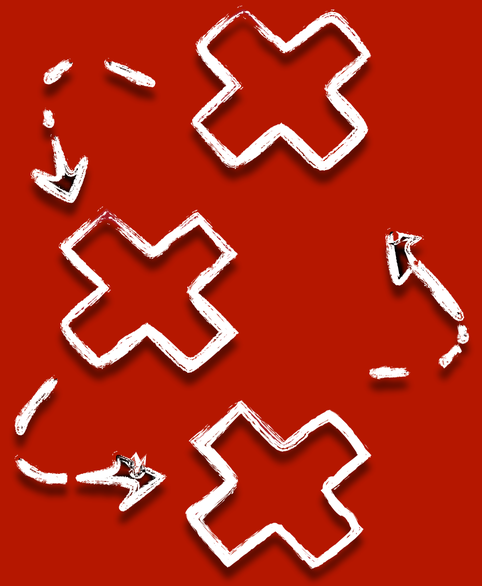


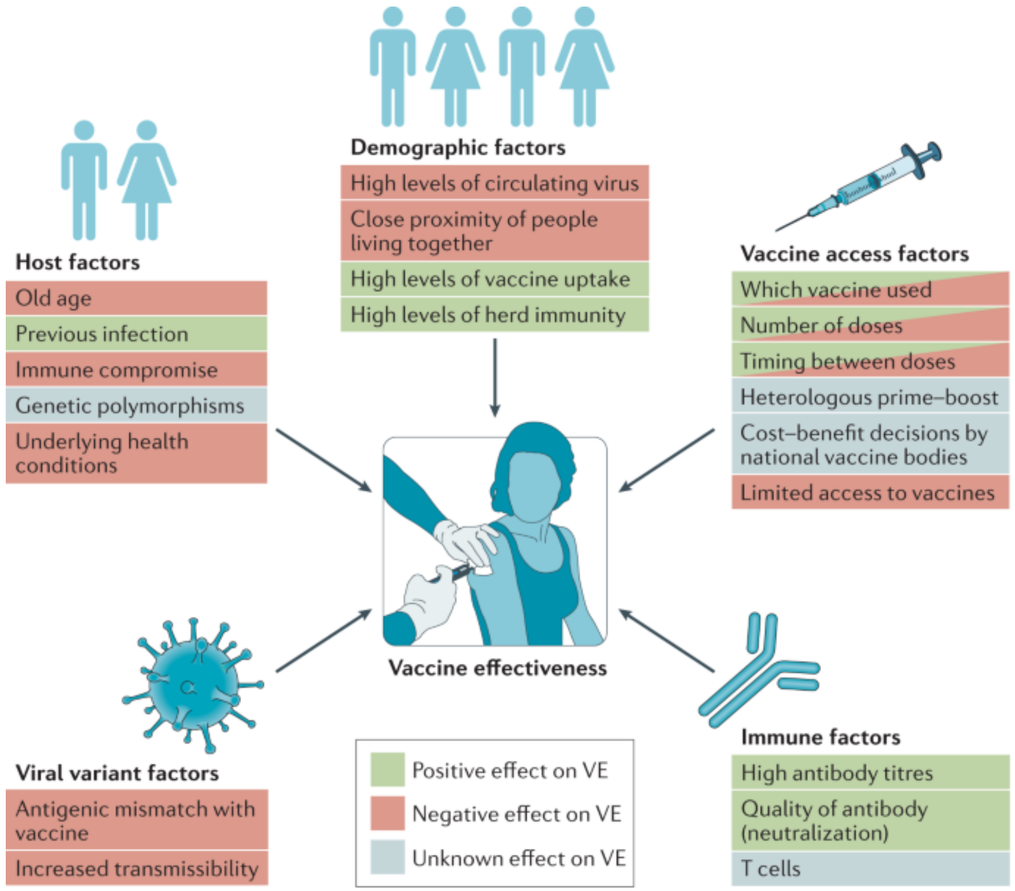
Deep learning 2: Causality & DL

1.1: Introduction

Lecturer: Sara Magliacane

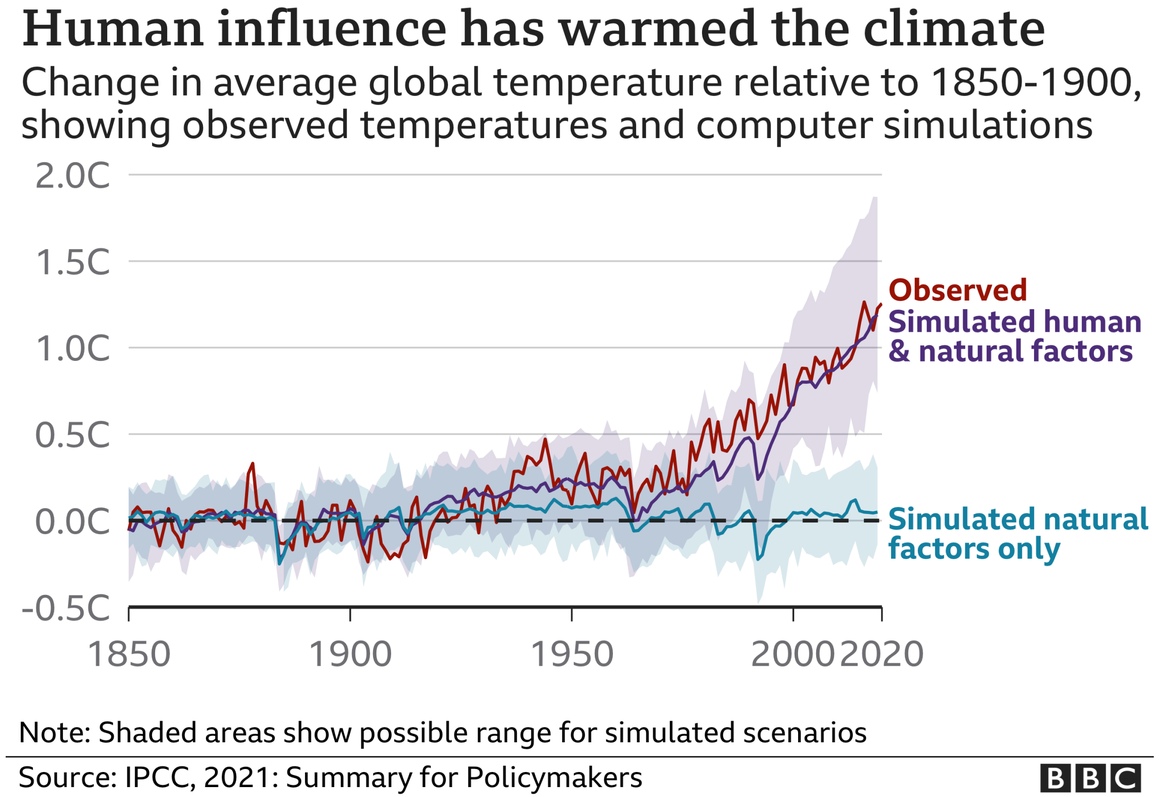
UvA - Spring 2022

Causal questions are ubiquitous: healthcare



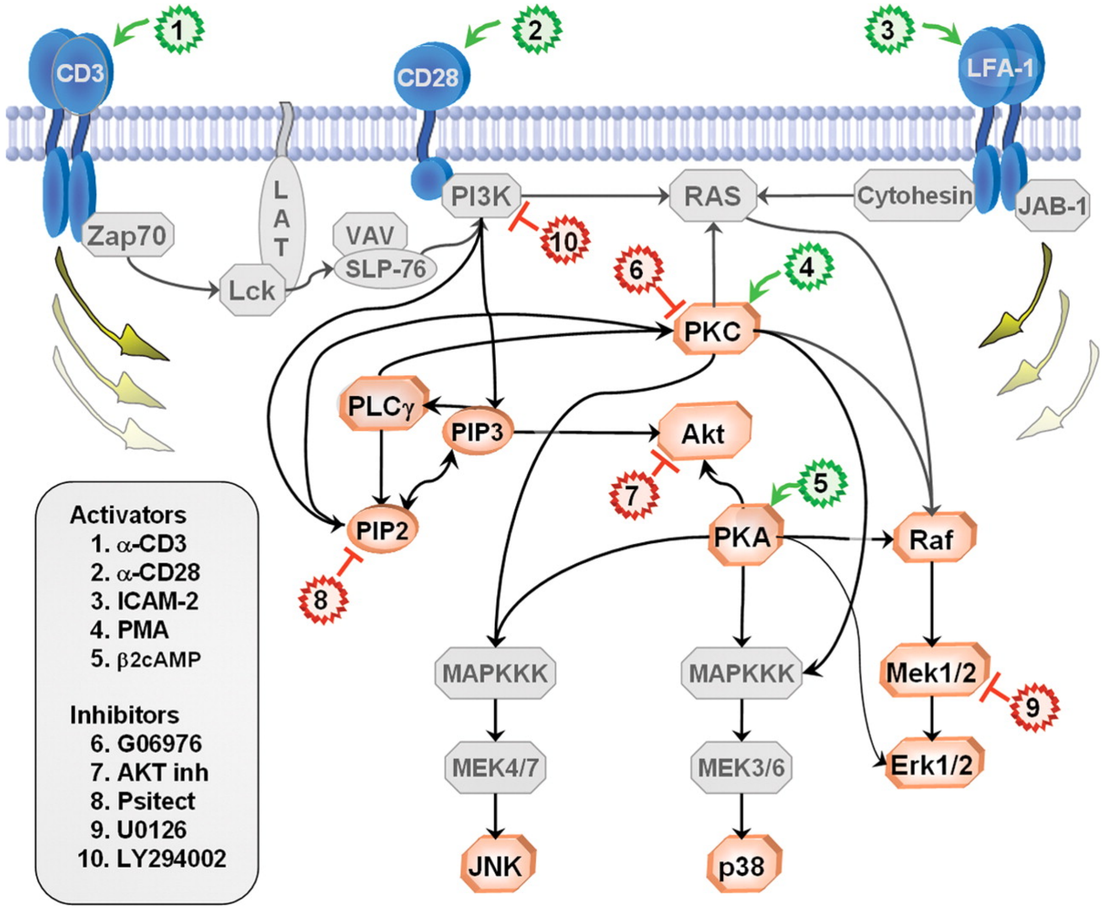
https://www.nature.com/articles/s41577-021-00592-1

Causal questions are ubiquitous: climate change



https://www.bbc.com/news/science-environment-58600723

Causal questions are ubiquitous: biology



https://www.science.org/doi/abs/10.1126/science.1105809

Correlation or causation? Direction? Alternative explanations?

