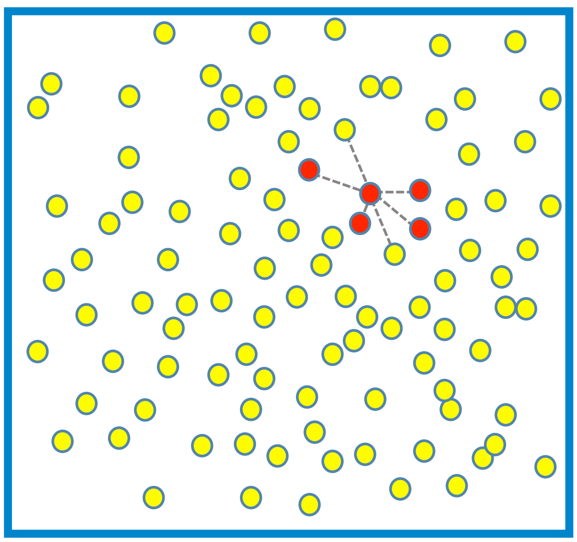
Lesson Three Student Team Challenges

Working with your team members, answer the following questions using what you have learned about the infection feedback loop, the SIR model and other aspects of infection spread. Be prepared to discuss your answers and your reasoning behind the answers with the whole class.

1) If you were a public health official who saw the diagram below on day 2 of a spreading infectious disease, what policies might you propose to decrease the infection?



Day 2: 100 people, 95 susceptible, 5 infected.

2) **Social distancing** is helpful. With social distancing people decrease the rate at which they see each other, and/or they see each other but maintain a 6-foot distance. How would you explain that in a Yellow-Red-Green diagram of disease spread? (Teachers: people will be far from each other, will have fewer contacts, and a smaller fraction of all contacts will result in new infection). How would you explain that in the equation for R_0? (Teachers: the parameters λ and p should each be reduced.) Do you think that social distancing can be viewed as a balancing feedback loop? Explain your reasoning. (Teachers: There is no right or wrong answer. But often in societies, when people start doing good things for themselves and others, other people observe and then follow, suggesting a loop that balances against the infection-causing reinforcing loop.)

3) **Vaccination** can also help. Vaccination decreases the population of susceptibles. How can you explain the beneficial effects of vaccination in the Yellow-Red-Green population diagrams of disease spread that we have been looking at? (Teachers: Vaccination is like taking a yellow dot, and turning it immediately to green [without a transition from red]. They will no longer be susceptible). Does the process of people lining up for vaccinations represent in some way a reinforcing feedback loop or a balancing feedback loop? Virtuous or vicious? Explain your reasoning.

4) **Vaccination and Herd Immunity.** Is there a relationship between vaccination and herd immunity? If so, what is it? To make your response specific, let us assume that only half of the population took a vaccination prior to flu season and that the vaccine is only 50% effective (i.e., that is, vaccination prevents flu in only 50% of vaccinated people). For a such a population suffering from a flu with $R_0 = 2.0$, what is the new value for Herd Immunity? Does that make sense to you? Explain.

5) **Super spreaders.** Suppose we have an infectious disease such as COVID-19 or flu and we have measured the value of the basic reproductive number, $R_0 = 2.0$.

   a. Before we go on, please write down in words precisely what you think this means: "$R_0 = 2.0$." Please do not look ahead.

   Now there is phenomenon known as Super Spreaders. A super spreader may infect 10, 20 or even 50 people. Suppose as an example, we find for the current disease we are looking at, there are 3 different types of super spreaders, Type 1 infecting 10, Type 2 infecting 20 and Type 3 infecting 50. There are an equal number of each type of super spreader. Of course, in addition to super spreaders, there are the more regular types of the population who are NOT super spreaders.

   b. An expert epidemiologist comes up to you and asserts that with this disease, even with its super spreaders, we still measure $R_0 = 2.0$. This appears to be impossible! Is it possible? Yes or No, explain by example calculations. (Teachers: $R_0 = 2.0$ means that the AVERAGE number of infections generated by an infected person is 2. It does not mean that each infected person infects precisely 2 others; many will infect zero others. The students who understand this must then offer a probability distribution for the "random variable" R_0 such that is contains equal numbers of Type 1, Type 2 and Type 3 super spreaders and still results in a mean number of infections per infected person of 2.0. A quick way to do this is have all other persons infect zero others; then, the effect of the super spreaders is to create the value $R_0 = 2.0$. Clearly the fraction of the population that is super spreaders is very small -- can the students offer a numerical example?)

c. A recent article in the *New York Times*, was entitled, "Just Stop the Super Spreading." https://www.nytimes.com/2020/06/02/opinion/coronavirus-superspreaders.html The authors claimed that recent research has shown that "20 percent of Covid-19 cases accounted for 80 percent of transmissions." Another finding: "Seventy percent of the people infected did not pass the virus on to anyone." Does this sound familiar? What we did in part (b) above was far from an academic exercise! Suppose using information from the *New York Times* article, we found a way to reduce the number of super spreaders by X percent, where X ranges from zero to 100%. As we vary X from 0 to 100, can you suggest how that will reduce R_0? (assuming that R_0 starts a 2.0, as we assumed in part b)?