

Using systems to understand population health

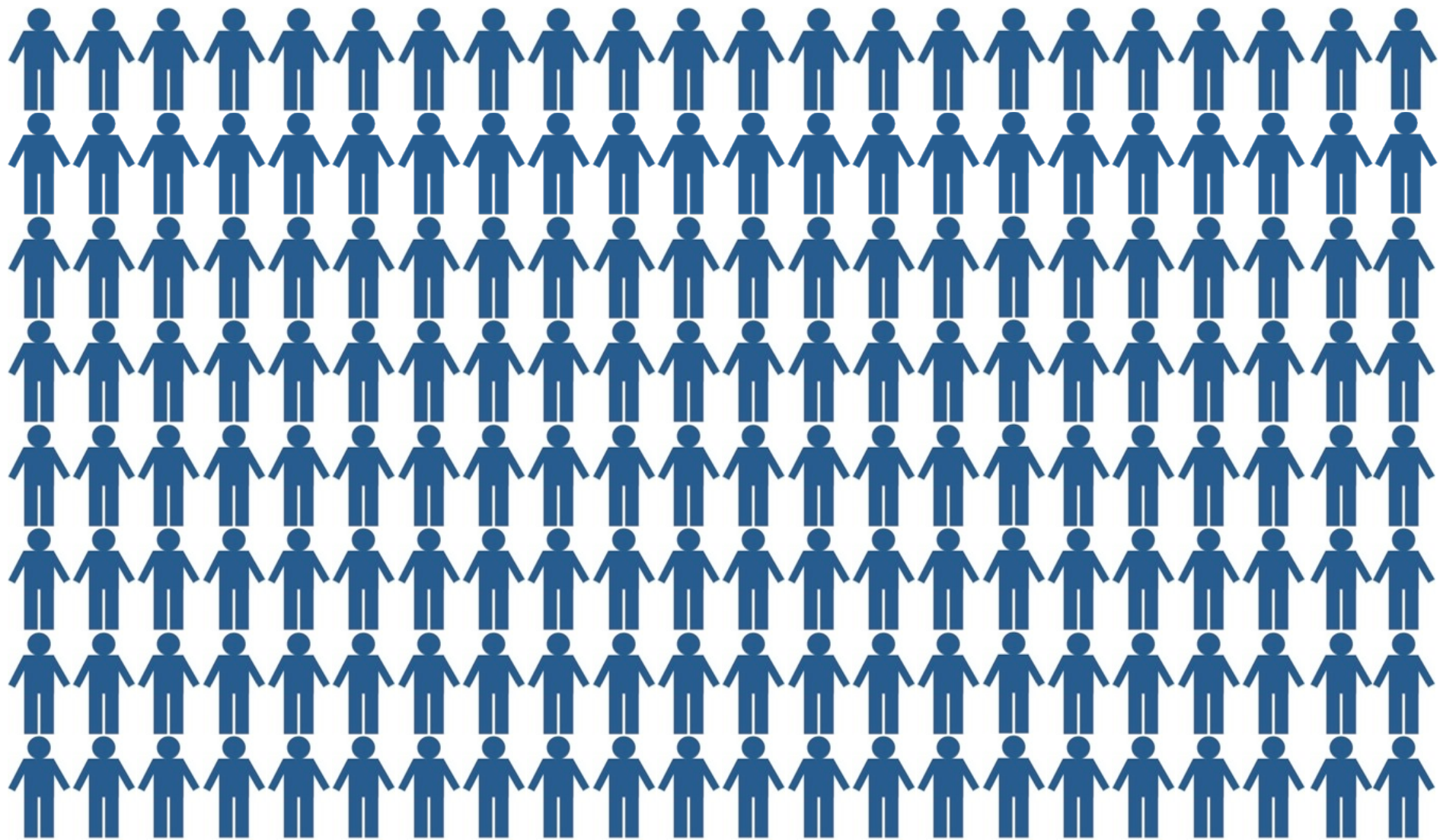
Sandro Galea

A central motivation: population health

“The health outcomes of a group of individuals, including the distribution of such outcomes within the group”

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Why? So that we may intervene



Populations are

1. Heterogeneous, ie have diversity of agents
2. Characterized by nonlinear dynamics
3. Characterized by contact structure, networks, organization
4. Have feedback, adaptation, learning, evolution
5. Stochastic with important tails
6. Display emergent properties



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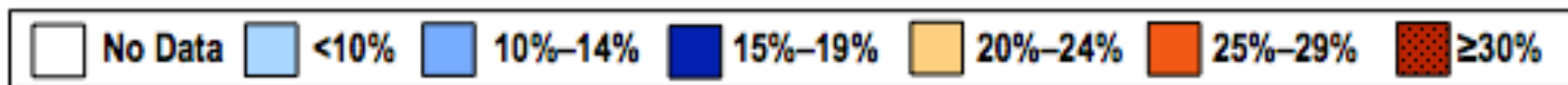
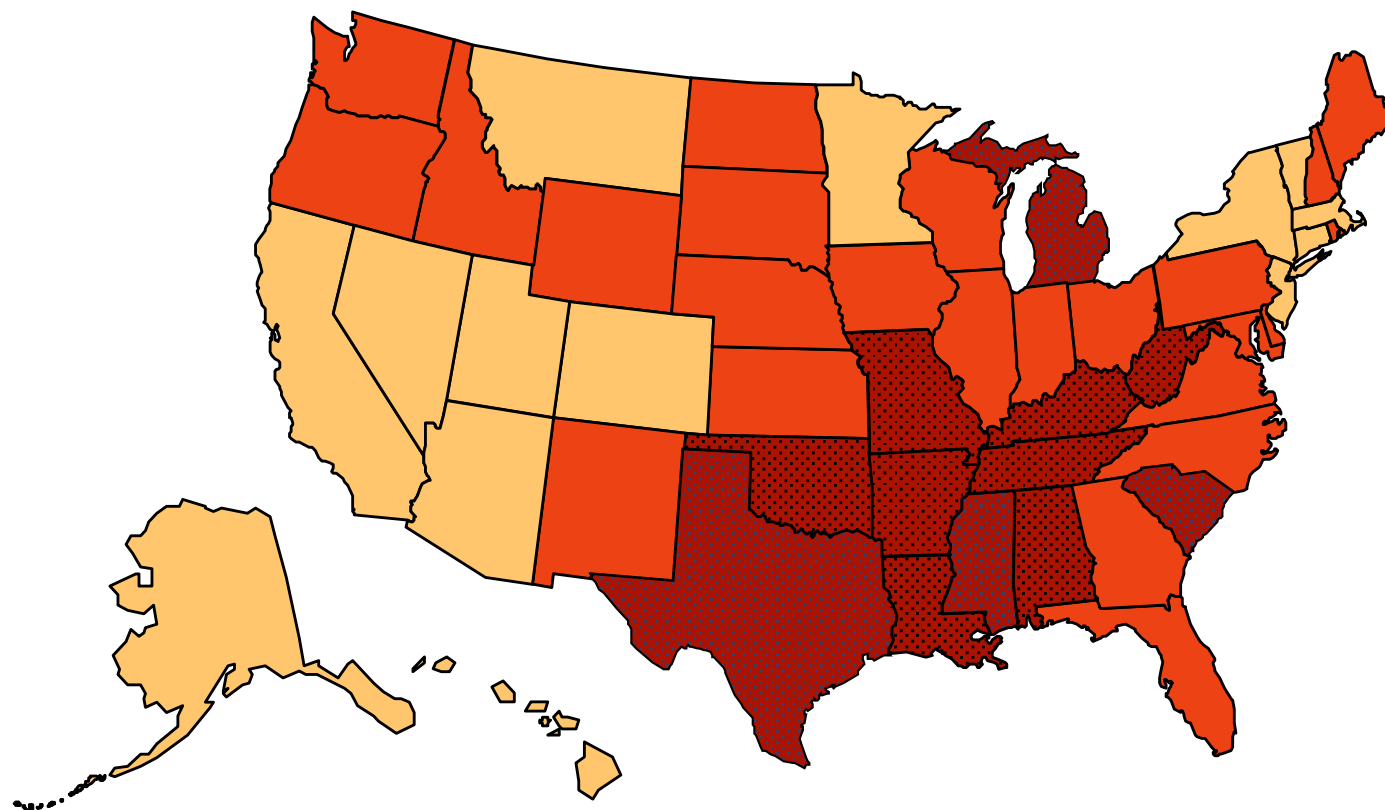
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Complex systems

Obesity among U.S. adults, 2010

(*BMI ≥ 30 , or ~ 30 lbs. overweight for 5' 4" person)



The foundations of population health

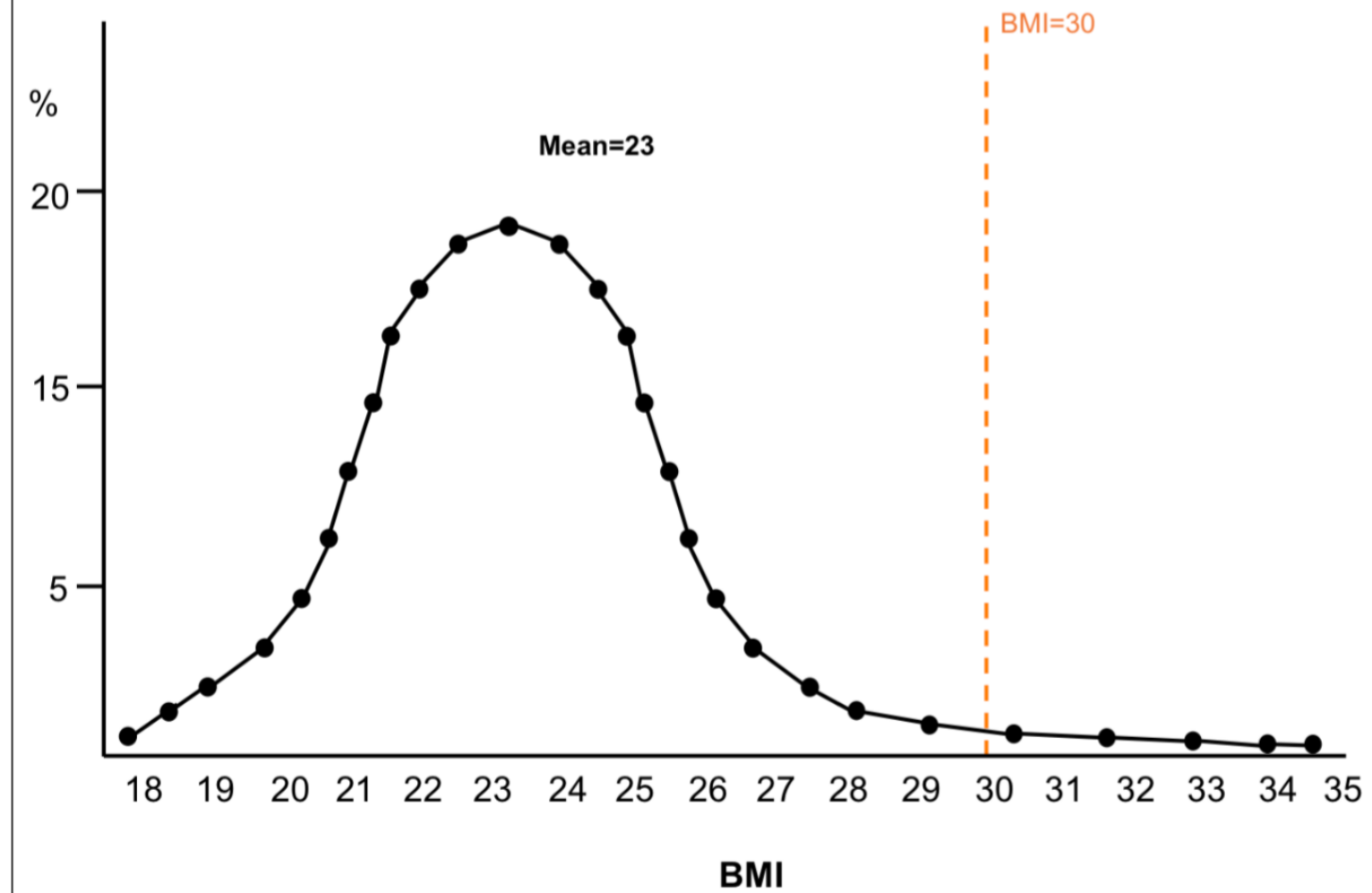
1. Population health manifests as a continuum.
2. The causes of differences in health across populations are not necessarily an aggregate of the causes of differences in health within populations.
3. Large benefits to population health may not improve the lives of all individuals.
4. The causes of population health are multilevel, accumulate throughout the life course, and are embedded in dynamic interpersonal relationships.
5. Small changes in ubiquitous causes may result in more substantial change in the health of populations than larger changes in rarer causes.
6. The magnitude of an effect of exposure on disease is dependent on the prevalence of the factors that interact with that exposure.
7. Prevention of disease often yields a greater return on investment than curing disease after it has started.
8. Efforts to improve overall population health may be a disadvantage to some groups; whether equity or efficiency is preferable is a matter of values.
9. We can predict health in populations with much more certainty than we can predict health in individuals.

