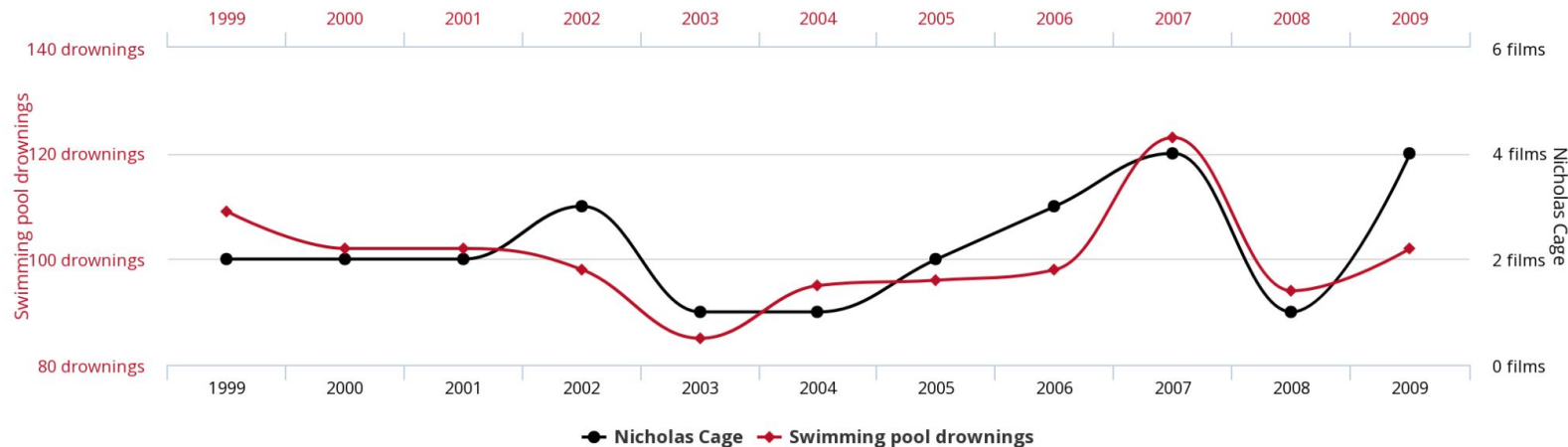


Number of people who drowned by falling into a pool correlates with Films Nicolas Cage appeared in



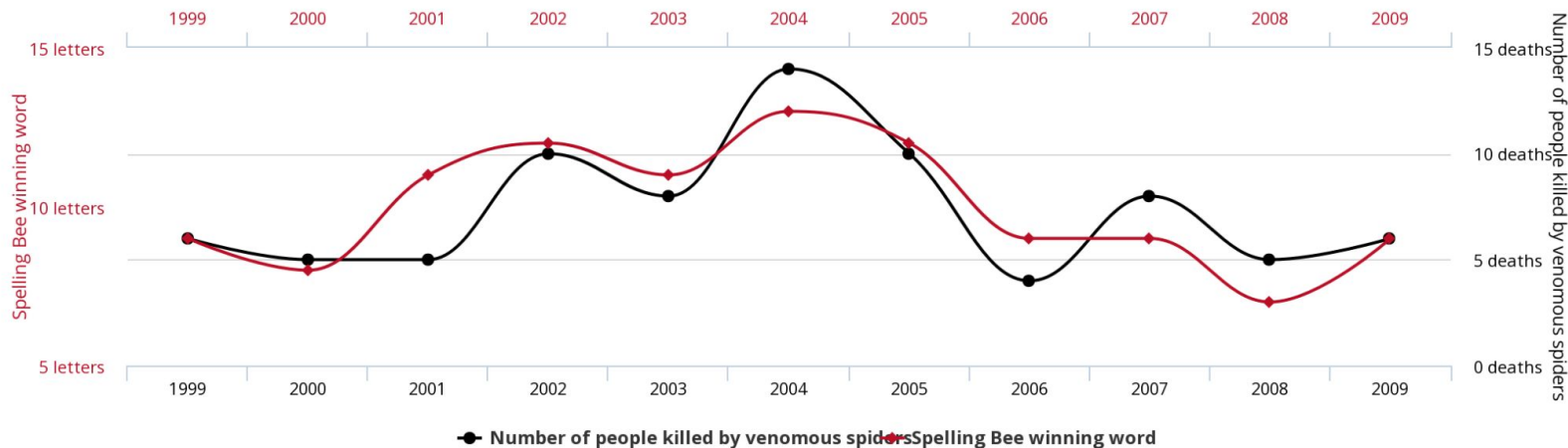
tylervigen.com



Letters in Winning Word of Scripps National Spelling Bee

correlates with

Number of people killed by venomous spiders



tylervigen.com



Correlation



Causality

CAUSALITY

PART I - CONFOUNDING

André dos Santos, *Ph.D.*



**Have you ever
noticed that,
among the people
you date**

**the
attractive
ones tend to
be jerks?**

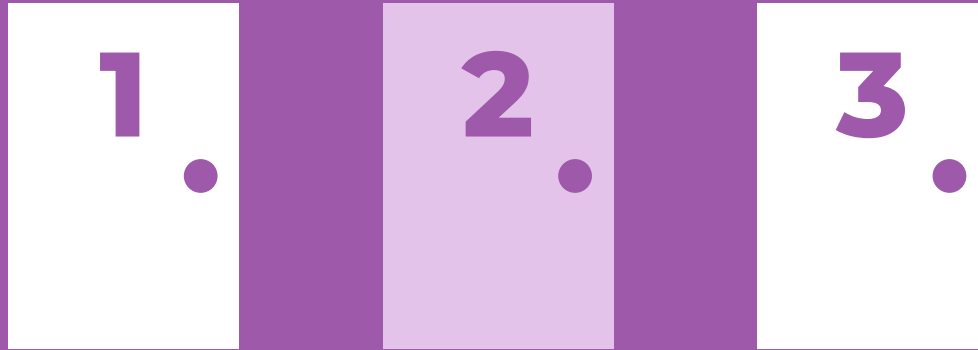
The Monty Hall problem

"Let's make a deal"



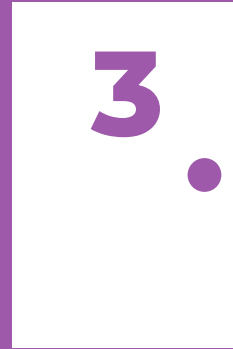
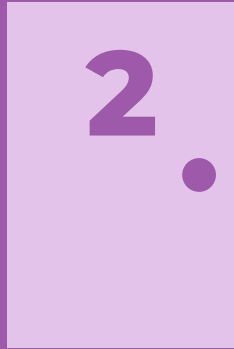
The Monty Hall problem

"Let's make a deal"



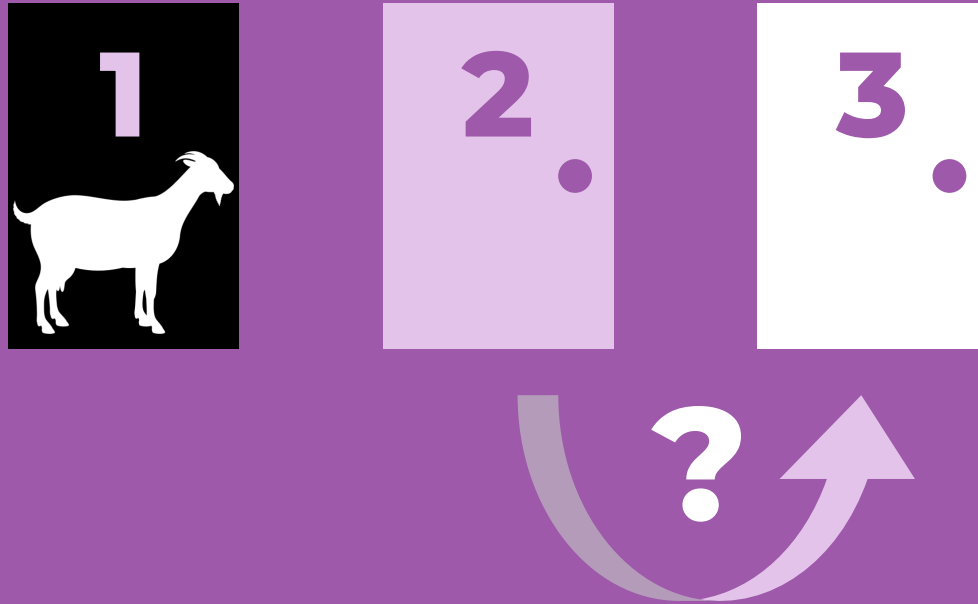
The Monty Hall problem

"Let's make a deal"



