if events A and B can not both occur; i.e.,  $\Pr(A, B) = 0$

Q: What would mutually exclusive events look like in the Venn diagram?

A: The circles would not overlap

# Probability rules - Additive rule

Q: If the ball is in play, what is the probability of getting a hit in big league baseball?



$$\Pr(\text{hit}) =$$

$$= \Pr(1\text{B or } 2\text{B or } 3\text{B or HR})$$

$$= \Pr(1\text{B}) + \Pr(2\text{B}) + \Pr(3\text{B}) + \Pr(\text{HR})$$

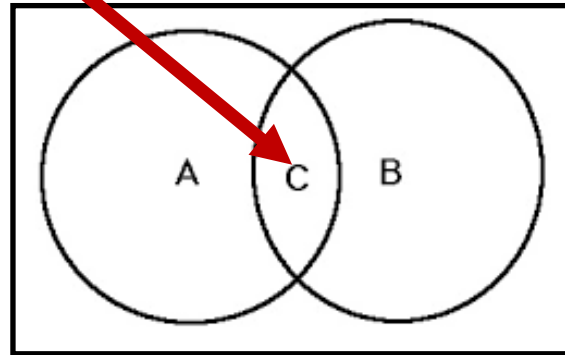
$$= 7/36 + 1/36 + 1/36 + 1/36$$

$$= 10/36$$

# Multiplicative Rule

The probability of two events A *and* B occurring is:

$$\Pr(A, B) = \Pr(A|B) \times \Pr(B)$$



Probability of B happening  
×

Probability of A happening  
given B happened

Special case: two events are **independent** if:

$$\Pr(A, B) = \Pr(A) \times \Pr(B)$$

i.e., if the occurrence of B does not effect the probability of A happening

# Big League Baseball

Recall that the first pitch for Big League Baseball is modeled using...

A single die is rolled:

- If a 2 or 3 occurs, a ball is pitched
- If a 4 or 5 occurs, a strike is pitched
- If a 1 or 6 occurs, a ball is hit in fair play

What is the probability one would strike out on three straight pitches?

- Answer:  $(1/3)^3 = 1/27$

# Strat-o-matic rules and tree diagrams

Each player is represented by a card:

1. A white single die is rolled to determine whether to use hitter or pitcher's card:

- 1-3 -> hitters card
- 4-6 -> pitcher's card



2. Then, two dice are rolled and their sum determines which play in the card should be used

3. For some plays additionally a 20 sided die is rolled for outcome

- and other tables/rules often need to be consulted

NELSON CRUZ rightfield-2 leftfield-3			BRANDON MCCARTHY pitcher-3 batting # 1		
TEXAS			PITCHING CARD		
1	2	3	4	5	6
2-flyball (cf)B 3-groundball (3b)A 4-groundball (3b)B 5-strikeout (ss)A 6-strikeout (ss)A 7-WALK 8-groundball (ss)A 9-strikeout (ss)A 10-groundball (p)B 11-groundball (ss)A++ 12-lineout (2b) into as many outs as possible	2-flyball (cf)A 3-groundball (ss)A++ 4-groundball (ss)A 5-strikeout (ss)A 6-strikeout (ss)A 7-flyball (rf)B 8-strikeout (ss)A 9-strikeout (ss)A 10-flyball (cf)B 11-groundball (ss)A++ 12-WALK	2-SINGLE* 1-2 lineout (3b) 3-20 3-WALK 4-groundball (3b)B 5-SINGLE 6-HOMERUN 7-HOMERUN 8-groundball (3b)A 9-DOUBLE** 10-HOMERUN 11-SINGLE 12-flyball (rf)B	2-groundball (p)B 3-FLYBALL (lf)X 4-flyball (cf)B 5-groundball (2b)C 6-SINGLE* 1-10 lineout (3b) 11-20 7-flyball (rf)B 8-DOUBLE** 1-12 SINGLE** 13-20 9-flyball (lf)C 10-popout (1b) 11-FLYBALL (rf)X 12-flyball (lf)B	2-lineout (ss) 1-2 DOUBLE 2-20 4-CATCHER'S CARD X 5-HOMERUN 1-19 DOUBLE 20 6-strikeout 7-GROUND-BALL(2b)X 8-flyball (cf)B 9-strikeout 10-GROUND-BALL(ss)X 11-strikeout 12-groundball (1b)C	2-groundball (1b)C 3-TRIPLE 3-GROUND-BALL(p)X 4-GROUND-BALL(3b)X 5-strikeout 6-WALK 7-SINGLE 8-WALK 9-GROUND-BALL(ss)X 10-FLYBALL (cf)X 11-GROUND-BALL(1b)X 12-groundball (p)B
2009 BATTING RECORD			2009 PITCHING RECORD		
AVG	AB	2B	3B	HR	RBI
260	452	21	1	33	76
BB	SO	SB	CS	SLG%	ONBASE%
W			L	ERA	STARTS
7	4	4.62	17	0	
HITS			HOMERUNS		

nal

# Strat-o-matic: analysis

Let's calculate the probability of different events...

Calculating the probability of getting a particular column in a pitcher or hitter's card is pretty simple

- Answer?



Calculating the sum of the two dice is a little more involved...

- What is the sample space here?
  - i.e., what are the possible outcomes here?
- Can you calculate the probability distribution?





