# Causality

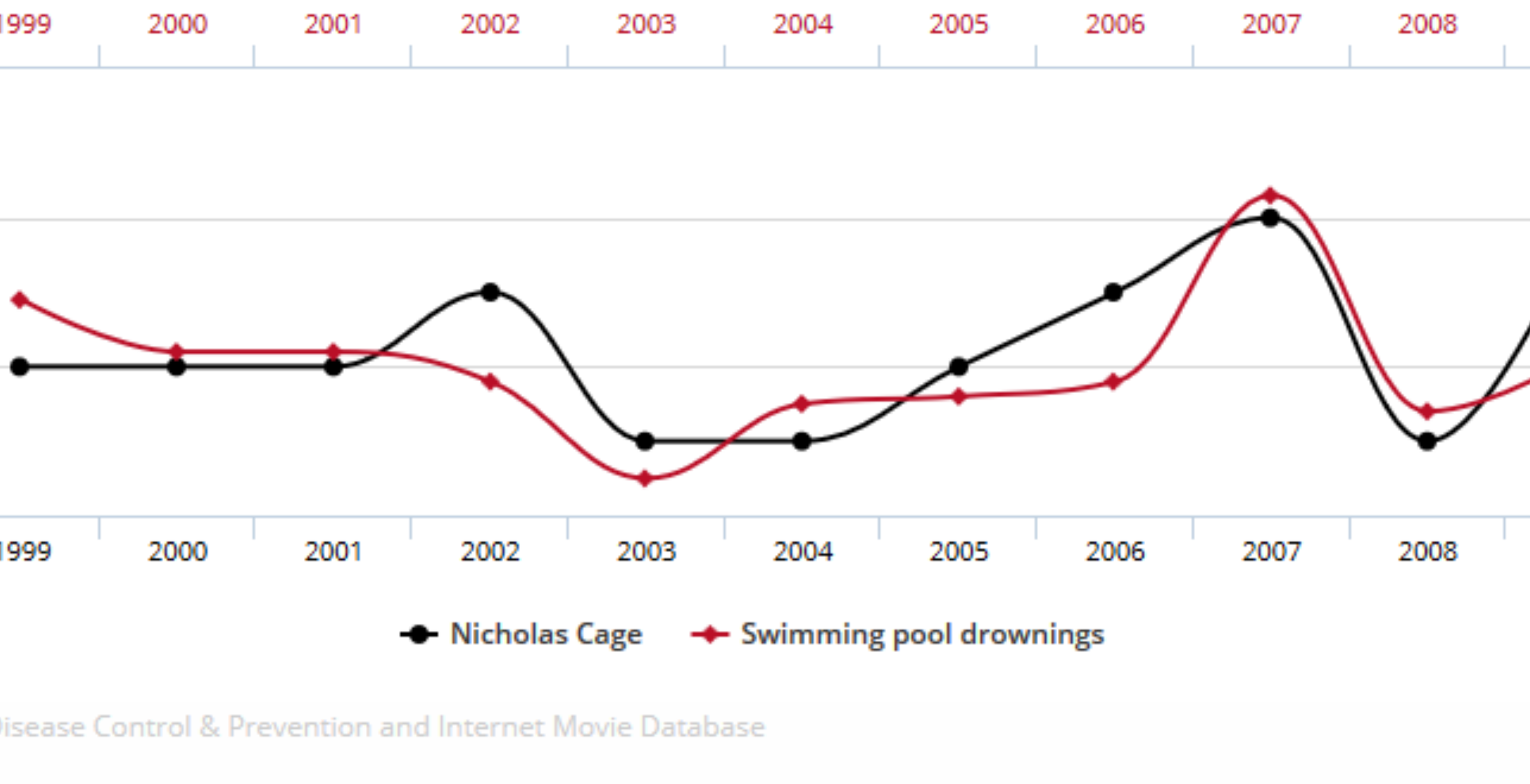
Julian Faraway

# Number of people who drowned by falling into a pool

correlates wtih

# Films Nicolas Cage appeared in

Correlation: 66.6% (r=0.666004, p>0.05)