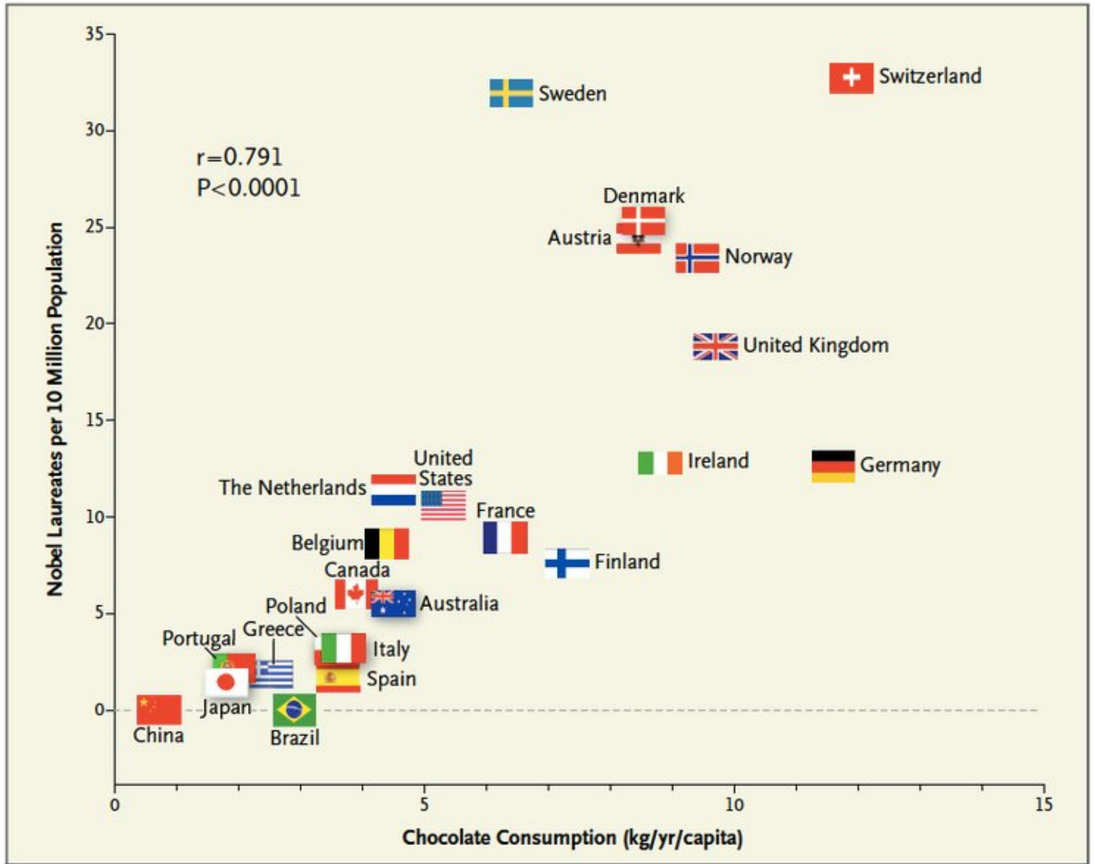
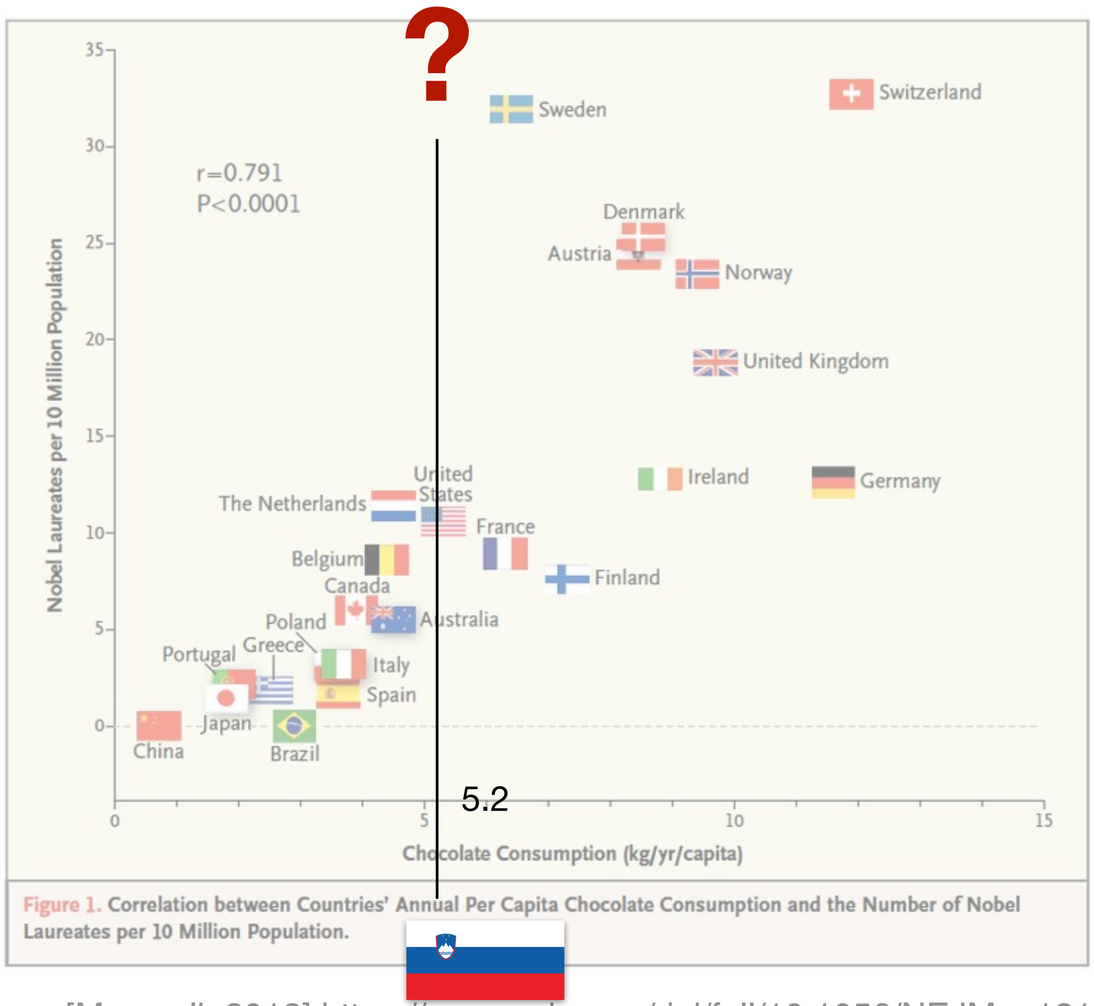


Figure 1. Correlation between Countries' Annual Per Capita Chocolate Consumption and the Number of Nobel Laureates per 10 Million Population.

[Messerli, 2012] https://www.nejm.org/doi/full/10.1056/NEJMon1211064

Correlation or causation? Can we predict a new data point?



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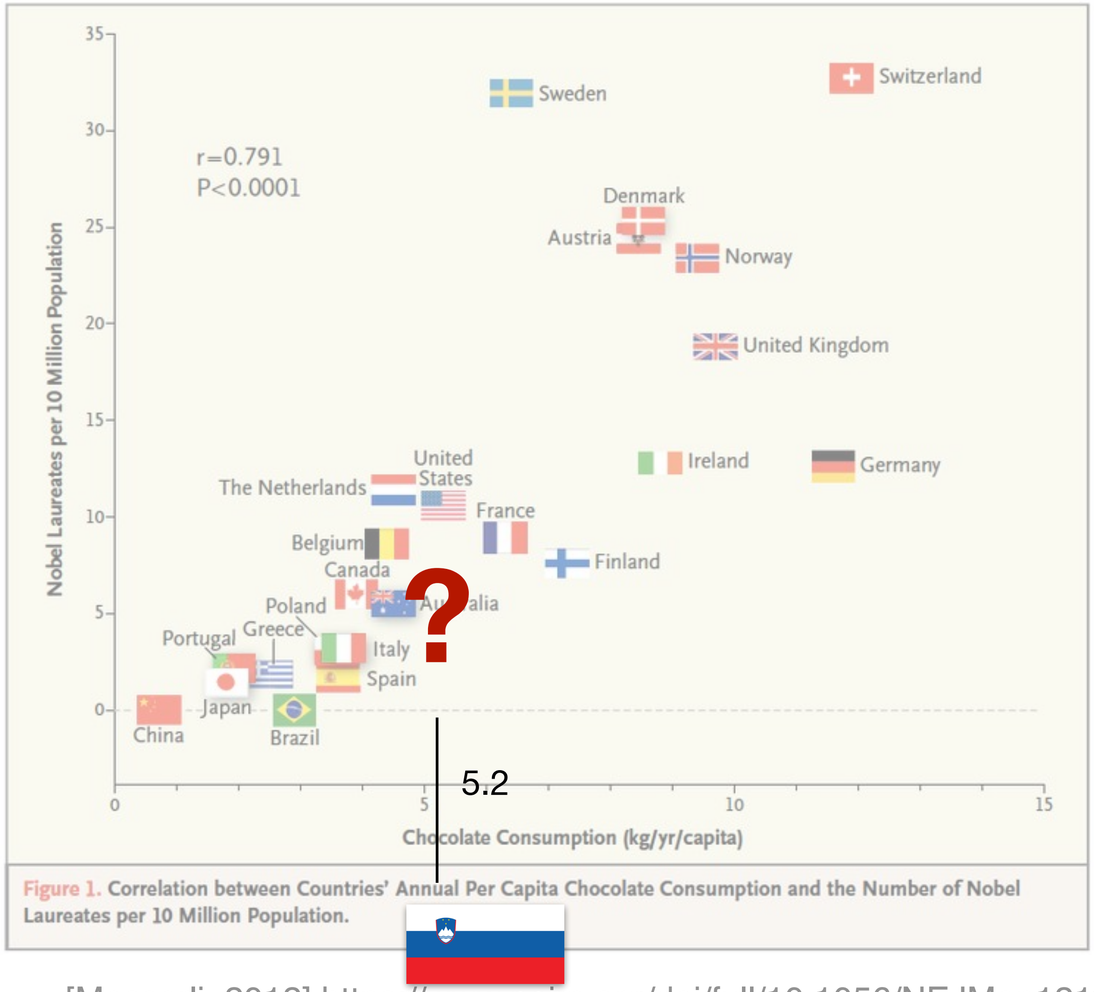

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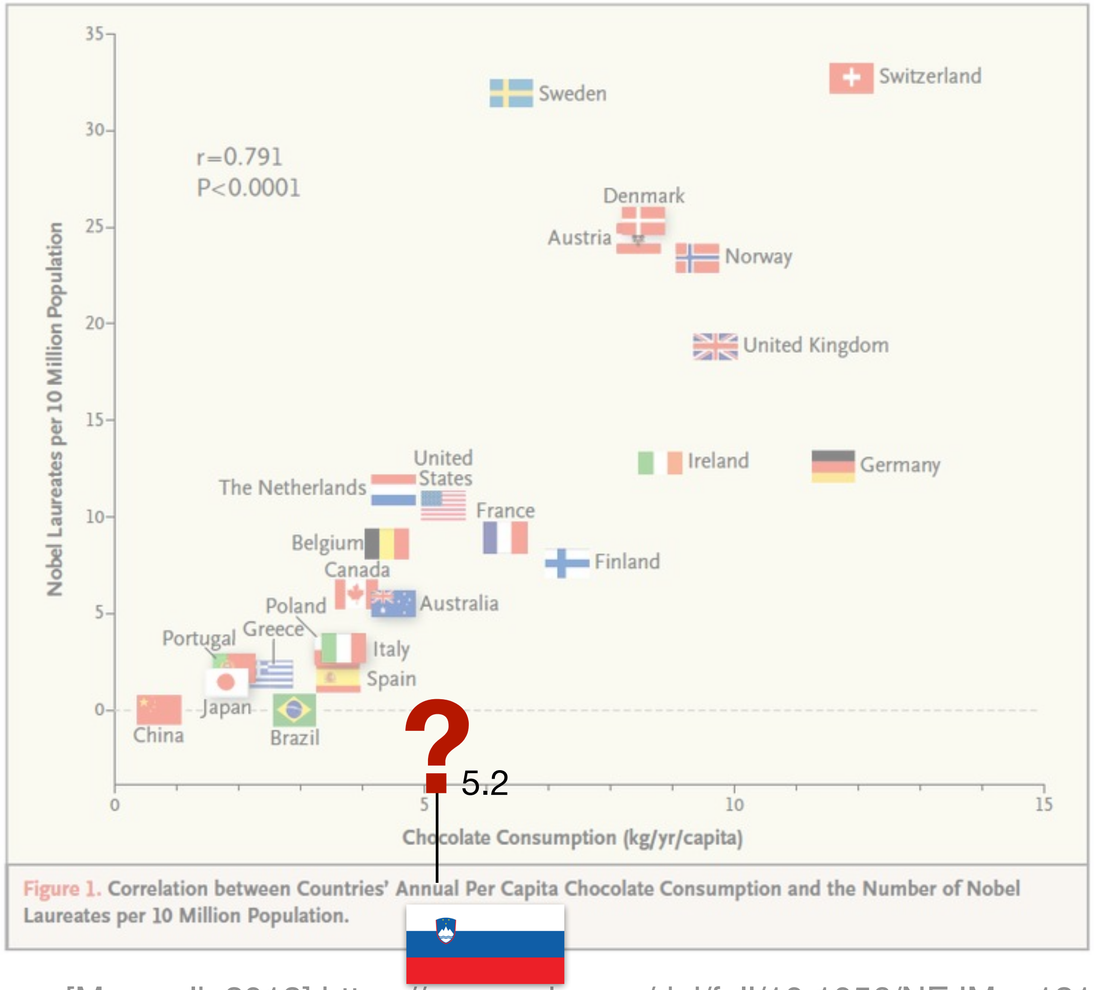

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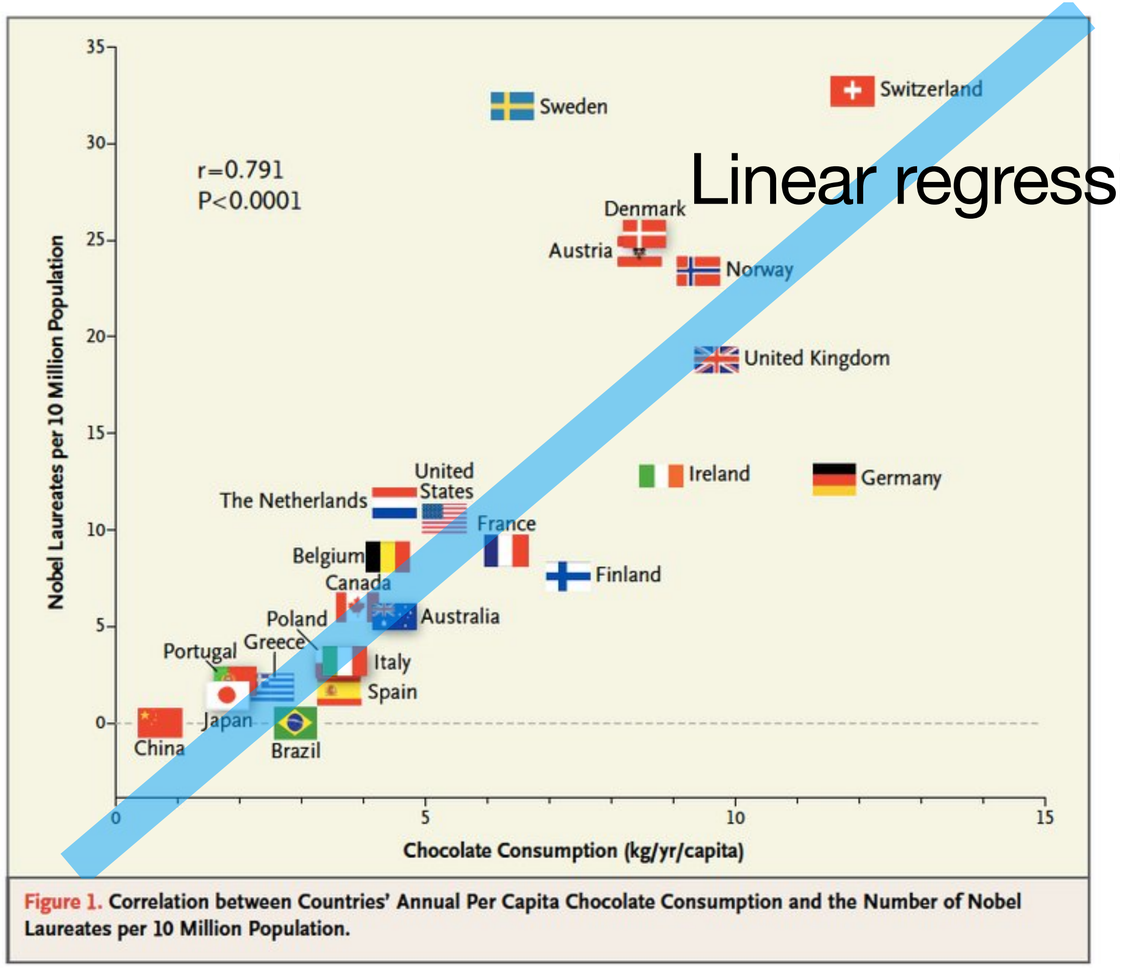