# Strat-o-matic: analysis

We can fill in the table below with the sum of the two dice and then calculate the probability of rolling a 2 to a 12

		2nd Die					
1st Die		1	2	3	4	5	6
	1						
	2						
	3						
	4			7			
	5						
	6						

# Strat-o-matic: analysis

We can fill in the table below with the sum of the two dice and then calculate the probability of rolling a 2 to a 12

		2nd Die					
1st Die		1	2	3	4	5	6
	1	2	3	4	5	6	7
	2	3	4	5	6	7	8
	3	4	5	6	7	8	9
	4	5	6	7	8	9	10
	5	6	7	8	9	10	11
	6	7	8	9	10	11	12

# Strat-o-matic: analysis

<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

## 2nd Die

**1st Die**

	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>1</b>	2	3	4	5	6	7
<b>2</b>	3	4	5	6	7	8
<b>3</b>	4	5	6	7	8	9
<b>4</b>	5	6	7	8	9	10
<b>5</b>	6	7	8	9	10	11
<b>6</b>	7	8	9	10	11	12

# Strat-o-matic: analysis

2	3	4	5	6	7	8	9	10	11	12
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

What is the probability of rolling a 1 on the white die **and then** getting a sum of 7 on the two red dice?

- $1/6 \cdot 6/36 = 6/216$

What is the probability of rolling a:

- 2 on the white die.... **and then** getting...
- Sum of 8 on the two red dice... **and then**...
- A number for 1-8 on the 20 sided die?
  - $1/6 \cdot 5/36 \cdot 8/20 = .00926$

# Strat-o-matic: analysis

2	3	4	5	6	7	8	9	10	11	12
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

What is the probability of rolling a 1 on the white die **or** a 6 on the white die?

- $1/6 + 1/6 = 2/6$

What is the probability of rolling a:

- 5 on the white die... **and then** getting ...
- a sum of 8 **or** a sum of 10 on the two red dice?
- $1/6 \cdot (5/36 + 3/36) = .0370$

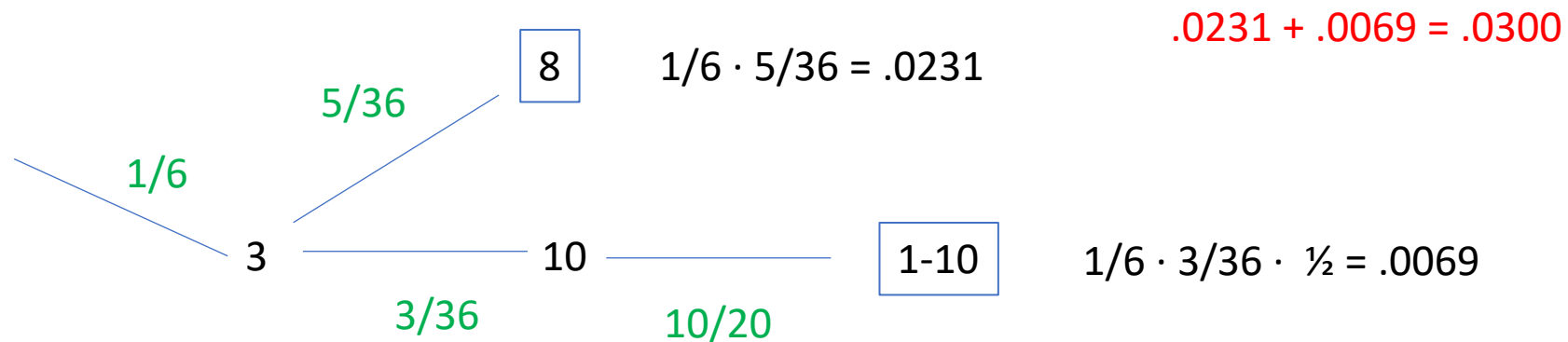
# Strat-o-matic: analysis

2	3	4	5	6	7	8	9	10	11	12
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

What is the probability of rolling a 3 on the white die

- and then getting a sum of 8 on the two red dice
- or a sum of 10 on the two red dice
  - and then a 1-10 on the 20 sided die?

Tree diagram!



# Strat-o-matic: Pujols vs. Kershaw

ALBERT PUJOLS			CLAYTON KERSHAW		
1st base-1 stealing-B running 1-11			pitcher-3 starter batting # 1		
ST. LOUIS			PITCHING CARD LOS ANGELES (NL)		
1	2	3	4	5	6
2-lineout (2b) into as many outs as possible	2-popout (2b) plus injury	2-flyball (lf)A	2-flyball (lf)C	2-groundball (p)B	2-WALK
3-groundball (ss)A++	3-popout (ss)	3-groundball (2b)A	3-FLYBALL (rf)X	3-GROUND- BALL(1b)X	3-GROUND- BALL(ss)X
4-HOMERUN	4-groundball (ss)A	4-groundball (ss)A	4-FLYBALL (cf)X	4-CATCHER'S CARD X	4-flyball (lf)C
5-HOMERUN	5-flyball (cf)B	5-SINGLE**	5-strikeout	5-strikeout	5-HOMERUN 1-2
6-HOMERUN 1-17	6-groundball (3b)A	6-SINGLE* 1-5	6-GROUND- BALL(ss)X	6-strikeout	flyball (lf)B 3-20
DOUBLE 18-20	7-flyball (lf)B	lineout (3b) 6-20	7-GROUND- BALL(2b)X	7-TRIPLE 1	6-DOUBLE** 1-14
7-DOUBLE	8-groundball (3b)A	7-WALK	8-strikeout	SINGLE** 2-20	SINGLE** 15-20
8-DOUBLE** 1-2	9-strikeout	8-groundball (ss)A	9-strikeout	8-strikeout	7-SINGLE* 1
SINGLE** 3-20	10-groundball (p)A	9-WALK	10-GROUND- BALL(3b)X	9-strikeout	lineout (1b) 2-20
9-groundball (ss)A++	11-groundball (ss)A	10-WALK	11-FLYBALL (lf)X	10-strikeout	8-WALK
10-SINGLE	12-foulout (c)	11-groundball (3b)A	12-groundball (p)B	11-GROUND- BALL(p)X	9-WALK
11-SINGLE		12-flyball (rf)B		12-groundball (2b)C	10-groundball (2b)C
12-popout (ss)					11-groundball (1b)C
					12-flyball (cf)B

