Herd immunity in a network

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Introduction

Herd immunity

Disease types

Networks

Herd immunity

Protect the flock by immunizing

Disease types

Networks

Herd immunity

- R_0: 'basic reproduction number'

  Avg. no. of people infected pr. person

- p_c: herd immunity threshold

  $p_c = 1 - 1/R_0$

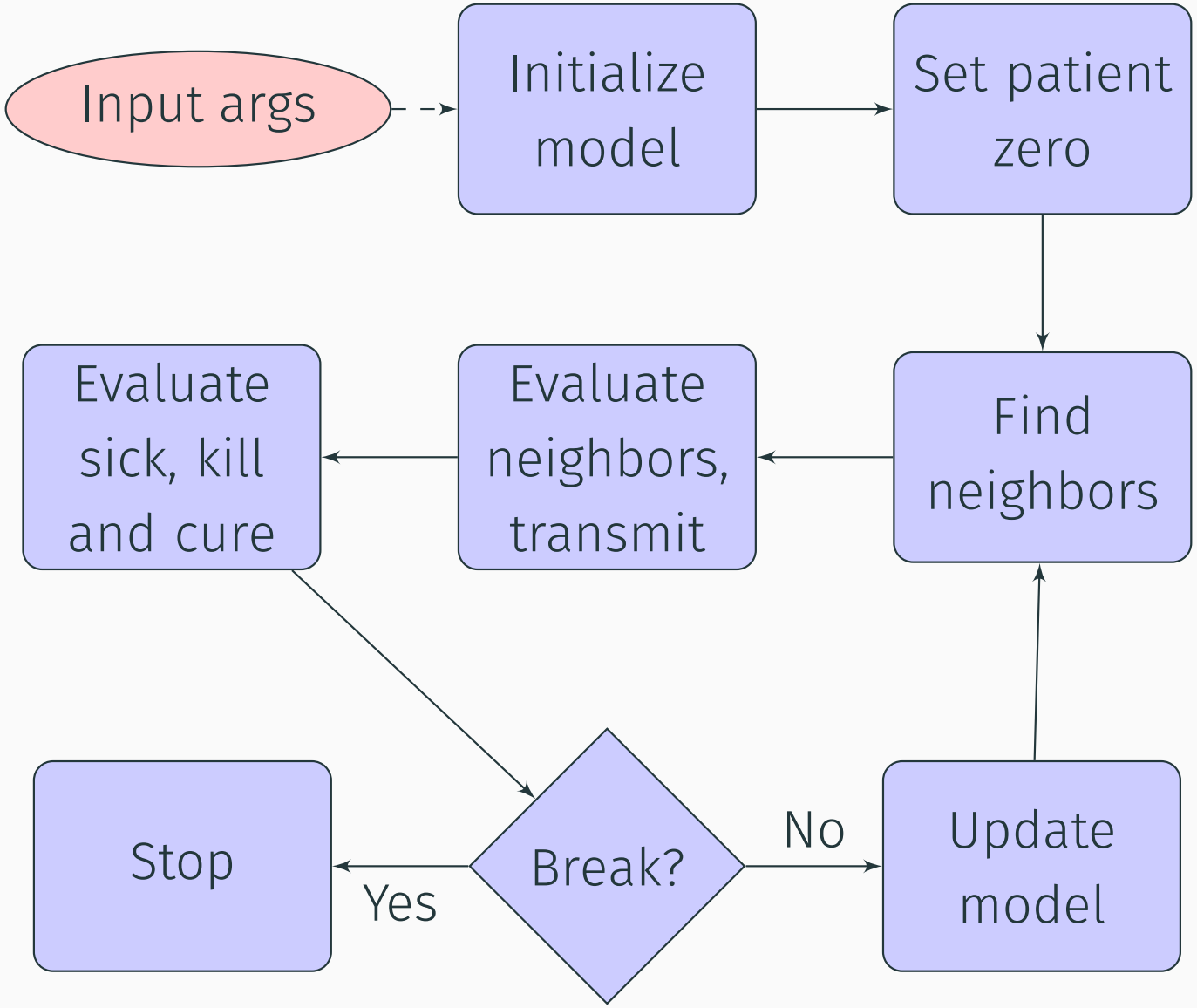
- Herd immunity passively protects whole population