Disease Control & Prevention and Internet Movie Database

# Correlation is not Causation

**Completely Gullible** ⟷ **Utterly Cynical**

**Correlation is evidence of Causation**

# David Hume

*Enquiry Concerning*
*Human Understanding*

**1748**

introduces the idea of the
counterfactual

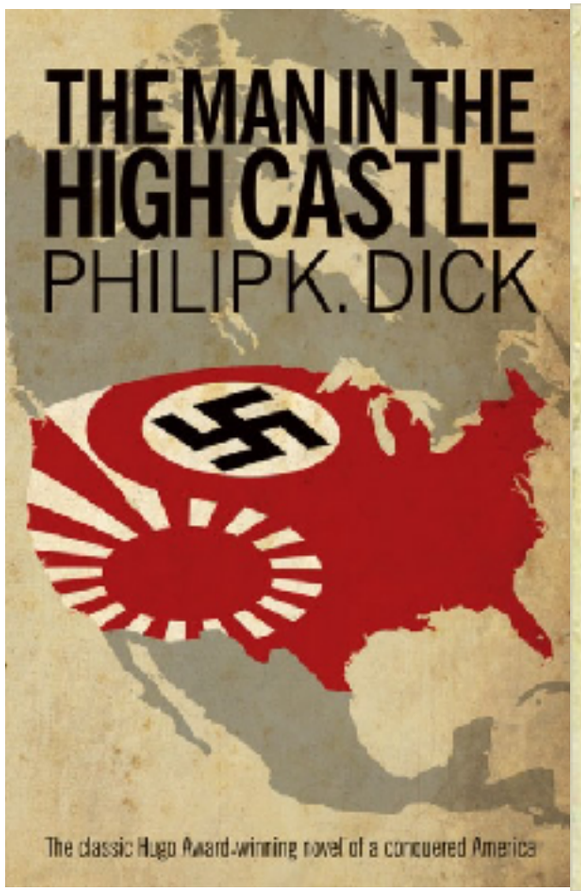
An object is the cause of another..

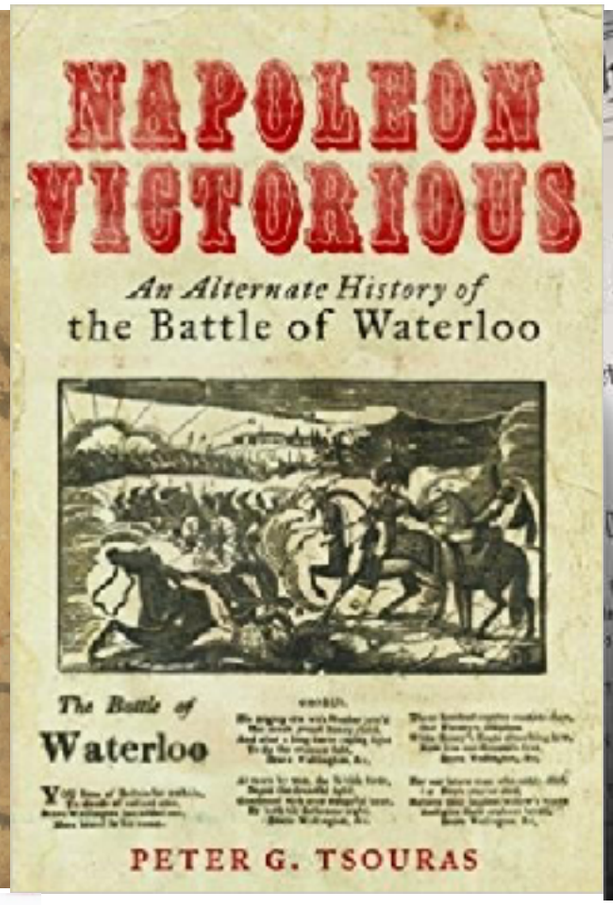
*“if the first object had not been,*
*the second never had existed”*

**Action** → **Outcome**

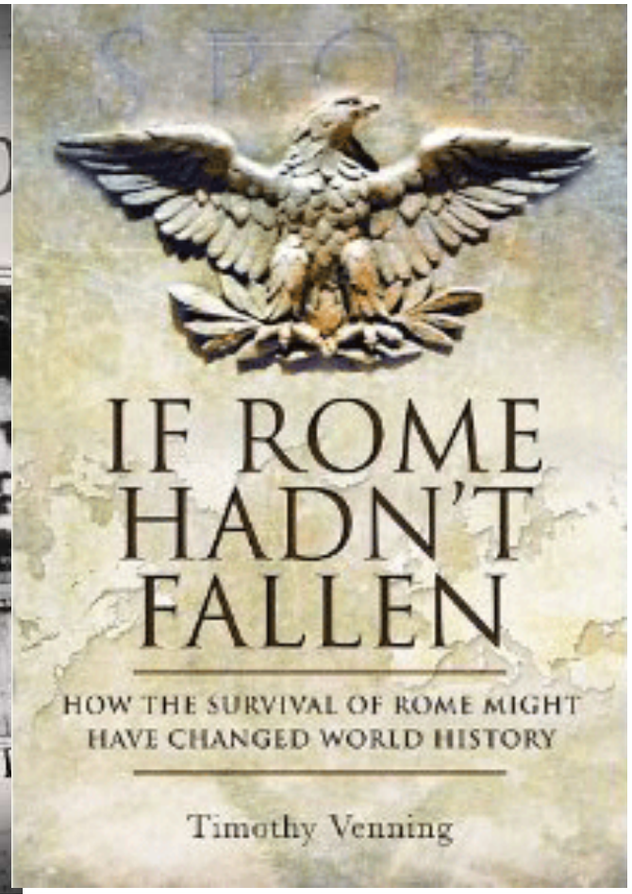
**Difference is the effect of the action**