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Principle 1. Population health manifests as a continuum

Figure 1. Distribution of BMI in two populations illustrating health as a continuum in the population

Panel A



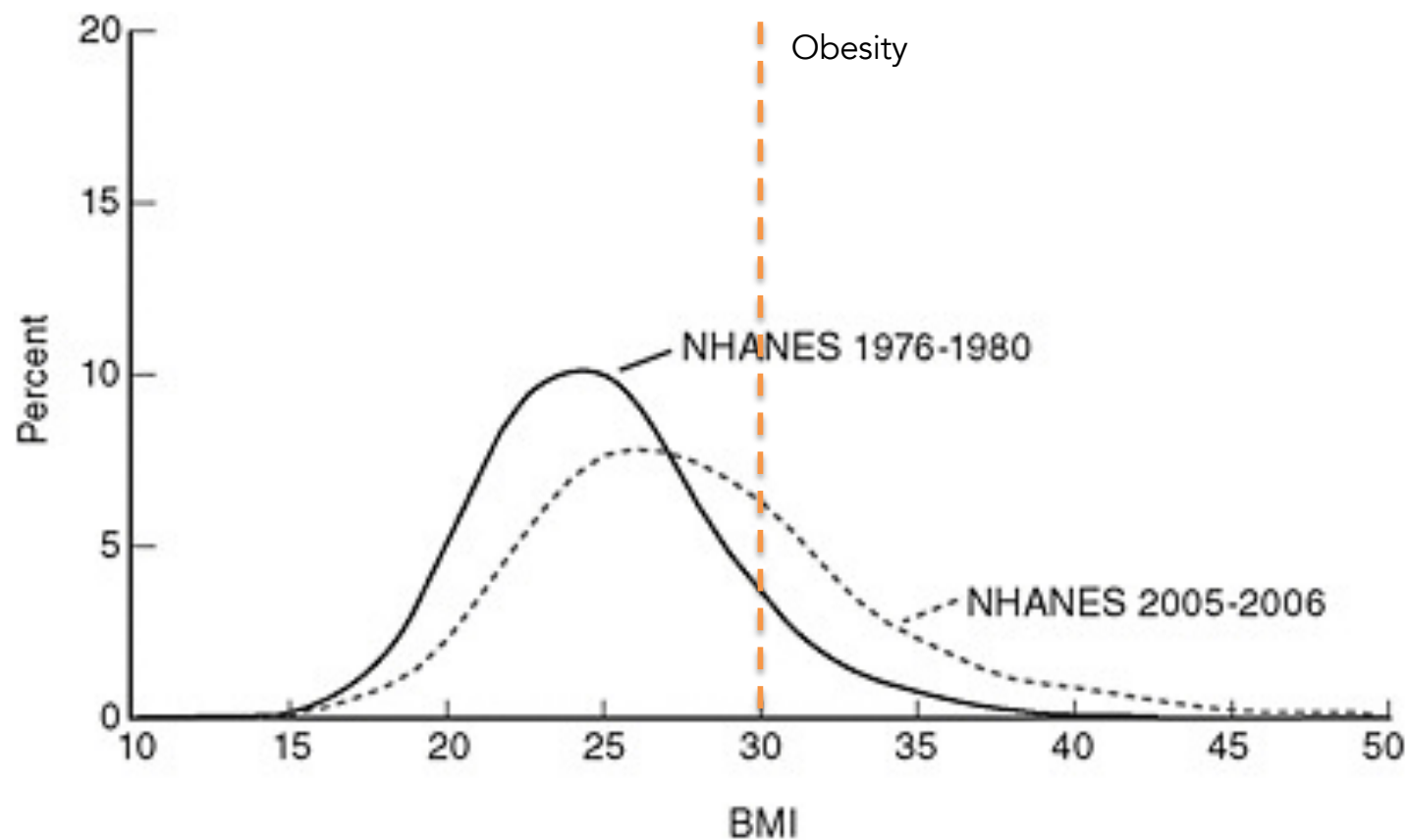


FIGURE 1-1 Changes in the distribution of body mass index (BMI) between 1976-1980 and 2005-2006 among U.S. adults aged 20-74. NOTE: NHANES = National Health and Nutrition Examination Survey, a continuous program of studies designed to assess the health and nutritional status of a nationally representative sample of children and adults in the United States. SOURCE: Ogden et al., 2007. <https://www.nap.edu/read/12847/chapter/3#24>

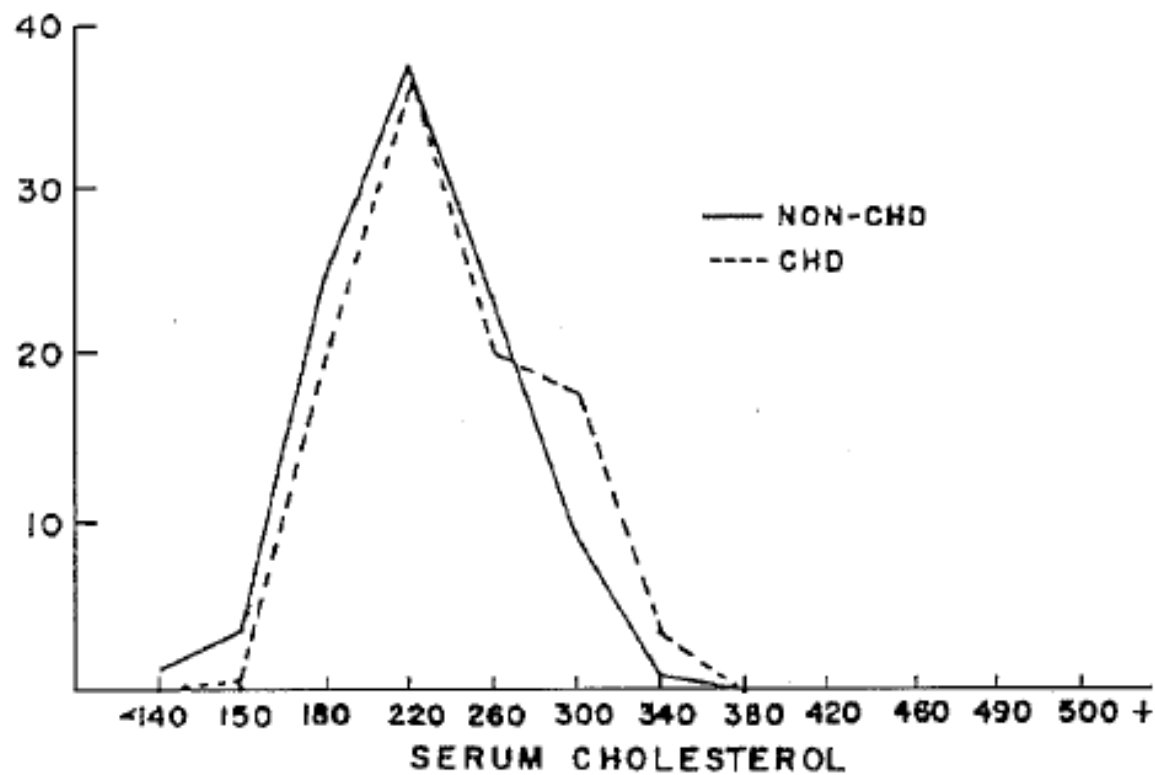


Figure 3 Percentage distribution of serum cholesterol levels (mg/dl) in men aged 50-62 who did or did not subsequently develop coronary heart disease (Framingham Study⁵)