Linear regression, NNs, …

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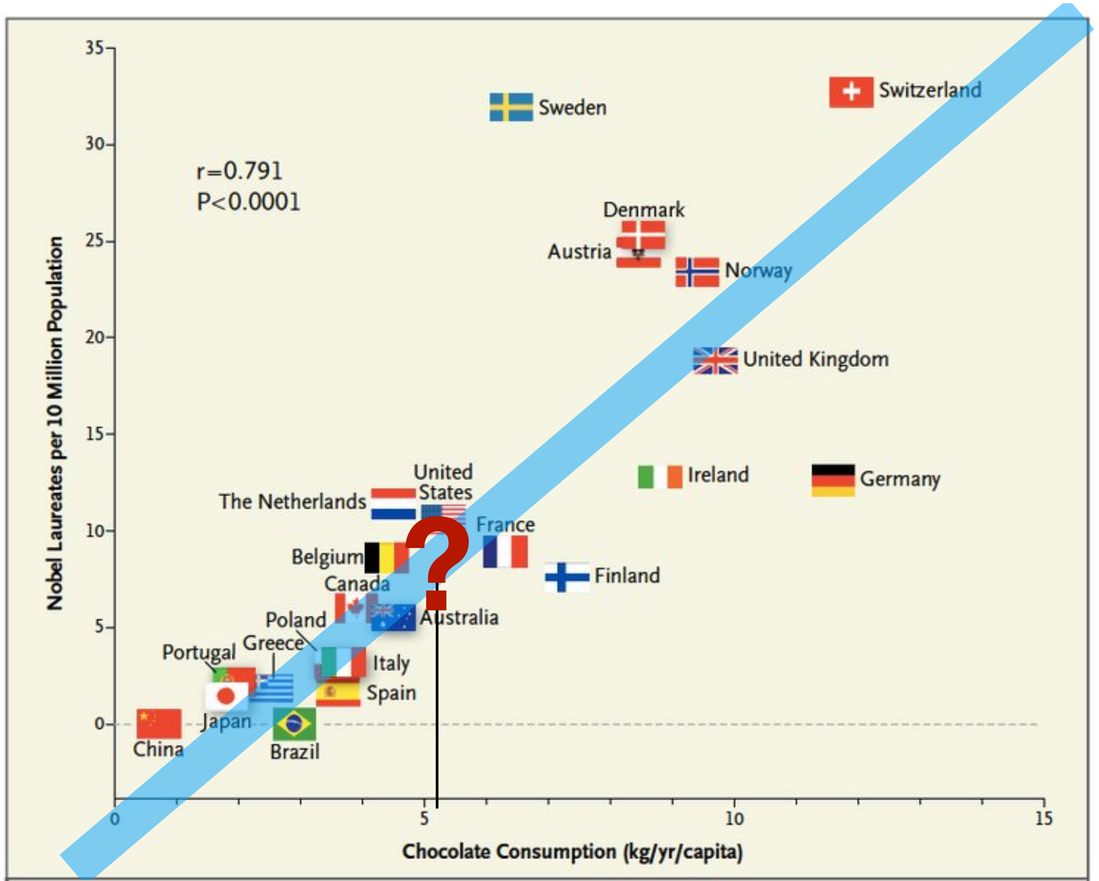

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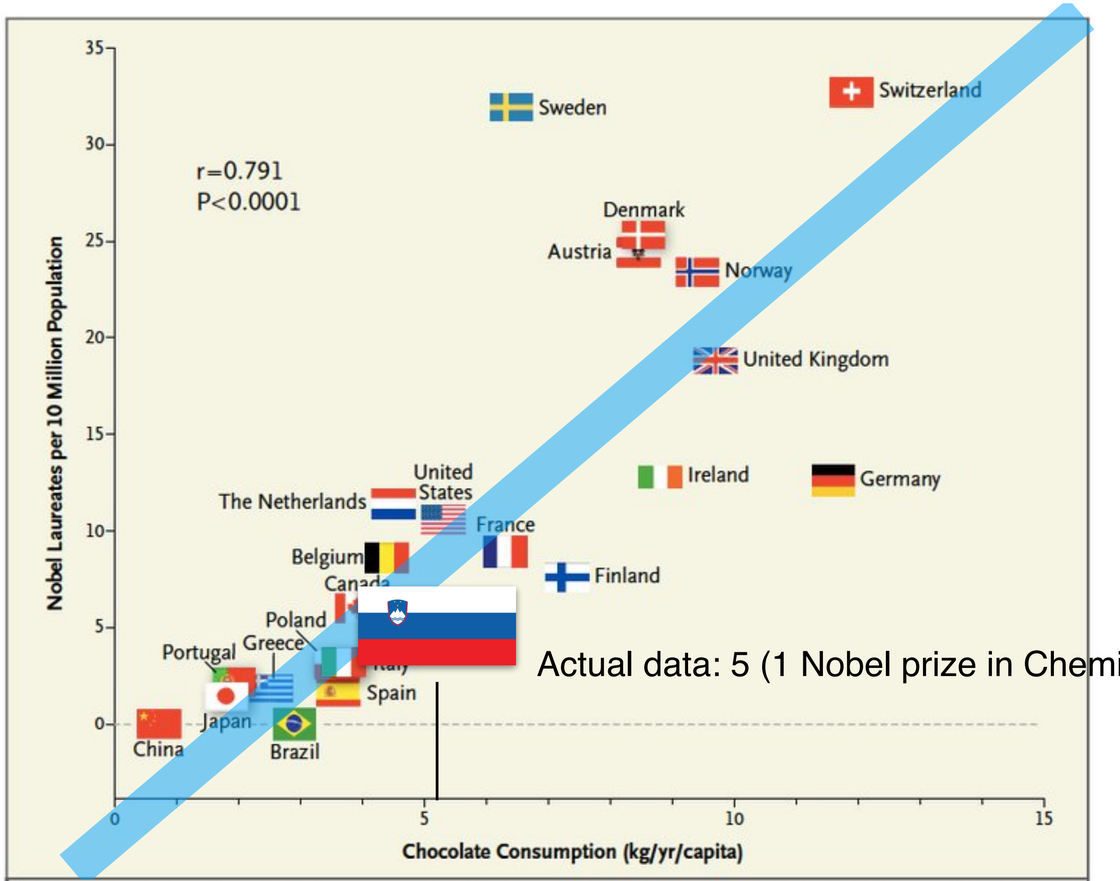

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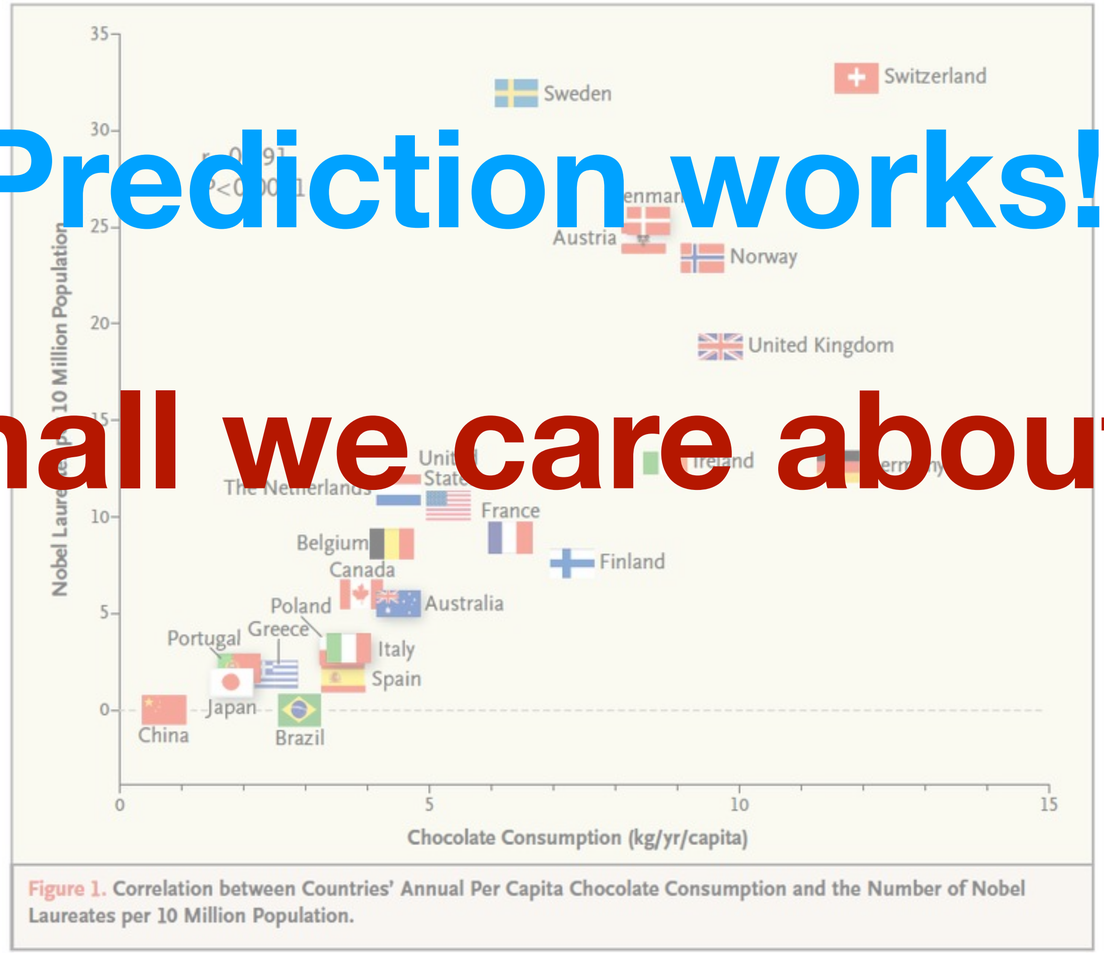
Actual data: 5 (1 Nobel prize in Chemistry in 1928, but Slovenia only has 2M citizens)

[Messerli, 2012] https://www.nejm.org/doi/full/10.1056/NEJMon1211064

Correlation or causation? Can we predict a new data point?



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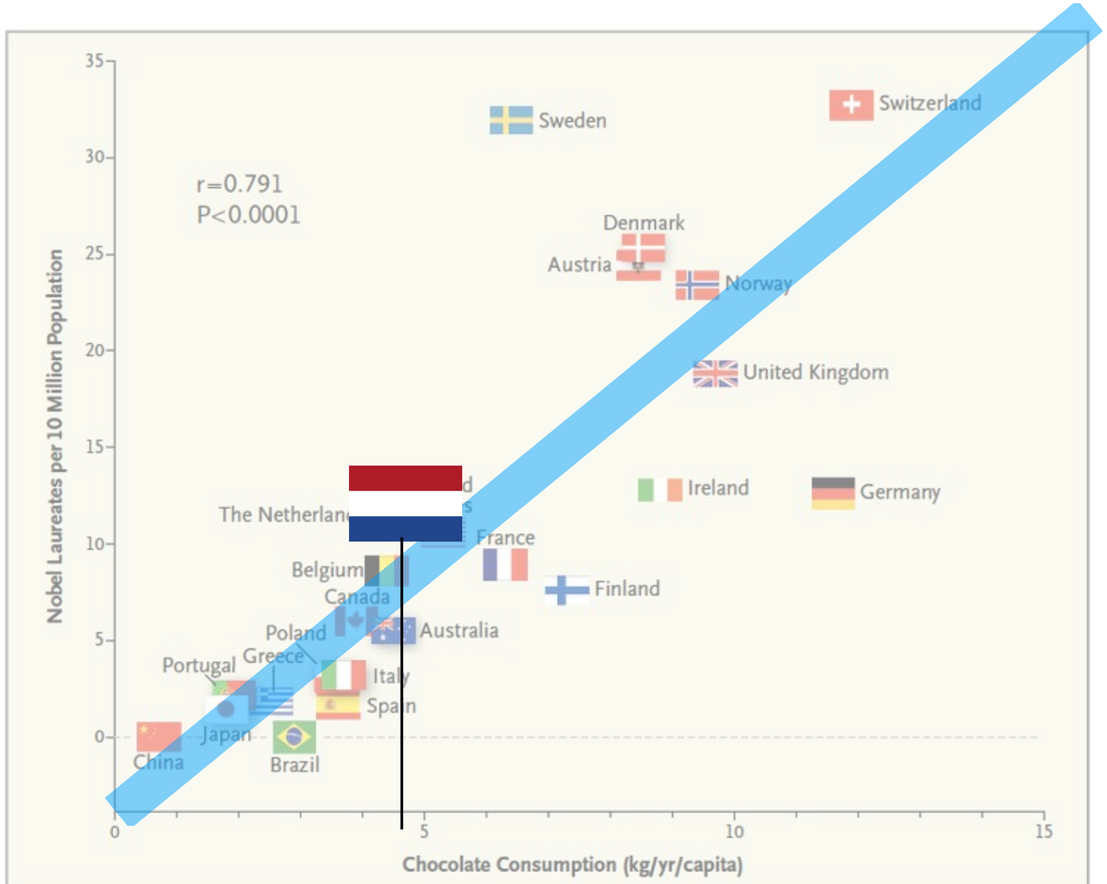
Prediction works!!!