**Counterfactual Action** → **Counterfactual Outcome**

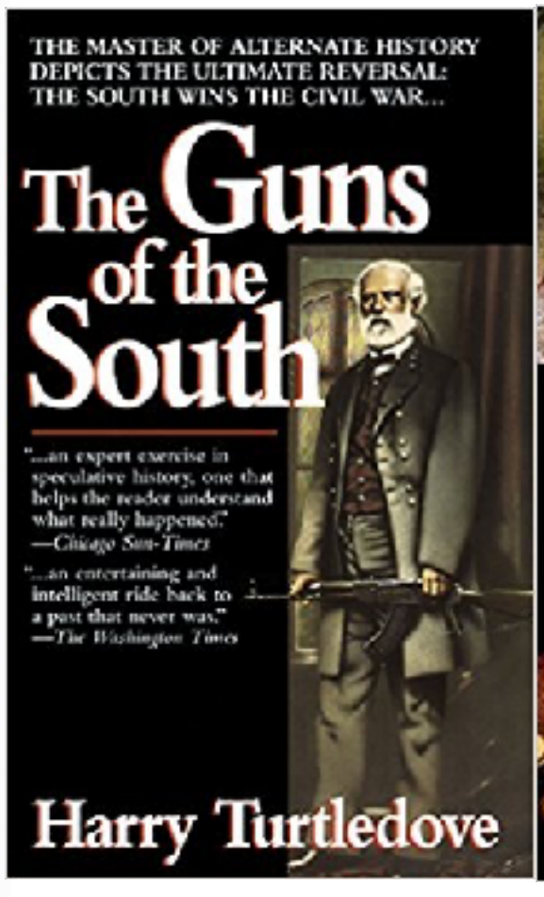

THE MAN IN THE HIGH CASTLE
PHILIP K. DICK
The classic Hugo Award-winning novel of a conquered America

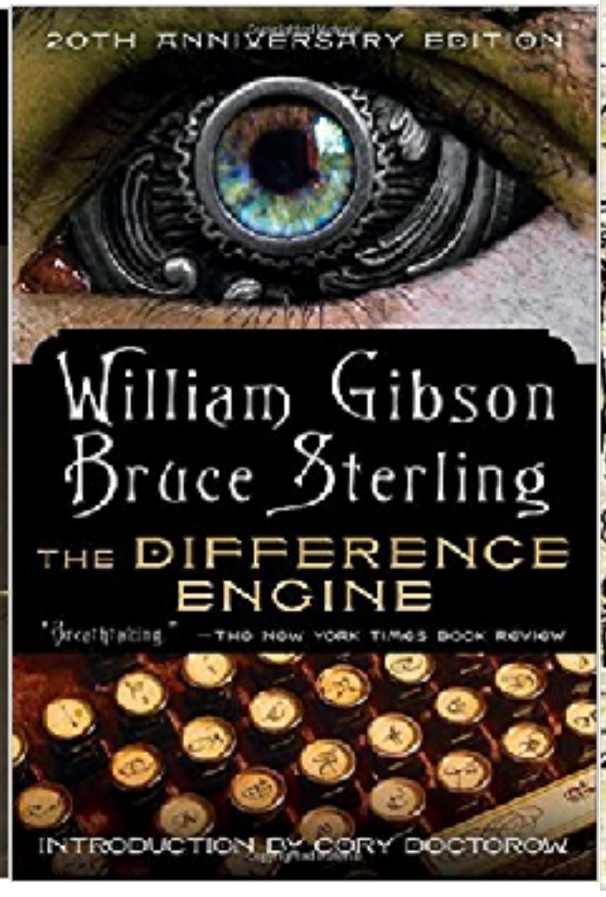

NAPOLEON VICTORIOUS
An Alternate History of the Battle of Waterloo
The Battle of Waterloo
PETER G. TSOURAS

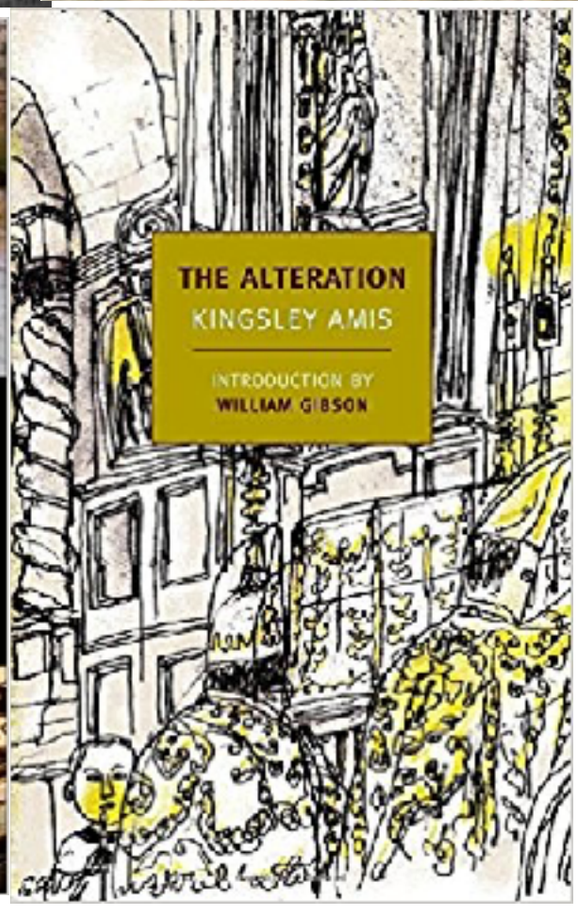
The New York Times
ARCHDUKE FRANZ FERDINAND LIVES!
A World Without World War I
by Richard Ned Lebow


