

Herd immunity in a network

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Herd immunity

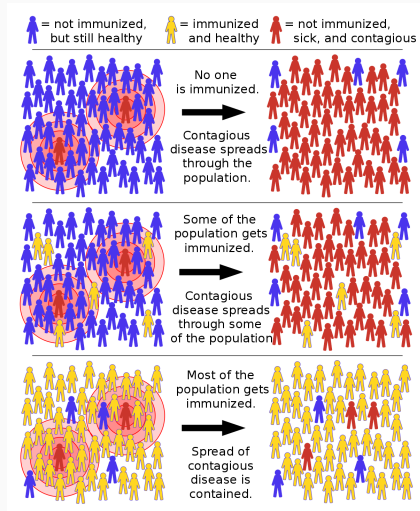


Figure 1: By Tkarcher - Own work, CC BY-SA 4.0,
<https://commons.wikimedia.org/w/index.php?curid=56760604>

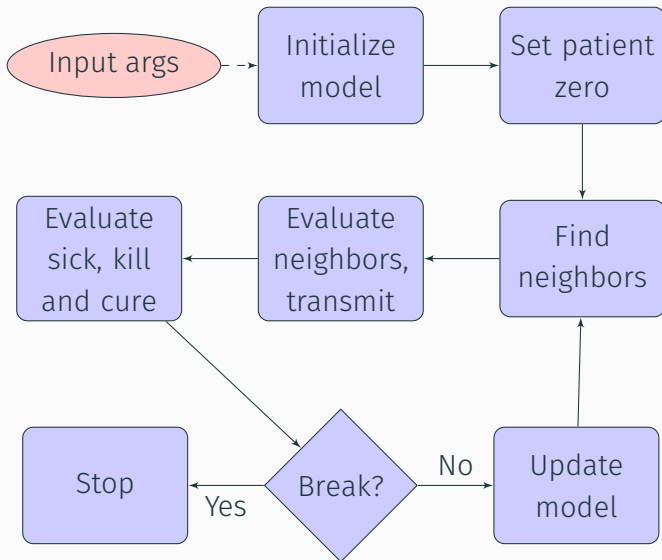
Let's frontload some variables!

- R_0 : 'basic reproduction number'
 - Avg. no. of people infected pr. person
- $HIT = 1 - 1/R_0$
- N : no. of people initially
- n_{sick} : no. of sick people
- n_{immune} : no. of immune people
- n_{dead} : no. of dead people
- n_{healthy} : no. of healthy people (not immune)
- $R_e = R_0 \cdot n_{\text{healthy}} / (N - n_{\text{dead}})$

	R_0	Mortality rate	HIT
Ebola	1.5-2.5	0.25-0.90	0.33-0.60
Measles	12-18	0.15	0.92-0.94
Polio	5-7	0.15-0.30	0.80-0.86

Table 1: Data from https://en.wikipedia.org/wiki/Herd_immunity

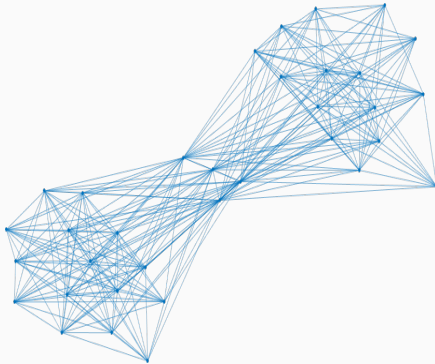
Code



- Small world
- Scale free
- Random
- Custom network (two cities with commuters. Random networks for each city)

Custom network

Custom network, simulating two cities with commuters



Movie time: two cities, death

Movie time: two cities, immunity

Movie time: two cities, immunity

Success criteria

- Real world
 - Disease no longer endemic
- Our model
 - Discussion of alternate criteria
 - Percolation
 - Effective reproductive number
 - $R_e = \text{fraction of susceptible individuals} \cdot R_0 \leq 1$
 - $n_{\text{sick}} = 0$ and $n_{\text{healthy}} \neq 0$
 - $n_{\text{healthy}} = 0$
 - **Total sick < arbitrary threshold**

The simulations

- Test 20 values of p_I (0 to 0.95, in steps of 0.05)

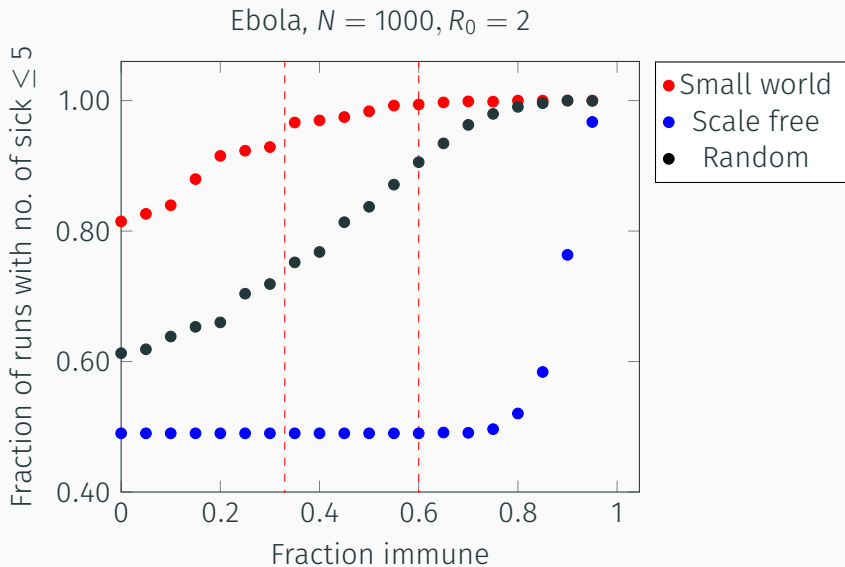
The simulations

- Test 20 values of p_I (0 to 0.95, in steps of 0.05)
- For each p_I test 50 different networks, and test each network 50 times (random distribution of patient zero and immune nodes)