The Monty Hall problem

"Let's make a deal"



The Ladder of Causation



SEEING

ASSOCIATION



DOING

INTERVENTION

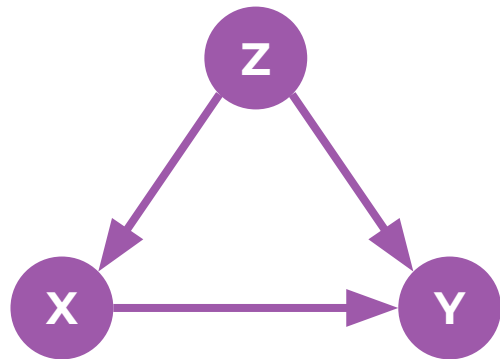


IMAGINING

COUNTERFACTUALS

Confounding

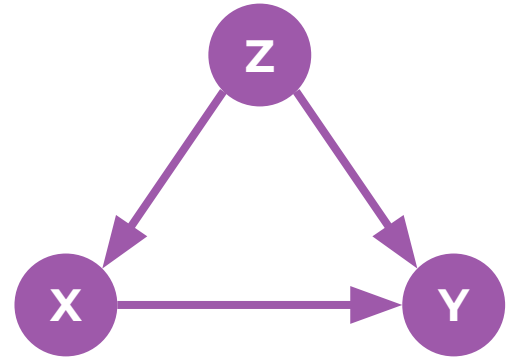
- Not a statistical notion
- $P(Y|X) \neq P(Y|\text{do}(X))$
- **Discrepancy** between what we want to assess (the causal effect) and what we actually do assess using statistical method



Backdoor path is any path from X to Y that starts with an arrow pointing into X.

$$X \leftarrow Z \rightarrow Y$$

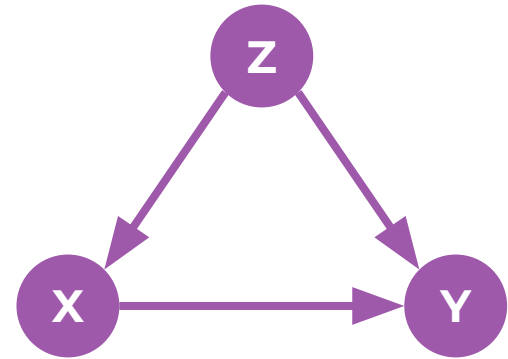
X and Y will be **deconfounded** if we block every backdoor path.



Backdoor path is any path from X to Y that starts with an arrow pointing into X.

$$X \leftarrow Z \rightarrow Y$$

X and Y will be **deconfounded** if we block every backdoor path.