Why shall we care about causality?

[Messerli, 2012] https://www.nejm.org/doi/full/10.1056/NEJMon1211064

Helping the Dutch government with decision making



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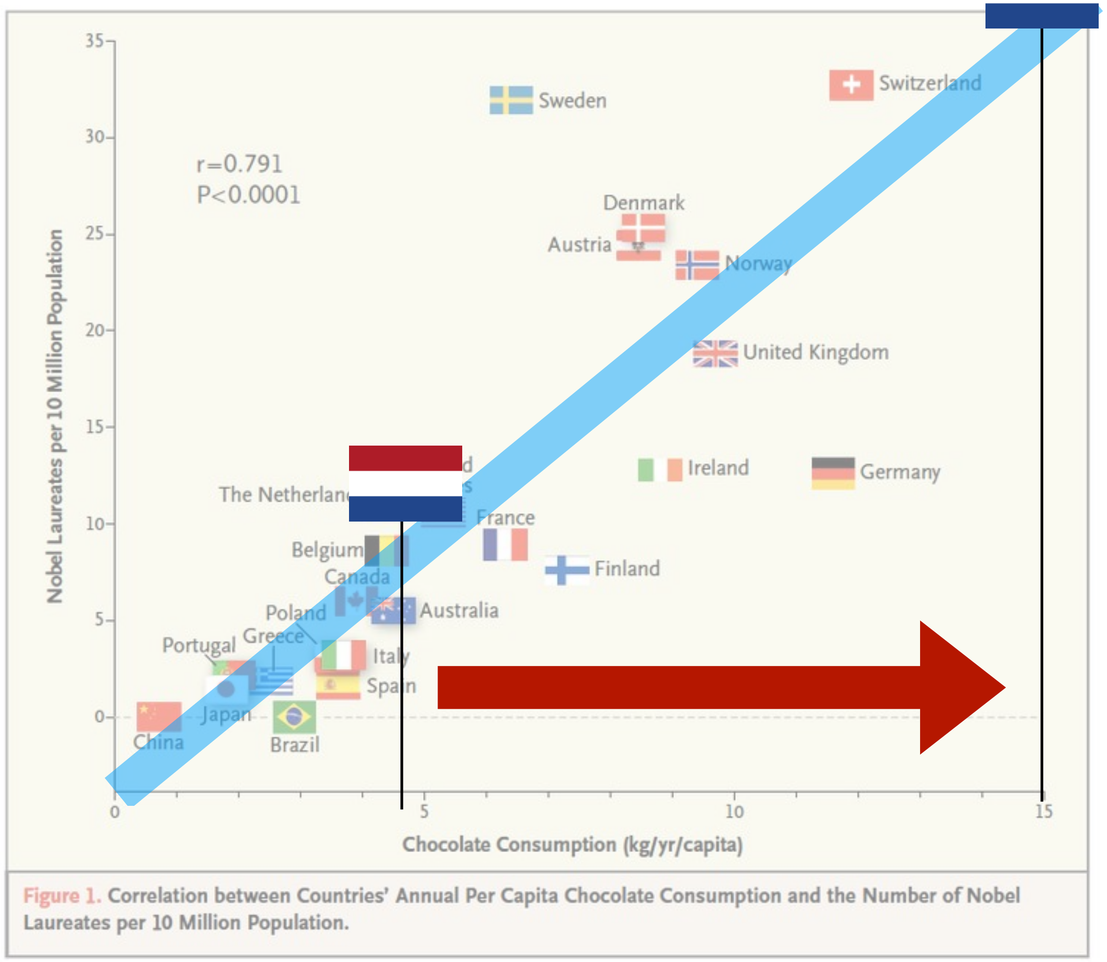

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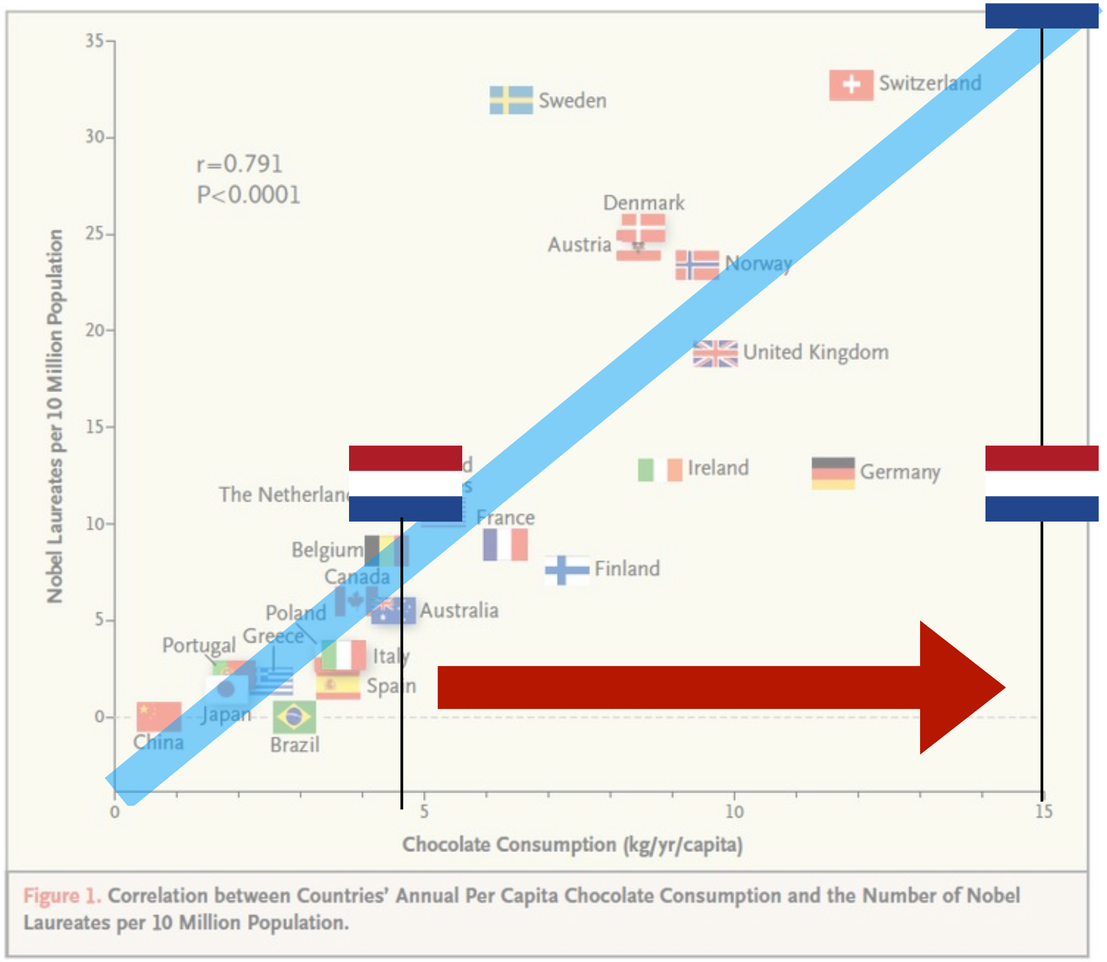

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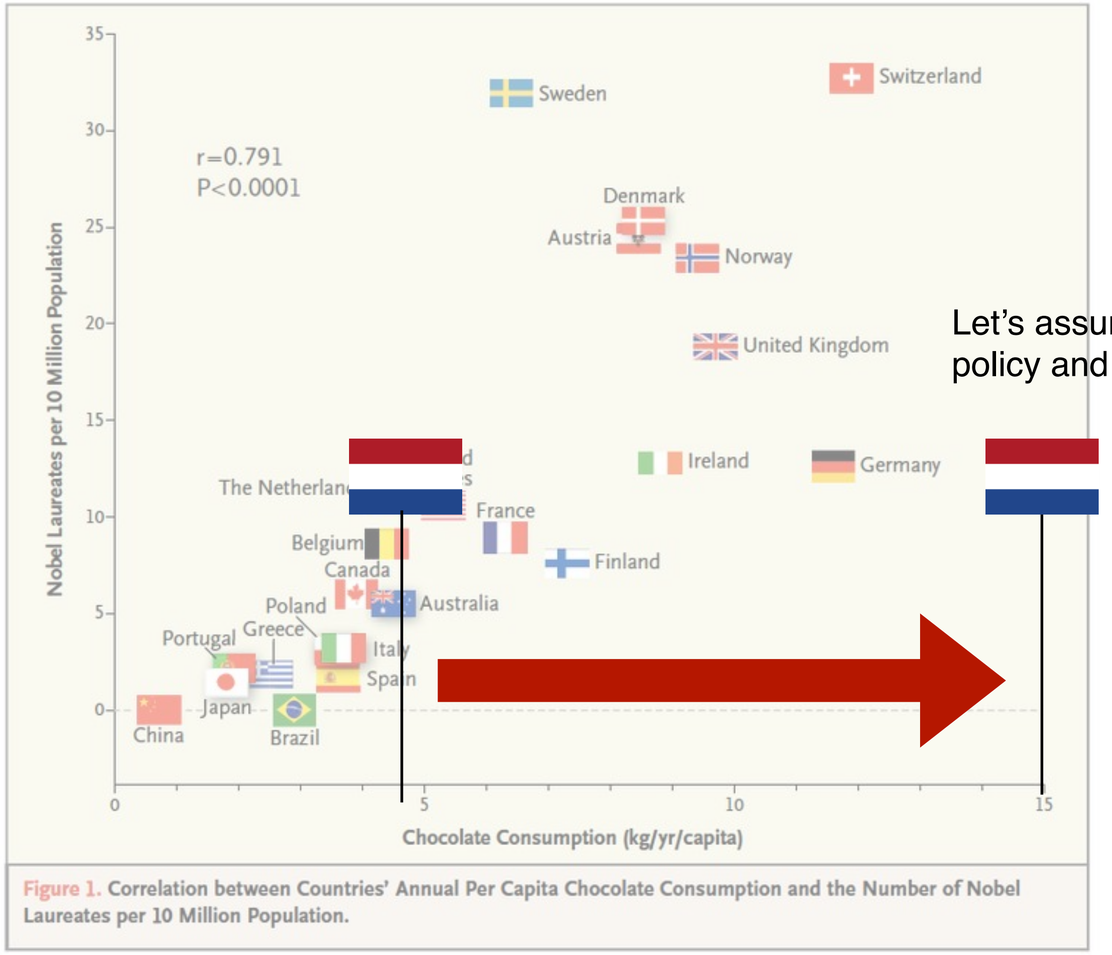

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Let's assume we implement the "Eat more chocolate" policy and this happens

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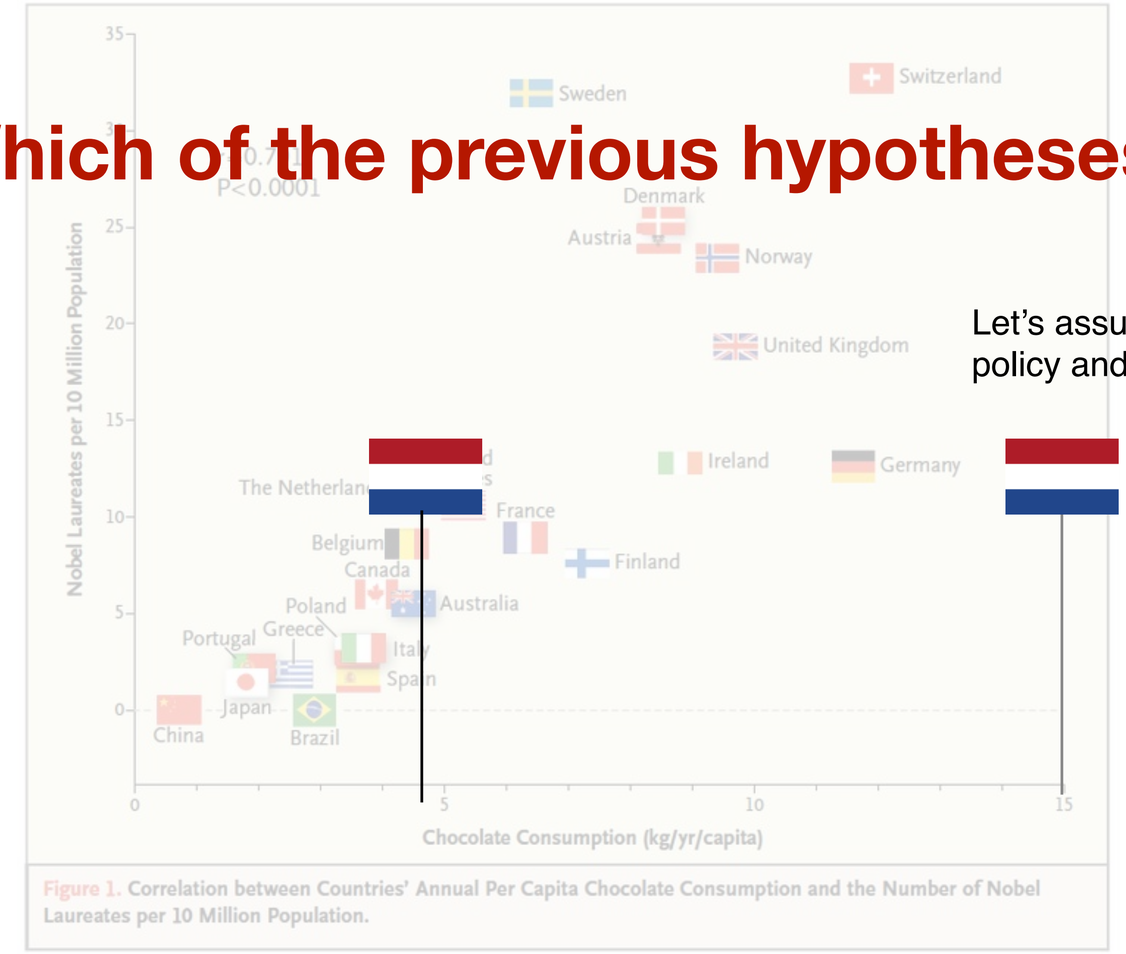
Correlation or causation? Direction? Alternative explanations?