What is the probability of a hitting a double?

# Strat-o-matic: Pujols vs. Kershaw

ALBERT PUJOLS			CLAYTON KERSHAW		
1st base-1 stealing-B running 1-11			pitcher-3 starter batting # 1		
ST. LOUIS			PITCHING CARD LOS ANGELES (NL)		
1	2	3	4	5	6
2-lineout (2b) into as many outs as possible	2-popout (2b) plus injury	2-flyball (lf)A	2-flyball (lf)C	2-groundball (p)B	2-WALK
3-groundball (ss)A++	3-popout (ss)	3-groundball (2b)A	3-FLYBALL (rf)X	3-GROUND- BALL(1b)X	3-GROUND- BALL(ss)X
4-HOMERUN	4-groundball (ss)A	4-groundball (ss)A	4-FLYBALL (cf)X	4-CATCHER'S CARD X	4-flyball (lf)C
5-HOMERUN	5-flyball (cf)B	5-SINGLE**	5-strikeout	5-strikeout	5-HOMERUN 1-2
6-HOMERUN 1-17	6-groundball (3b)A	6-SINGLE* 1-5	6-GROUND- BALL(ss)X	6-strikeout	flyball (lf)B 3-20
DOUBLE 18-20	7-flyball (lf)B	lineout (3b)	7-GROUND- BALL(2b)X	7-TRIPLE 1	6-DOUBLE** 1-14
7-DOUBLE	8-groundball (3b)A	6-20	8-strikeout	SINGLE** 2-20	SINGLE** 15-20
8-DOUBLE** 1-2	9-strikeout	7-WALK	9-strikeout	8-strikeout	7-SINGLE* 1
SINGLE** 3-20	10-groundball (p)A	8-groundball (ss)A	10-GROUND- BALL(3b)X	9-strikeout	lineout (1b) 2-20
9-groundball (ss)A++	11-groundball (ss)A	9-WALK	11-FLYBALL (lf)X	10-strikeout	8-WALK
10-SINGLE	12-foulout (c)	10-WALK	12-groundball (p)B	11-GROUND- BALL(p)X	9-WALK
11-SINGLE		11-groundball (3b)A		12-groundball (2b)C	10-groundball (2b)C
12-popout (ss)		12-flyball (rf)B			11-groundball (1b)C
					12-flyball (cf)B

What is the probability of a hitting a double?