Diseases

	R_0	Mortality rate	HIT
Ebola	1.5-2.5	0.25-0.90	0.33-0.60
Bubonic plague	3	0.6	0.67
Pneumonic plague	2	0.90-0.95	0.50
Measles	12-18	0.15	0.92-0.94
Flu	1.5-1.8	0.001	0.33-0.44
SARS	2-5	0.096	0.50-0.80
Polio	5-7	0.15-0.30	0.80-0.86

Table 1: Data from `https://en.wikipedia.org/wiki/Herd_immunity` & `https://www.duo.uio.no/bitstream/handle/10852/45490/KDPlagueThesis.pdf?sequence=9`

Code

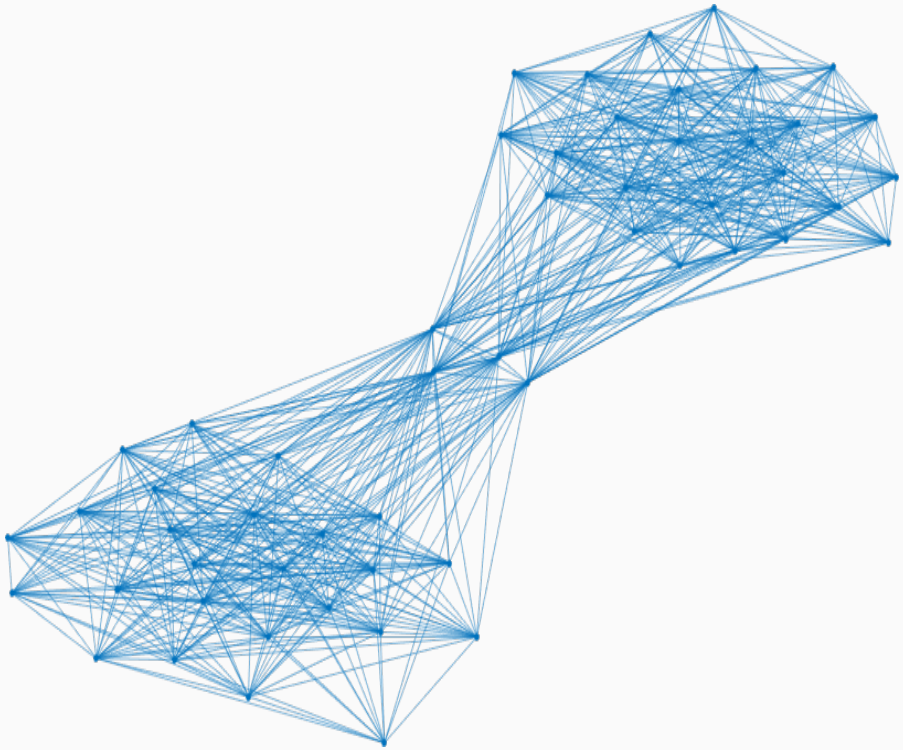

Input args
Initialize model
Set patient zero
Find neighbors
Evaluate neighbors, transmit
Evaluate sick, kill and cure
Break?
No
Yes
Update model
Stop

Networks

- Small world
- Scale free
- Random
- Custom network (two cities with commuters)