IF ROME HADN'T FALLEN
HOW THE SURVIVAL OF ROME MIGHT HAVE CHANGED WORLD HISTORY
Timothy Venning

STEVEN SPIELBERG
BACK TO THE FUTURE
A ROBERT ZEMECKIS FILM


THE MASTER OF ALTERNATE HISTORY DEPICTS THE ULTIMATE REVERSAL: THE SOUTH WINS THE CIVIL WAR...
The Guns of the South
"...an expert exercise in speculative history, one that helps the reader understand what really happened." —Chicago Sun-Times
"...an entertaining and intelligent ride back to a past that never was." —The Washington Times
Harry Turtledove


20TH ANNIVERSARY EDITION
William Gibson
Bruce Sterling
THE DIFFERENCE ENGINE
"breathtaking" —THE NEW YORK TIMES BOOK REVIEW
INTRODUCTION BY CORY DOCTOROW


THE ALTERATION
KINGSLEY AMIS
INTRODUCTION BY WILLIAM GIBSON

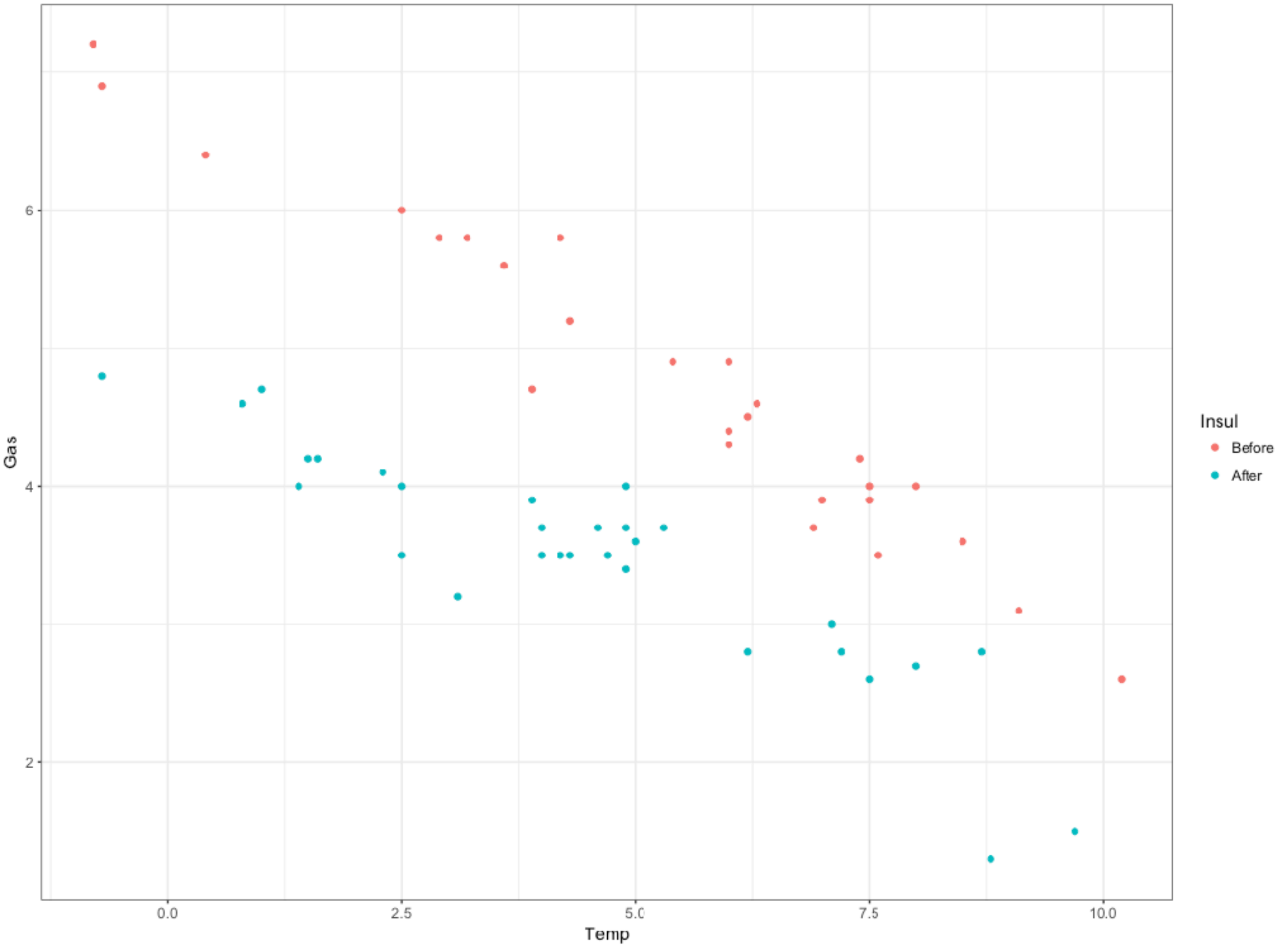
# Problems with Counterfactuals

- Never get to observe

- Can the counterfactual action/decision/assignment potentially occur? What if I bought a new car instead of repairing the old one? What if I were the other gender?