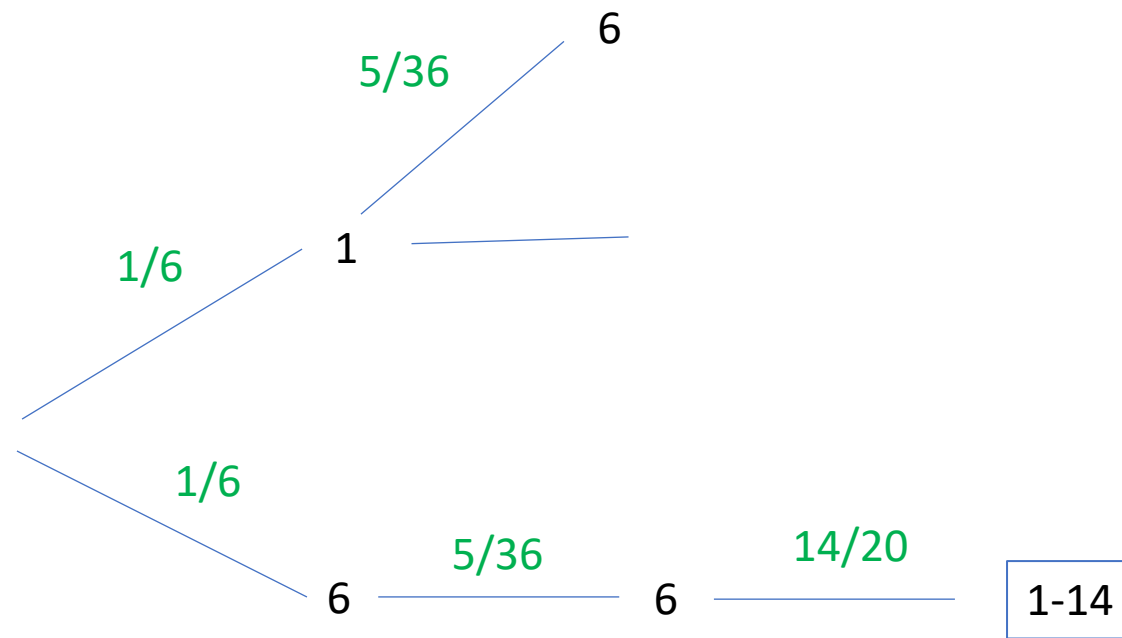


# Strat-o-matic: Pujols vs. Kershaw

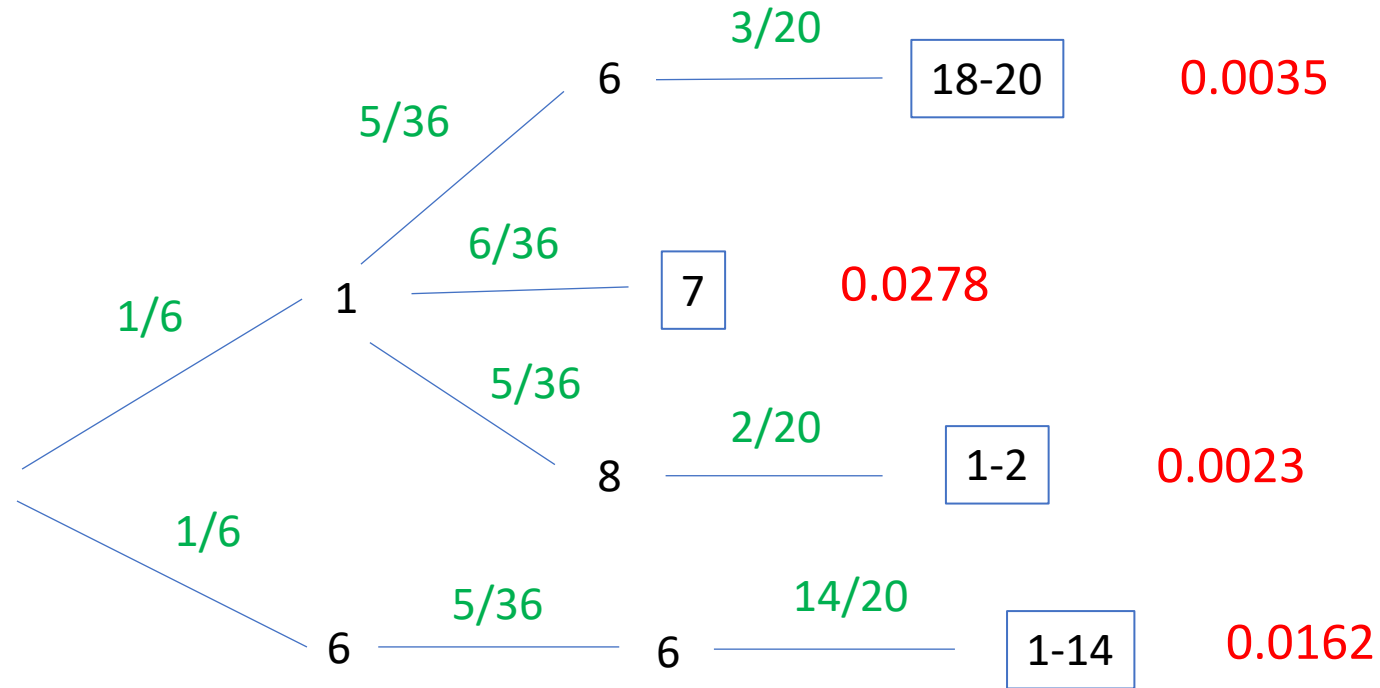
ALBERT PUJOLS			CLAYTON KERSHAW		
1st base-1			pitcher-3		
stealing-B			starter		
running 1-11			batting # 1		
ST. LOUIS			PITCHING CARD LOS ANGELES (NL)		
1	2	3	4	5	6
2-lineout (2b) into as many outs as possible 3-groundball (ss)A++ 4-HOMERUN 5-HOMERUN 6-HOMERUN 1-17 DOUBLE 18-20 7-DOUBLE 8-DOUBLE** 1-2 SINGLE** 3-20 9-groundball (ss)A++ 10-SINGLE 11-SINGLE 12-popout (ss)	2-popout (2b) plus injury 3-popout (ss) 4-groundball (ss)A 5-flyball (cf)B 6-groundball (3b)A 7-flyball (lf)B 8-groundball (3b)A 9-strikeout 10-groundball (p)A 11-groundball (ss)A 12-foulout (c)	2-flyball (lf)A 3-groundball (2b)A 4-groundball (ss)A 5-SINGLE** 6-SINGLE* 1-5 lineout (3b) 6-20 7-WALK 8-groundball (ss)A 9-WALK 10-WALK 11-groundball (3b)A 12-flyball (rf)B	2-flyball (lf)C 3-FLYBALL (rf)X 4-FLYBALL (cf)X 5-strikeout 6-GROUND- BALL(ss)X 7-GROUND- BALL(2b)X 8-strikeout 9-strikeout 10-GROUND- BALL(3b)X 11-FLYBALL (lf)X 12-groundball (p)B	2-groundball (p)B 3-GROUND- BALL(1b)X 4-CATCHER'S CARD X 5-strikeout 6-strikeout 7-TRIPLE 1 SINGLE** 2-20 8-strikeout 9-strikeout 10-strikeout 11-GROUND- BALL(p)X 12-groundball (2b)C	2-WALK 3-GROUND- BALL(ss)X 4-flyball (lf)C 5-HOMERUN 1-2 flyball (lf)B 3-20 6-DOUBLE** 1-14 SINGLE** 15-20 7-SINGLE* 1 lineout (1b) 2-20 8-WALK 9-WALK 10-groundball (2b)C 11-groundball (1b)C 12-flyball (cf)B