Custom network

Custom network, simulating two cities with commuters



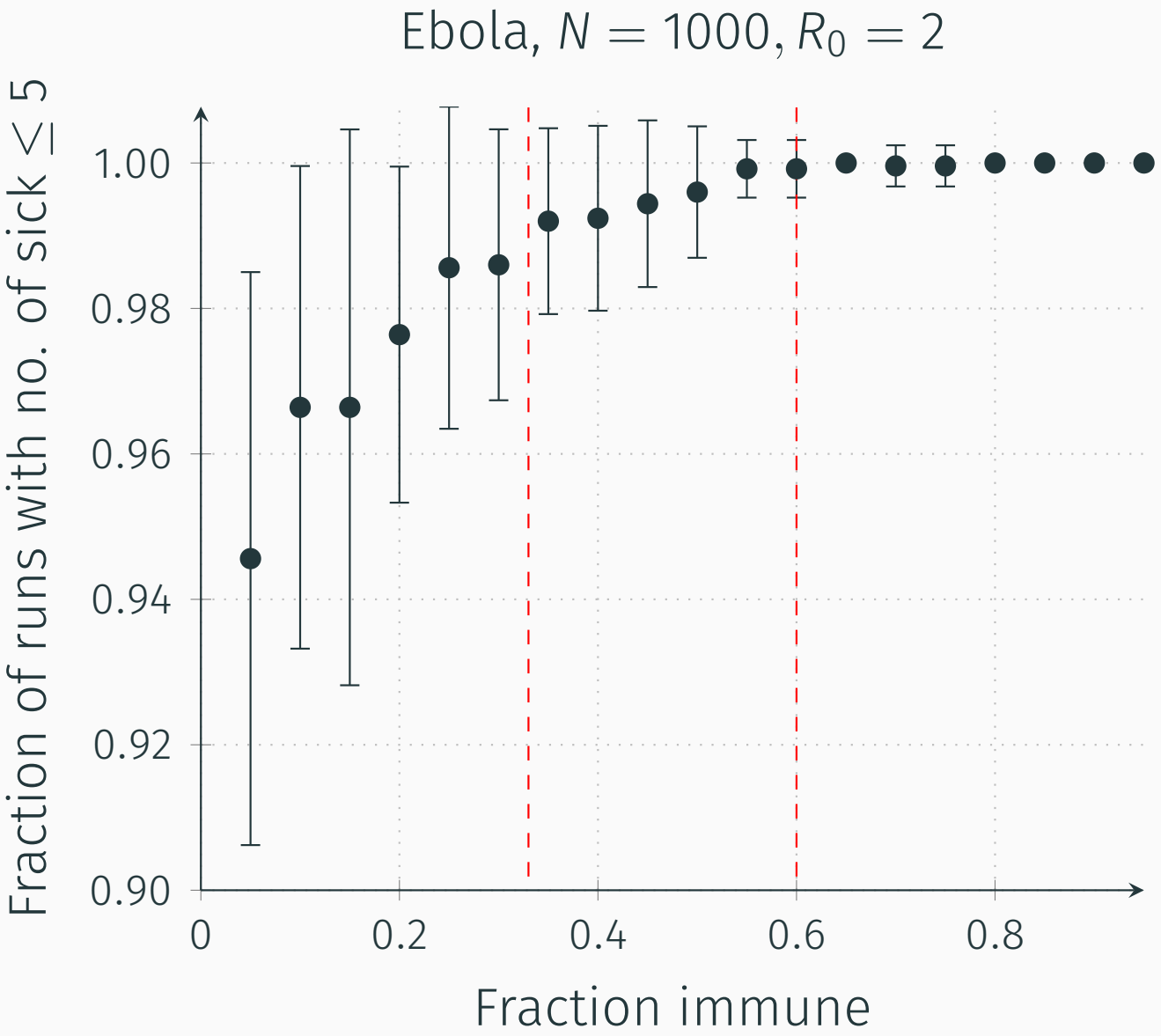
Success criteria

- Real world
  - No percolation
  - Disease no longer endemic
- Our model
  - Unable to define percolation
  - Discussion of alternate criteria
    - **Total sick $<$ arbitrary threshold**
    - Effective reproductive number ≤ 1
    - $n_{\text{sick}} = 0$ and $n_{\text{healthy}} \neq 0$
    - $n_{\text{healthy}} = 0$