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Which of the previous hypotheses is still valid?

Let's assume we implement the "Eat more chocolate" policy and this happens

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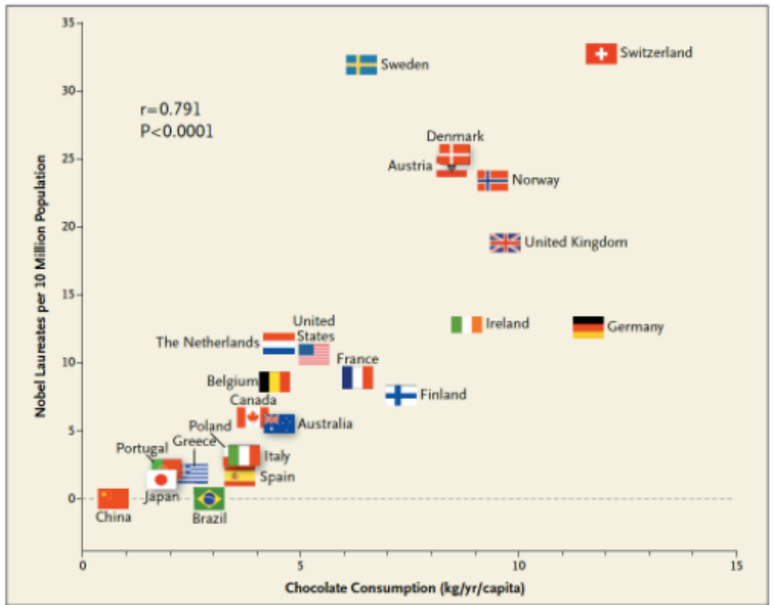
Correlation or causation - Optional quiz on Canvas

[Optional] Correlation or causation?

Instructions

Given only the data plotted in this graph, which of the following hypotheses is plausible (without using any domain knowledge?)



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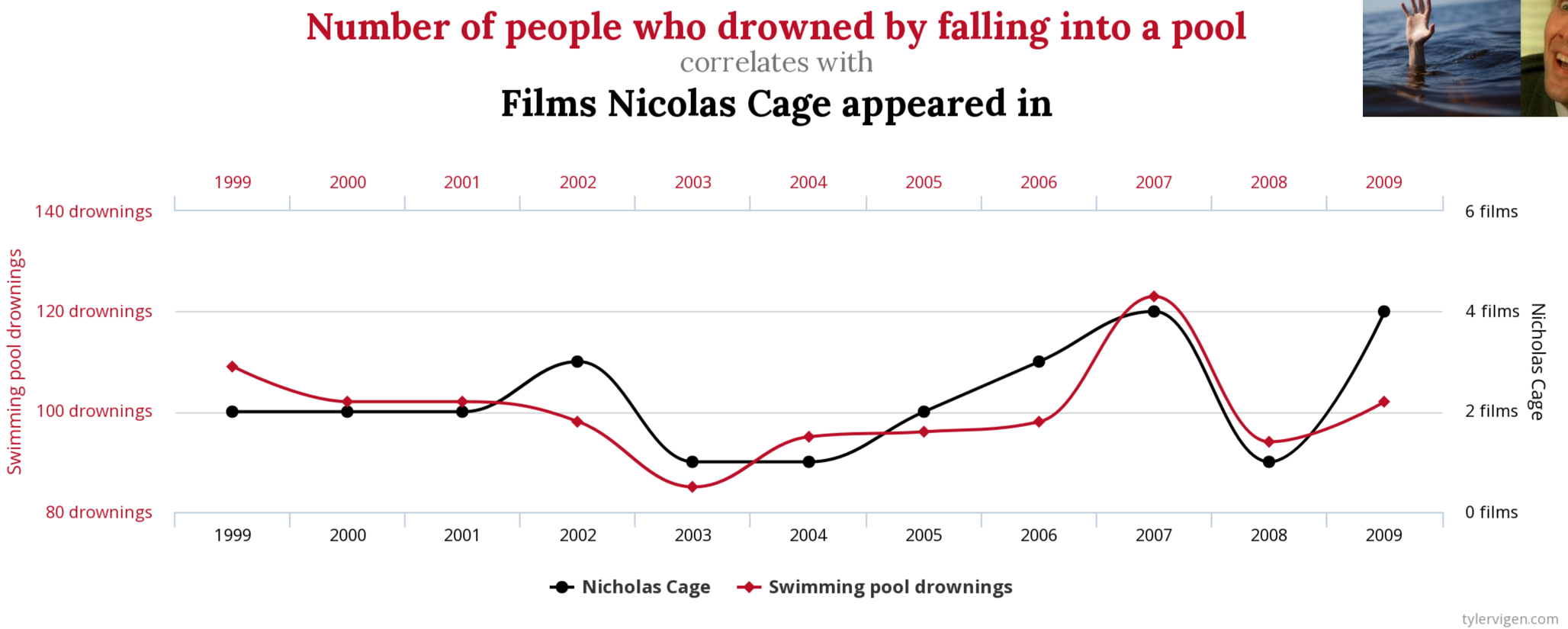

http://tylervigen.com/spurious-correlations

Causal Hierarchy [Pearl 2009, 2018]

https://mobile.twitter.com/yudapearl

Causal Hierarchy [Pearl 2009, 2018]

Most ML

Level (Symbol)	Typical Activity	Typical Questions	Examples
1. Association $P(y\|x)$	Seeing	What is? How would seeing X change my belief in Y?	What does a symptom tell me about a disease? What does a survey tell us about the election results?

Causal Hierarchy [Pearl 2009, 2018]

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Causal Hierarchy [Pearl 2009, 2018]

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3. Counterfactuals $P(y_x\|x', y')$	Imagining, Retrospection	Why? Was it X that caused Y? What if I had acted differently?	Was it the aspirin that stopped my headache? Would Kennedy be alive had Oswald not shot him? What if I had not been smoking the past 2 years?

Causal Hierarchy [Pearl 2009, 2018]

Most ML

Causality

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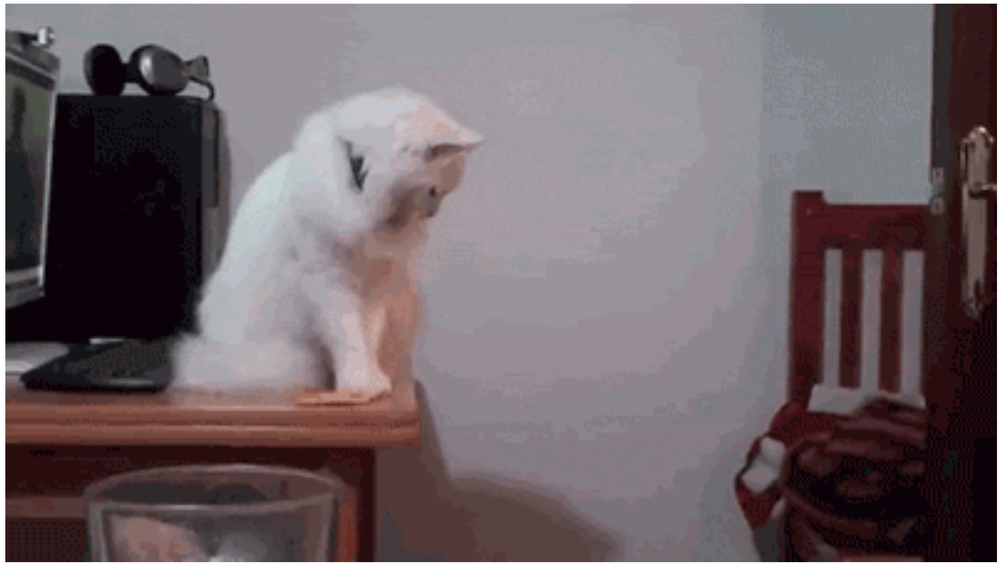
We know what causality is not, but what is it?



The classical approach to causality is based on **experimentation**.

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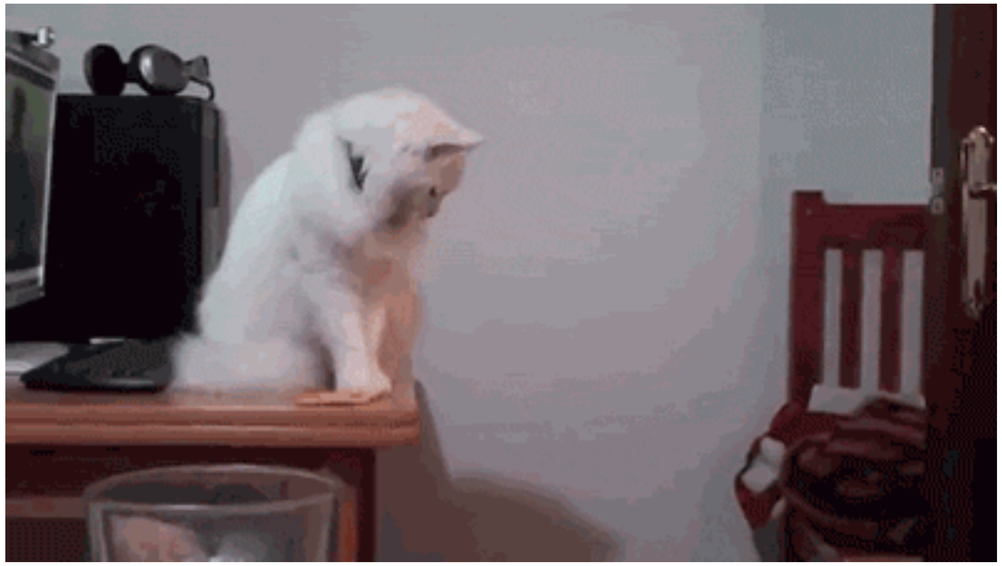

The classical approach to causality is based on **experimentation.**

Can we use a definition of causality based on **manipulation** (interventions)?

A working definition

Intuitive definition: A variable A causes another variable B, if changing/ intervening upon variable A , changes (the distribution of) B

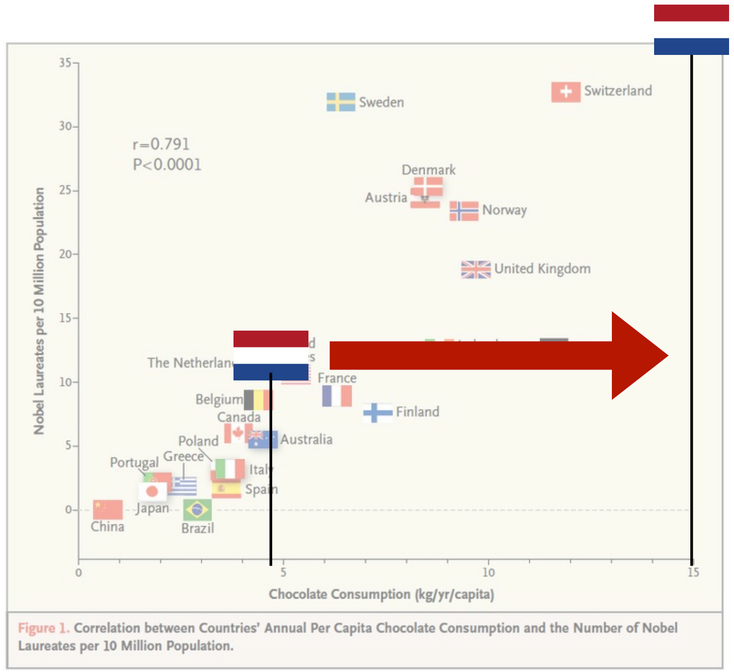

Figure 1. Correlation between Countries' Annual Per Capita Chocolate Consumption and the Number of Nobel Laureates per 10 Million Population.

