

Modeling the SARS Outbreak in Toronto, Canada

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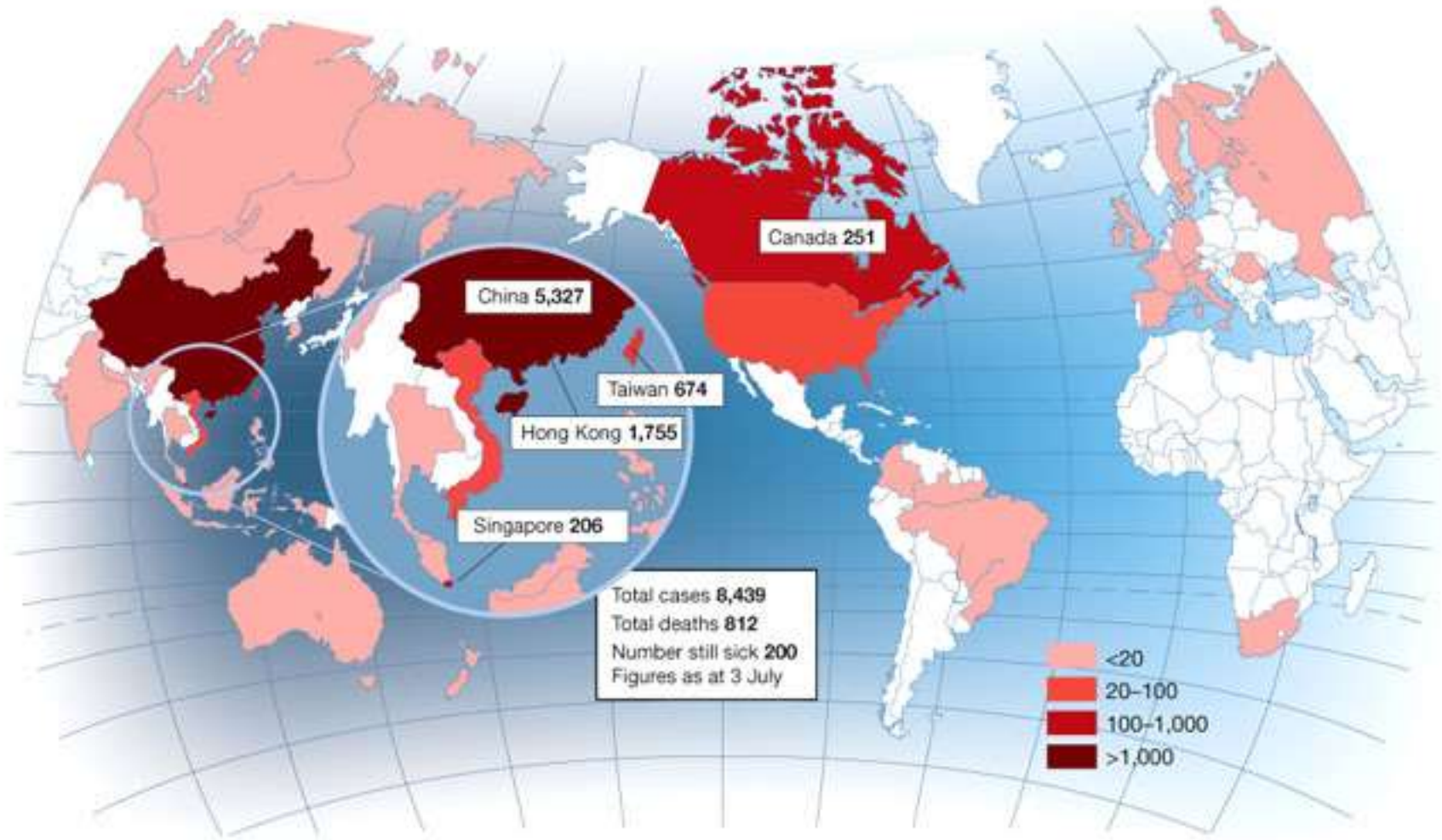
SARS Background

- Classified as a coronavirus, the same class as the common cold
- Highly infectious



- First case reported November 2002 in China
- First case in Toronto reported February 2003
- No reported cases since May 2004

SARS Worldwide



Pattern of an Epidemic [Map]. Retrieved: June 13, 2012, from:
<http://www.nature.com/nature/focus/sars/images/outbreak.jpg>

Spread of SARS

- Travels in water droplets spread by coughing/sneezing
- Droplets can be infectious for up to 6 hours
- Household disinfectants like bleach are effective at killing the virus



- Often gloves and masks are not enough to prevent infection, any close contact can put you at risk

Symptoms & Biology

SARS OUTBREAK

Sars virus: Tell-tale signs...

