Application of Mathematical Modeling to Herd Immunity

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Mathematical modeling is a powerful way to comprehend emerging properties/behaviors in social problems involving many parameters acting simultaneously and non-linearly. Current epidemiological models are often ‘compartmental’, forcing the mathematician to make strict assumptions. I attempted agent-based modeling to avoid assumptions that are unattainable for infectious diseases. Measles is the leading cause of vaccine-preventable deaths worldwide. My goal was to identify the “herd immunity” threshold, or the minimum number of people that need to be vaccinated to protect the population as a whole. Such threshold is important to prevent outbreaks and protect those who are immunocompromised and/or cannot receive vaccination. I contextualized my data through two outbreaks (2019-Brooklyn, NY; 2015-Anaheim, CA) . Using the NetLogo platform for coding, I created four ‘agents’: healthy but unvaccinated, vaccinated and/or immune, infected, and immunocompromised (cannot be vaccinated). After careful validation, my Measles model yielded two major results: (i) As a function of vaccination rates, I saw an exponential decrease in infections, demonstrating that every vaccination counts toward herd immunity. In fact, if the Brooklyn neighborhood (9% vaccinated) had increased vaccination to a third of the population, the number of infected could have been reduced by 80%. (ii) I found that 93% of the population must be vaccinated to achieve measles herd immunity. Thus, my modeling approach produced data comparable to the CDC, suggesting that this model can predict disease development without prior knowledge. This model can be adapted to novel diseases (such as COVID-19) to help predict disease development and the efficacy of hygiene measures, quarantine, and social-distancing.