In an alternative universe:

NL eats more chocolate => more Nobel

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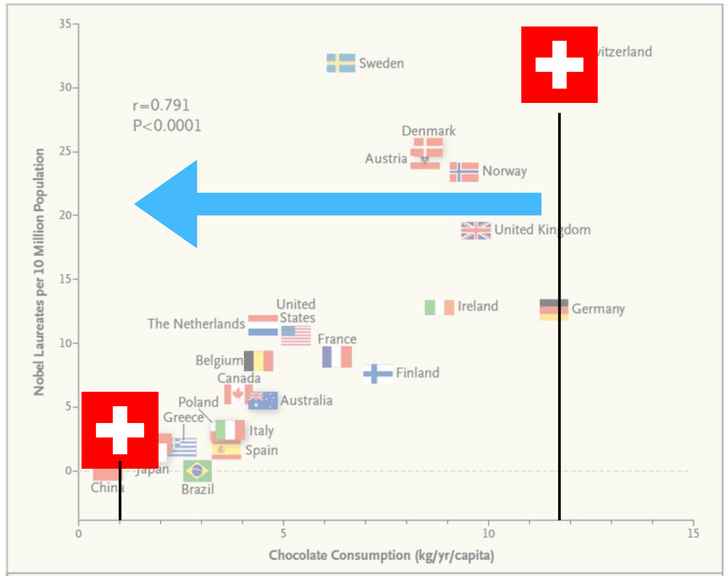

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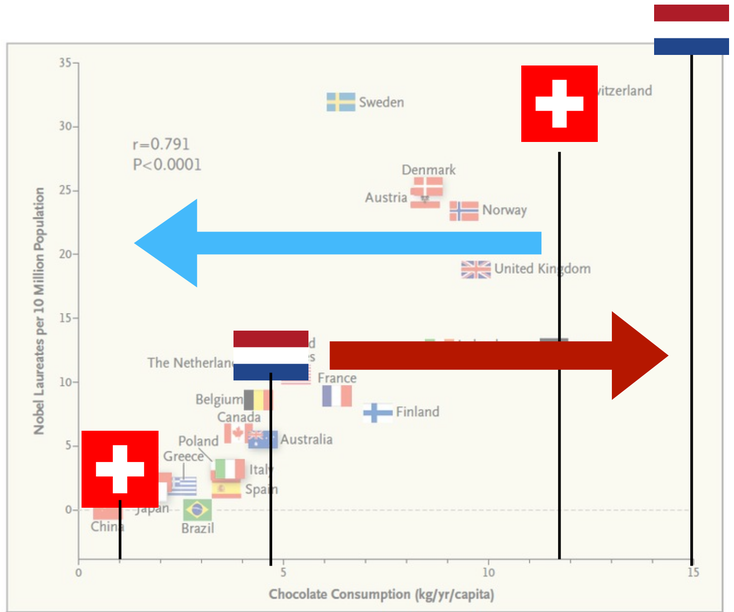

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… and similarly for other countries

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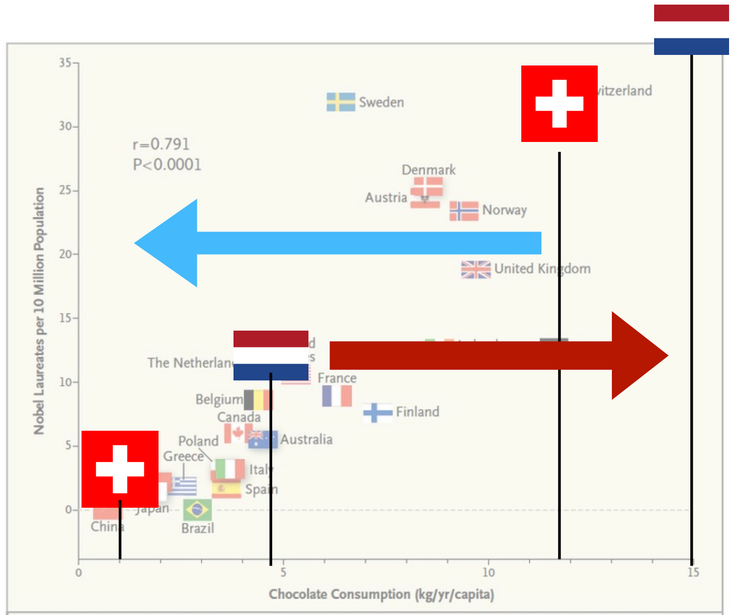

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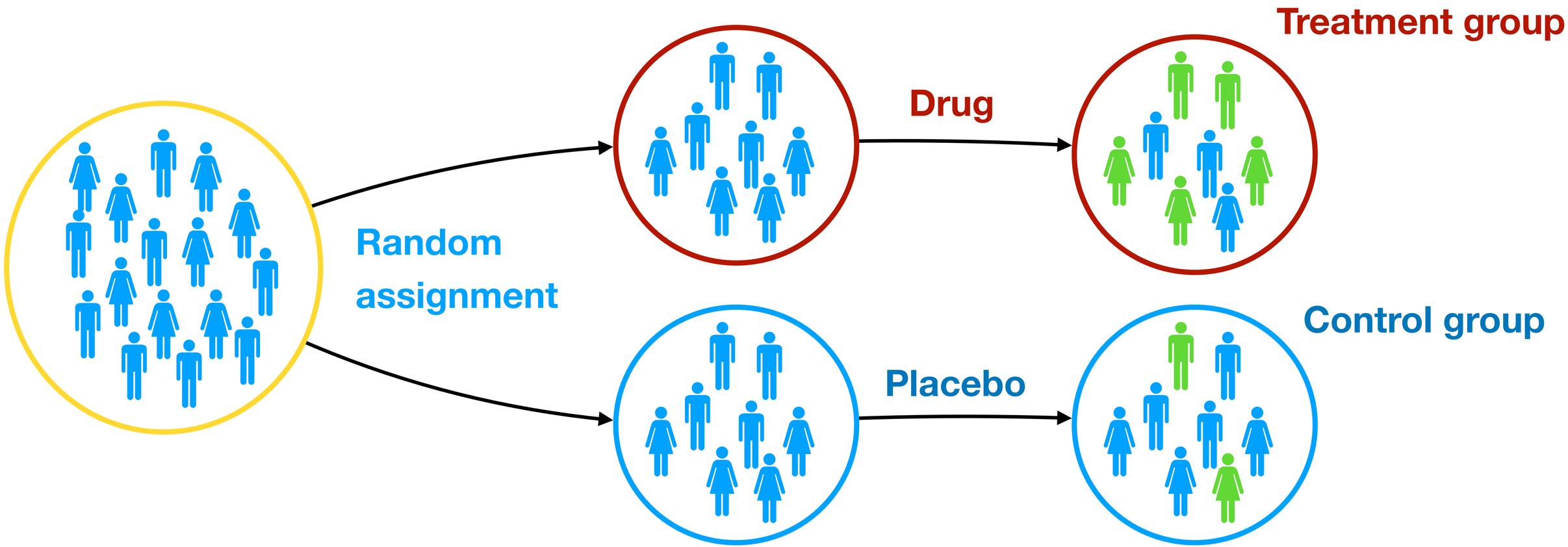
… and similarly for other countries

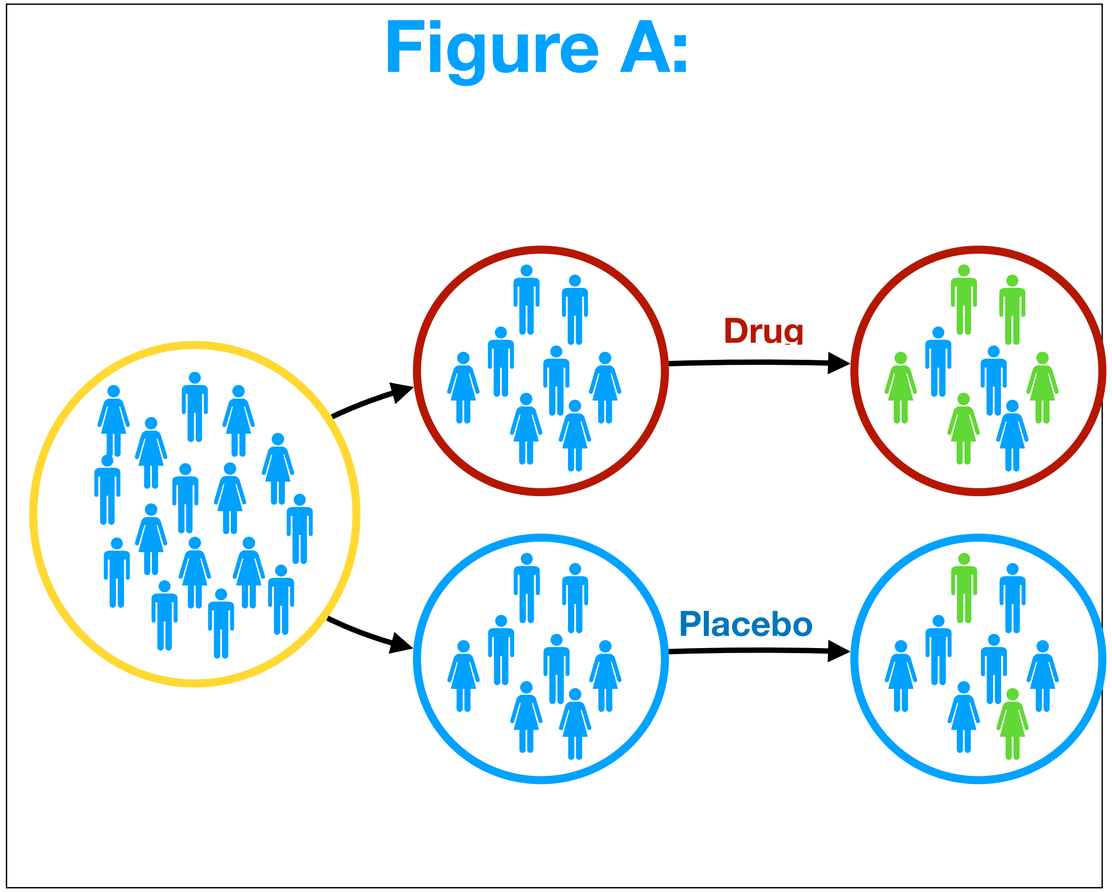
Chocolate => Nobel prizes

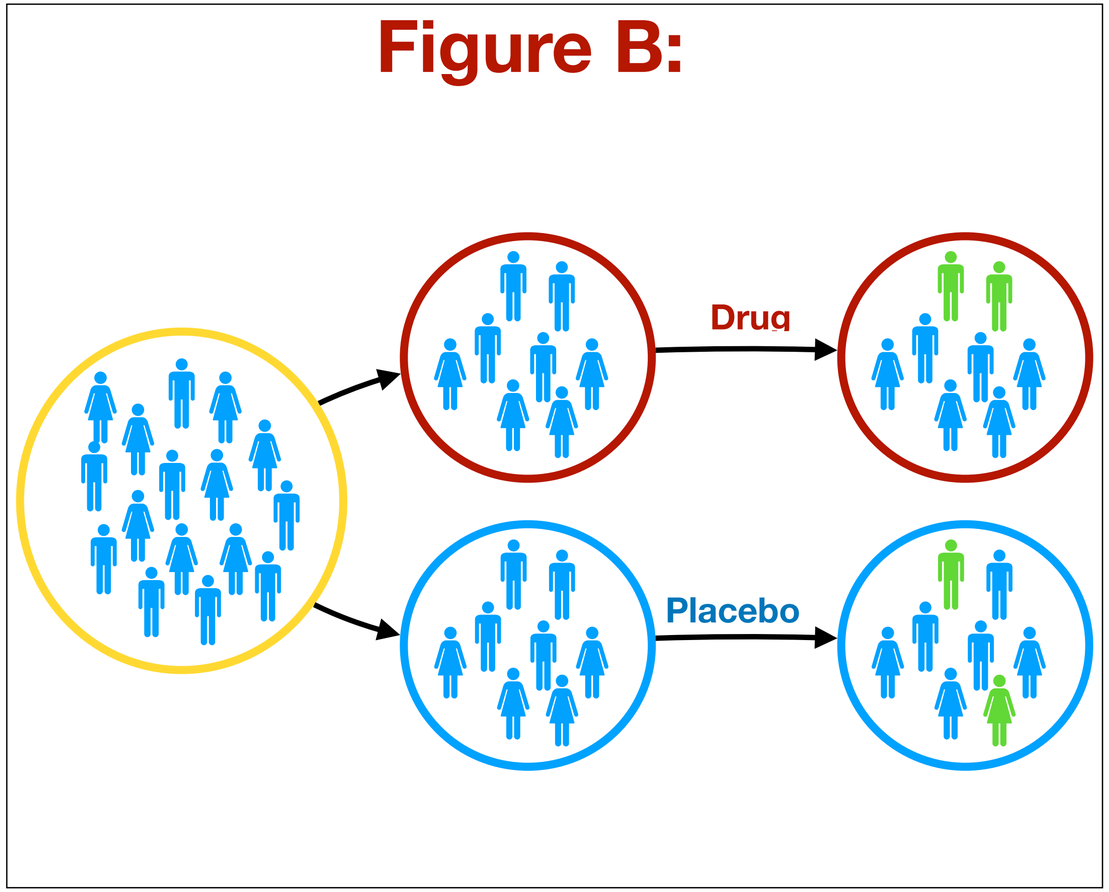
Based on experimental data

Gold standard of experiments: Randomized Controlled Trials (RCTs)



RCT: Spot the difference?