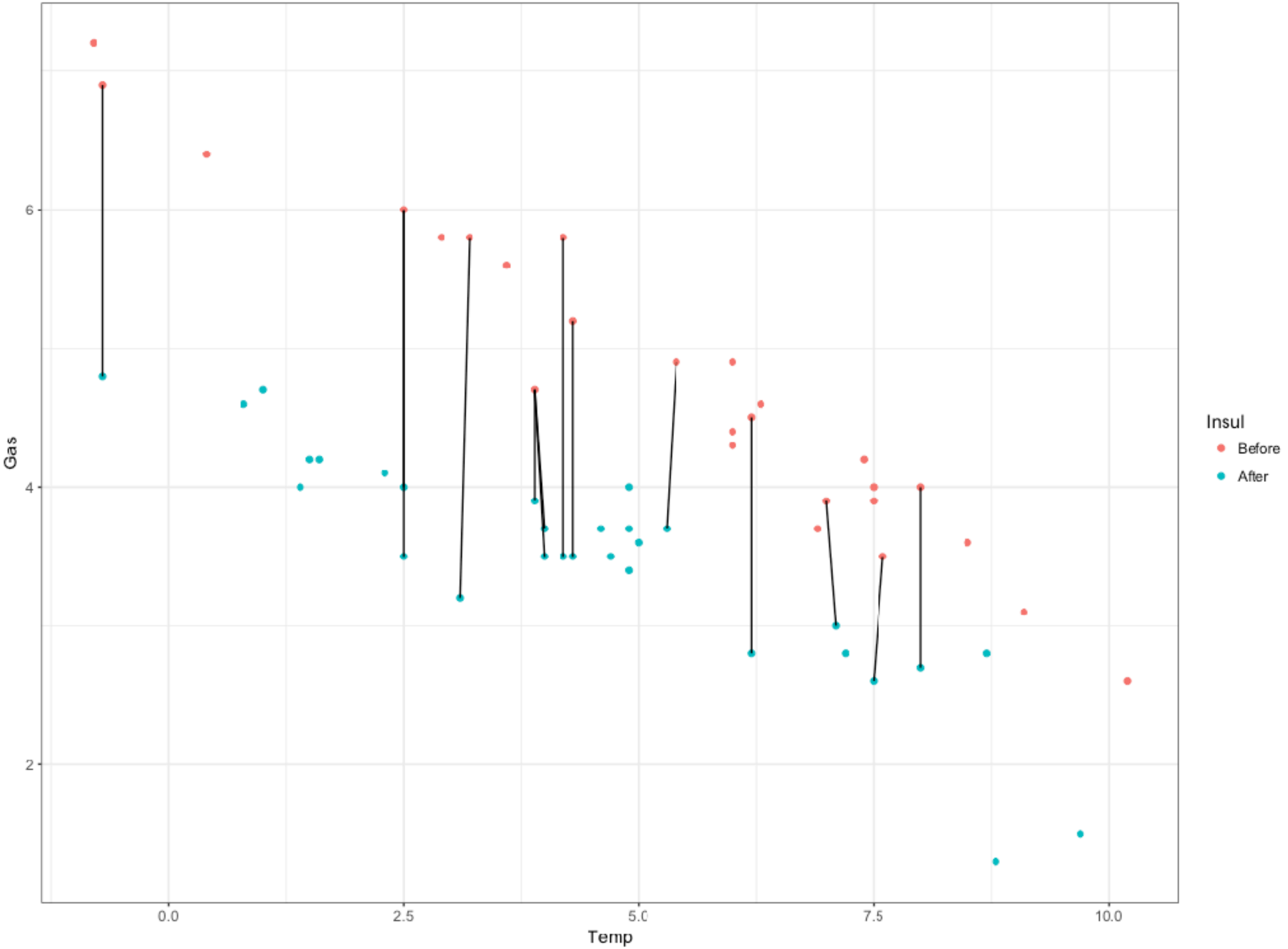
- Counterfactual approximations in time and space. Both actions occur but at different times or locations. Additional assumptions are necessary.

