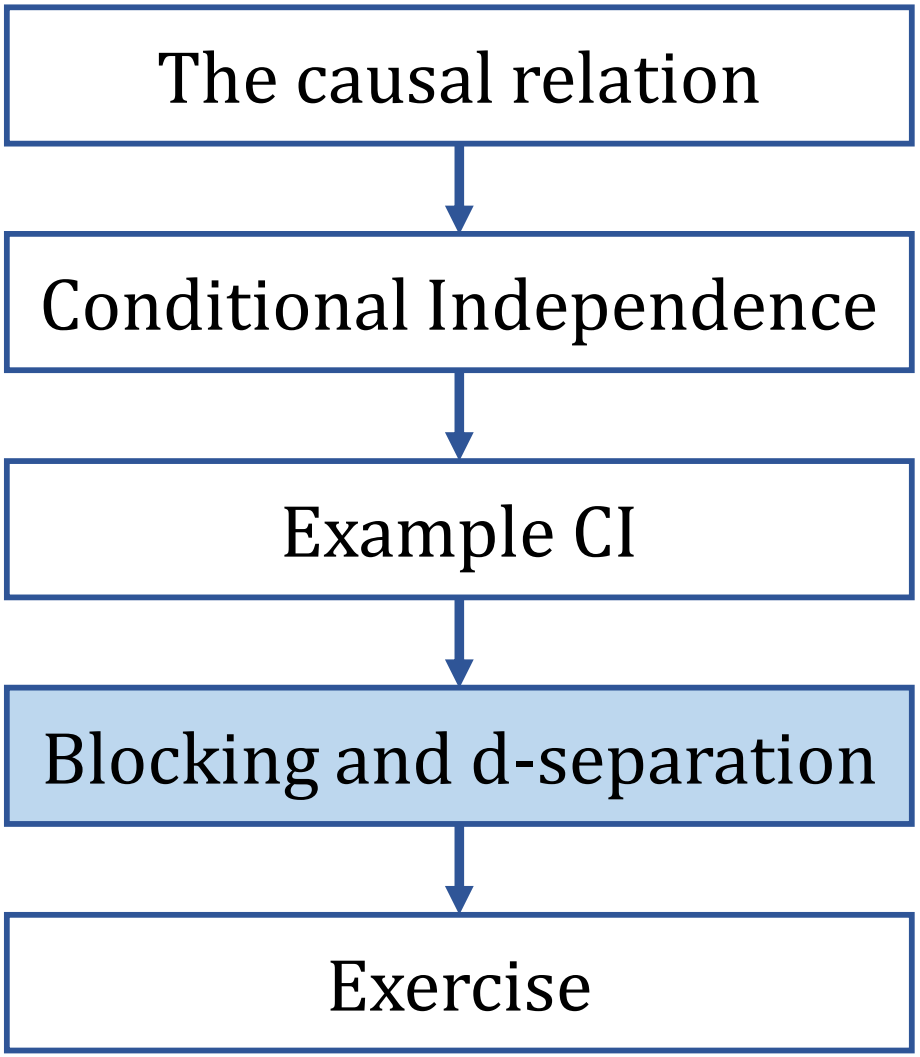