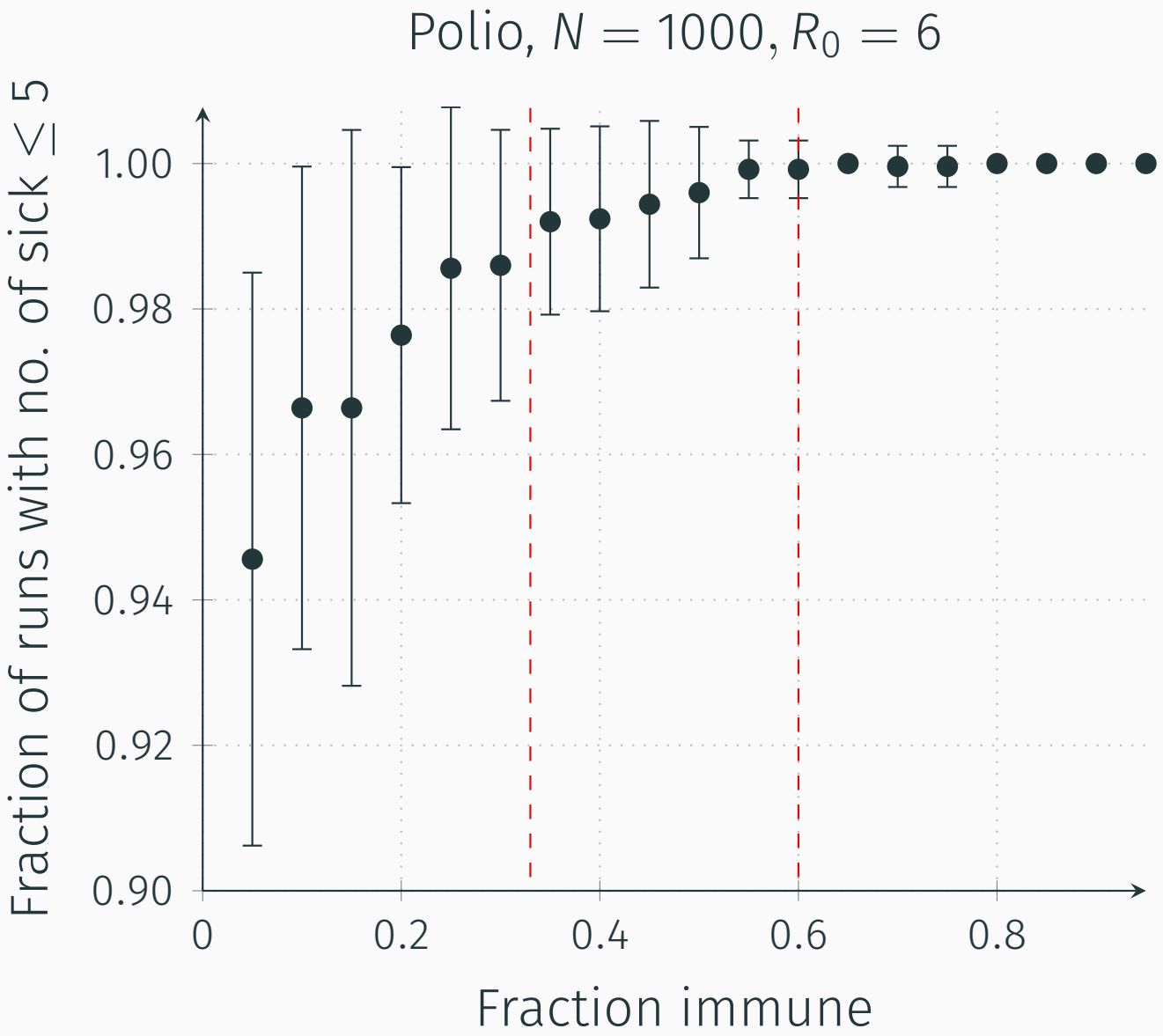
The simulations

- Run each disease 50 times on each network
- With 20 p_I values
- Save relevant output

