ESRP 310 Fall 2007, 6th Lab, September 27, 2007
SLIC Room available 2 to 5 pm

Dr. Ford will arrive at 2:30 pm

Agenda: Simulating the Dynamics of an Epidemic

We will use the 6th lab to practice modeling the rapid growth in the number of people infected during an epidemic. Imagine a population of 1,000 people, two of which happen to be infected with influenza. The other 998 have never been exposed to influenza, so they are vulnerable to catching the disease. Suppose we are told that the influenza can spread rapidly with over 50% of the population infected within 15-20 days. By 40-50 days, all of the population will have been infected and recovered.

Begin by drawing the reference mode in the space below. Time will be in days, and nearly all of the population will be affected by the 50th day. Draw a time graph of the affected population over the 50-day time horizon.

Label your time graph according to the fundamental shapes mentioned in Chapter 1. Your reference mode should resemble one of the following: exponential growth, exponential decay, S shaped growth, overshoot or oscillations.

A model of the spread of the influenza might include the stocks and flows shown in Fig. 1. You may have seen a version of this model in one of you text books. It sometimes goes by the name S I R, where the letters stand for the three stocks of people: susceptible, infected and recovered. We will assume that the average infected person recovers in around ten days. Fig. 1 shows that the recoveries flow depends on the number of infected people and the days to recover. Since we strive for simple algebra, the equation for recoveries is

Infected Population/days to recover

This equation yields a curious value at the start of the simulation: 2 people/10 days = 0.2 people/day

Don't worry about the fractional value. The model is providing a continuous approximation to the recovery process. We now have everything represented except the infections per day.

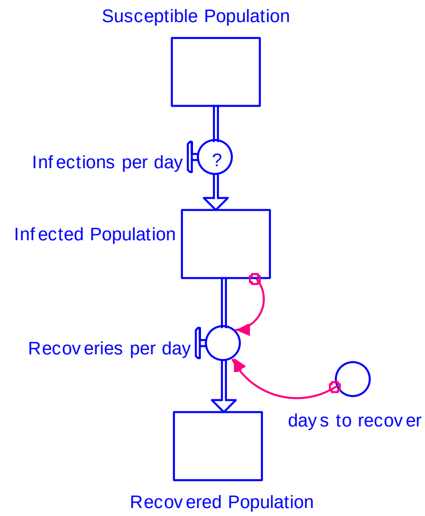

Figure 1. Getting started on an epidemic model.

Explaining infections is the key to understanding the spread of an epidemic. Let's assume that each infected person has 10 contacts with other people each day. With 2 infected people at the start, the daily contacts would be 20 per day. Next, assume that 5% of these contacts lead to infections. This means that 5% of the 20 contacts per day will lead to new infections. The initial value of this flow is 1 per day. This will cause the number of infected persons to grow rapidly at the start of the simulation.

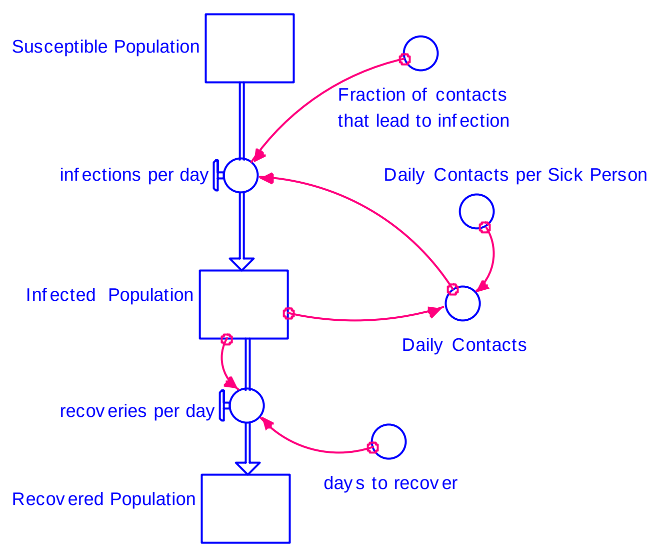

Figure 2. First model of the Epidemic

Build and Simulate the First Model

Build the model in Fig. 2 and simulate it for 20 days with DT = 0.25 days. Before hitting the Run button, be sure that the "non-negative" option on each stock is NOT checked. Turn in a time graph of the three populations. (Scale all three populations on a scale from 0 to 1,000). Explain whether the results are plausible. If they are not plausible, explain what is missing from the model. (Give your best explanation before looking ahead in the exercise.)

Next Exercise: Build the model in Figure 3 and Simulate

The next model assumes that the number of daily contacts for a sick person will depend on the fraction of the population that is susceptible. At the beginning of the simulation, the fraction is 1, and the number of contacts will be 10 (the same as the previous model). However, as the fraction declines over time, the number of daily contacts will decline as well. If none of the population is susceptible, there will be zero contact for each sick person per day. We will use a nonlinear graph (~) to represent the relationship shown in Table 1.

Fraction of population that is susceptible	Number of Daily Contacts for each Sick Person
0.0	0
0.2	3
0.4	6
0.6	8
0.8	9
1.0	10

Table 1. Assumption for number of daily contacts by each sick person.