Flow of Information In Causal Graph



CHAIN

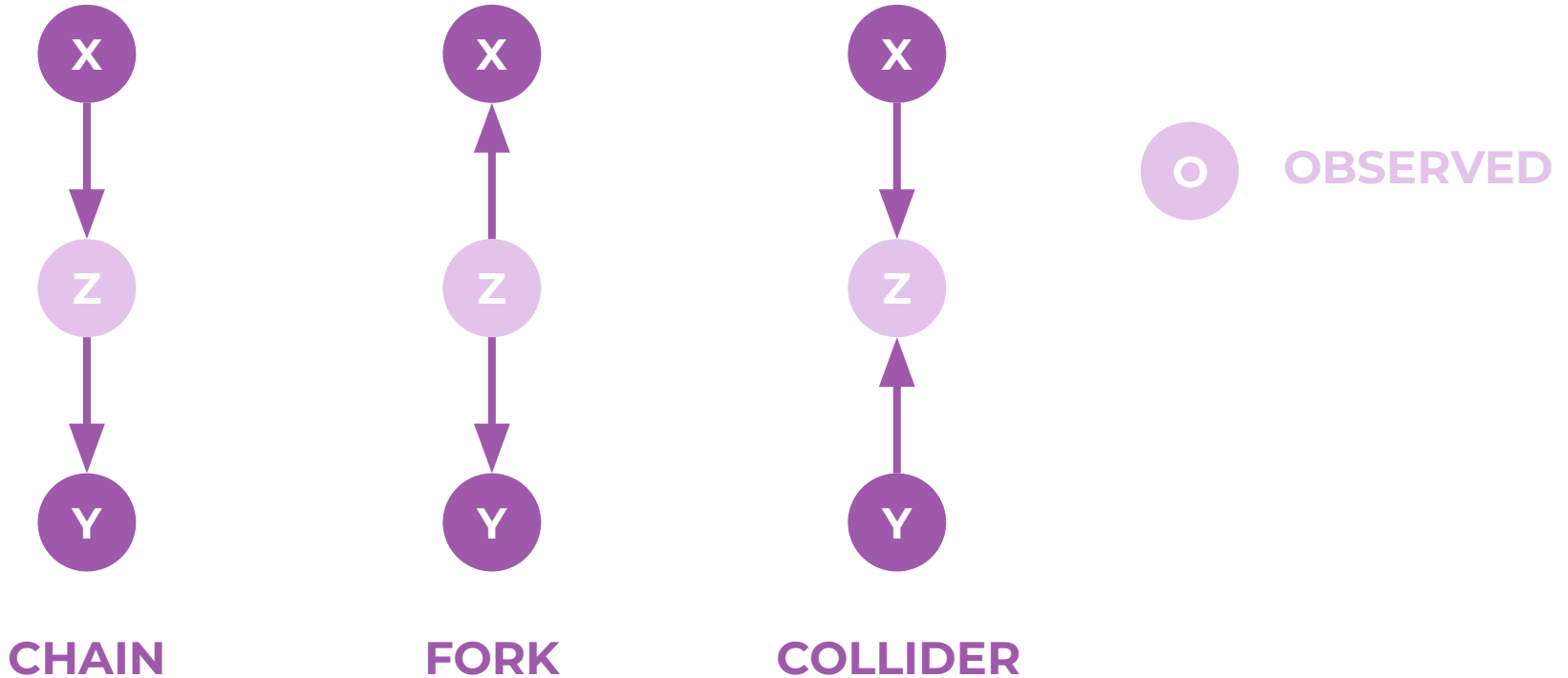


FORK

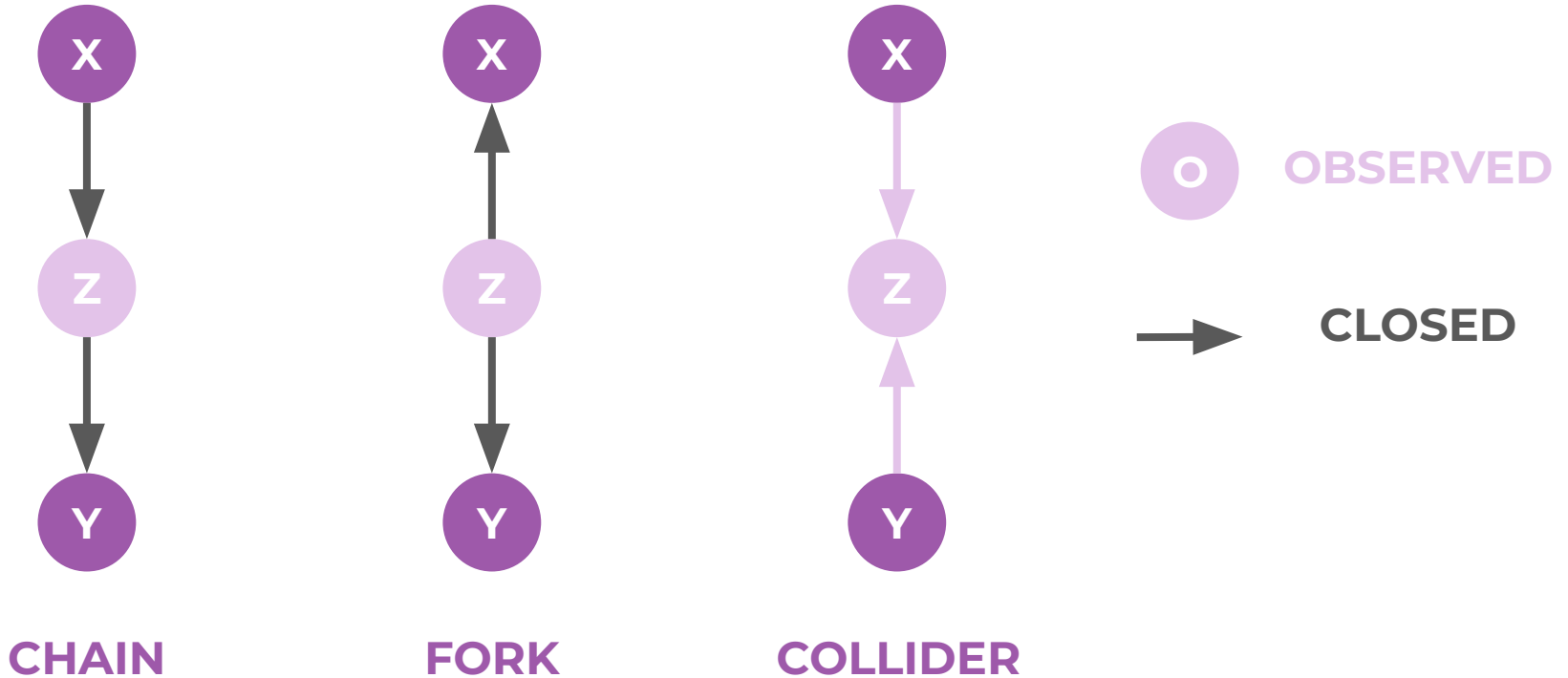


COLLIDER

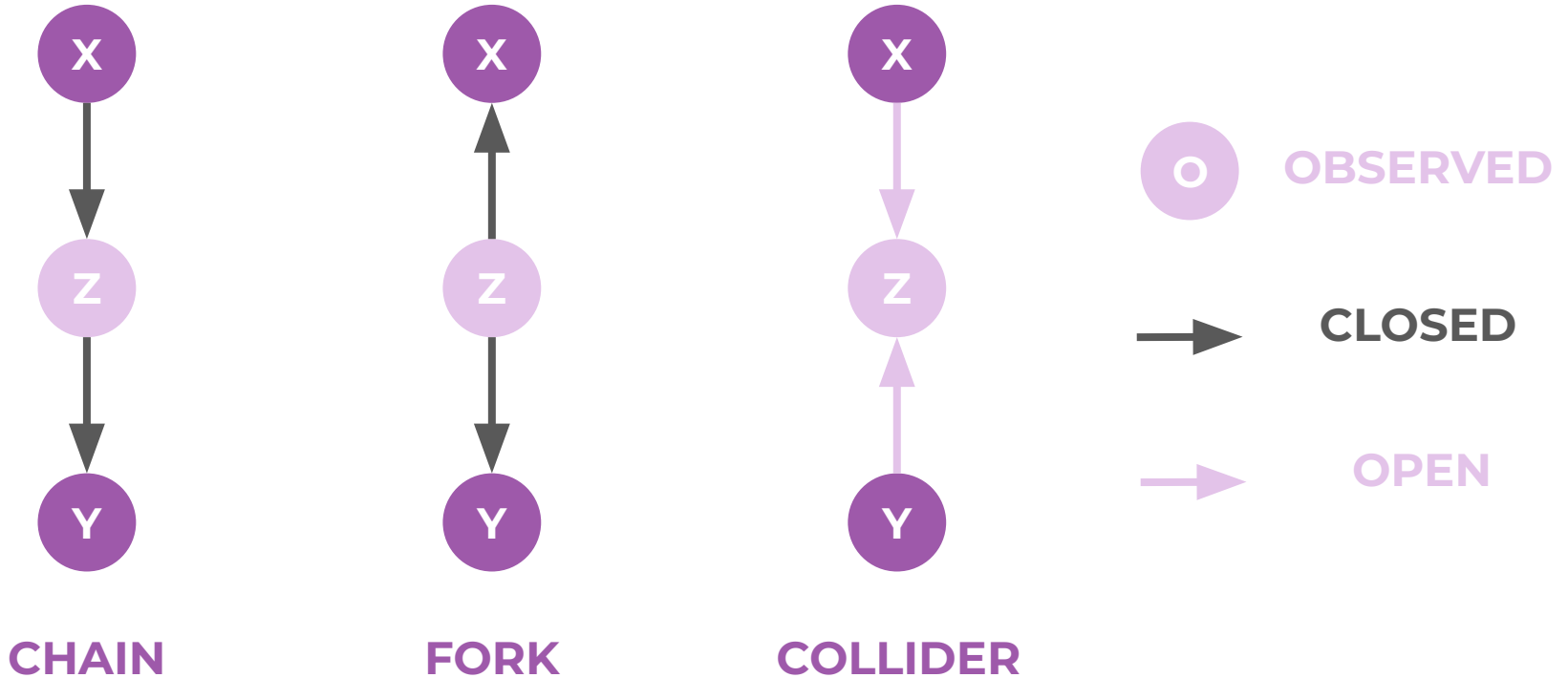
Flow of Information In Causal Graph



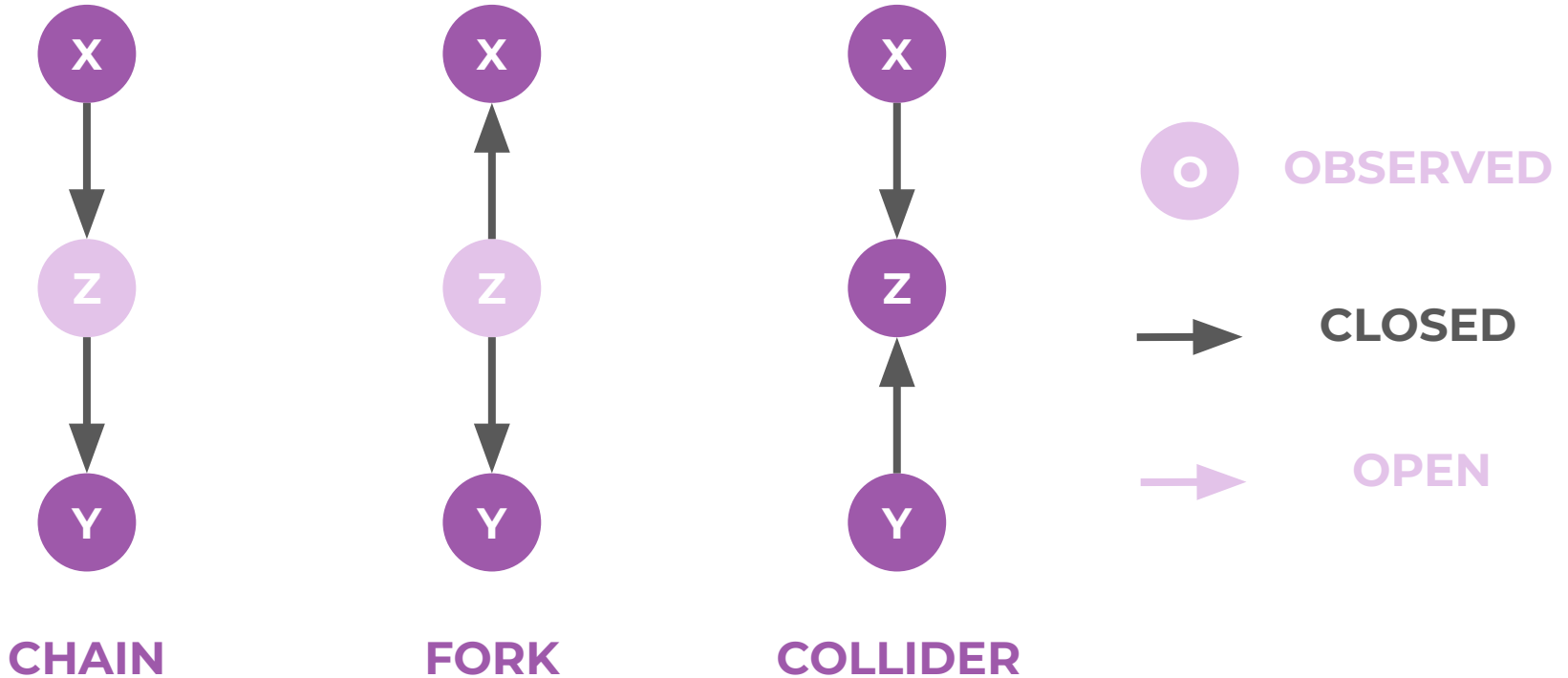
Flow of Information In Causal Graph



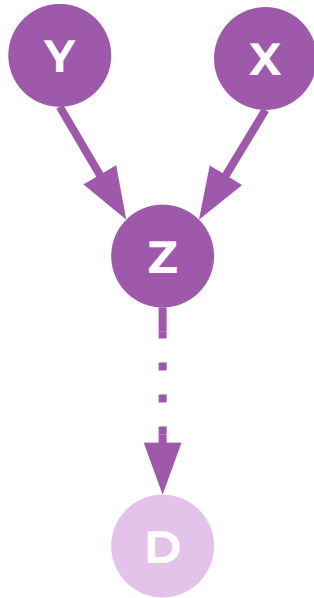
Flow of Information In Causal Graph



Flow of Information In Causal Graph



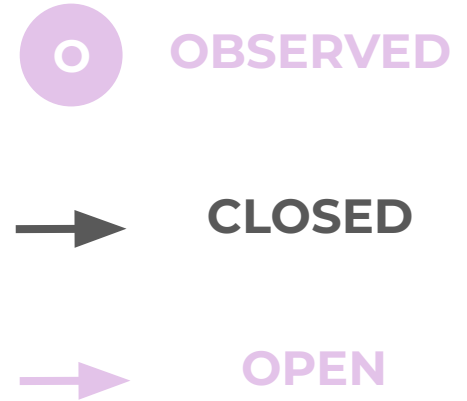
Flow of Information In Causal Graph



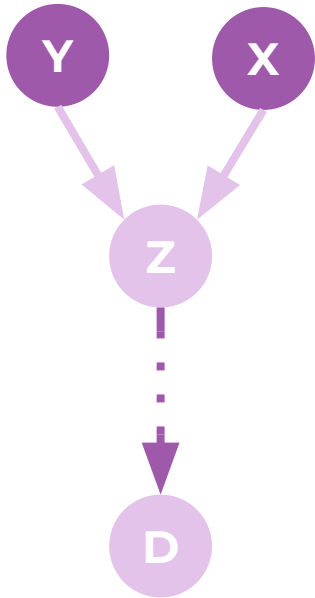
***DESCENDENTS**



COLLIDER



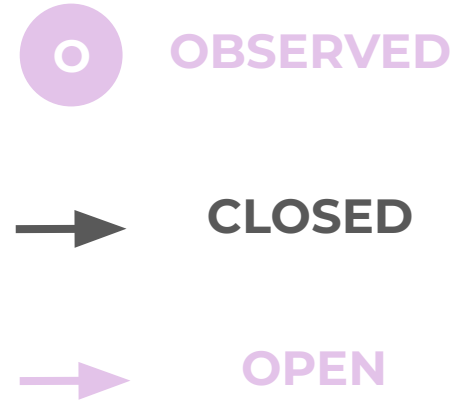