- Many more philosophical objections


Gas
6
4
2
0.0
2.5
5.0
7.5
10.0
Temp
Insul
Before
After

# Matching

- Identify pairs of observations that are identical/similar in the covariates but have different treatments.
- Attempts to approximate the counterfactual outcome
- Exact matching can be difficult where observations are multivariate – *propensity score* matching can help
- Unobserved characteristics of the pair may be different in a consistent manner thus voiding the causal conclusion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Before
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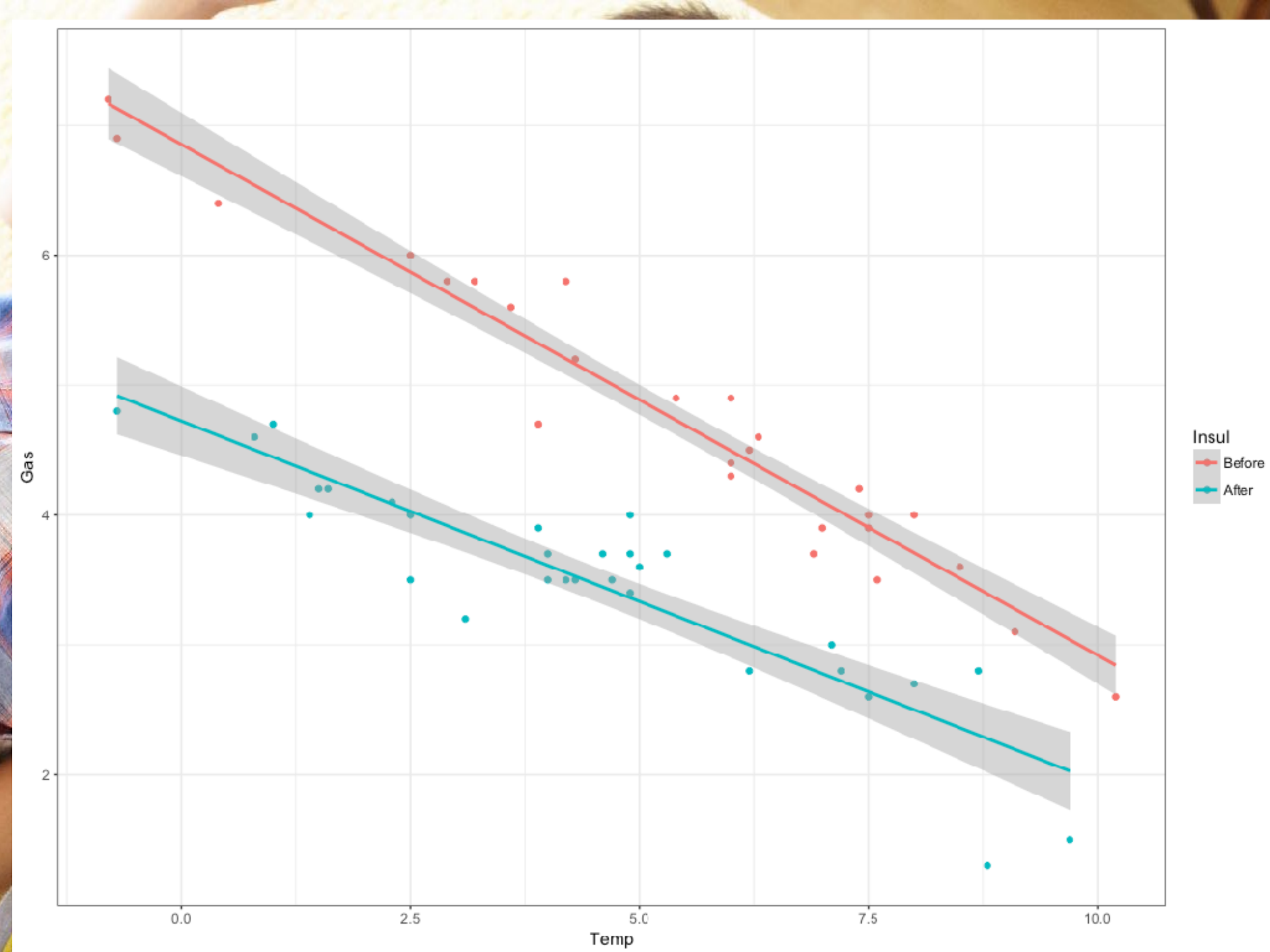
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7.5
10.0
Temp
Insul
Before
After