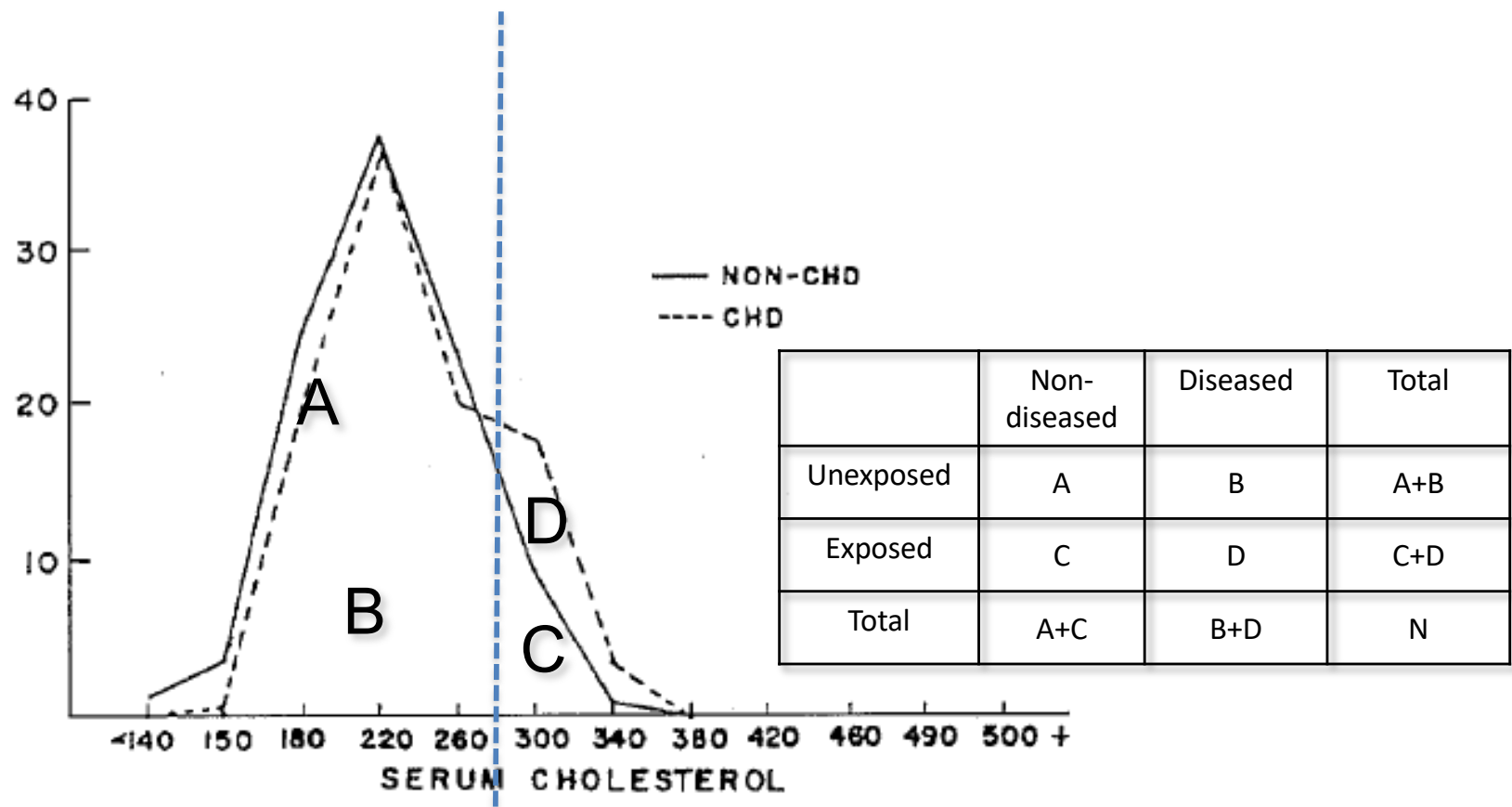


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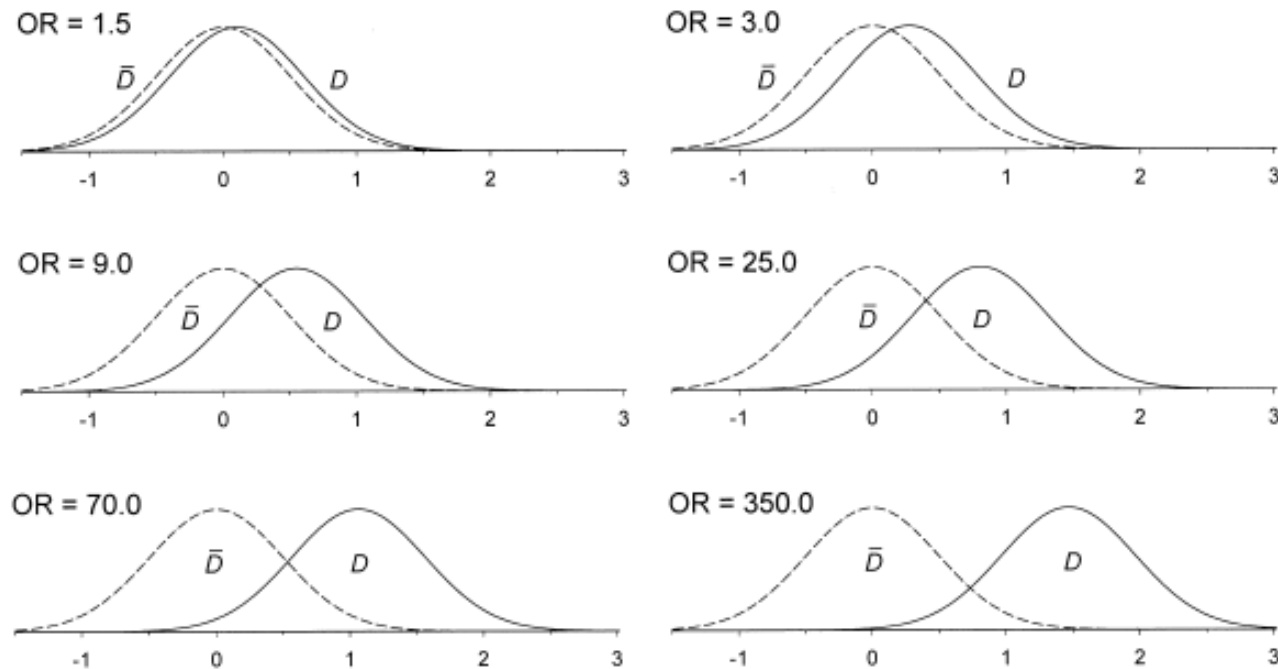
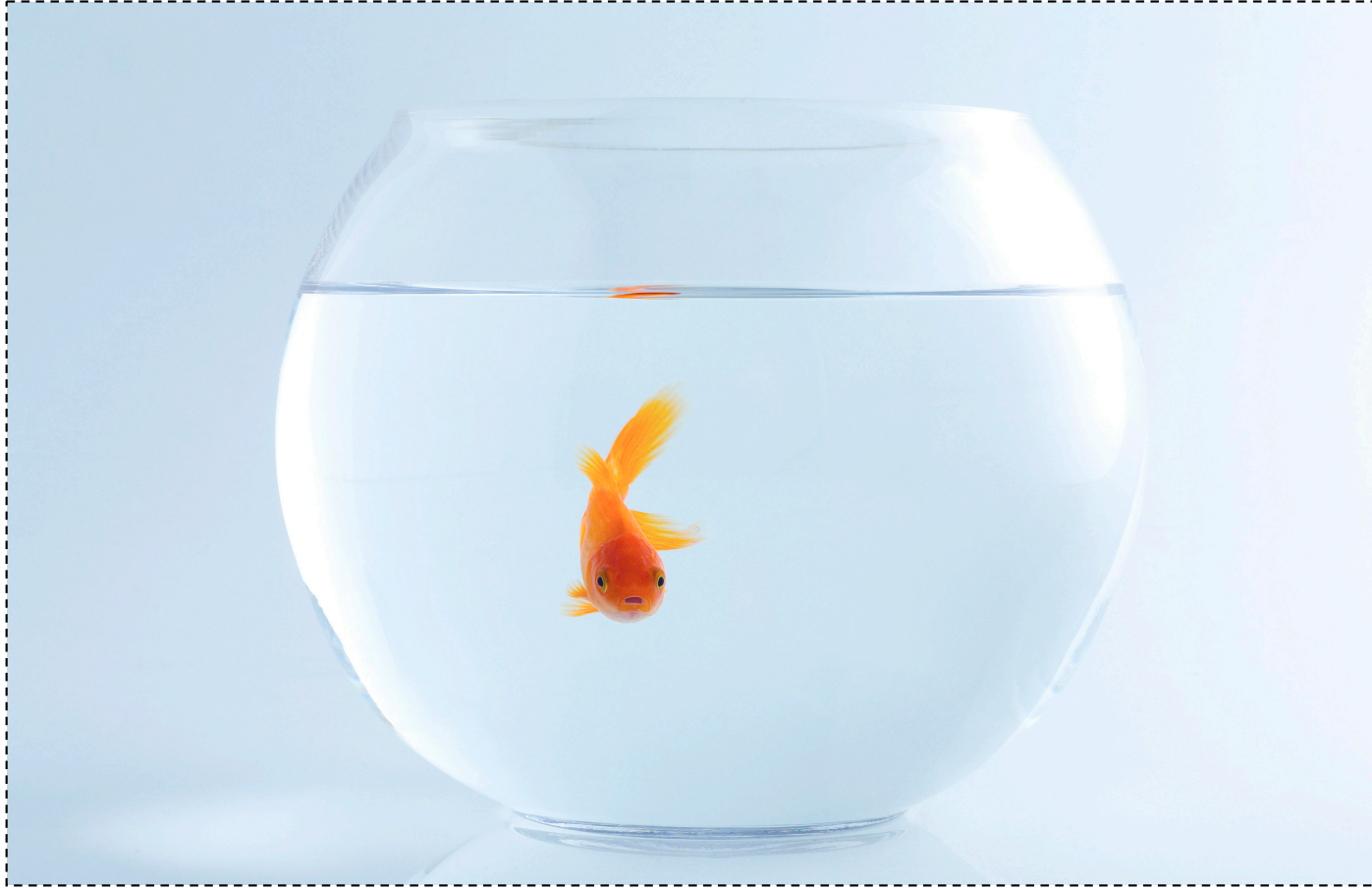
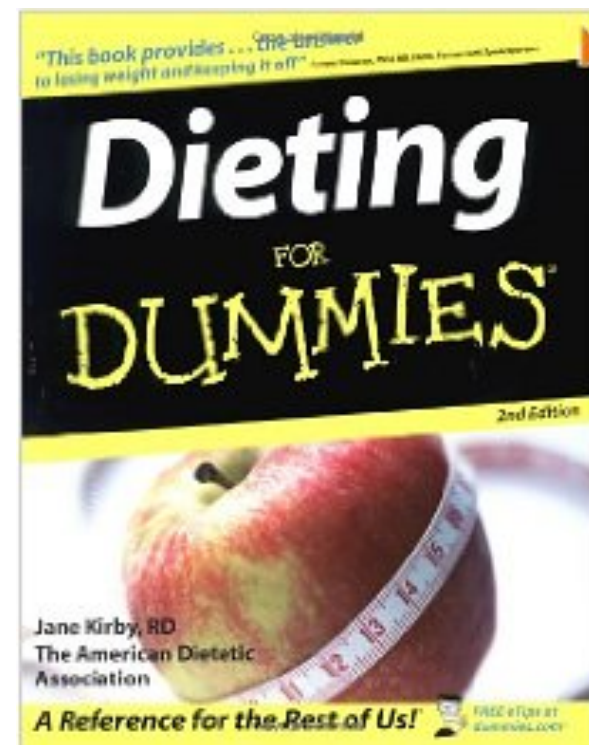
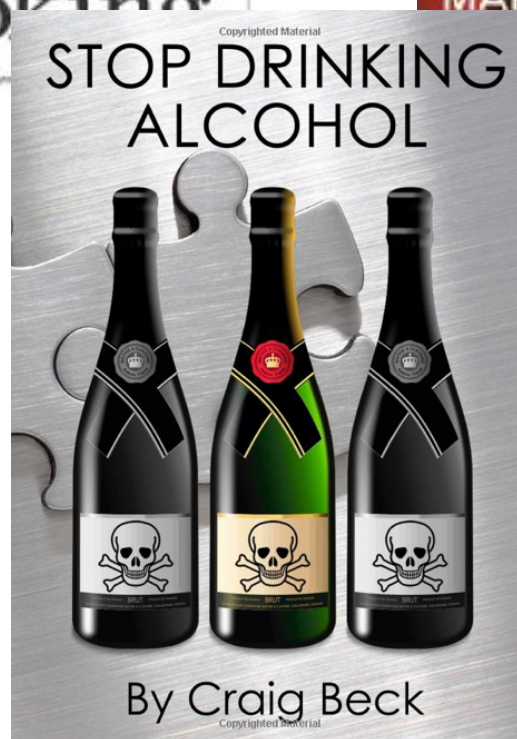
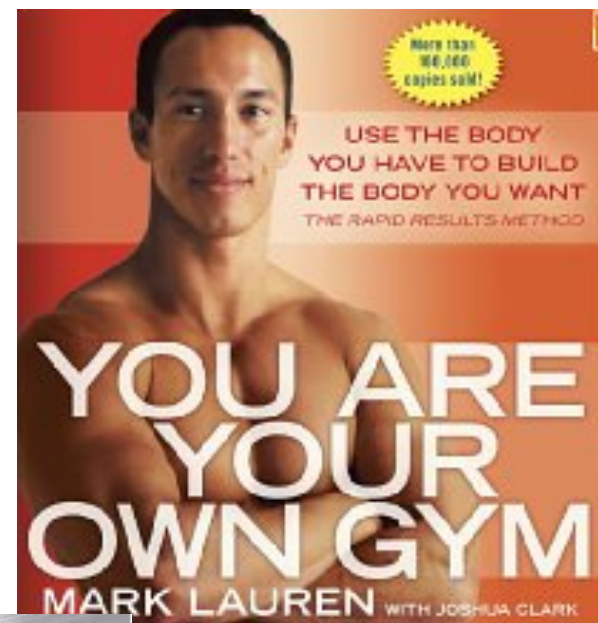
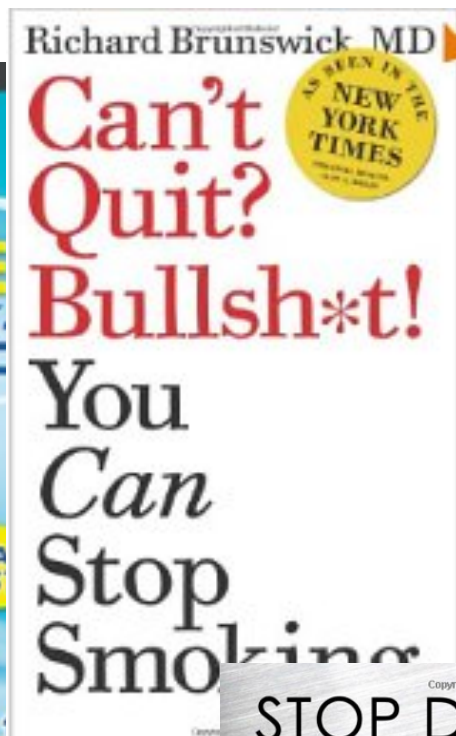