2	3	4	5	6	7	8	9	10	11	12
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

# Tree diagram



# Tree diagram



$$.0035 + .0278 + .0023 + .0162 = .0498$$

# Strat-o-matic: Pujols vs. Kershaw

ALBERT PUJOLS			CLAYTON KERSHAW		
1st base-1 stealing-B running 1-11			pitcher-3 starter batting # 1		
ST. LOUIS			PITCHING CARD LOS ANGELES (NL)		
1	2	3	4	5	6
2-lineout (2b) into as many outs as possible	2-popout (2b) plus injury	2-flyball (lf)A	2-flyball (lf)C	2-groundball (p)B	2-WALK
3-groundball (ss)A++	3-popout (ss)	3-groundball (2b)A	3-FLYBALL (rf)X	3-GROUND- BALL(1b)X	3-GROUND- BALL(ss)X
4-HOMERUN	4-groundball (ss)A	4-groundball (ss)A	4-FLYBALL (cf)X	4-CATCHER'S CARD X	4-flyball (lf)C
5-HOMERUN	5-flyball (cf)B	5-SINGLE**	5-strikeout	5-strikeout	5-HOMERUN 1-2
6-HOMERUN 1-17	6-groundball (3b)A	6-SINGLE* 1-5	6-GROUND- BALL(ss)X	6-strikeout	flyball (lf)B 3-20
DOUBLE 18-20	7-flyball (lf)B	lineout (3b) 6-20	7-GROUND- BALL(2b)X	7-TRIPLE 1	6-DOUBLE** 1-14
7-DOUBLE	8-groundball (3b)A	7-WALK	8-strikeout	SINGLE** 2-20	SINGLE** 15-20
8-DOUBLE** 1-2	9-strikeout	8-groundball (ss)A	9-strikeout	8-strikeout	7-SINGLE* 1
SINGLE** 3-20	10-groundball (p)A	9-WALK	10-GROUND- BALL(3b)X	9-strikeout	lineout (1b) 2-20
9-groundball (ss)A++	11-groundball (ss)A	10-WALK	11-FLYBALL (lf)X	10-strikeout	8-WALK
10-SINGLE	12-foulout (c)	11-groundball (3b)A	12-groundball (p)B	11-GROUND- BALL(p)X	9-WALK
11-SINGLE		12-flyball (rf)B		12-groundball (2b)C	10-groundball (2b)C
12-popout (ss)					11-groundball (1b)C
					12-flyball (cf)B

What is the probability of a hitting a home run?