The total population may be set to 1,000, or it may be defined with the "summer" feature (+). Fig. 3 shows the summer symbol, so you know that the total population is the sum of the three stocks. Set the fraction of contacts that lead to infections at 0.05, the same value used previously. Then simulate the model for 50 days with DT = 0.25 days. **Document your results with a time graph of the three populations, all displayed on the same scale [0,1000].**

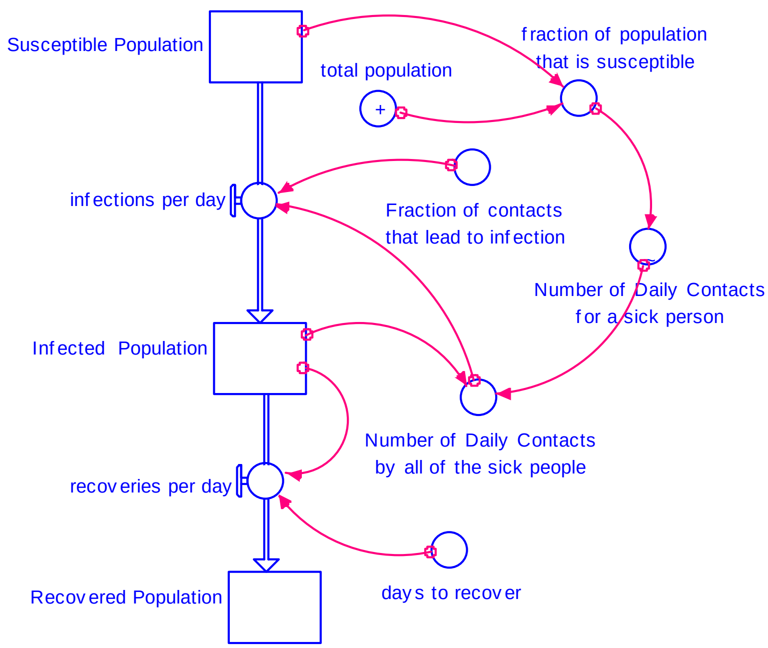

Figure 3. Second model of the Epidemic

With 50 days, it will be convenient to ask for a time graph with five grid segments. Your graph should show the infected population peaking at 583 persons in the 18th day. This is a very rapid epidemic. By the 18th day, over 58% of the population would be infected! The epidemic will have largely run its course by the 50th day. The number of affected people is the sum of the infected and recovered population. This number will be nearly 1,000 by the 50th day. **Does this simulation result match your reference mode drawn on the first page?**

Next Exercise: Complete the Causal Loop Diagram

Figure 4 shows a word and arrow diagram of the epidemic model in Figure 3. But the diagram is not complete. Your job is to complete the diagram by labeling each arrow with a + or a – at the tip of the arrowhead. If you see a feedback loop, label it as a positive feedback loop (+) or as a negative feedback loop (-).

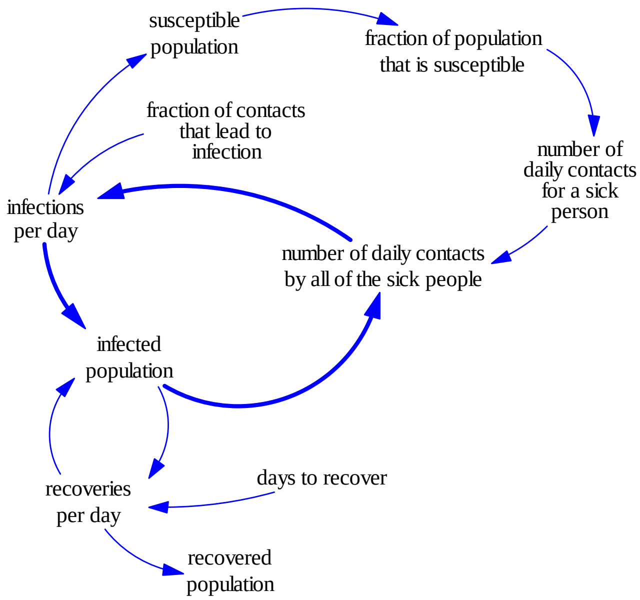

Figure 4. Causal loop diagram with labels missing.

Final Exercise

Figure 5 shows the loops in the flowers model from page 80 of the book. There are three loops in this model. Match up each of these three loops with the loop in Figure 4 that serves a similar function in the epidemic model.

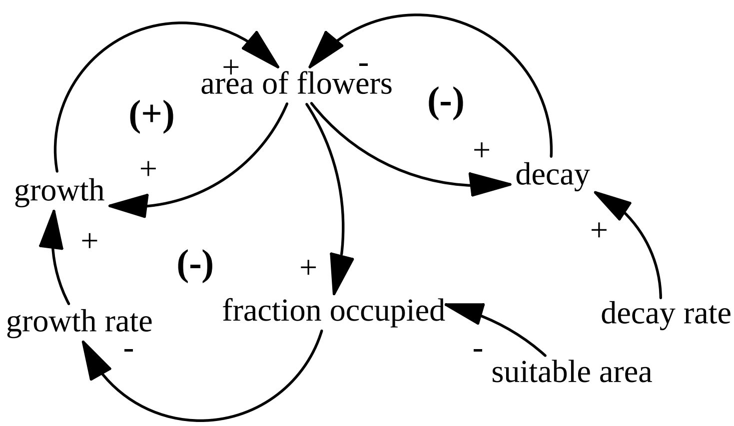

Figure 5. Three feedback loops in the flowers model.