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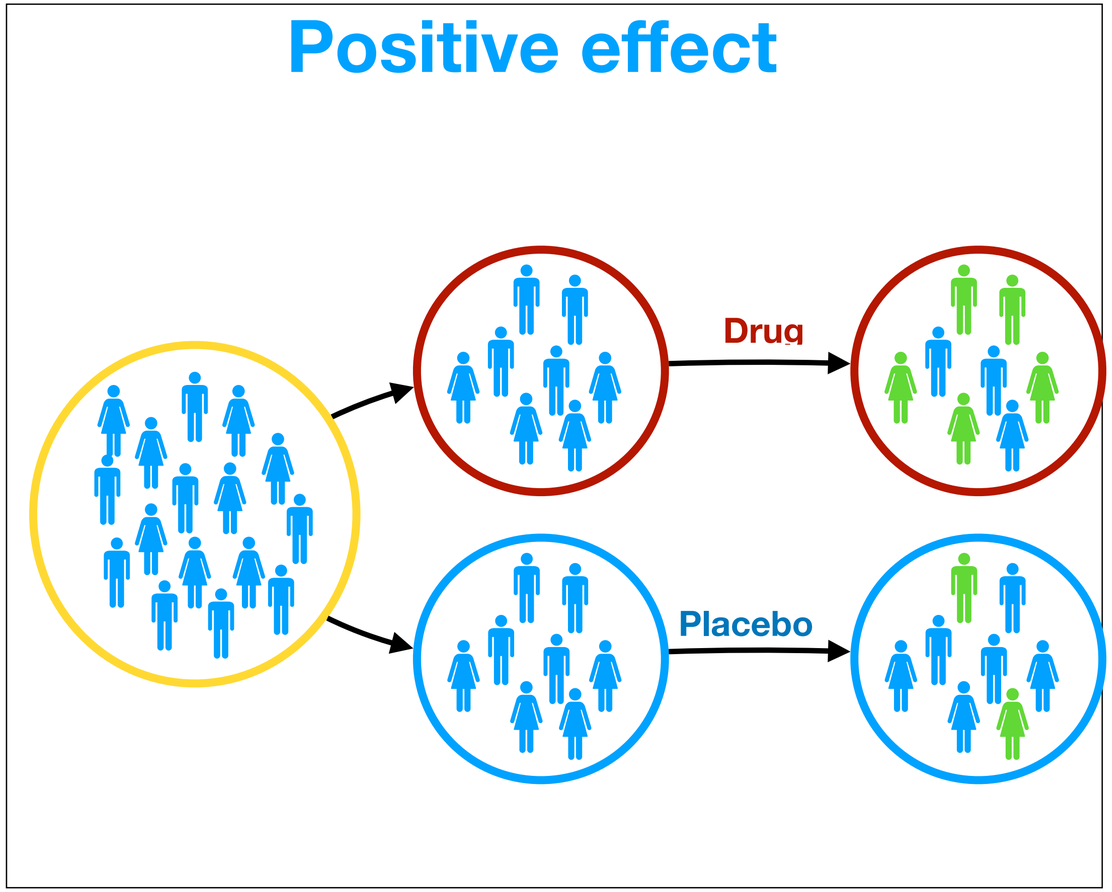
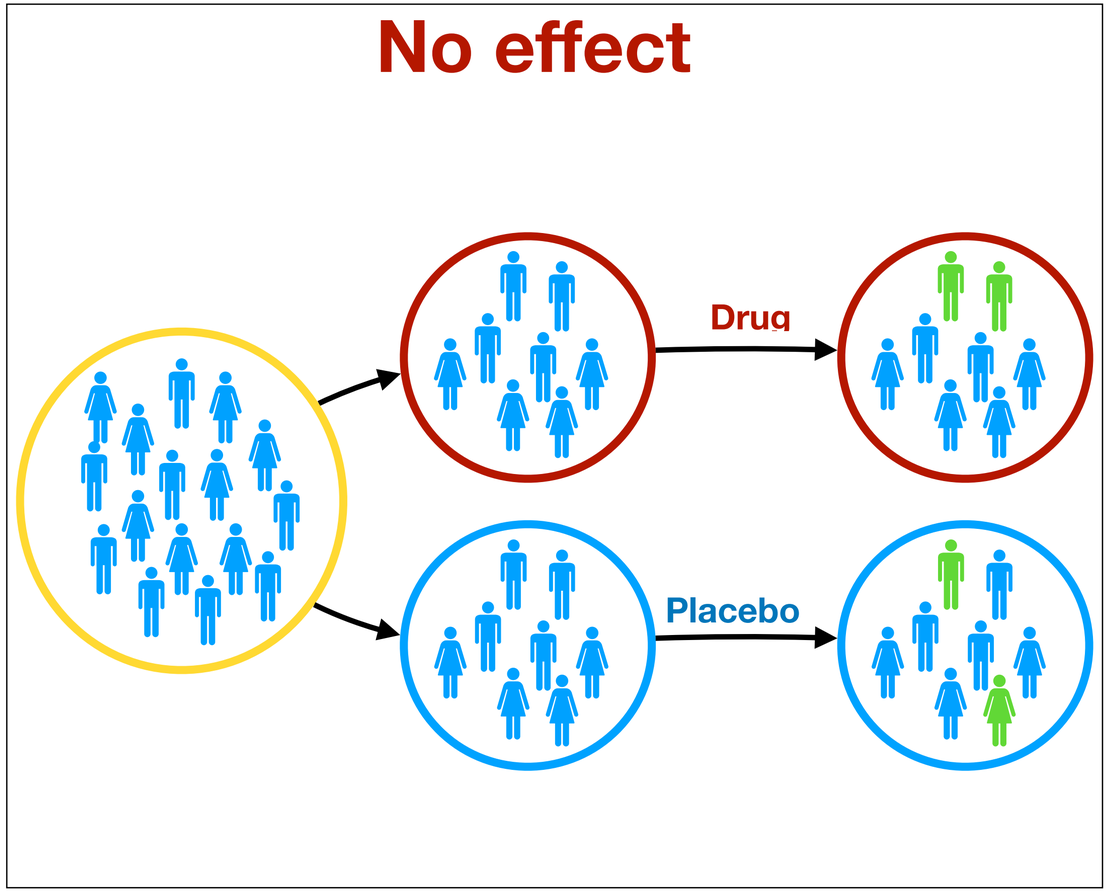




https://www.researchgate.net/publication/256031307_Test_Learn_Adapt_Developing_Public_Policy_with_Randomised_Controlled_Trials

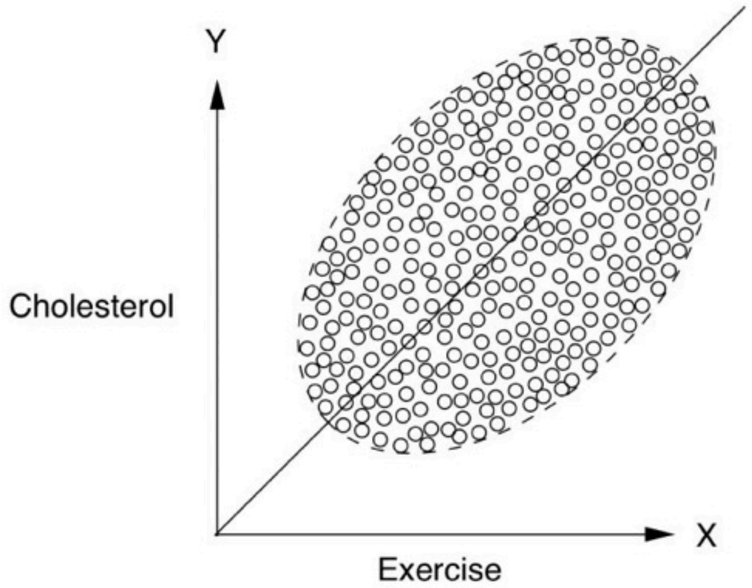
Experimental/interventional vs observational data

- **Experimental data:** We perform an experiment by changing variable A **(intervention)** and check the effects on the other variables
  - For example, we can encourage one country to eat more chocolate
  - Or to test if a drug works, we set up an RCT

- Sometimes these experiments are **expensive**, **unfeasible** or **unethical** (e.g. consider forcing people to smoke to see what effects it has)
  - In this case, we use **observational (non-experimental)** data

What if we don't have an RCT?

Let's assume we have **observational data** (e.g. data collected by hospitals)



From the Book of Why [Pearl 2018]

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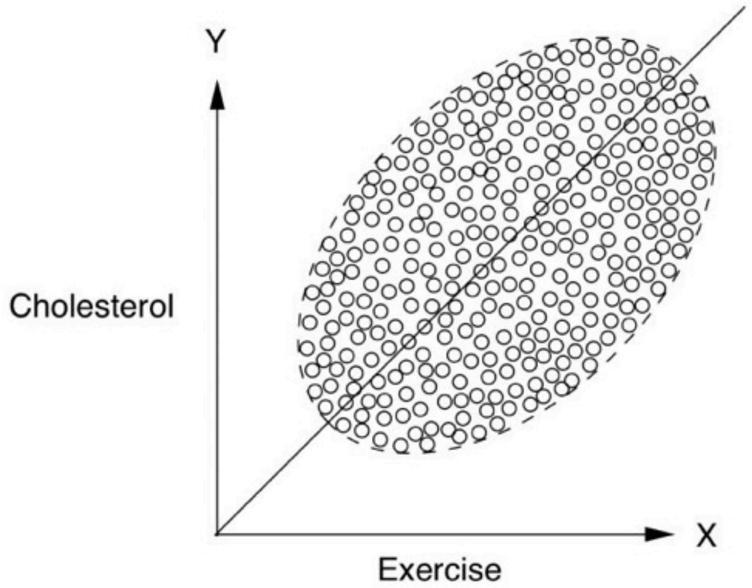

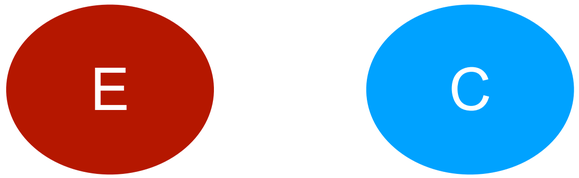

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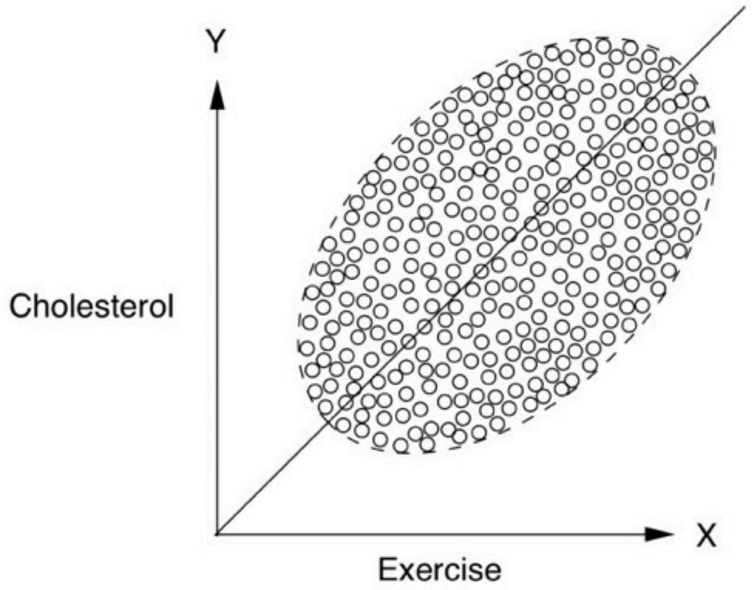
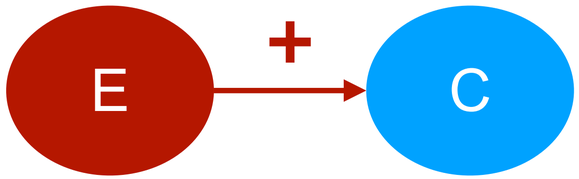