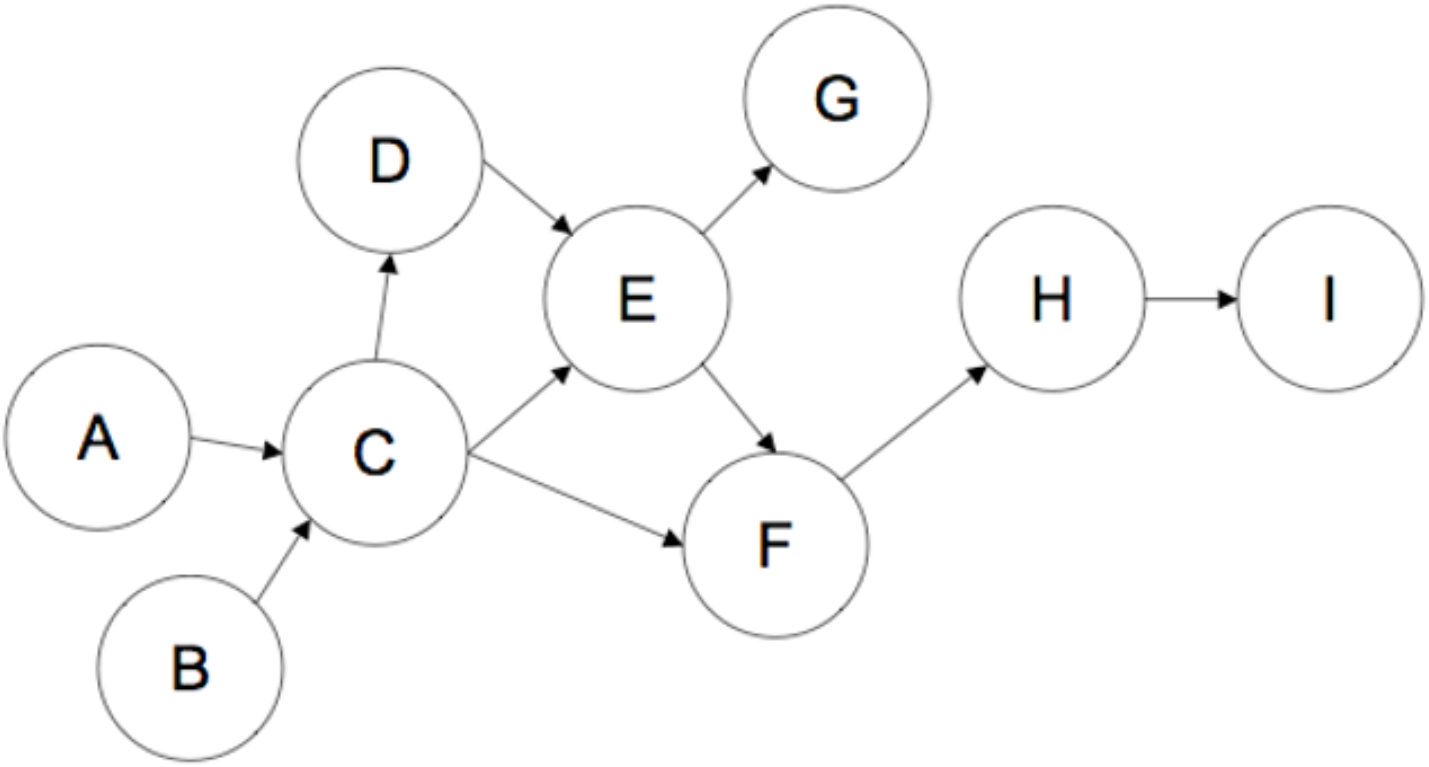
Overview