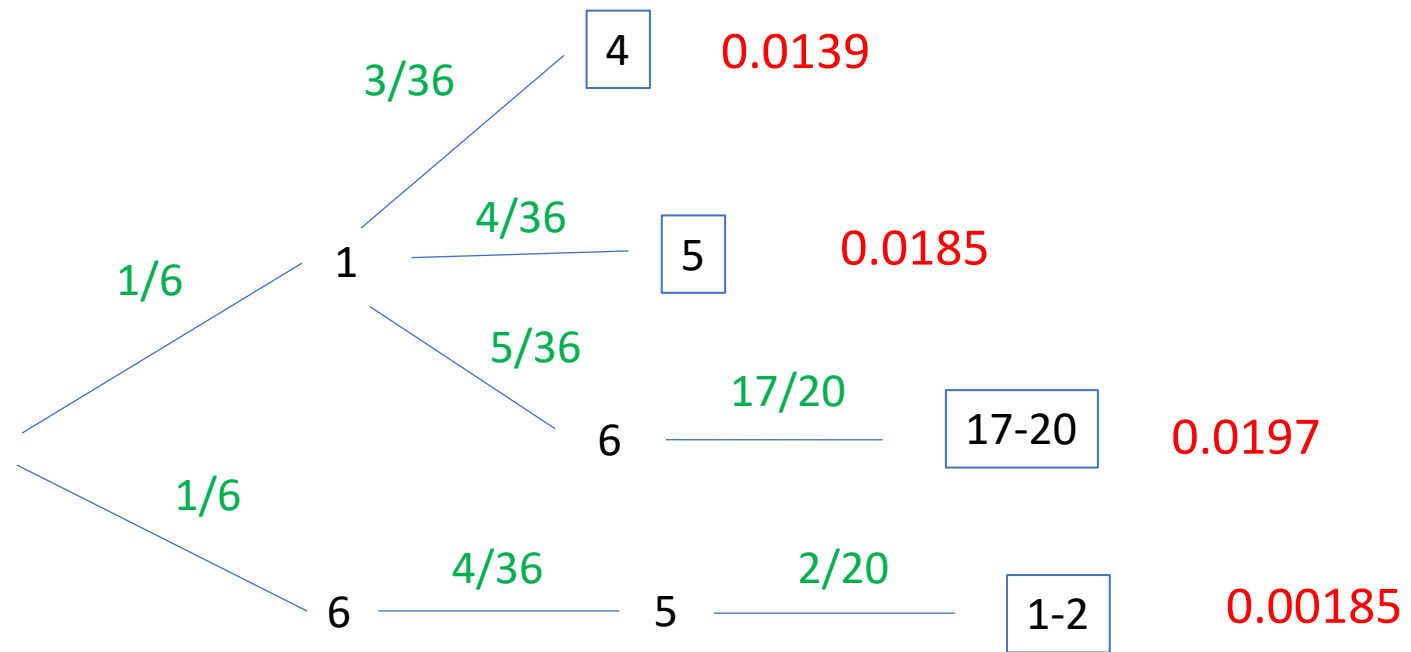
# Strat-o-matic: Pujols vs. Kershaw

ALBERT PUJOLS			1st base-1	stealing-B	CLAYTON KERSHAW			pitcher-3	starter
			running 1-11			batting # 1			
ST. LOUIS			PITCHING CARD			LOS ANGELES (NL)			
1	2	3	4	5	6	4	5	6	
2-lineout (2b) into as many outs as possible 3-groundball (ss)A++	2-popout (2b) plus injury 3-popout (ss) 4-groundball (ss)A	2-flyball (lf)A 3-groundball (2b)A 4-groundball (ss)A	2-flyball (lf)C 3-FLYBALL (rf)X 4-FLYBALL (cf)X	2-groundball (p)B 3-GROUND- BALL(1b)X 4-CATCHER'S CARD X	2-WALK 3-GROUND- BALL(ss)X 4-flyball (lf)C 5-HOMERUN 1-2	5-strikeout 6-GROUND- BALL(ss)X 7-GROUND- BALL(2b)X 8-strikeout 9-strikeout 10-GROUND- BALL(3b)X 11-FLYBALL (lf)X 12-groundball (p)B	5-strikeout 6-strikeout 7-TRIPLE 1 SINGLE** 2-20 8-strikeout 9-strikeout 10-strikeout 11-GROUND- BALL(p)X 12-groundball (2b)C	flyball (lf)B 3-20 6-DOUBLE** 1-14 SINGLE** 15-20 7-SINGLE* 1 lineout (1b) 2-20 8-WALK 9-WALK 10-groundball (2b)C 11-groundball (1b)C 12-flyball (cf)B	
4-HOMERUN 5-HOMERUN 6-HOMERUN 1-17 DOUBLE 18-20 7-DOUBLE 8-DOUBLE** 1-2 SINGLE** 3-20 9-groundball (ss)A++ 10-SINGLE 11-SINGLE 12-popout (ss)	5-flyball (cf)B 6-groundball (3b)A 7-flyball (lf)B 8-groundball (3b)A 9-strikeout 10-groundball (p)A 11-groundball (ss)A 12-foulout (c)	5-SINGLE** 6-SINGLE* 1-5 lineout (3b) 6-20 7-WALK 8-groundball (ss)A 9-WALK 10-WALK 11-groundball (3b)A 12-flyball (rf)B							

What is the probability of a hitting a home run? Tree diagram!