Flow of Information In Causal Graph



***DESCENDENTS**



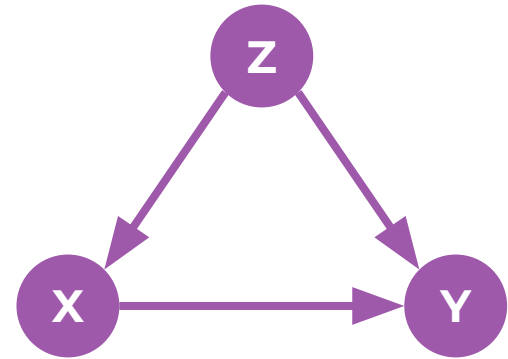
COLLIDER

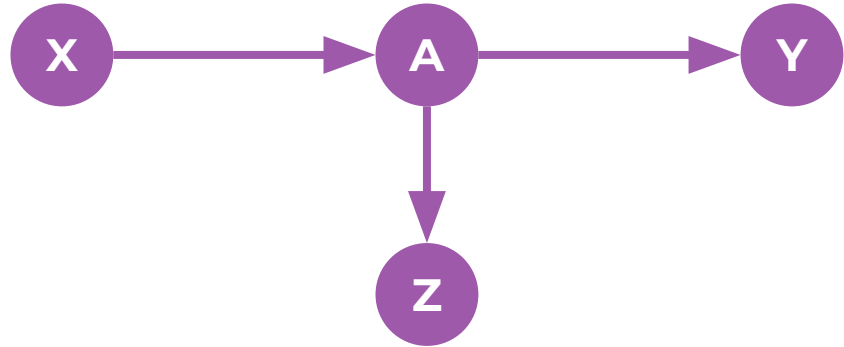


Backdoor path is any path from X to Y that starts with an arrow pointing into X.



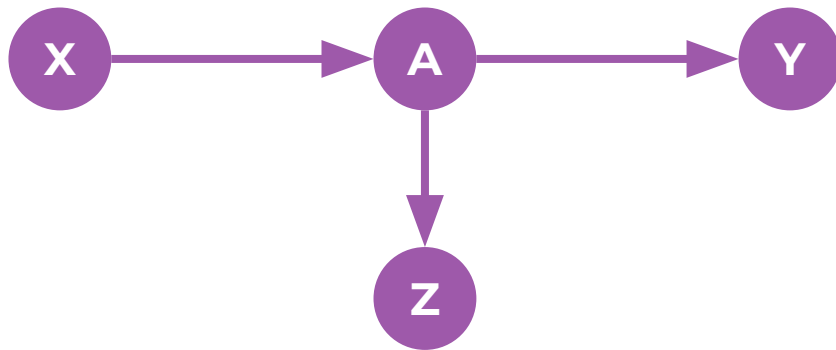
X and Y will be **deconfounded** if we block every backdoor path.

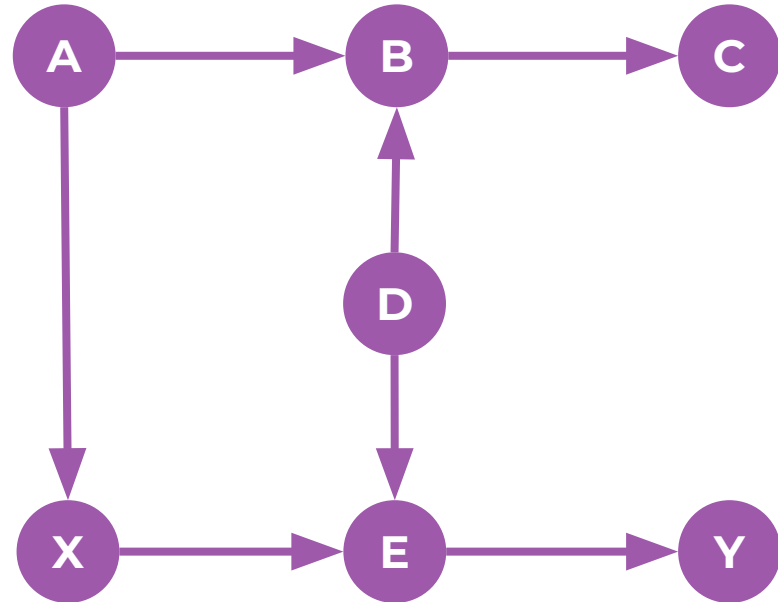






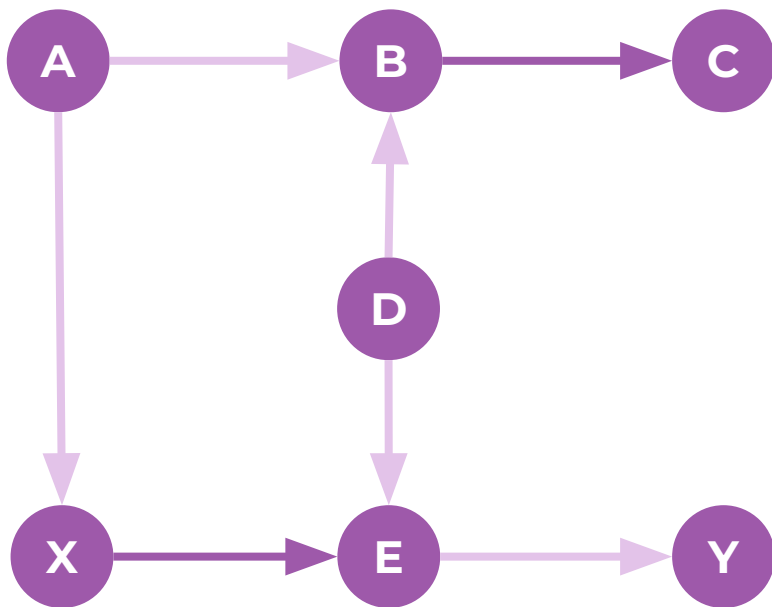
- No backdoor





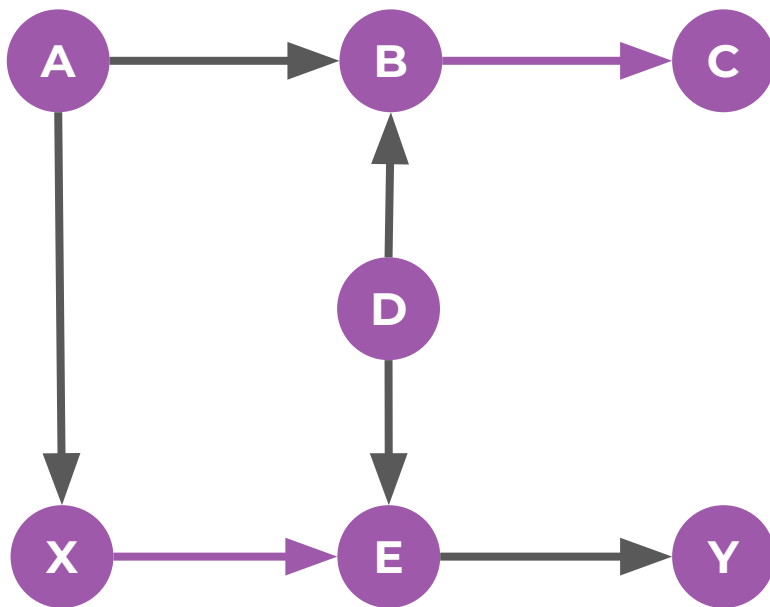


- One backdoor path
- $X \leftarrow A \rightarrow B \leftarrow D \rightarrow E \rightarrow Y$