SIGNS AND SYMPTOMS

Incubation period:
two to 10 days.

First main symptoms

- High fever of more than 38 deg C
- Muscle aches

Other symptoms

- Dry cough
- Headache
- Muscular stiffness
- Loss of appetite
- Malaise (extreme tiredness)
- Confusion
- Rash
- Diarrhoea

SCIENTISTS and doctors around the world have made breakthroughs over the last two months in the war against severe acute respiratory syndrome.

Much more is known about the dreaded virus since *The New Paper's* first infographics ran on Mar 27.

Here are the latest findings:

THE VIRUS

- Can be excreted in large amounts by infected people in their stool and urine. This raises the distinct possibility that less than vigorous hygiene - particularly a lack of hand-washing - can lead to its spread on surfaces in the home and elsewhere.
- Can survive for at least 24 hours on a plastic surface at room temperature.
- Can live for up to four days in human waste.
- Viable indefinitely at 0 degrees.
- Is killed by disinfectants such as bleach, ethanol, phenol, formaldehyde and paraformaldehyde.

STILL UNKNOWN

- The amount of virus needed to infect a person.
- Whether a discharged Sars patient is still capable of excreting the virus and for how long.

DO'S AND DON'TS

- Wash your hands often, especially after touching surfaces.
- Avoid touching your face in general.
- The body is not sterile and the virus can enter the respiratory system through the nose, mouth and eyes.
- Do not spit in public places. If you must, do it in the toilet where it can be flushed down the toilet or tank.
- If you have a fever of 38 deg C, see a doctor straight away.
- Always see the same doctor, do not doctor hop.
- And wear a mask on the way to see the doctor.
- Always cough and sneeze into a tissue or handkerchief.
- Take your temperature at least twice a day.
- Adults have a fever when their temperature is 37.7 deg C and above (ear temperature), 37.3 deg C and above (mouth) and 37.2 deg C and above (armpit).
- Children have a fever when their temperature is 37.9 deg C and above (ear), 37.6 deg C and above (mouth) and 37.3 deg C and above (armpit).
- Do not self-medicate if you are going to visit a doctor, because it may interfere with his diagnosis and treatment of your illness.

Late stage symptoms

- Shortness of breath or breathing difficulties;
- Changes in chest X-rays indicative of pneumonia.

Final stage

- Pneumonia (inflammation of the lungs) triggers off lung failure. The lung is no longer able to exchange the air breathed in into oxygen for the blood.
- The patient dies.