The causal relation
Conditional Independence
Example CI
Blocking and d-separation
Exercise

Causal assumptions

- Now suppose we are prepared to make some causal assumptions, most importantly:
  - there are no omitted variables that generate dependencies, and
  - all causal relations are necessary to establish the pattern of CIs
- Then we *can* deduce causal relations from correlational data (at least in principle)
- Quite a nice result!
- However, notice that data alone will not do the trick: *you need to put in causal assumptions (always...)*

Blocking and d-separation



A Directed Acyclic Graph (DAG)

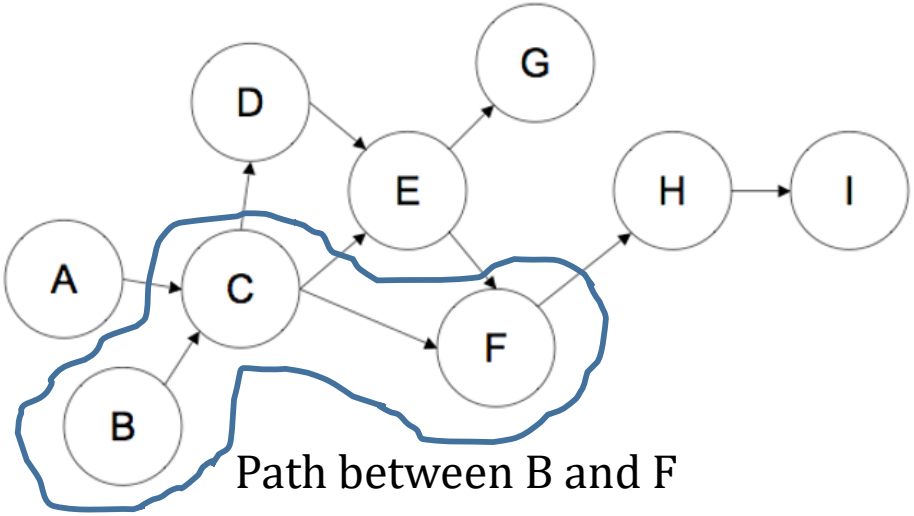
Blocking and d-separation

It would be nice if we could just look at the graph and see which CI relations it entails

Rule: if you want to know whether in a directed acyclic graph two variables A and B are independent given C, see if they are d-separated

- For this you have to (a) check all the paths between A and B, and (b) see if they are all *blocked*
- If all paths are blocked by C, then C d-separates A and B, and you can predict that A is independent of B given C

Blocking and d-separation



Path between B and F

- A *path* between two variables is formed by a series of edges that you can travel to reach one variable from the other, without retracing your steps
- In the above graph, the path depicted is B-C-F
- Note that B-C-F and F-C-B are not distinct paths: the orientation of the links doesn't matter for identifying paths
- So for identifying paths, you only need to look at the network structure, not at the directions of the links

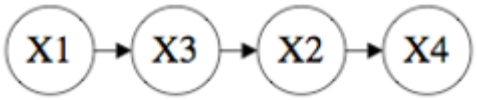
When is a path blocked?

- A path between A and B is said to be blocked by a variable C if:
  - A and B are connected by a chain in which C is the middle node (A→C→B or A←C←B), or
  - A and B are connected by a common cause, and C is that common cause (A←C→B), or
  - A and B are connected by a common effect ('collider'), but C is not that common effect, and C is not one of the effects of the common effect.

Blocking and d-separation

Does X3
block the path from X1
to X2?

1. X3 is the middle node in a chain



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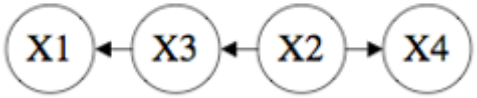
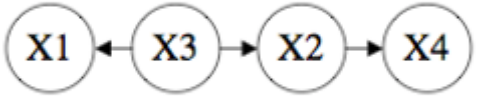
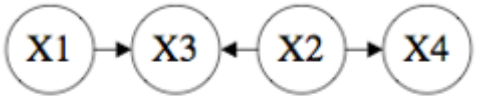


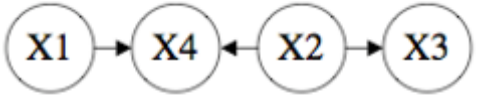
3. X3 is the common cause



4. X3 is the common effect



5. X3 isn't on the path



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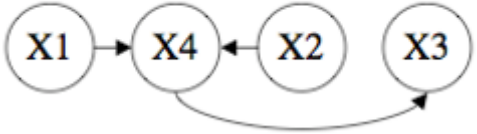