FIGURE 2. Probability distributions of a marker, X , in cases (solid curves) and controls (dashed curves) consistent with the logistic model $\log\text{-it}P(D=1|X) = \alpha + \beta X$. It has been assumed that X has a mean of 0 and a standard deviation of 0.5 in controls so that a unit increase represents the difference between the 84th and 16th percentiles of X in controls. The marker is normally distributed, with the same variance in cases. The odds ratio (OR) per unit increase in X is shown.

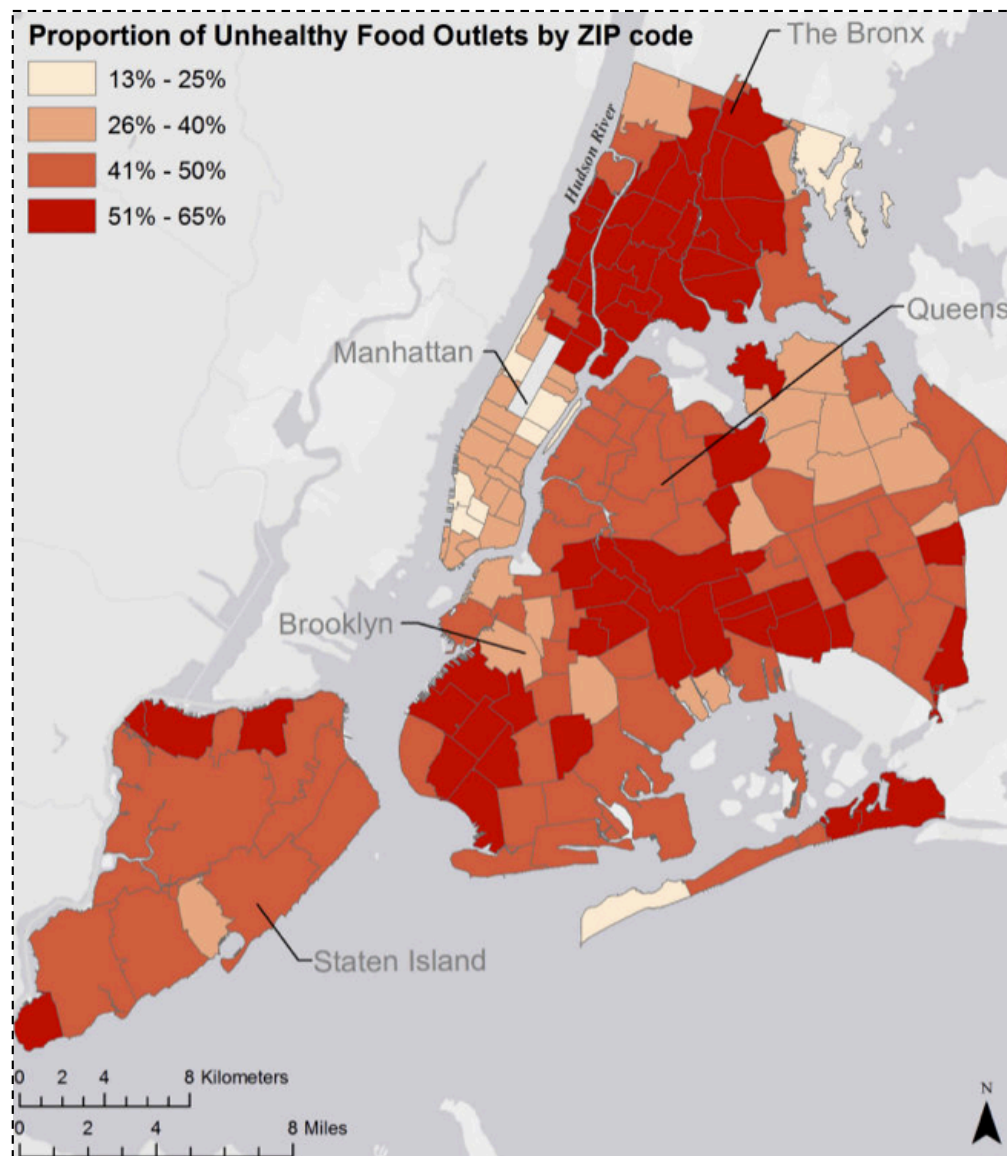
Principle 5. Small changes in ubiquitous causes may result in more substantial change in the health of populations than larger changes in rarer causes.



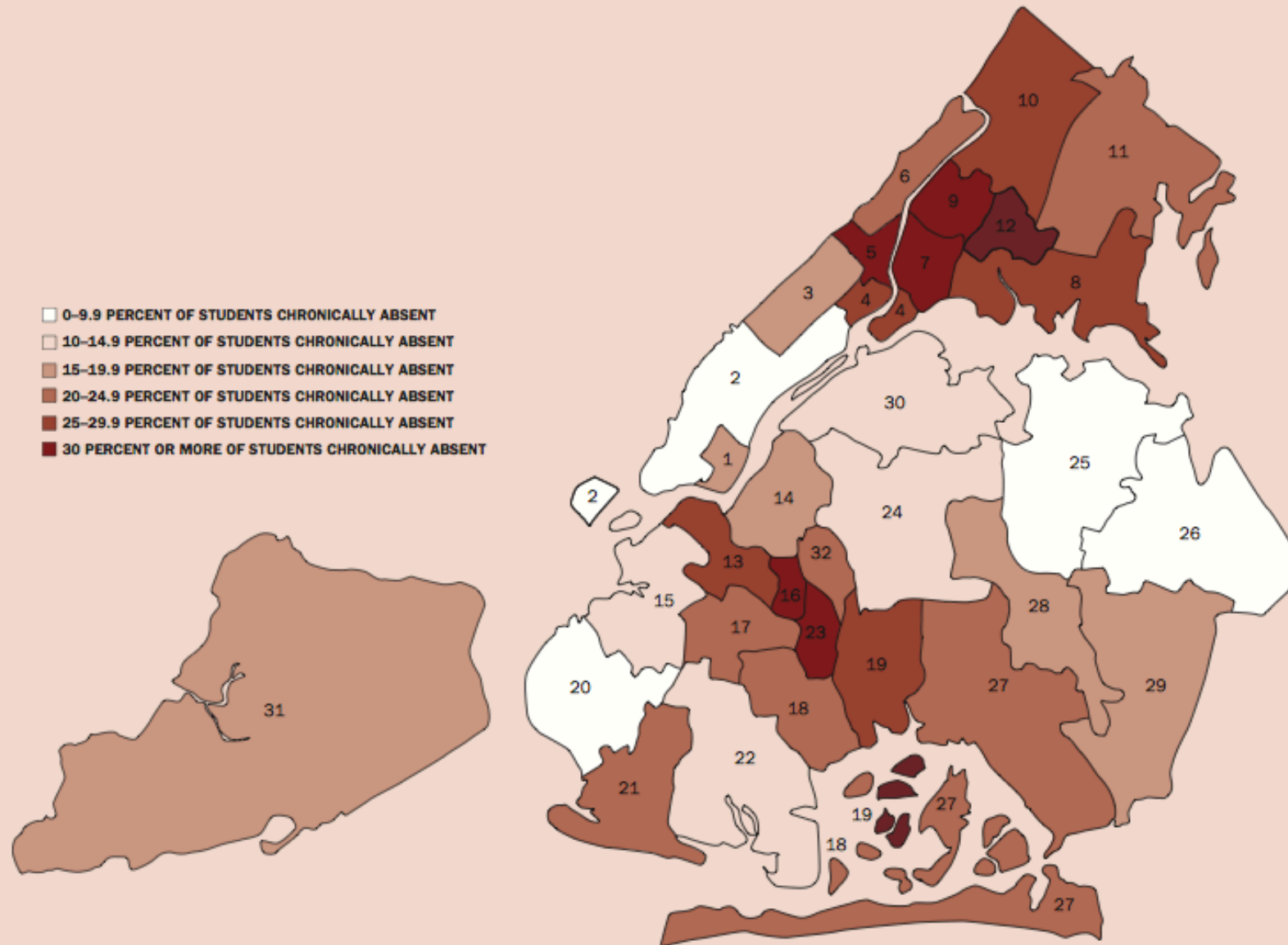


Food		20 Years Ago	Today
Bagel		140 calories (3" diameter)	350 calories (6" diameter)
Muffin		210 calories (1.5 oz)	500 calories (4 oz)
Cheeseburger		333 calories	590 calories
Pasta (Spaghetti & Meatballs)		500 calories	1025 calories
French Fries		210 calories (2.4 oz)	610 calories (6.9 oz)
Soda		85 calories (6.5 oz)	250 calories (20 oz)
Theater Popcorn		270 calories (5 cups)	630 calories (1 tub)
Turkey Sandwich		320 calories	820 calories
Pizza		500 calories (2 slices)	850 calories (2 calories)