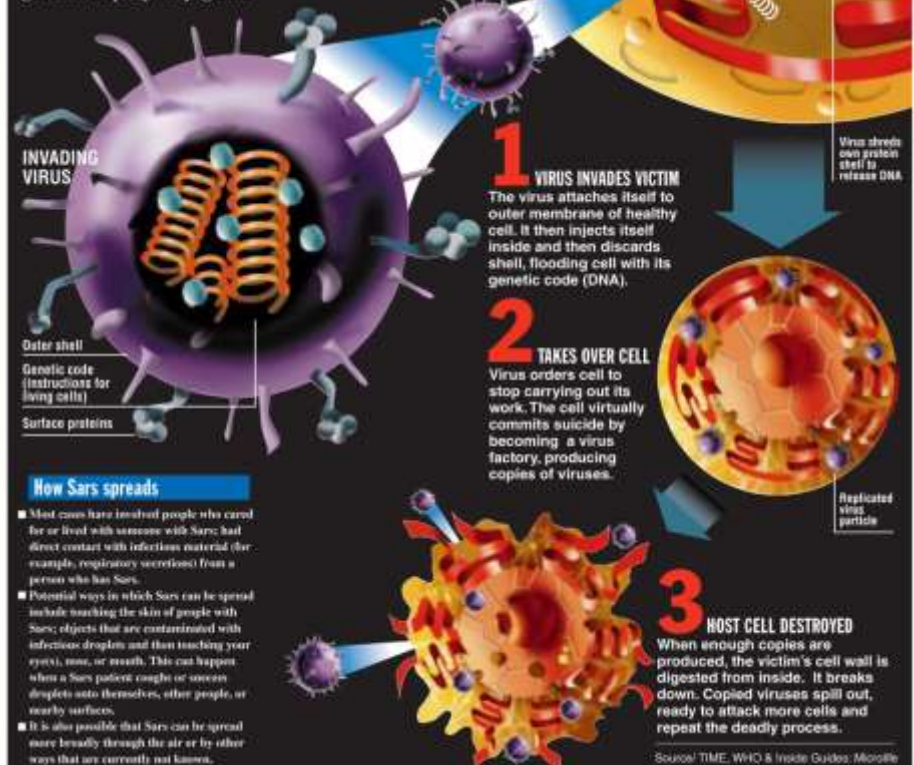
Words: NG WAI CHINE

Graphics: CEL GULAPA

SARS OUTBREAK

...and what it does to your body

Infographics journalist CEL GULAPA gives a step-by-step guide



Sars Virus: Tell-Tale signs and what it does to your body. Retrieved: June 12, 2012, from: <http://tnpgallery.wordpress.com/infographics/>

Source: TIME, WHO & Inside Guides, Microfile

Treatment

- Resistant to traditional antibiotics and antiviral treatments
- Currently only symptoms can be treated
 - Steroids to reduce inflammation
 - Respirators to assist breathing