# (Linear) Modelling

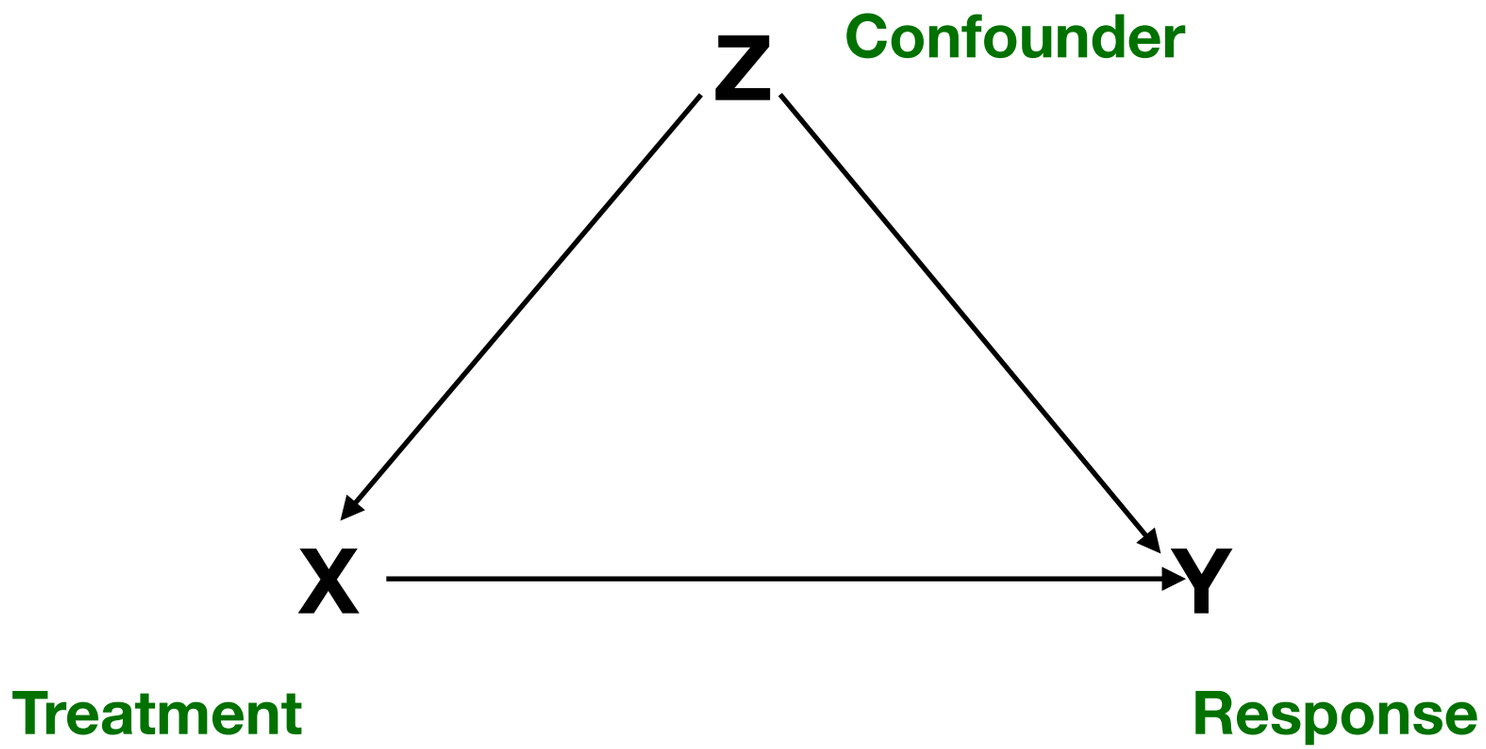
- Difference between the treatments is expressed as parameter(s) in the model.