Poor food environment in New York City

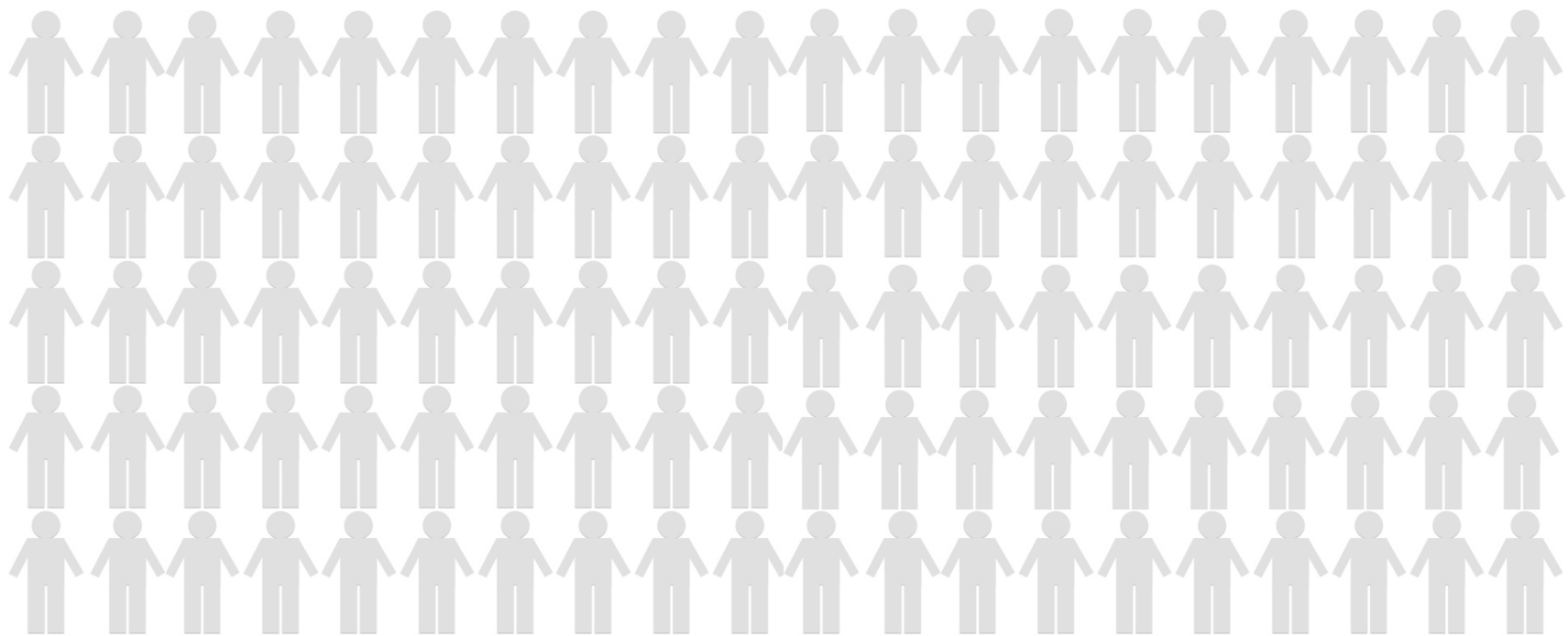


LEVELS OF ELEMENTARY SCHOOL CHRONIC ABSENTEEISM BY DISTRICT



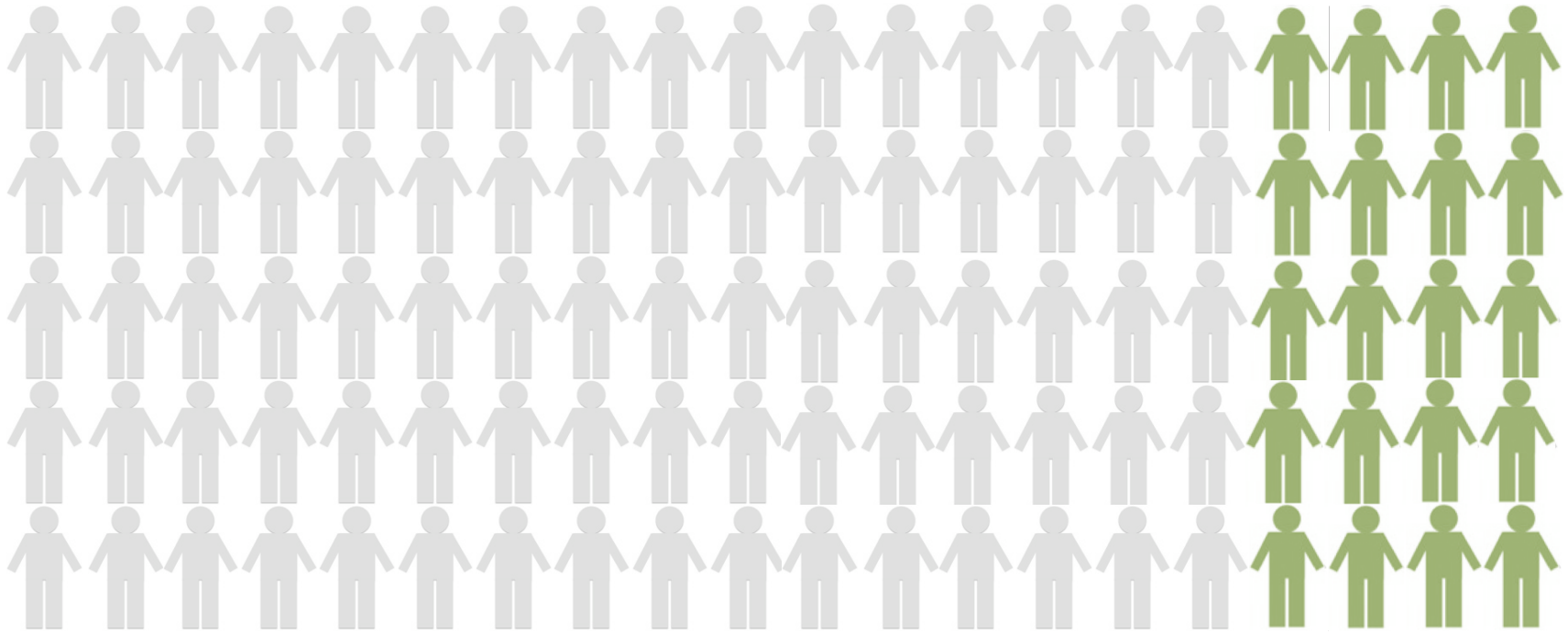
Principle 6. The magnitude of an effect of exposure on disease is dependent on the prevalence of the factors that interact with that exposure.

How much of our obesity risk is determined by our genes?





 = GE+



 = ENV+



 = OB+

Scenario 1



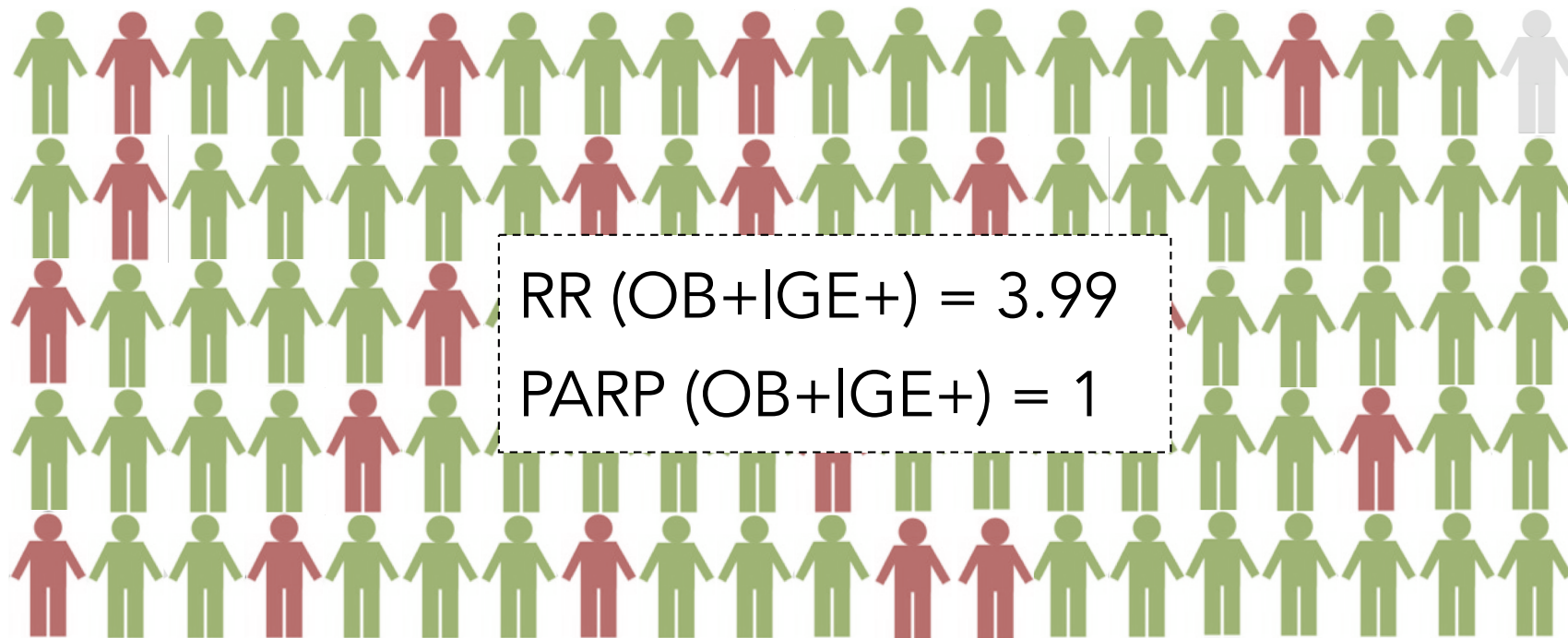
 = GE+  = OB+  = ENV+

Scenario 1



 = GE+  = OB+  = ENV+

Scenario 1



 = GE+  = CA+  = ENV+

Scenario 2



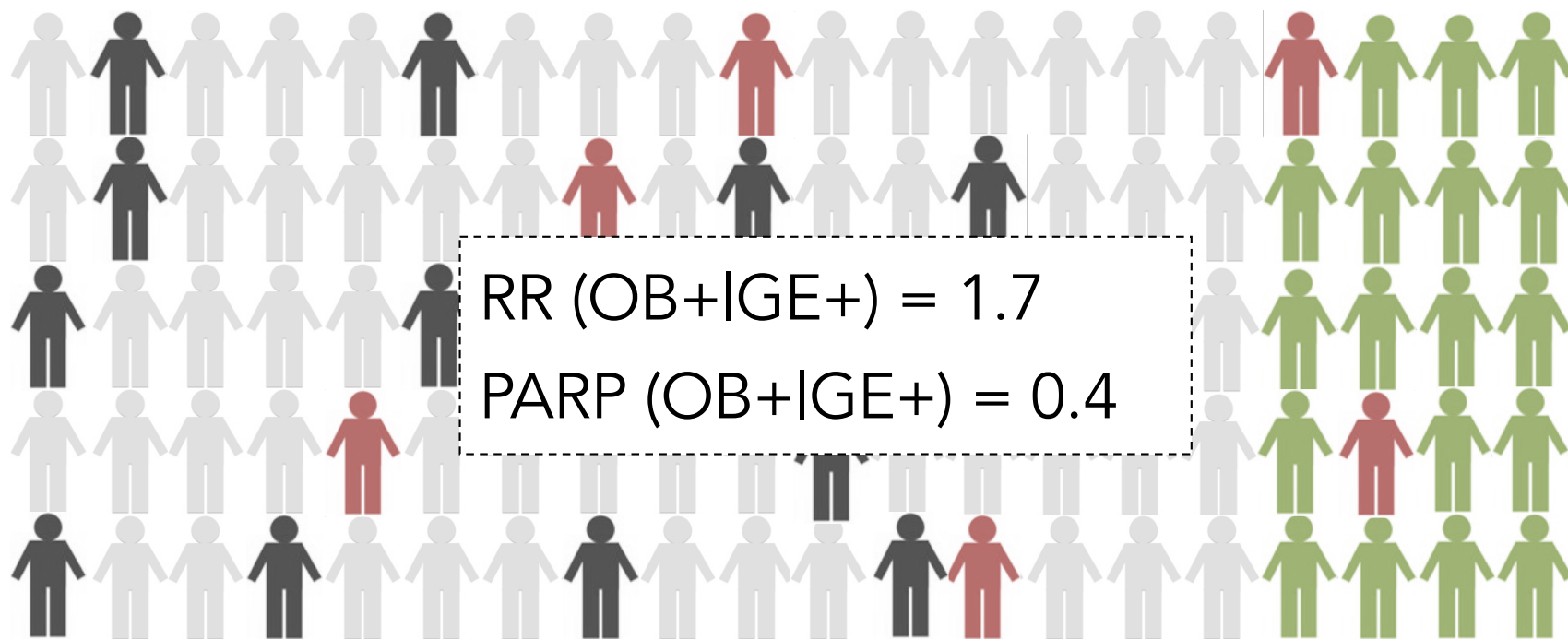
 = GE+  = OB+  = ENV+

Scenario 2



 = GE+  = OB+  = ENV+

Scenario 2



 = GE+  = OB+  = ENV+

Therefore under a very plausible assumption of co-occurring causes, the gene-obesity association can only be understood if we understand the urban factors that create the conditions for disease