- People over 65 are at higher risk of death

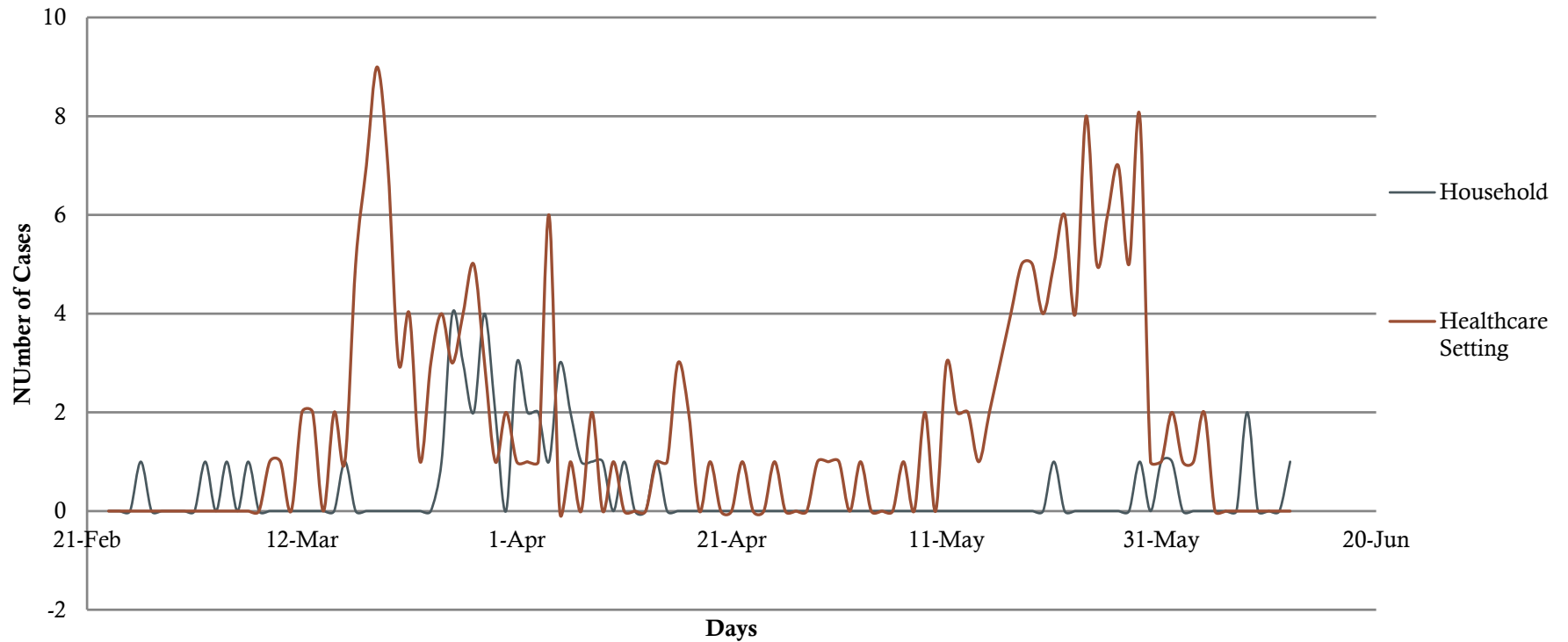
The Data

Date	New cases				Date	New cases				Date	New cases			
	T	F	H	O		T	F	H	O		T	F	H	O
Feb. 23	1	0	0	0	Mar. 31	0	0	2	1	May 12	0	0	2	0
Feb. 26	0	1	0	0	Apr. 1	1	3	1	0	May 13	0	0	2	0
Feb. 28	1	0	0	0	Apr. 2	0	2	1	0	May 14	0	0	1	0
Mar. 3	0	1	0	0	Apr. 3	0	2	1	2	May 15	0	0	2	0
Mar. 5	0	1	0	0	Apr. 4	0	1	6	0	May 16	0	0	3	0
Mar. 7	0	1	0	0	Apr. 5	0	3	0	1	May 17	0	0	4	0
Mar. 9	0	0	1	0	Apr. 6	0	2	1	1	May 18	0	0	5	0
Mar. 10	0	0	1	0	Apr. 7	0	1	0	1	May 19	0	0	5	0
Mar. 12	0	0	2	0	Apr. 8	0	1	2	0	May 20	0	0	4	0
Mar. 13	1	0	2	0	Apr. 9	0	1	0	0	May 21	0	1	5	0
Mar. 15	0	0	2	0	Apr. 10	0	0	1	0	May 22	0	0	6	0
Mar. 16	0	1	1	0	Apr. 11	0	1	0	0	May 23	0	0	4	0
Mar. 17	0	0	5	0	Apr. 14	0	1	1	0	May 24	0	0	8	0
Mar. 18	0	0	7	0	Apr. 15	0	0	1	0	May 25	0	0	5	0
Mar. 19	0	0	9	0	Apr. 16	0	0	3	0	May 26	0	0	6	0
Mar. 20	0	0	7	0	Apr. 17	0	0	2	0	May 27	0	0	7	0
Mar. 21	0	0	3	0	Apr. 19	0	0	1	0	May 28	0	0	5	0
Mar. 22	0	0	4	0	Apr. 22	0	0	1	0	May 29	0	1	8	0
Mar. 23	0	0	1	0	Apr. 25	0	0	1	0	May 30	0	0	1	0
Mar. 24	1	0	3	0	Apr. 29	0	0	1	0	May 31	0	1	1	0
Mar. 25	0	1	4	0	Apr. 30	0	0	1	0	Jun. 1	0	1	2	0
Mar. 26	0	4	3	0	May 1	0	0	1	0	Jun. 2	0	0	1	0
Mar. 27	0	3	4	0	May 3	0	0	1	0	Jun. 3	0	0	1	0
Mar. 28	0	2	5	0	May 7	0	0	1	0	Jun. 4	0	0	2	0
Mar. 29	0	4	3	0	May 9	0	0	2	0	Jun. 8	0	2	0	0
Mar. 30	0	2	1	0	May 11	0	0	3	0	Jun. 12	0	1	0	0