- Avoids the need for matching

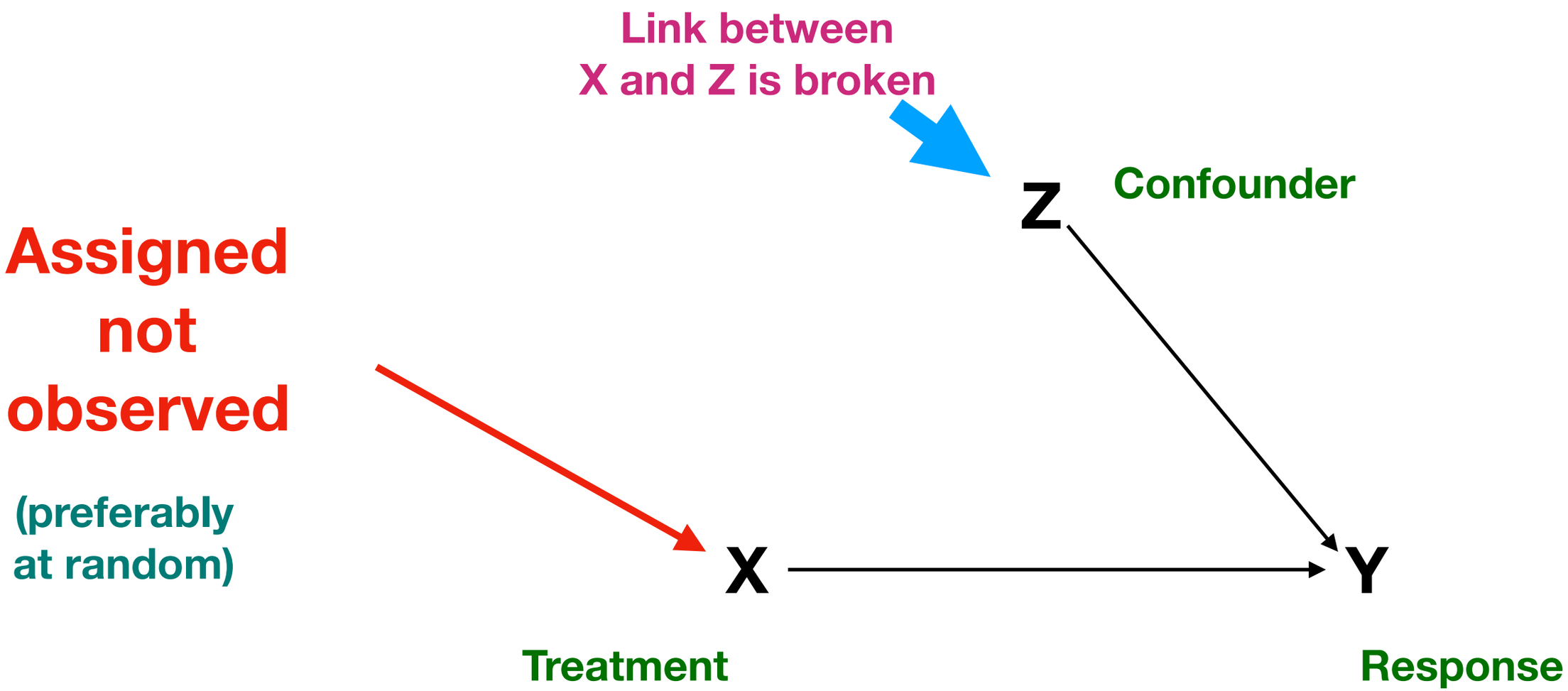
- Requires additional assumptions

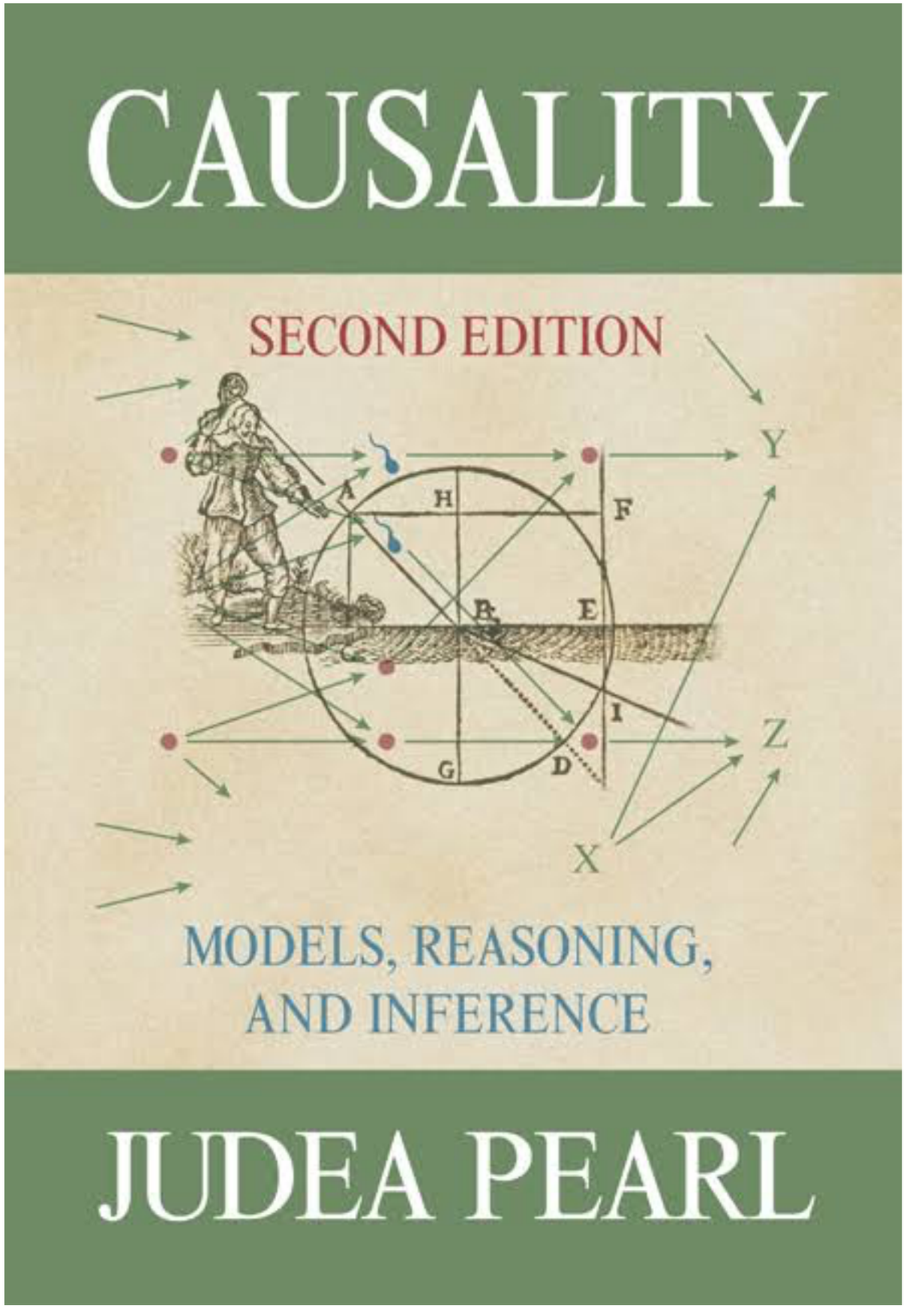
- Non-treatment predictors are called *confounders.* Including such variables in the model is called *adjusting for the confounder.*

# Graphical Models



# Experiment


Link between
X and Z is broken
Z
Confounder
Assigned
not
observed
(preferably
at random)
X
Y
Treatment
Response




# Unified Theory of Causality

Statistical/Probabilistic reasoning alone cannot support causal inference

Determining the joint probability distribution of variables alone says nothing about causation

**P(Disease | Symptom)**

Pearl promises to determine the necessary set of non-data assumption that are sufficient to make a causal conclusion

# Bradford Hill Criteria

Strength

Consistency

Specificity

Temporality

Biological Gradient

Plausibility

Coherence

Experiment

Analogy

**Qualitative and somewhat specific to epidemiology**