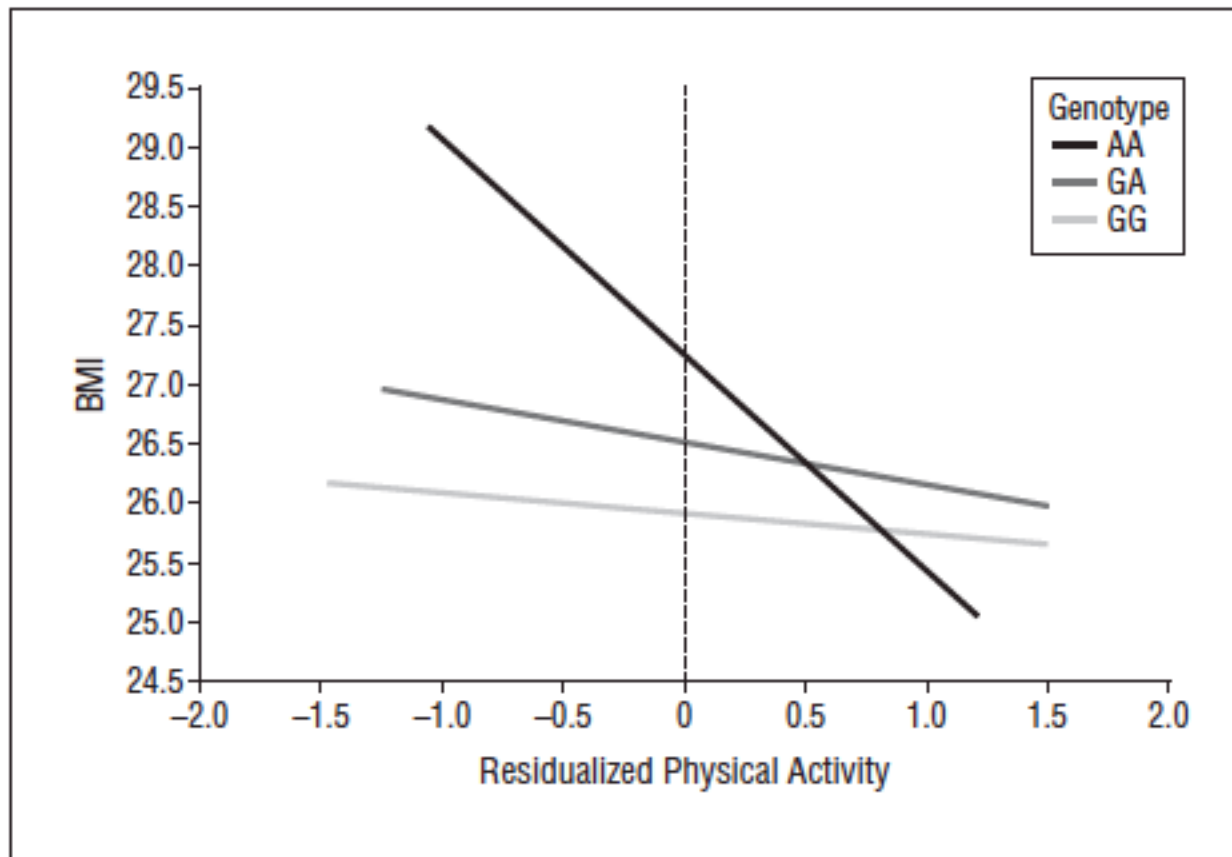
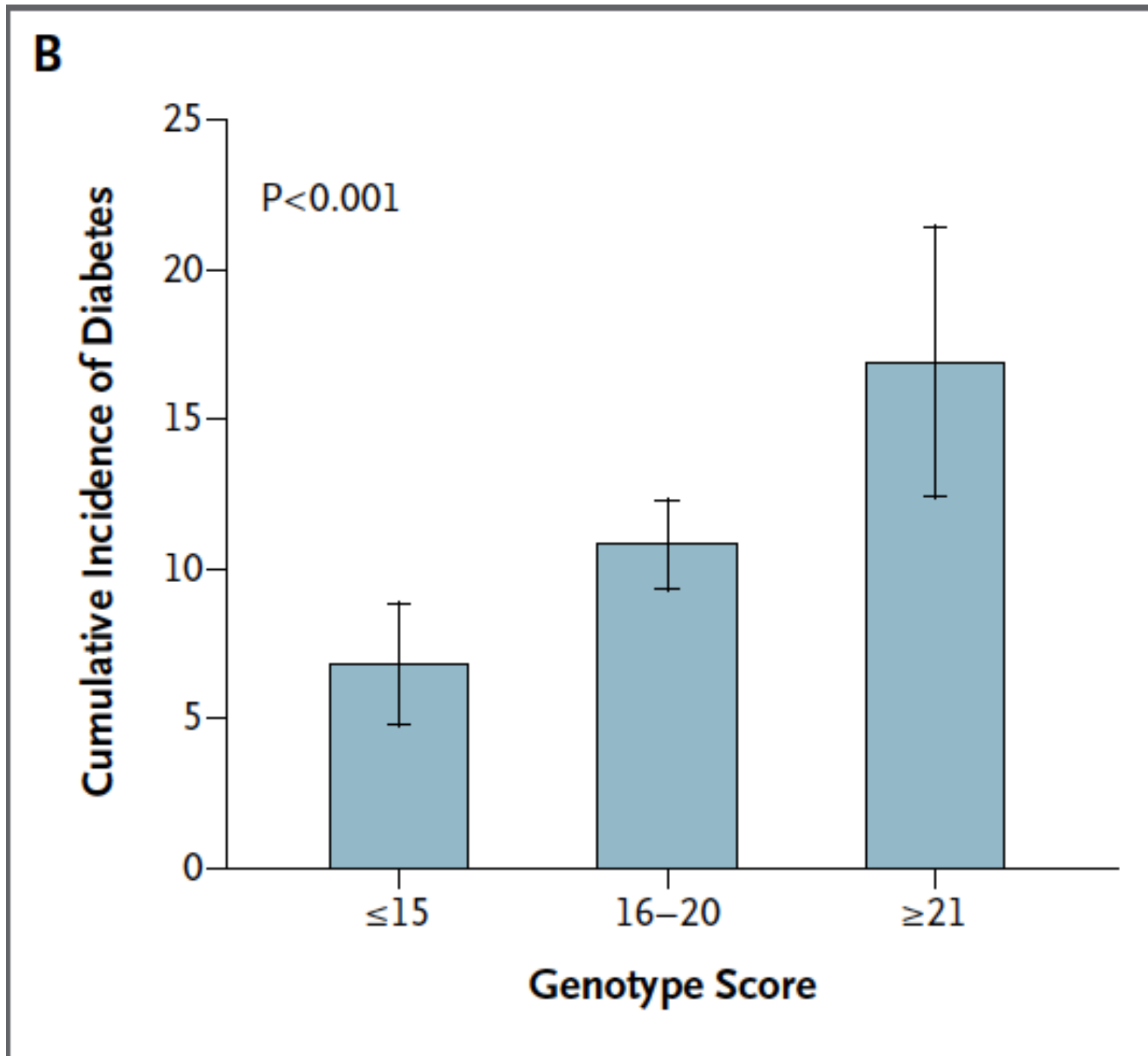
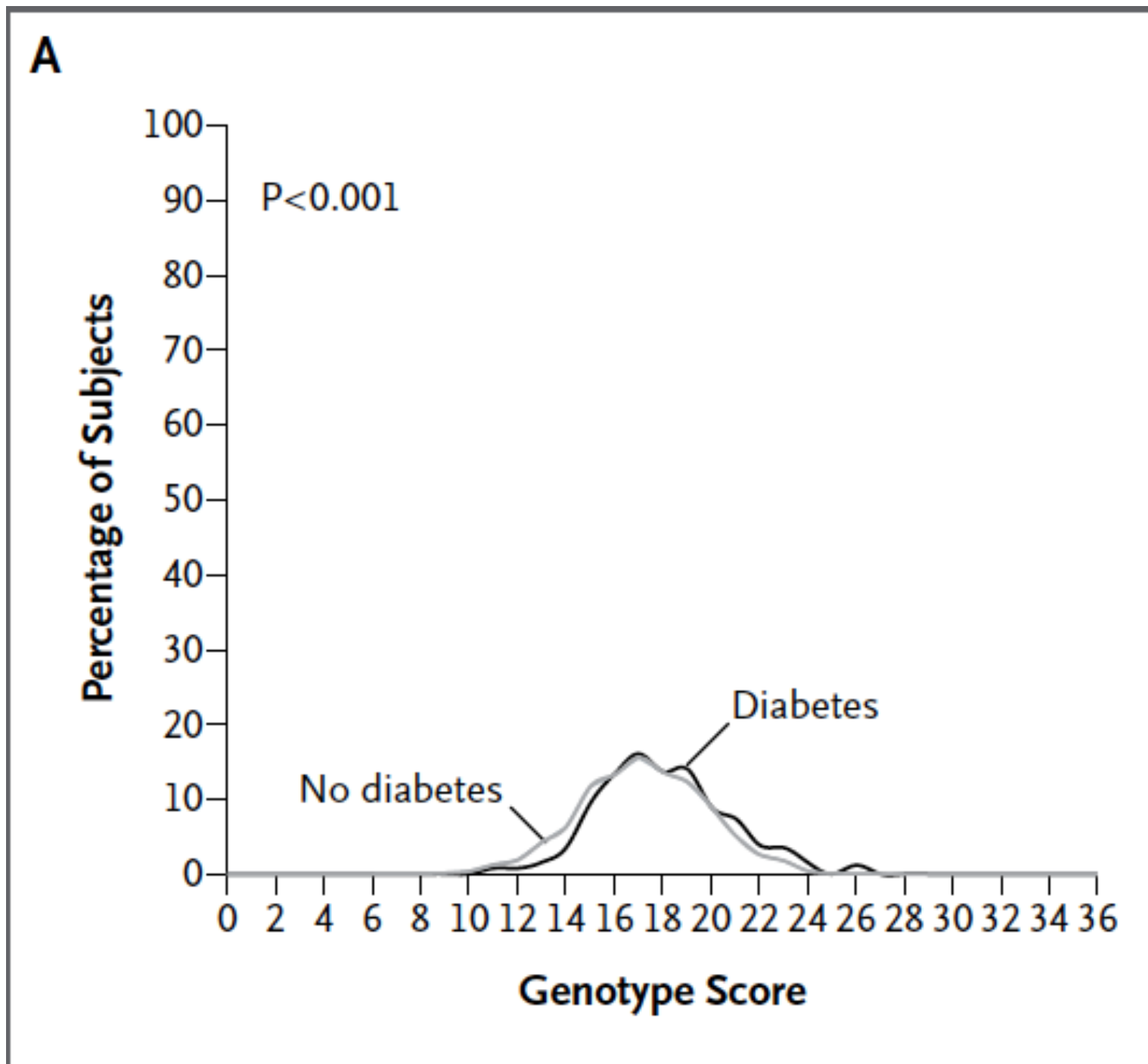


Figure 3. Predicted body mass index (BMI), calculated as weight in kilograms divided by height in meters squared, as a function of residualized age- and sex-specific ln-transformed physical activity accelerometer counts according to *FTO* rs1861868 genotypes. On the left side of the plot (low physical activity), BMI levels are strikingly dissimilar between rs1861868 genotypes. In contrast, on the right side of the plot, similar BMI levels can be seen across genotypes, particularly in subjects with very high levels of physical activity.