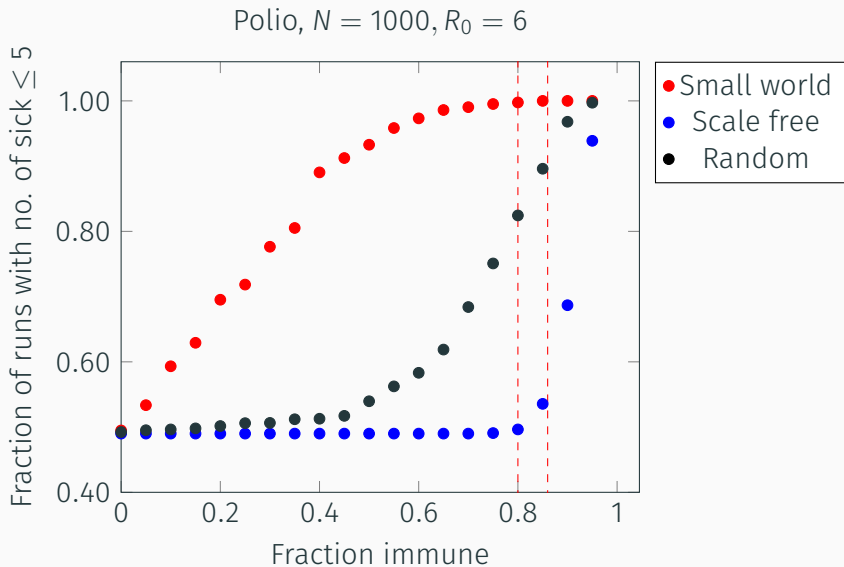
The simulations

- Test 20 values of p_I (0 to 0.95, in steps of 0.05)
- For each p_I test 50 different networks, and test each network 50 times (random distribution of patient zero and immune nodes)
- Save relevant output

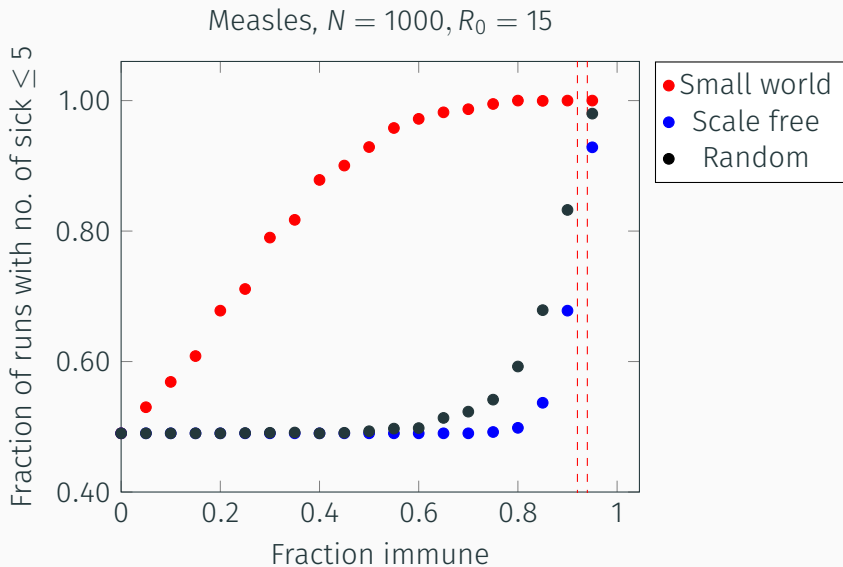
Results



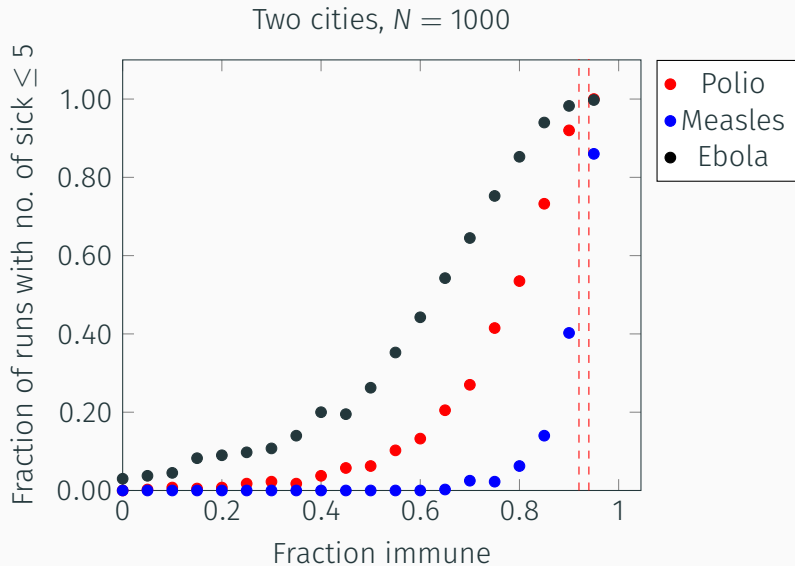
Results



Results



Results



Conclusion

Simulating the spread of disease is easy. Defining herd immunity is hard.