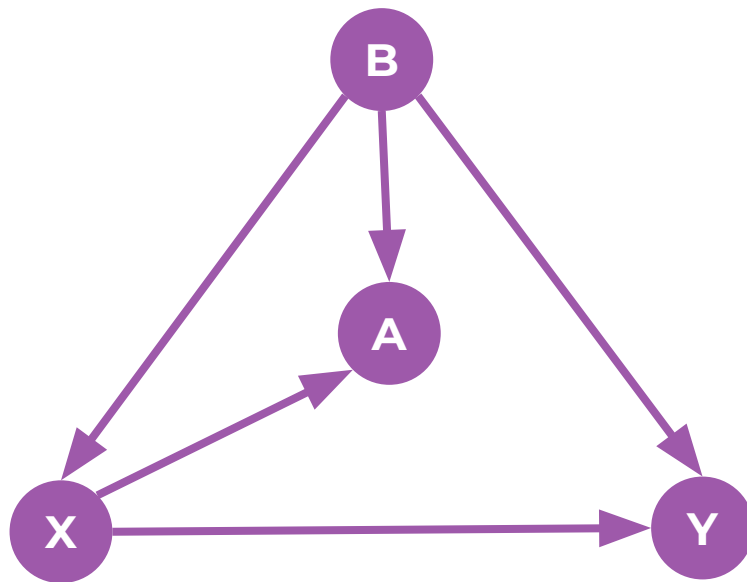


- One backdoor path
- $X \leftarrow A \rightarrow B \leftarrow D \rightarrow E \rightarrow Y$
- Control \emptyset



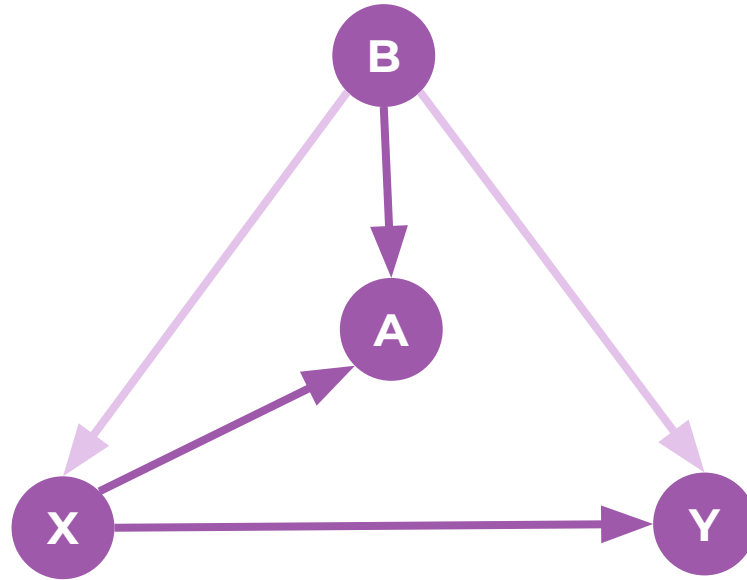


- One backdoor path
- $X \leftarrow B \rightarrow Y$



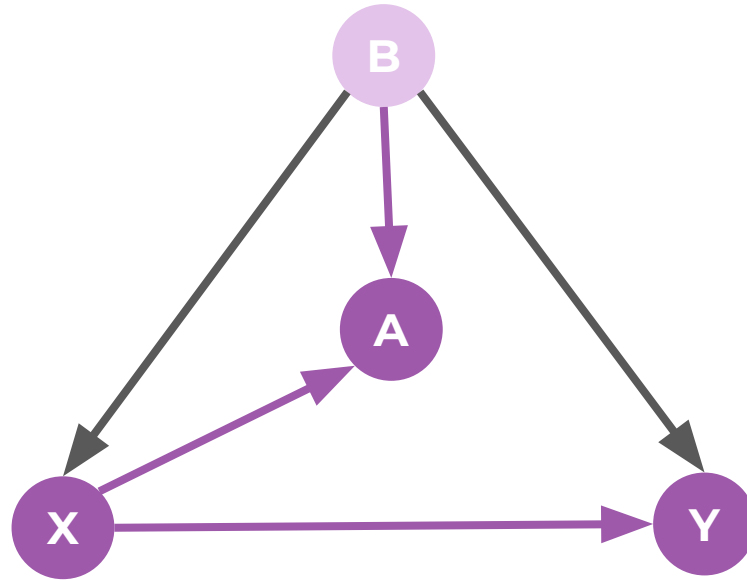


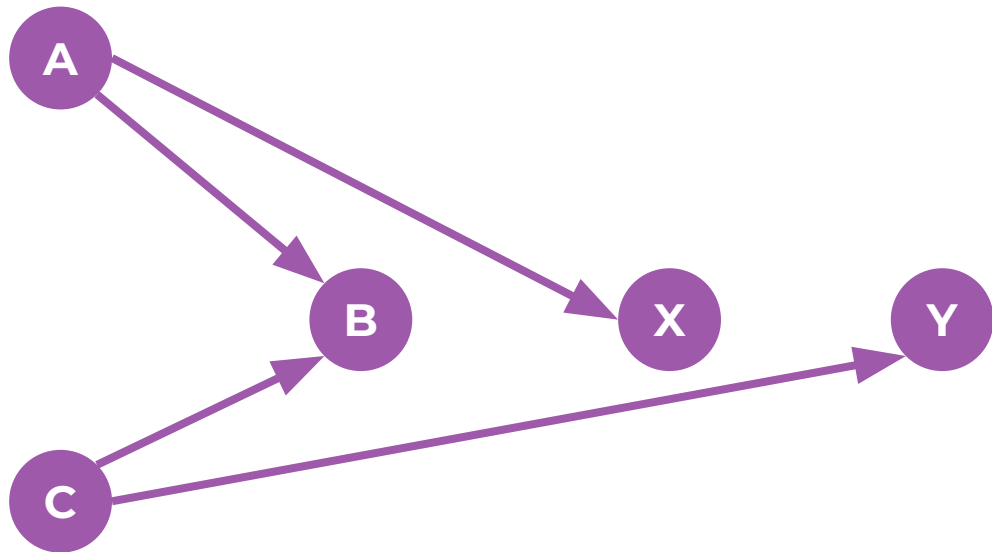
- One backdoor path
- $X \leftarrow B \rightarrow Y$





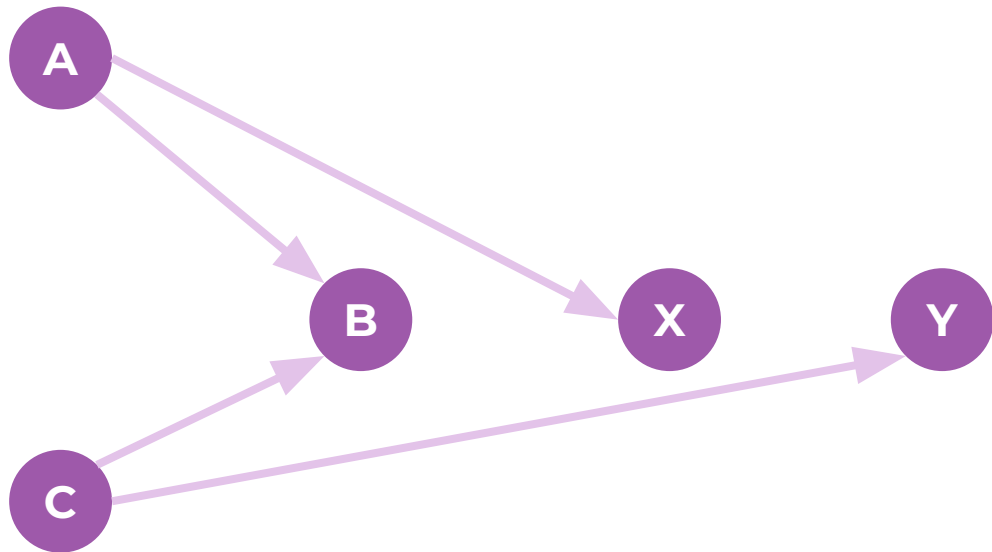
- One backdoor path
- $X \leftarrow B \rightarrow Y$
- Control B