Meigs JB, Shrader P, Sullivan LM, McAteer JB, Fox CS, Dupuis J, Manning AK, Florez JC, Wilson PW, D'Agostino RB Sr, Cupples LA. Genotype score in addition to common risk factors for prediction of type 2 diabetes. N Engl J Med. 2008 Nov 20;359(21):2208-19



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Back to populations

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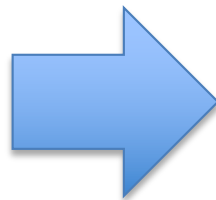
Systems and counterfactual thinking

Causes and counterfactuals

Observed



Counterfactual (parallel universe)

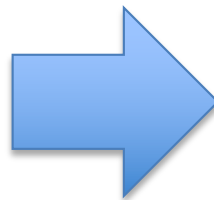


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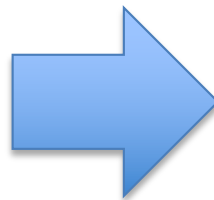


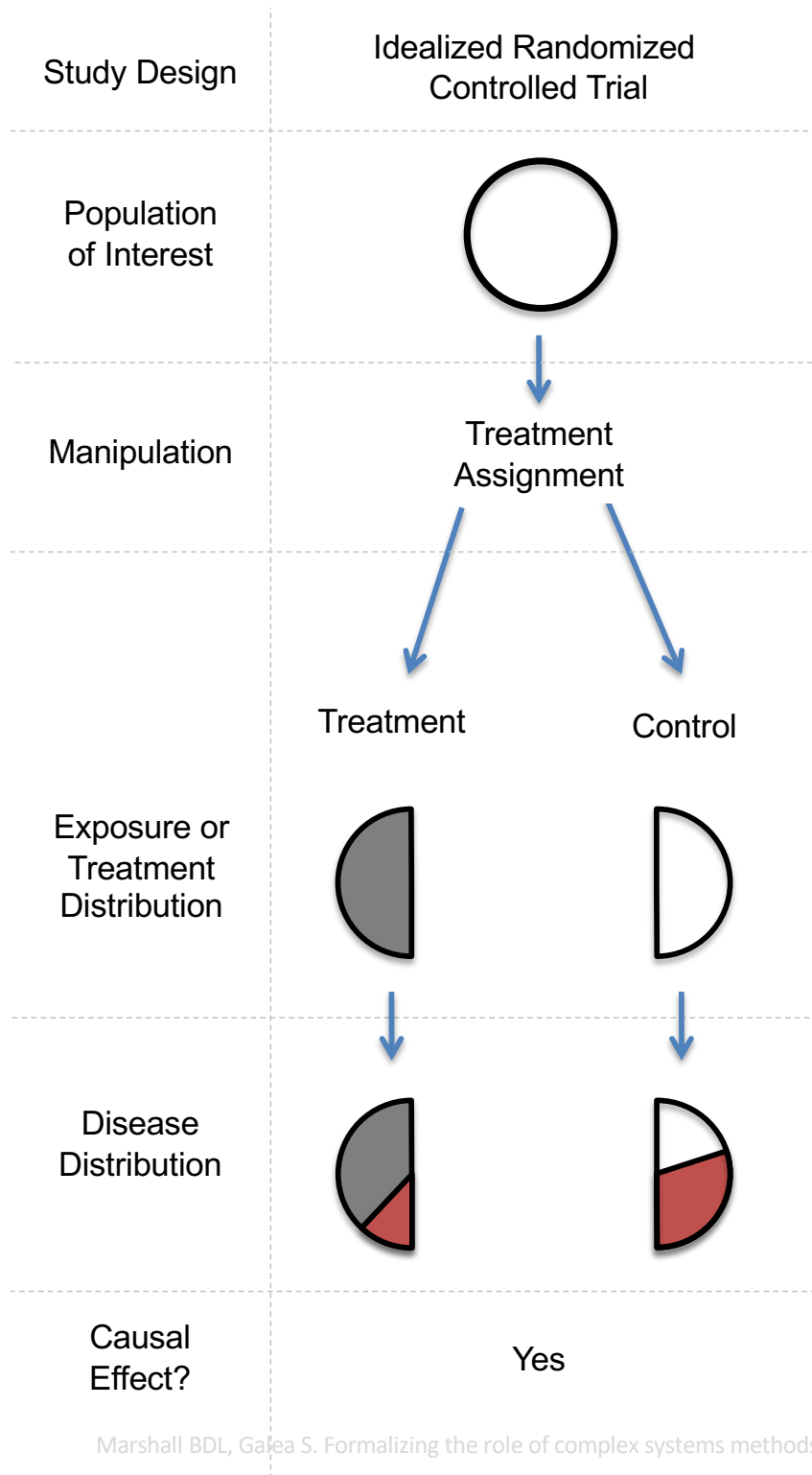
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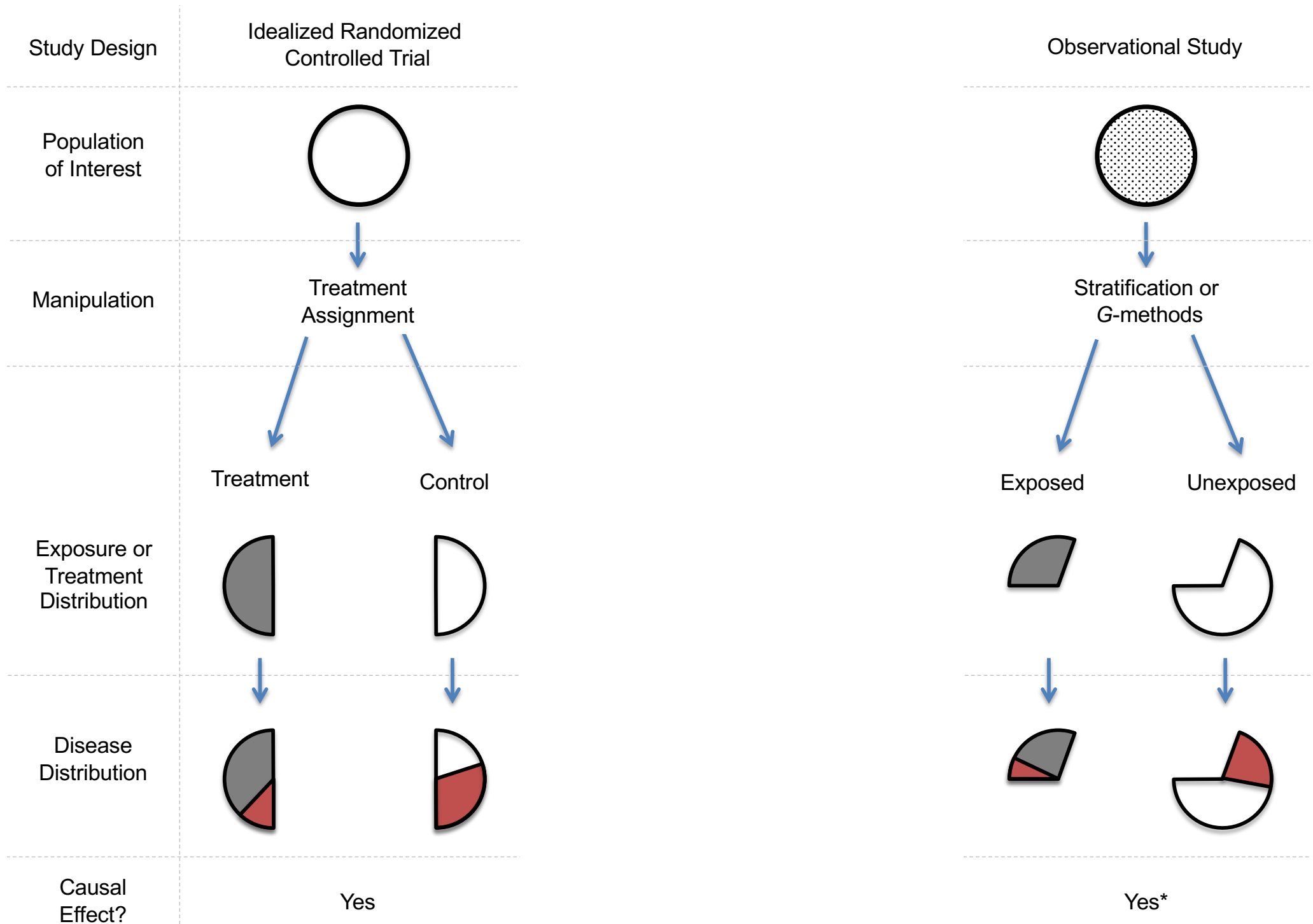
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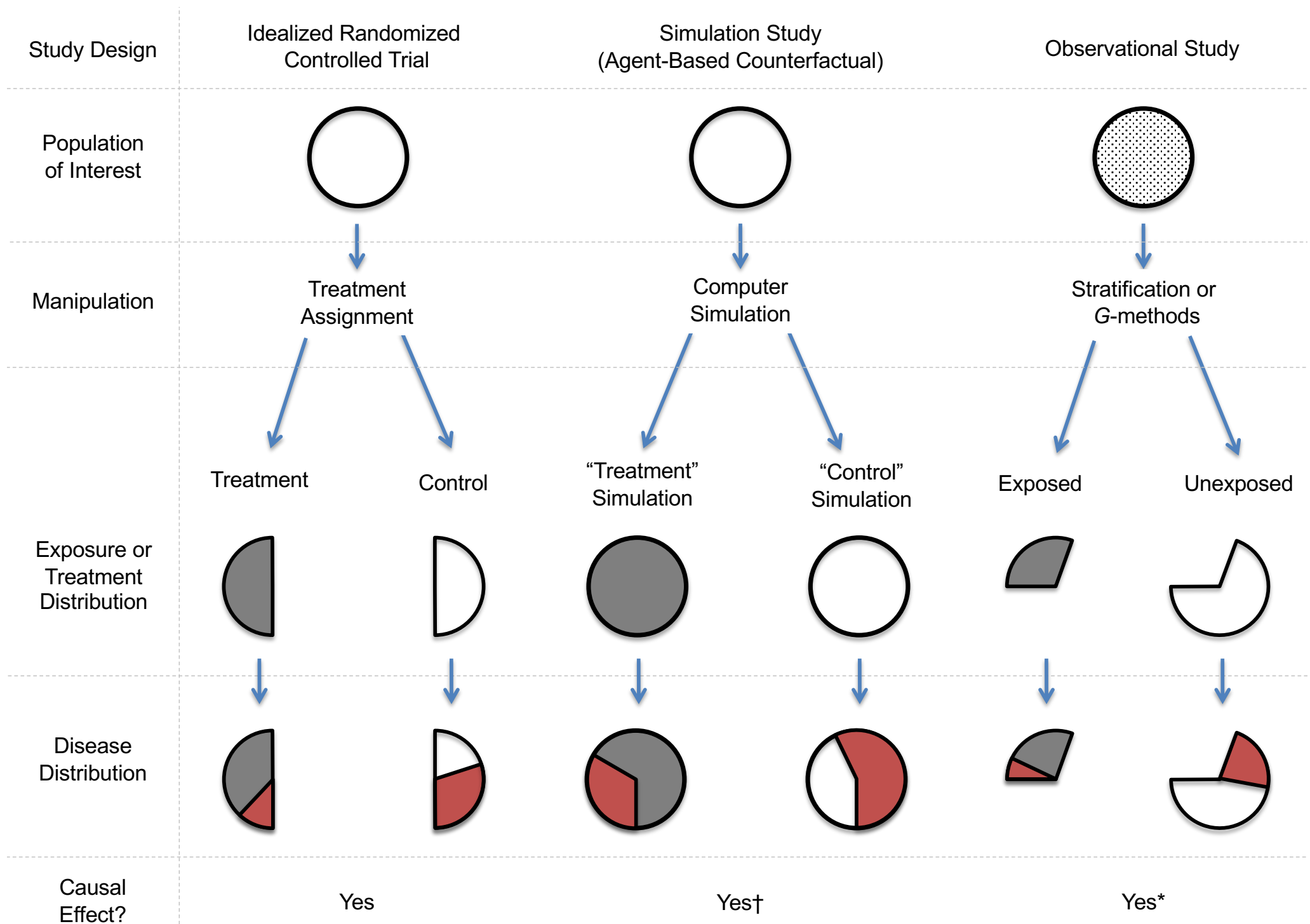