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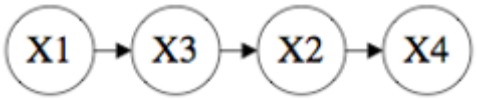
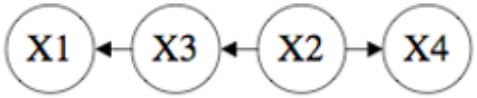
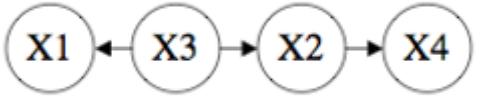
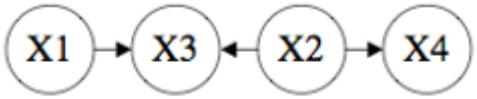
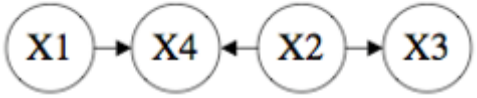
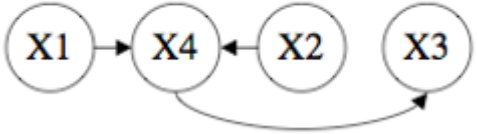
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		
3. X3 is the common cause		
4. X3 is the common effect		
5. X3 isn't on the path		
6. X3 isn't on the path		

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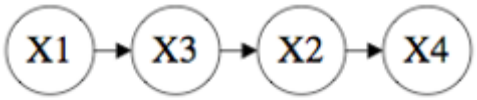
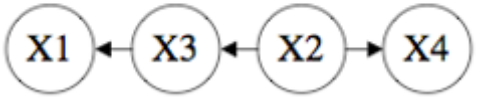
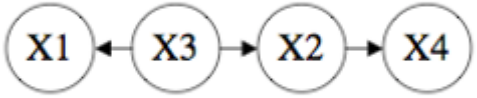
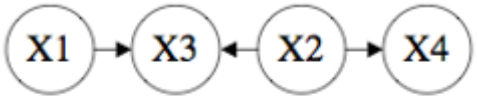
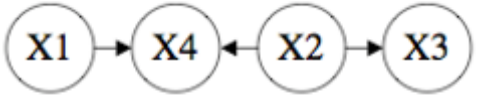
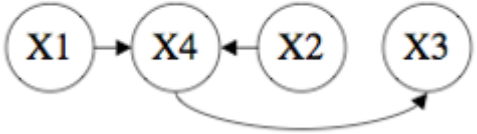
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		Yes
3. X3 is the common cause		
4. X3 is the common effect		
5. X3 isn't on the path		
6. X3 isn't on the path		

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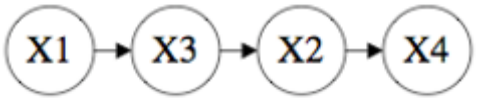
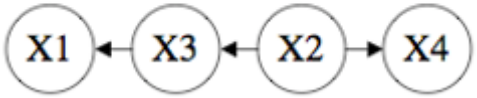
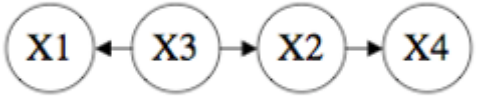
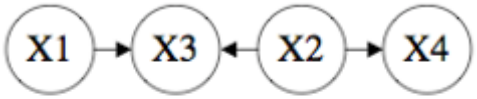
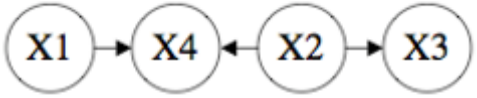
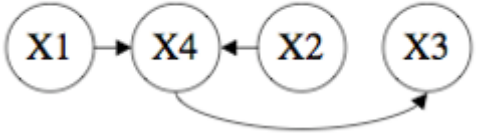
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		Yes
3. X3 is the common cause		Yes
4. X3 is the common effect		
5. X3 isn't on the path		
6. X3 isn't on the path		