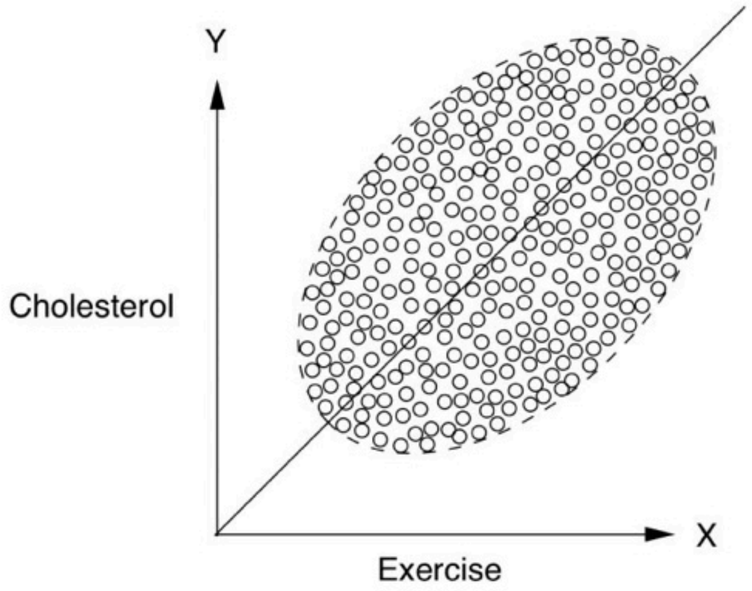


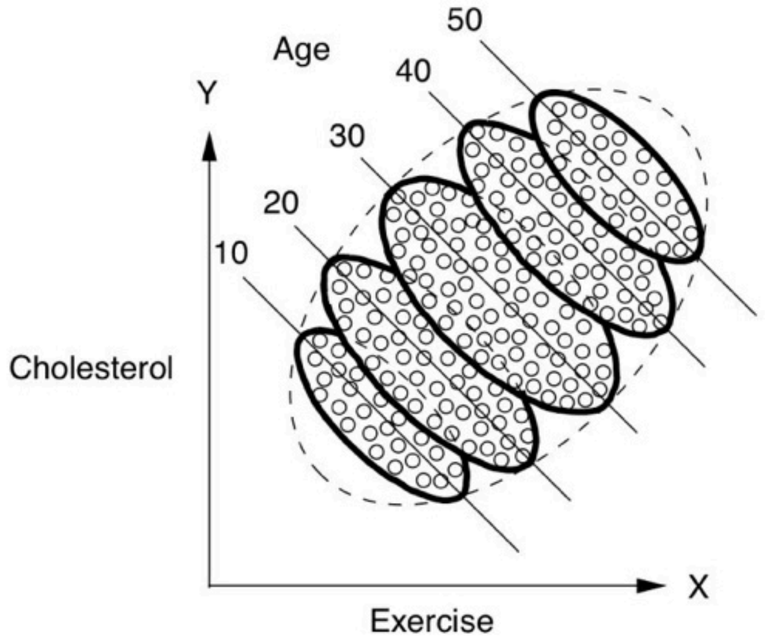
Exercise increases cholesterol

From the Book of Why [Pearl 2018]

What if we don't have an RCT? Careful!

Let's assume we have **observational data** (e.g. data collected by hospitals)

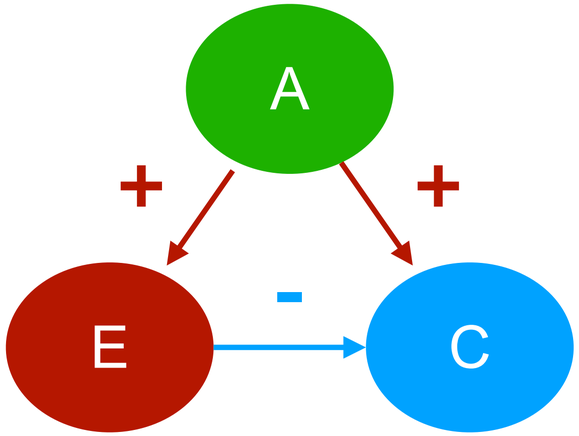




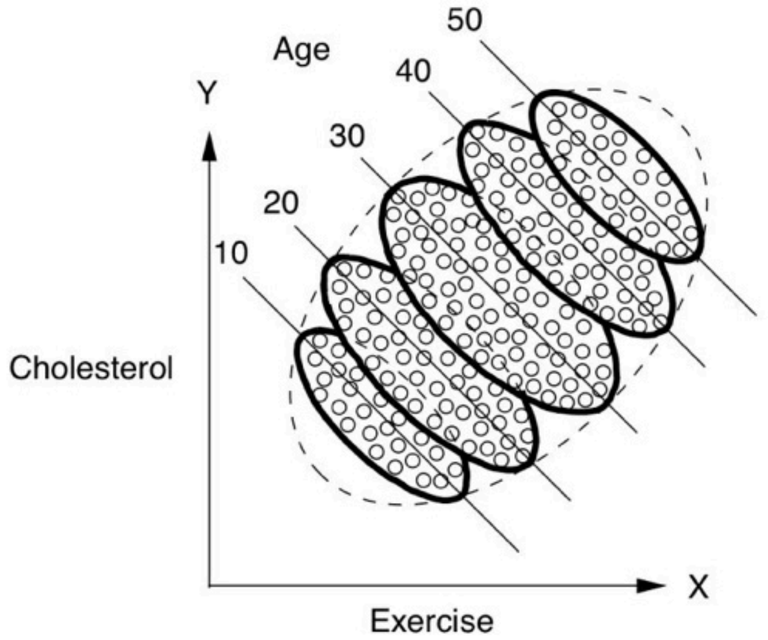
From the Book of Why [Pearl 2018]

What if we don't have an RCT? Opposite conclusion

Let's assume we have **observational data** (e.g. data collected by hospitals)



Exercise decreases cholesterol



From the Book of Why [Pearl 2018]

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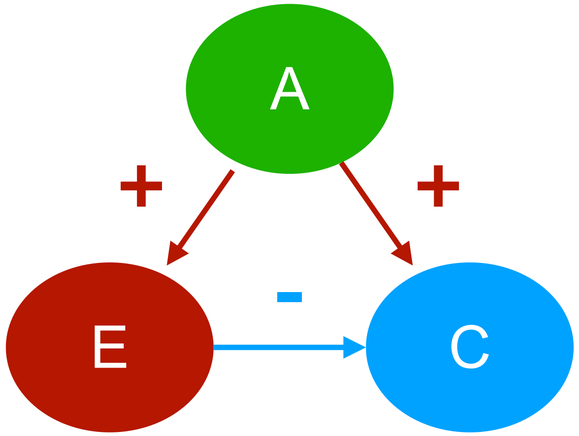

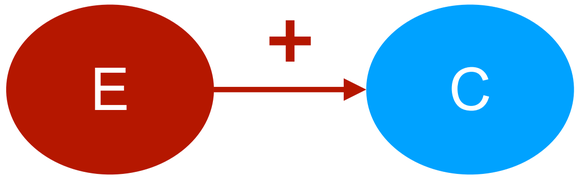

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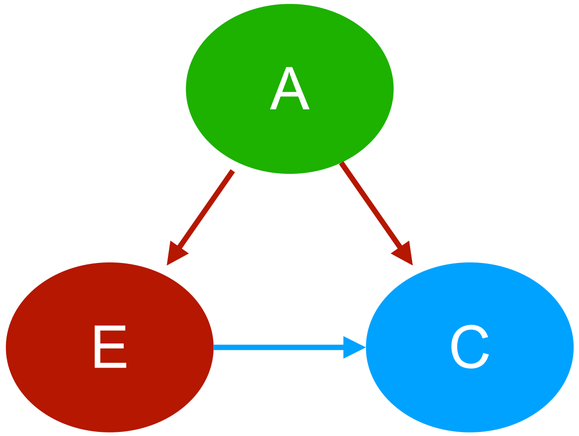
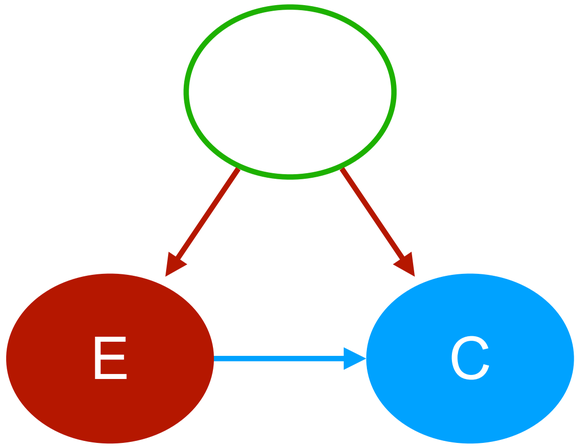


Controlling for confounding



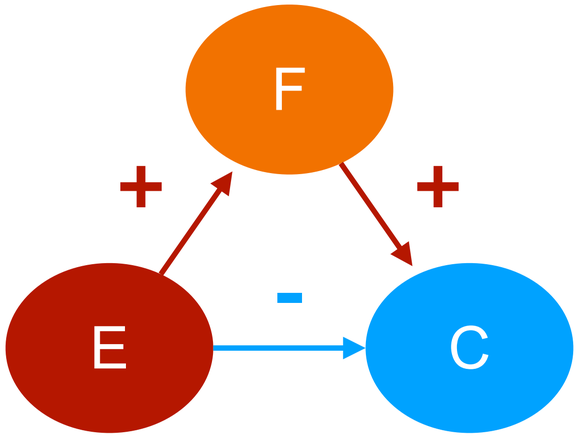
It confounds the effect

A is a confounder (a common cause of the treatment and outcome)

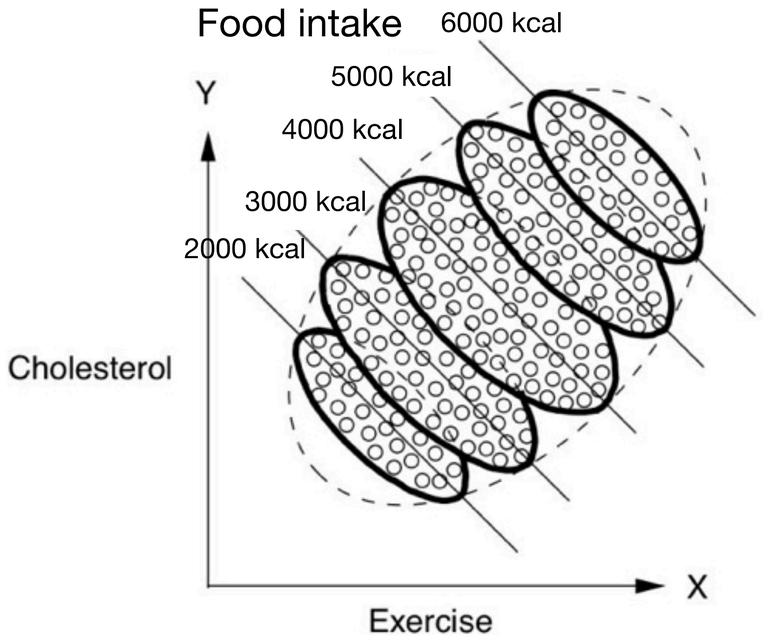
From the Book of Why [Pearl 2018]

Shall we always just control on everything?

In alternative universe:



Exercise **increases** cholesterol



Edited based on the Book of Why [Pearl 2018]

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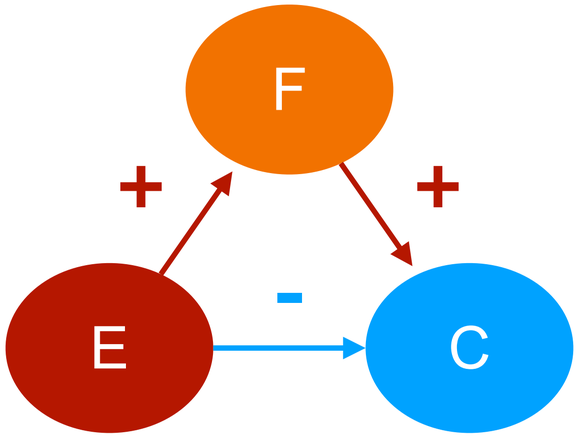

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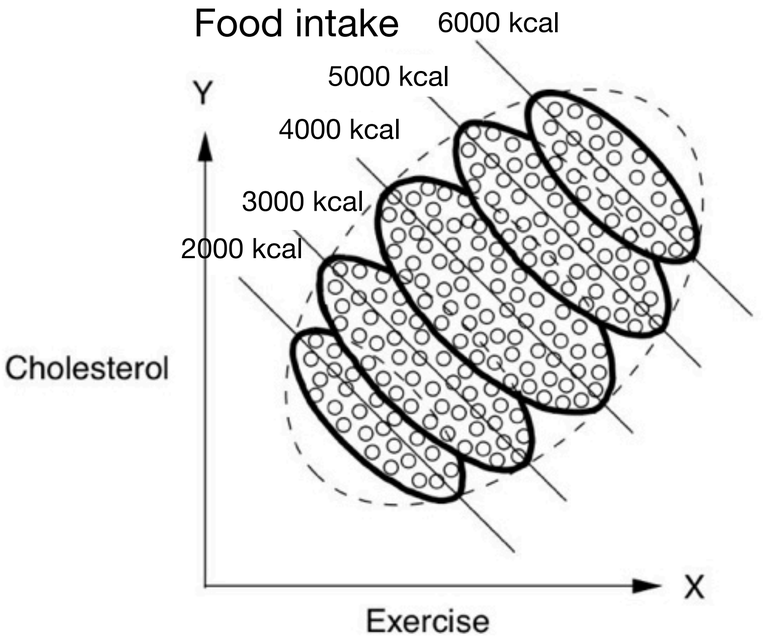

If we know the true causal graph, we can select **covariates** to **adjust** for.

Edited based on the Book of Why [Pearl 2018]

Simpson’s paradox: Optional quiz on Canvas

- In a hypothetical future there is a new disease and you are in charge of deciding which of the two new treatments, treatment A or treatment B is the most effective.

https://www.npmjs.com/package/blue-pill