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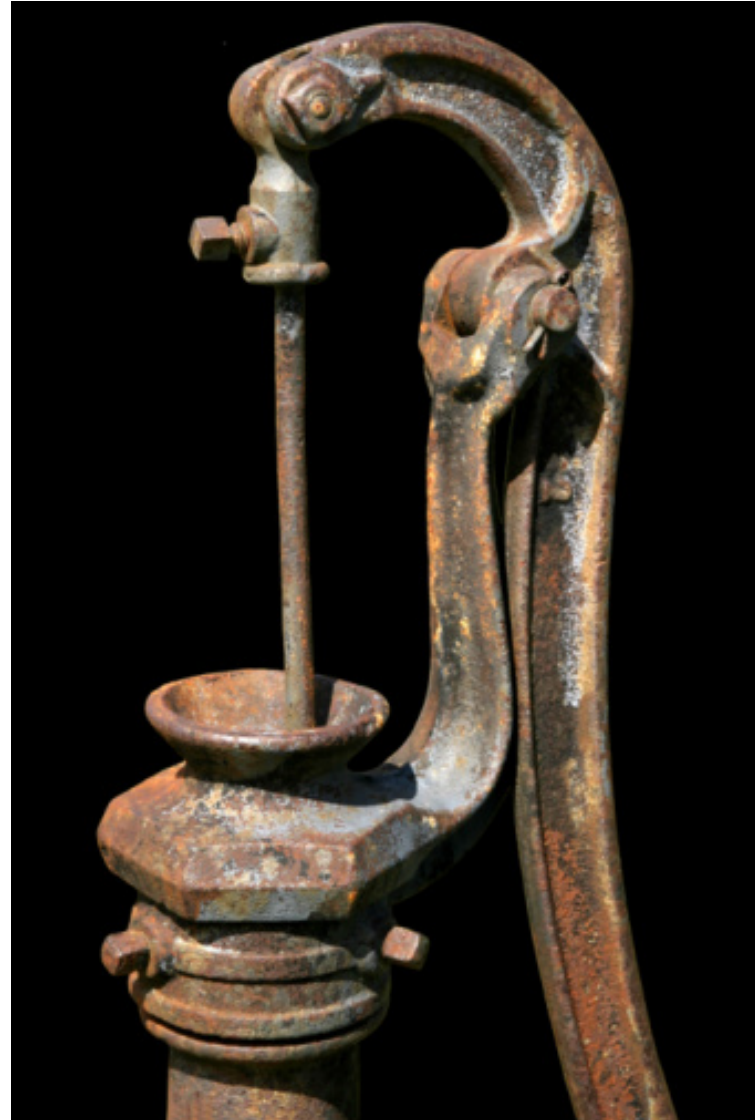




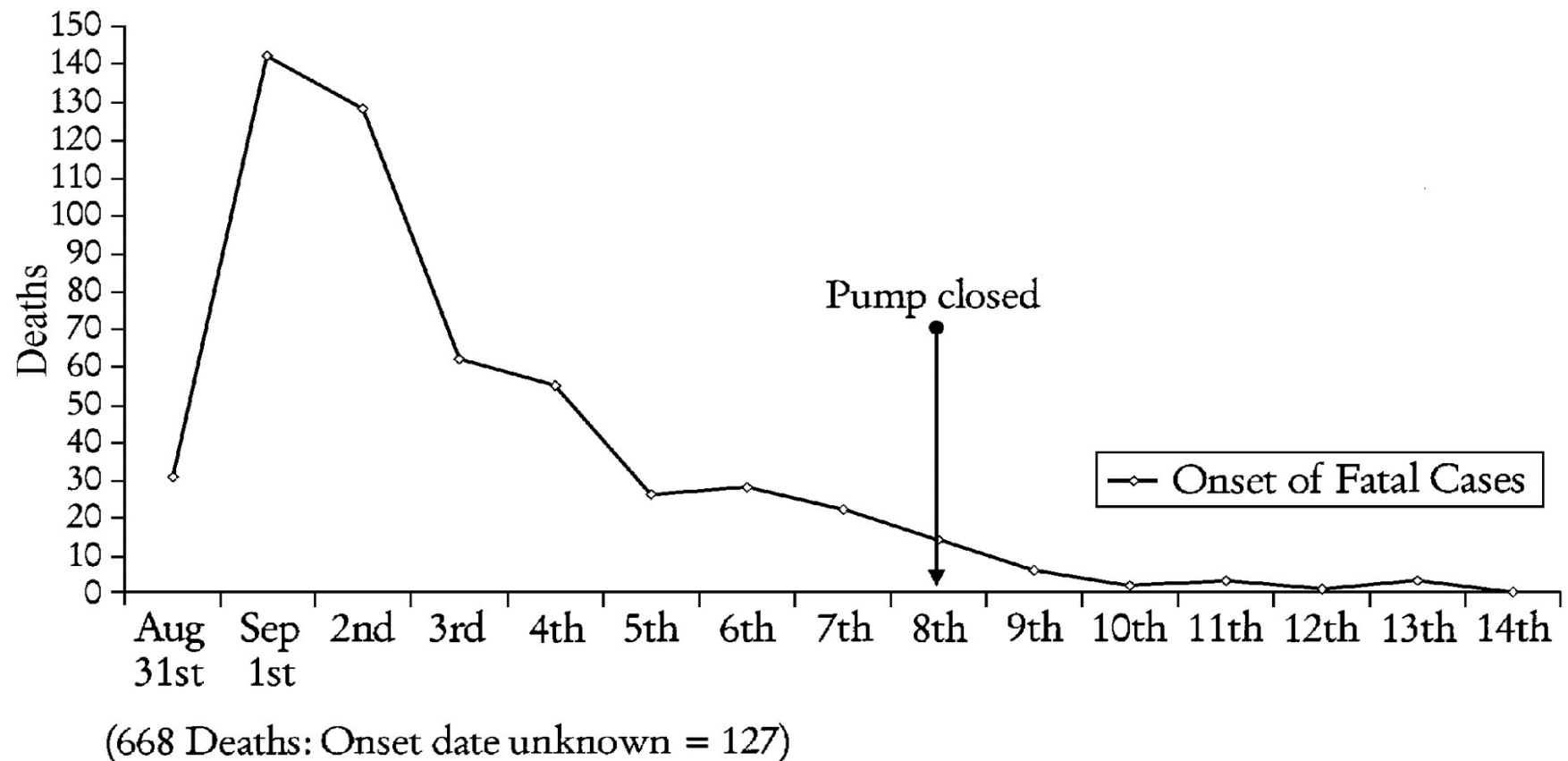


“ Everything should be made as simple as possible, but not simpler ”

Simple approaches, a foundational myth



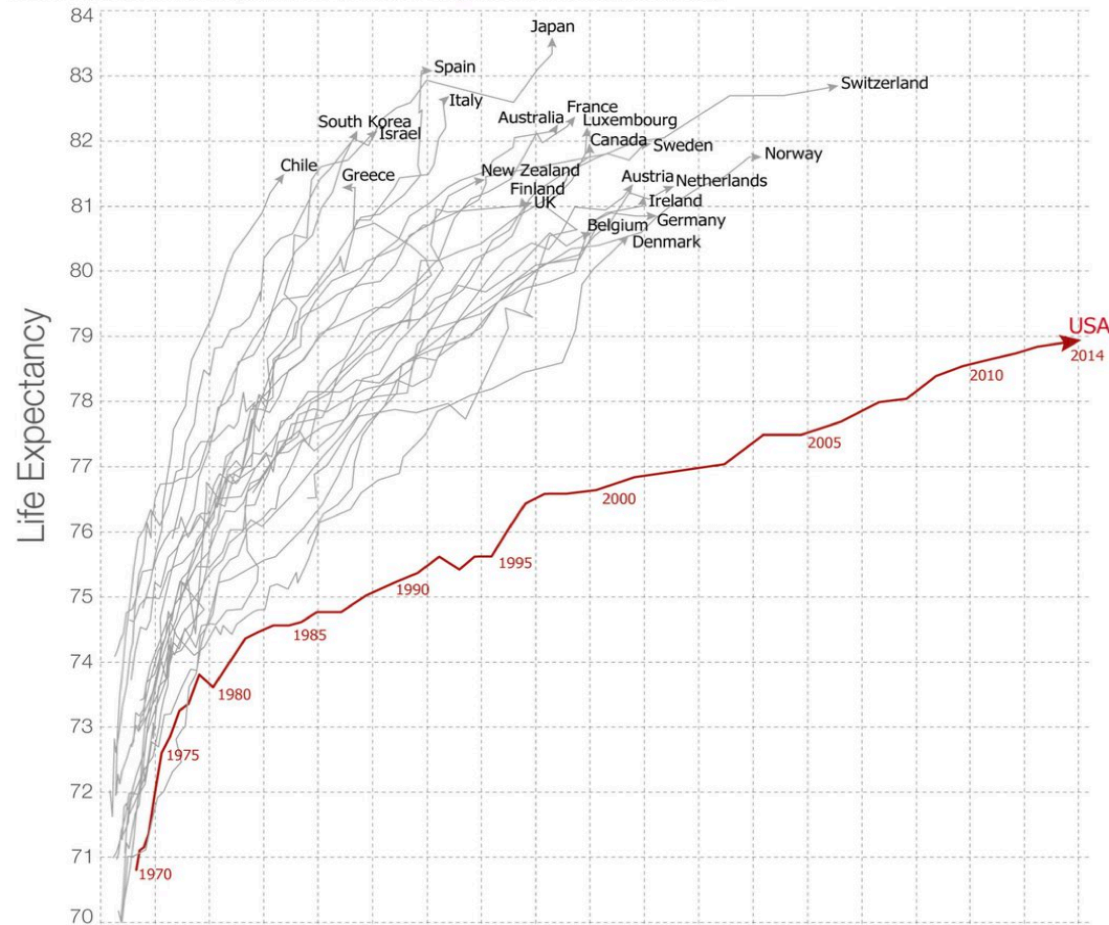
The effectiveness of simple approaches?



Life expectancy vs. health expenditure over time (1970-2014)

Our World
in Data

Health spending measures the consumption of health care goods and services, including personal health care (curative care, rehabilitative care, long-term care, ancillary services and medical goods) and collective services (prevention and public health services as well as health administration), but excluding spending on investments. Shown is total health expenditure (financed by public and private sources).



Our World in Data. "The link between health spending and life expectancy: The US is an outlier."

<<https://ourworldindata.org/the-link-between-life-expectancy-and-health-spending-us-focus>> Accessed September 7, 2016

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