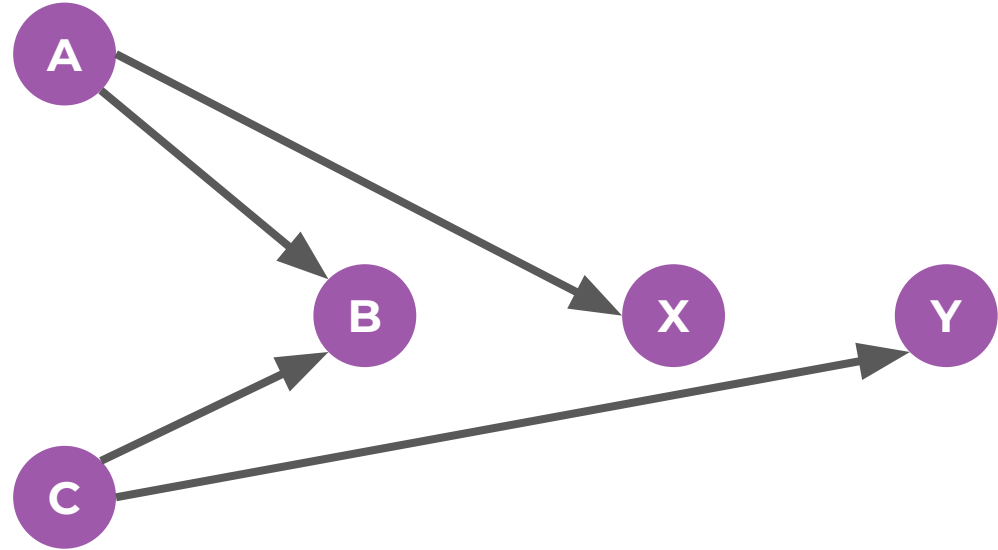


- One backdoor path
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$



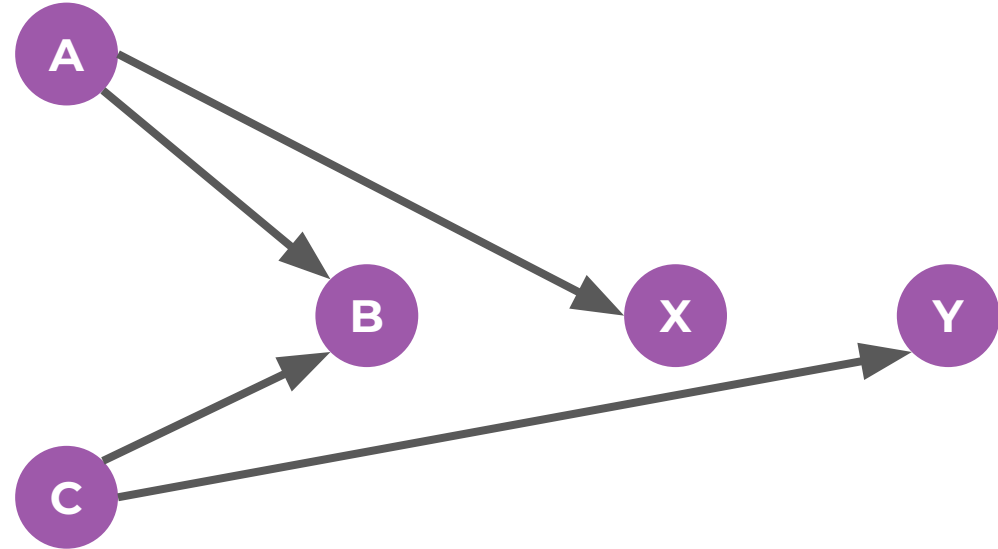


- One backdoor path
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$
- Control \emptyset



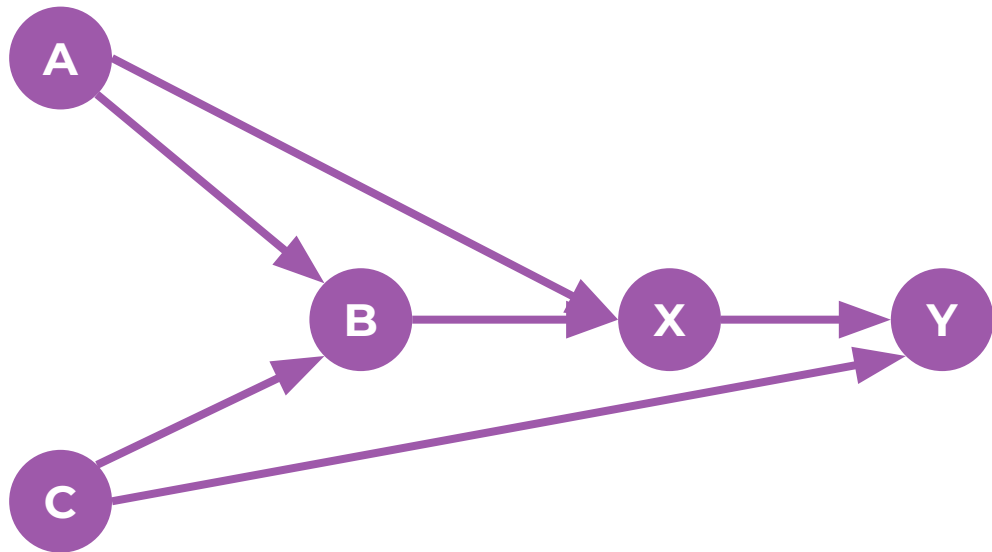


- One backdoor path
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$
- Control \emptyset



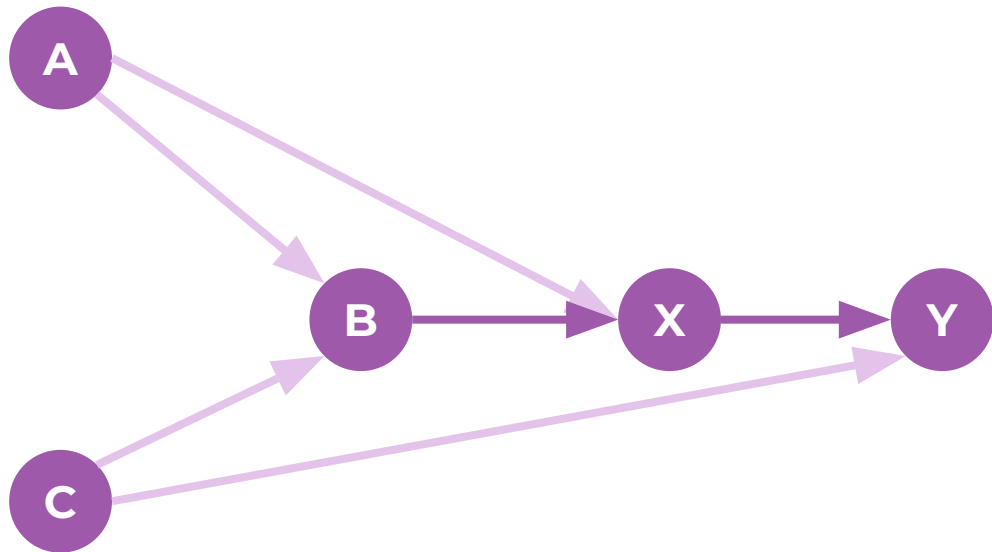
A := Societal norms
B := Seat belt usage
C := Safety and health related measures