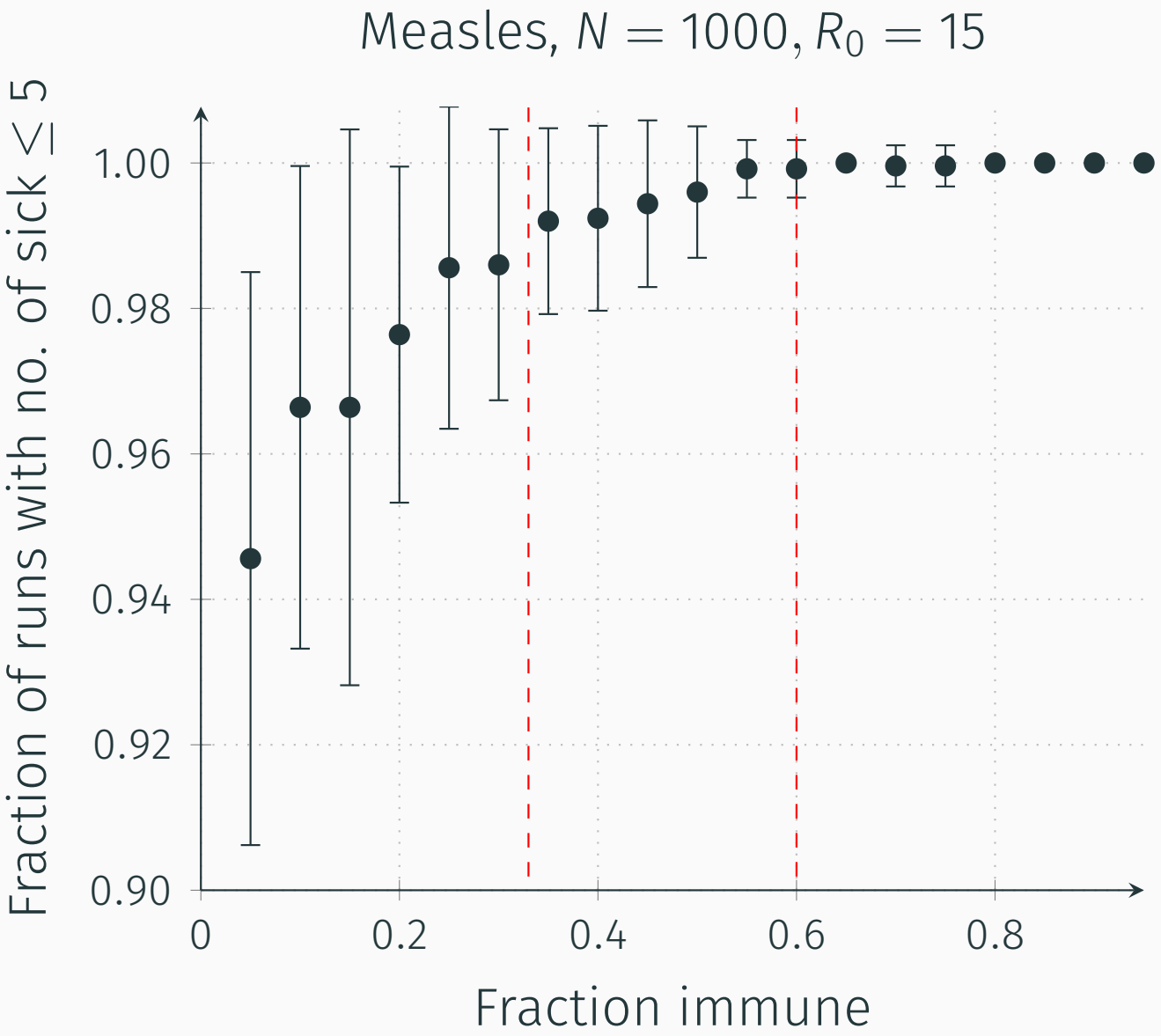
Results


Ebola, $N = 1000, R_0 = 2$
Fraction of runs with no. of sick ≤ 5
1.00
0.98
0.96
0.94
0.92
0.90
0
0.2
0.4
0.6
0.8
Fraction immune

Results


Polio, $N = 1000, R_0 = 6$
Fraction of runs with no. of sick ≤ 5
1.00
0.98
0.96
0.94
0.92
0.90
0
0.2
0.4
0.6
0.8
Fraction immune

Results


Measles, $N = 1000, R_0 = 15$
Fraction of runs with no. of sick ≤ 5
1.00
0.98
0.96
0.94
0.92
0.90
0
0.2
0.4
0.6
0.8
Fraction immune

Results

Video Galore