2	3	4	5	6	7	8	9	10	11	12
1/36	2/36	3/36	4/36	5/36	6/36	5/36	4/36	3/36	2/36	1/36

# Tree diagram



$$.0139 + .0185 + .0197 + .00185 = .0539$$

# Using probability notation with tree diagrams

$X_1$



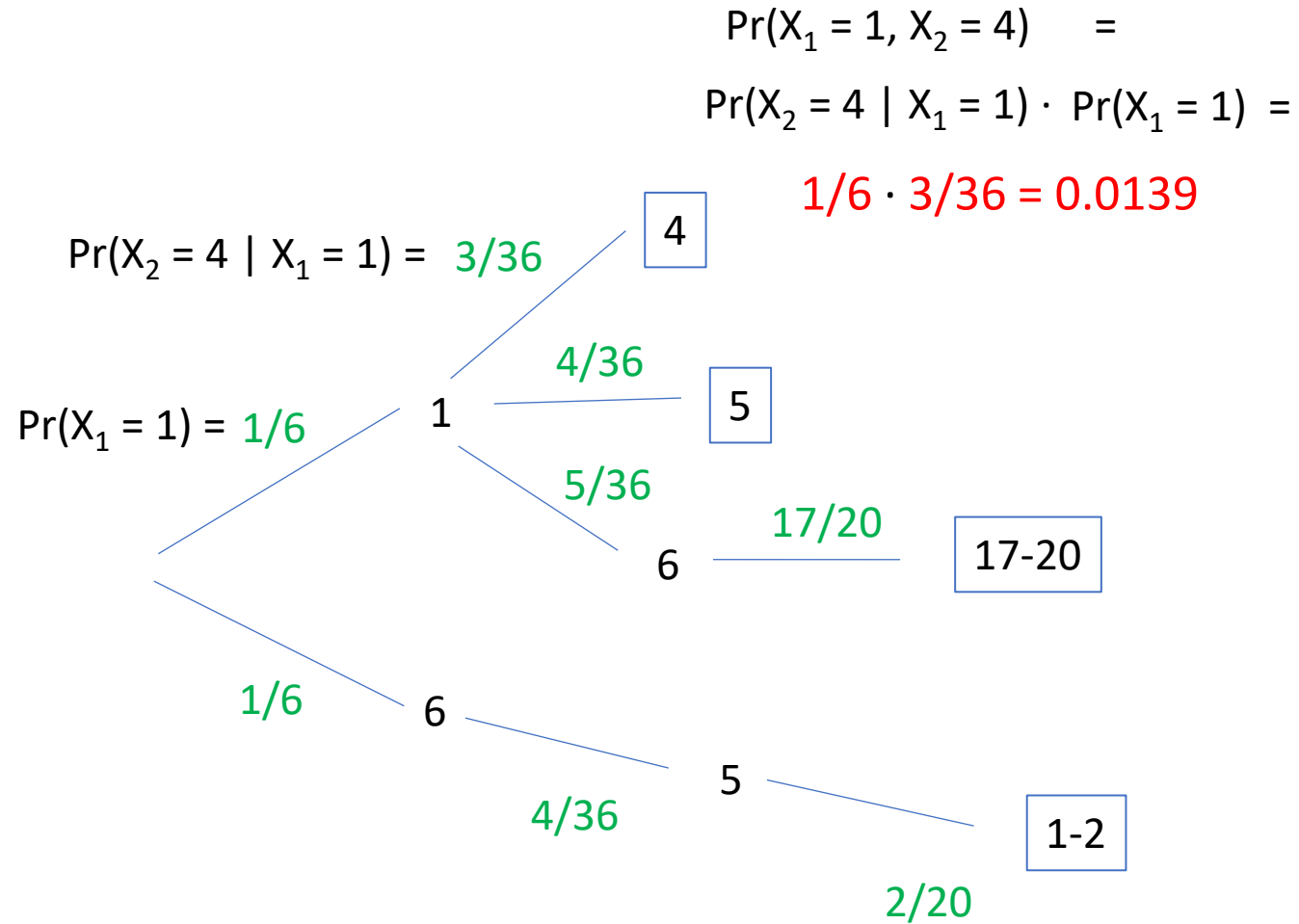
$X_2$



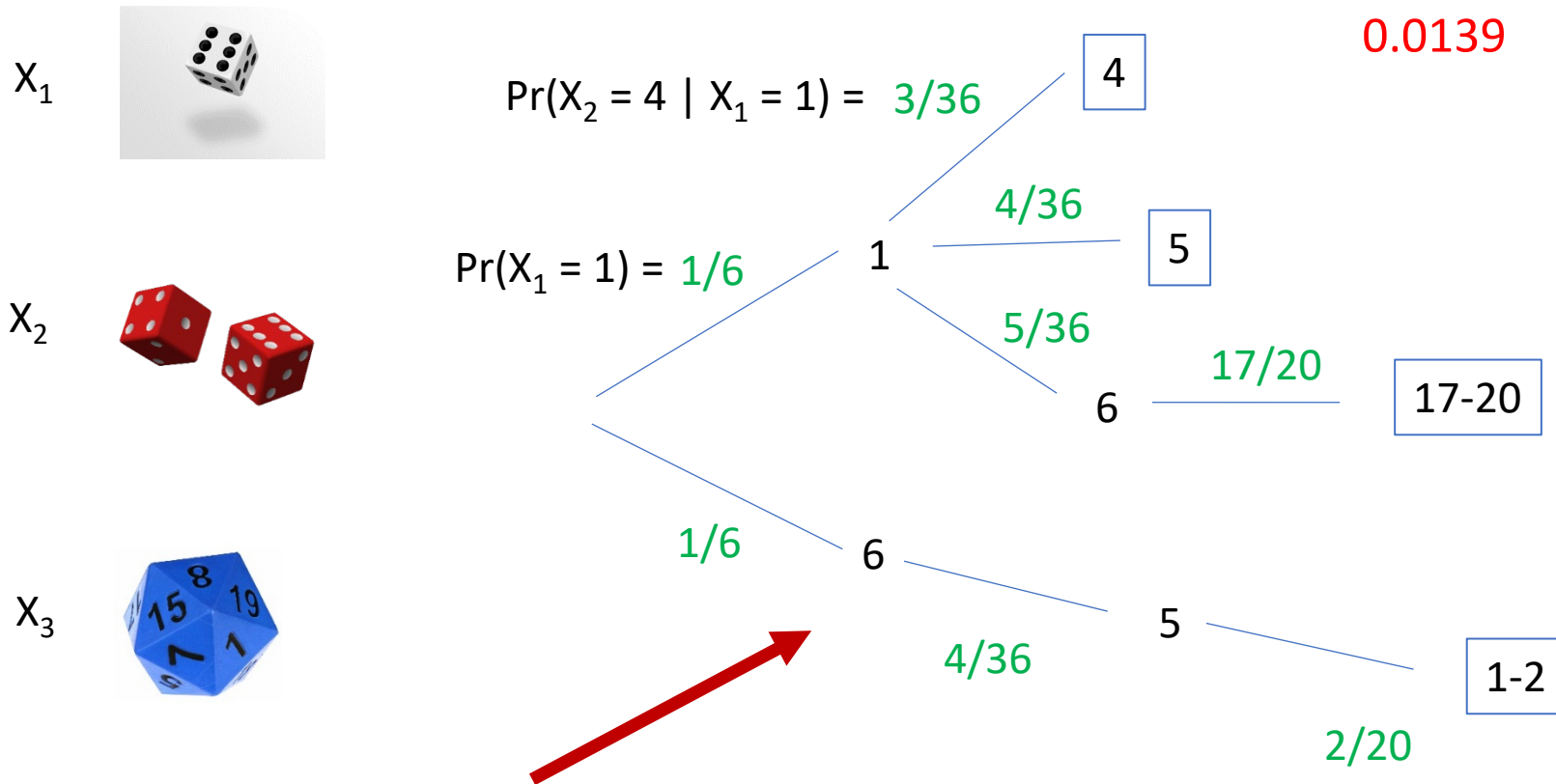
$X_3$



What is the sample space for  $X_1$  ?