X := Smoking
Y := Lung disease



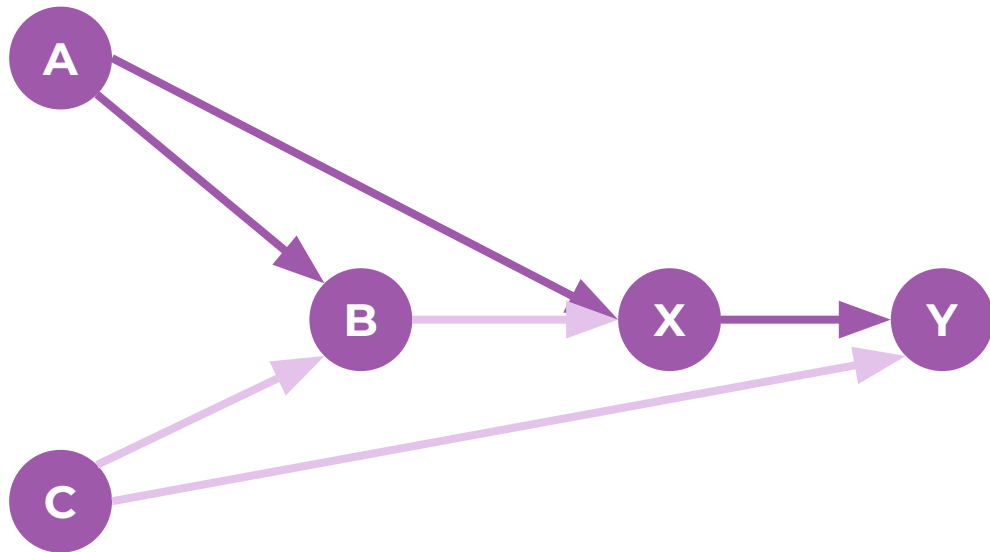


- Two backdoor paths
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$



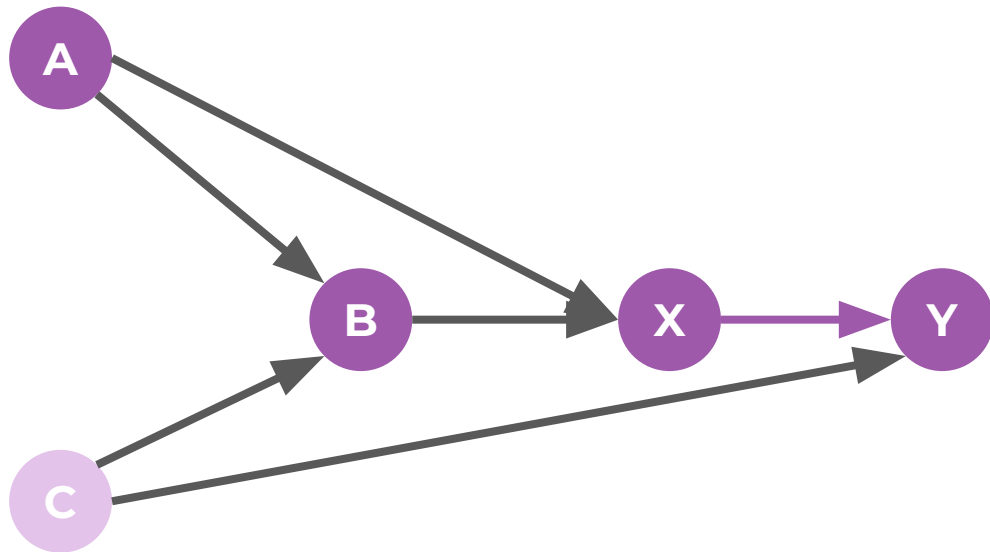


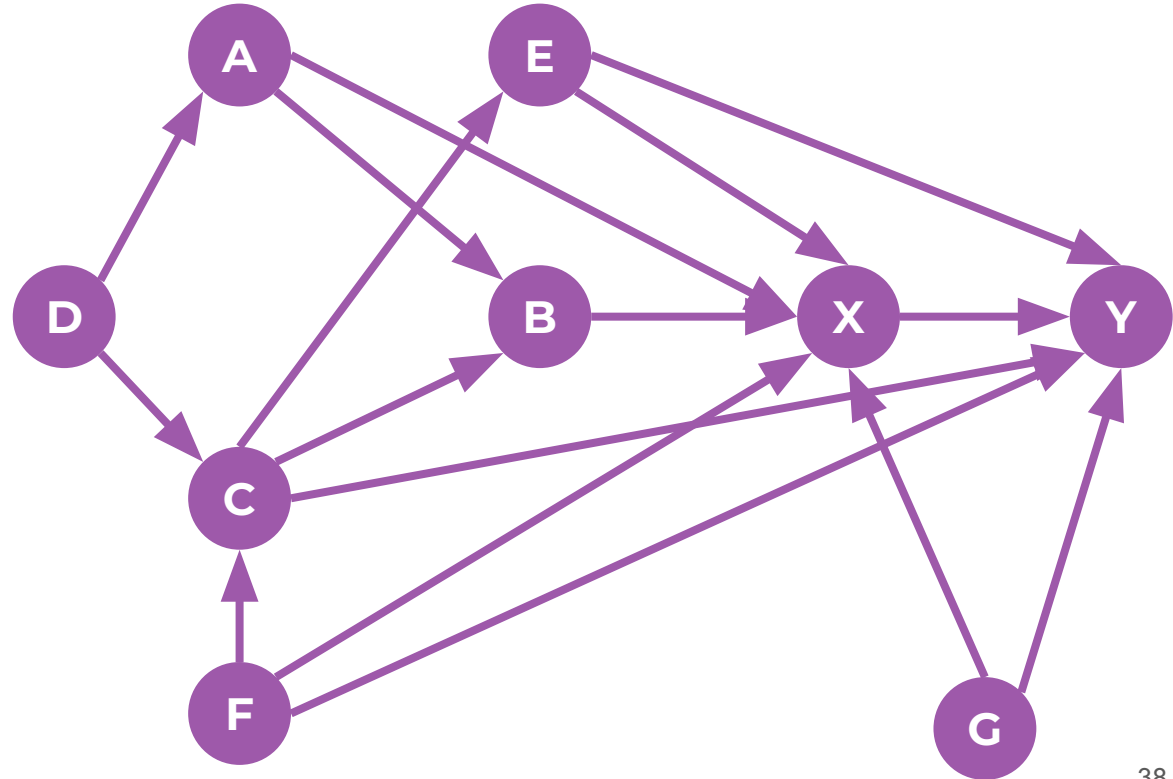
- Two backdoor paths
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$
 - $X \leftarrow B \leftarrow C \rightarrow Y$





- Two backdoor paths
 - $X \leftarrow A \rightarrow B \leftarrow C \rightarrow Y$
 - $X \leftarrow B \leftarrow C \rightarrow Y$
- Control C

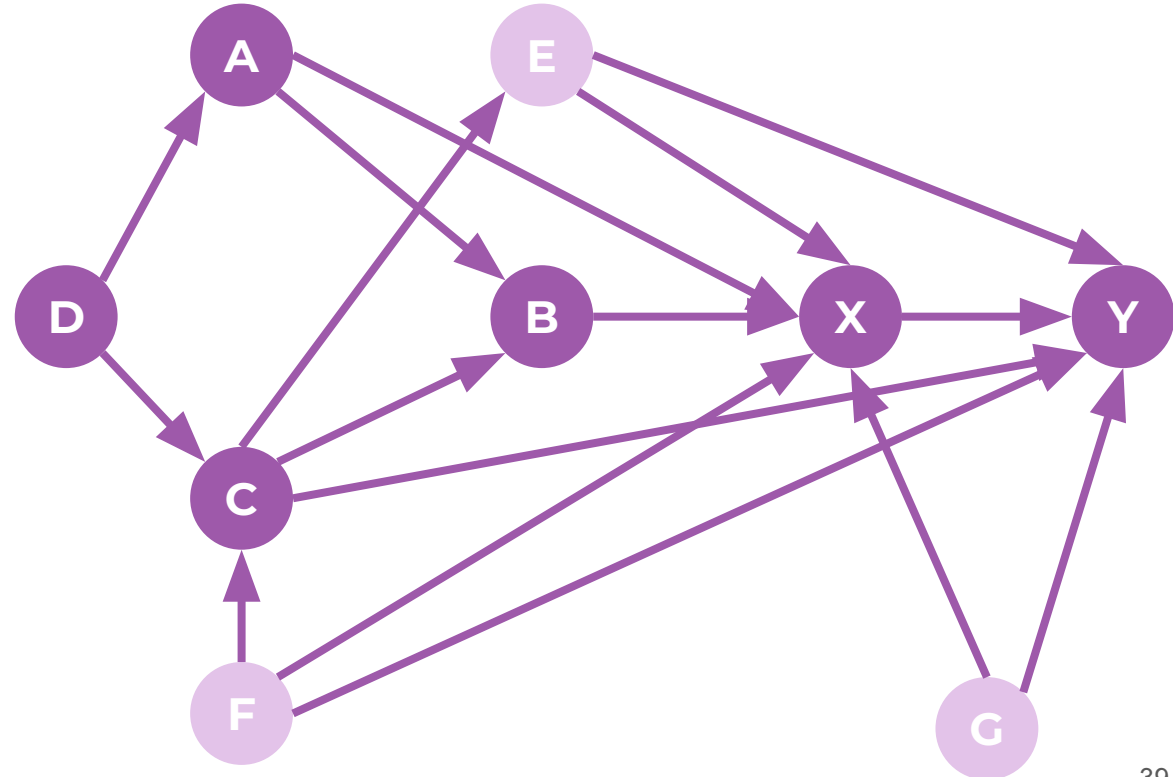




A := Societal norms
B := Seat belt usage
C := Safety and health related measures
D := Parental asthma
E := Chronic bronchitis
F := Sex
G := Socioeconomic status
X := Smoking
Y := Lung disease



