(1) What is a causal state? What does it mean for a causal state to be finely articulated?

A causal state is the set of definitions for the values of the alternative treatments in a study. To be finely articulated means that the state has a precise, specific, objective definition. For example, a state that isn't finely articulated is "high socioeconomic status". There are too many variables defining socioeconomic status, and the choice of which contribute more to "high" status (for example, income or education level) is left subjective. To finely articulate it, you could focus in on one aspect of socioeconomic status, like education level. In that case, your causal states might be "no diploma", "has high school diploma", "has college diploma", and "has post-graduate diploma".

(2) Why can't we measure individual level treatment effects, $Y^1 - Y^0$, in practice?

A unit can't be in two causal states at the same time. This is the "fundamental problem of causal inference": to directly measure the effectiveness of a treatment at the individual level, you need to observe the control outcome Y_0 and the test outcome Y_1 on the unit i simultaneously.

(3) Do you think the SUTVA might be violated (why? Why not?) for the causal effect of X on Y when

(a) X = "Having a college degree" and Y = "Future earnings"

SUTVA is the assumption that the potential outcomes, Y^1 and Y^0, for each individual are independent of the treatment status of the rest of the population. We can figure this out by imagining an experiment where we vary the size of the treatment and control groups, keeping one individual in mind, and reasoning about whether this should have an effect on the potential outcomes.

If we consider my earnings if I go to college, Y^1, it should depend on whether everyone else has gone to college (supply and demand). If everyone has a college degree, then the advantage it offers over the rest of the labor market is smaller, so I'll probably be paid less. That means my Y^1 potential outcome depends on everyone else's treatment assignment, and so SUTVA is violated.

(b) X = "Vaccinating individual i in a local population" and Y = "person i's chances of getting sick abroad"

We talked about this example in class, so I made this one tricky. In class, we said that we can focus on an individual in the local population who doesn't get vaccinated, so we're measuring Y^0 for that person. If nobody else is vaccinated, they're likely to get the disease, because they can catch it from anyone. If everyone else gets the vaccine,

they're unlikely to get the disease, since there's nobody to catch it from. That means their Y^0 state depends on the treatment status of the local population.
This logic doesn't work if the person is traveling abroad. In that case, the vaccination of their local population has no effect on the herd immunity of people abroad. Then, their Y^0 state doesn't vary with the size of the treated population, and SUTVA isn't violated.

(4) Use the notebook posted for this assignment from class to measure the ATE, ATC and ATT in the population when the naive estimator is unbiased.

(see the notebook for solutions)

(5) Let's explore bias with simulated data:

(see the notebook for solutions)

We're dropping this question, because I wrote it poorly. It should read

(a) This one should say to make the naive estimator an unbiased estimator for the ATC, but biased for the ATE and ATT.
(b) In this new data, which treatment effect is the naive estimator, E[Y|D=1] - E[Y|D=0] an unbiased estimator for? Is it unbiased for the ATE?
(c) What kind of bias does the naive estimator have for the ATE? Is it baseline bias, differential treatment effect bias, or both?

You'll find answers in the notebook!

(a) Copy and modify the data generating process to introduce bias in the ATT and ATE, but leave the ATC unbiased (hint: define the [usually unmeasured] Y^0 and Y^1 for each unit, then examine the assumptions A1 and A2).
(b) Use naive estimators to measure the (potentially biased) ATE, ATC and ATT.
(c) Which estimates are biased? Is the bias baseline bias, differential treatment effect bias, or both?