# Using probability notation with tree diagrams



Can we fill in the probability notation for the lower part of the tree where  $X_1 = 6$  ?



# Using probability notation with tree diagrams

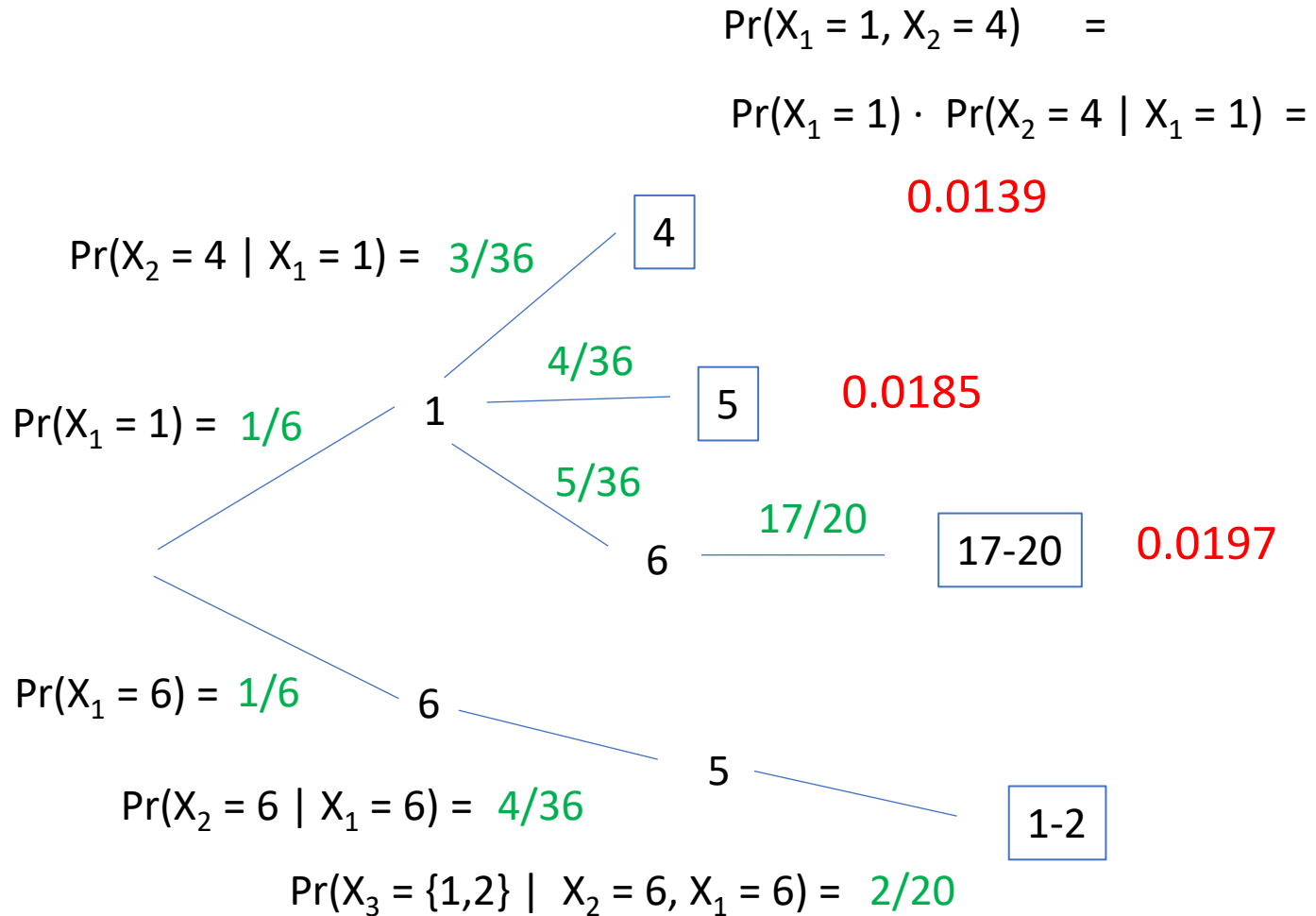
$X_1$



$X_2$



$X_3$



$$\Pr(X_1 = 6, X_2 = 6, X_3 = \{1,2\}) =$$

$$\Pr(X_1 = 6) \cdot \Pr(X_2 = 6 \mid X_1 = 6) \cdot \Pr(X_3 = \{1,2\} \mid X_1 = 6, X_2 = 6) = \text{0.00185}$$

# Lab 5

If there is time we can get started on lab 5 now

As always, due next Monday (3/15)