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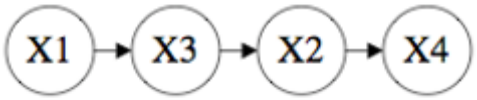
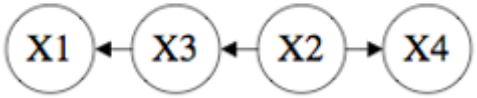
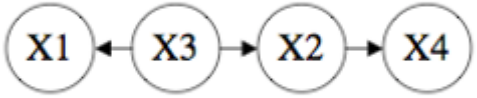
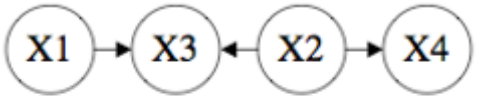
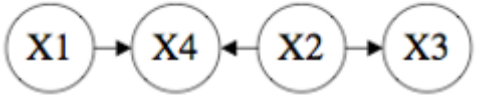
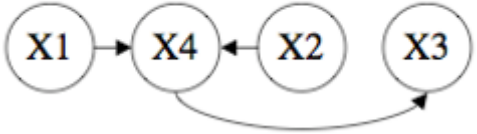
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		Yes
3. X3 is the common cause		Yes
4. X3 is the common effect		No
5. X3 isn't on the path		
6. X3 isn't on the path		

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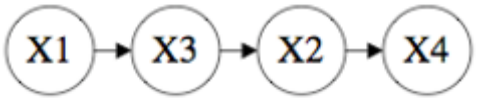
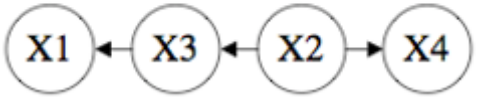
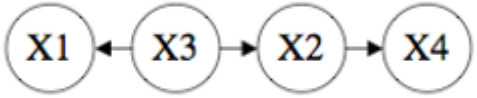
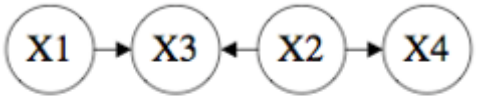
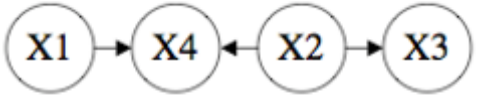
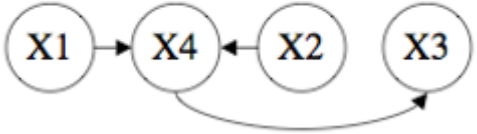
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		Yes
3. X3 is the common cause		Yes
4. X3 is the common effect		No
5. X3 isn't on the path		Yes (!)
6. X3 isn't on the path		

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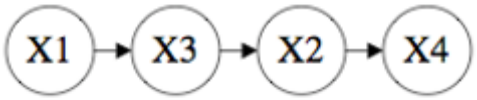
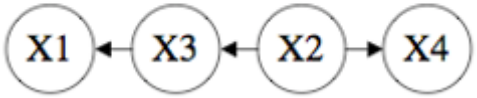
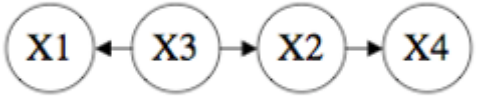
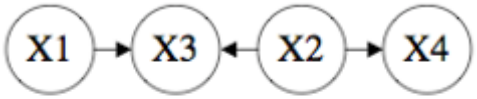
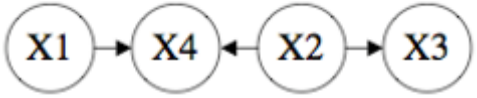
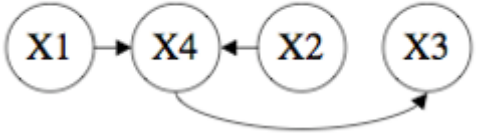
1. X3 is the middle node in a chain		Yes
2. X3 is the middle node in a chain		Yes
3. X3 is the common cause		Yes
4. X3 is the common effect		No
5. X3 isn't on the path		Yes (!)
6. X3 isn't on the path		No (!)

Practice!

(open d-separation_exercise.pdf)

Recipe: are A and B independent given C?

1. List every path between A and B
2. For every path, check whether C blocks it
3. If C blocks all the paths in step (2), then C d-separates A and B, and A is conditionally independent of B given C
4. Is C does not block all the paths in step (2), then C does not d-separate A and B. In this case anything may happen: we don't know.