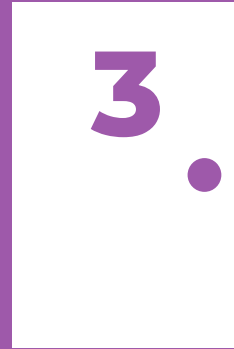
- Control E, F, and G












A := Societal norms
B := Seat belt usage
C := Safety and health related measures
D := Parental asthma
E := Chronic bronchitis
F := Sex
G := Socioeconomic status
X := Smoking
Y := Lung disease

The Monty Hall problem

"Let's make a deal"



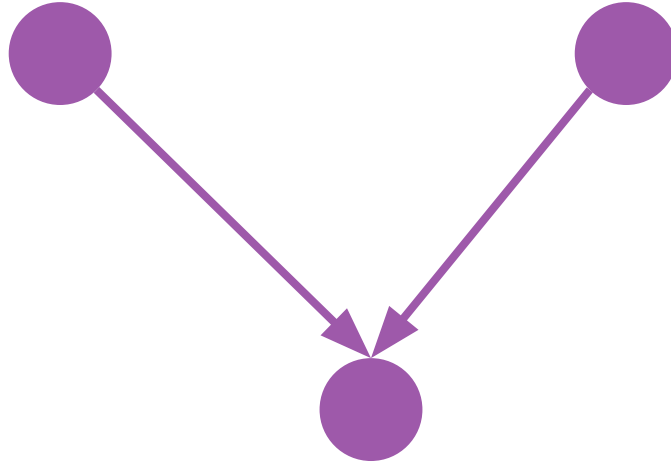
The Monty Hall problem

Chosen				
Door 1	Door 2	Door 3	Outcome if switch	Outcome if stay
			Lose	Win
			Win	Lose
			Win	Lose

The Monty Hall problem

Your Door

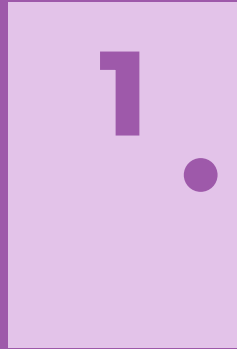
Location of Car



Second Door Opened







The Monty Hall problem 2.0

"Let's **fake** a deal"









The Monty Hall problem 2.0

"Let's **fake** a deal"

Door You Choose	Door with Car	Door Opened	Outcome if switch	Outcome if stay
1	1	2 	Lose	Win
1	1	3 	Lose	Win
1	2	2 	Lose	Lose
1	2	3 	Win	Lose
1	3	2 	Win	Lose
1	3	3 	Lose	Lose







The Monty Hall problem 2.0

"Let's **fake** a deal"

Door You Choose	Door with Car	Door Opened	Outcome if switch	Outcome if stay
1	1	2 	Lose	Win
1	1	3 	Lose	Win
1	2	2 	Lose	Lose
1	2	3 	Win	Lose
1	3	2 	Win	Lose
1	3	3 	Lose	Lose

The Monty Hall problem 2.0

"Let's **fake** a deal"

Door You Choose	Door with Car	Door Opened	Outcome if switch	Outcome if stay
1	1	2 	Lose	Win
1	1	3 	Lose	Win
1	2	2 	Lose	Lose
1	2	3 	Win	Lose
1	3	2 	Win	Lose
1	3	3 	Lose	Lose

The Monty Hall problem

Your Door

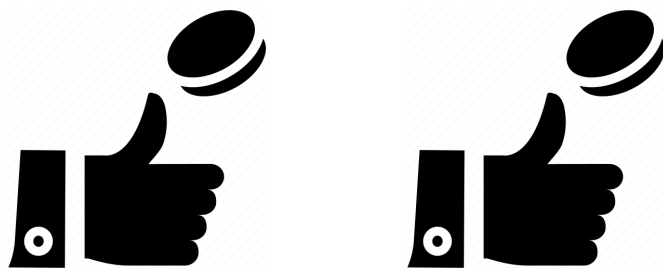
Location of Car



Second Door Opened

2 coins and 1 date

Berkson's Paradox



Write down the results only when **at least** one of them comes up **heads**

2 coins and 1 date

Berkson's Paradox

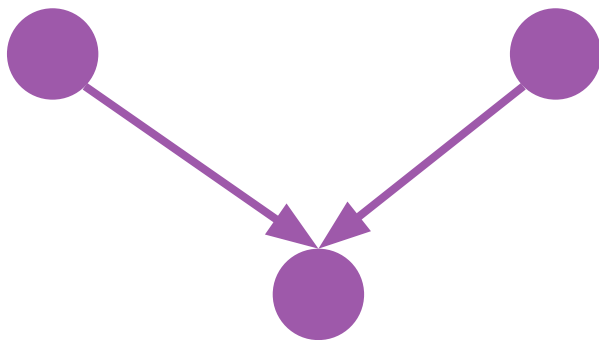
Coin 1	Coin 2	Ω
Heads	Heads	25
Heads	Tails	23
Tails	Heads	27

2 coins and 1 date

Berkson's Paradox

First coin toss

Second coin toss



Registered Event

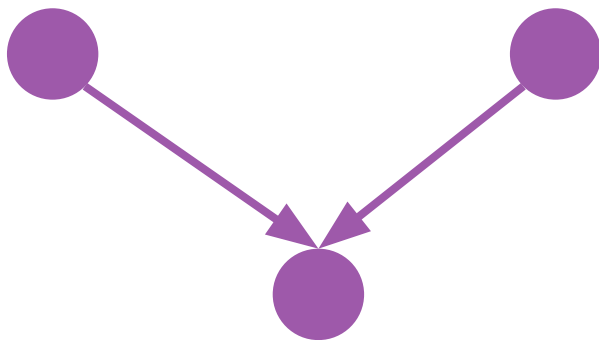
Coin 1	Coin 2	Ω
Heads	Heads	25
Heads	Tails	23
Tails	Heads	27
Tails	Tails	X

2 coins and 1 date

"How Not to Be Wrong" by Jordan Ellenberg

Attractiveness

Nice Personality



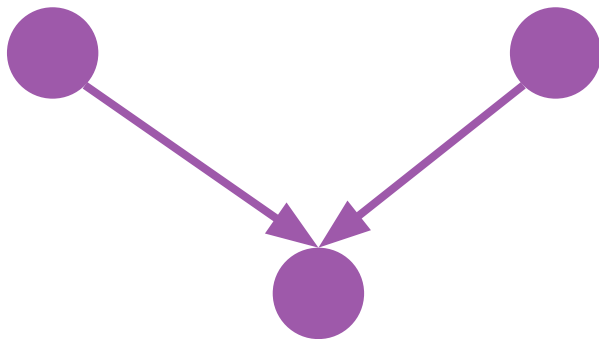
Dating Material

2 coins and 1 date

"How Not to Be Wrong" by Jordan Ellenberg

Attractiveness

Nice Personality



Dating Material

Nice



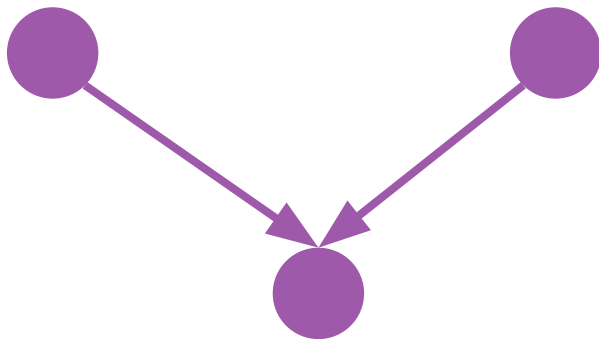
Attractive

2 coins and 1 date

"How Not to Be Wrong" by Jordan Ellenberg

Attractiveness

Nice Personality



Dating Material

Nice



Attractive

CAUSALITY

PART I - CONFOUNDING

André dos Santos, *Ph.D.*