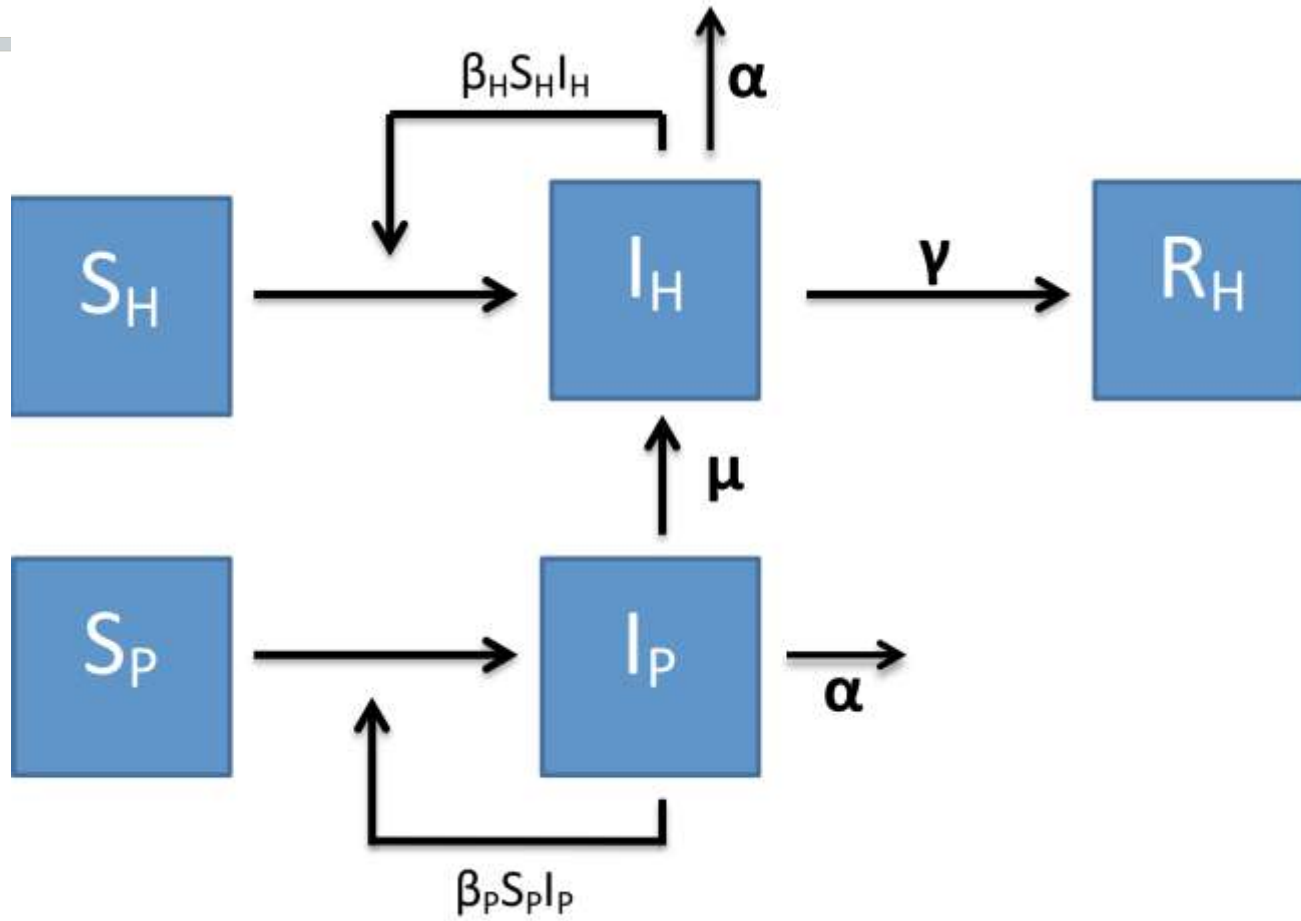
Figure 3: SARS outbreak in Canada 2003. Every case is listed on the date the patient showed the first symptoms, and classified by probable way of infection: T=travel, F=household, H=health care setting, O=others. Data from a graphic from the Health Canada webpage.

The Data

New Reported Infections



The Model



The Equations

$$\frac{dS_H}{dt} = -\beta_H S_H I_H$$

$$\frac{dI_H}{dt} = \beta_H S_H I_H + \mu I_P - \gamma I_H$$

$$\frac{dS_P}{dt} = -\beta_P S_P I_P$$

$$\frac{dI_P}{dt} = \beta_P S_P I_P - \mu I_P$$

$$\frac{dD_P}{dt} = \alpha I_P + \alpha I_H$$

S_H = hospital population

S_P = general public

I_H = infected in hospital

I_P = infected in general public

R_H = recovered

γ = rate of recovery = 1/14

μ = rate of entrance to hospital = 1/3

α = death rate from disease = 1/35

(Anderson, 2004)

Key Assumptions:

- People are infectious when they are symptomatic
- No super spreading events (SSE)

Basic Reproduction Number, R_0

Appearance of new infections

$$\vec{f} = \begin{bmatrix} \beta_H S_H I_H \\ \beta_P S_P I_P \end{bmatrix}$$

Rate of transfer between compartments

$$\vec{v} = \begin{bmatrix} -\mu I_P + \gamma I_H + \alpha I_H \\ \mu I_P \end{bmatrix}$$

Derivative of f & v at Disease Free Equilibrium

$$F = \begin{bmatrix} \beta_H S_H^0 & 0 \\ 0 & \beta_P S_P^0 \end{bmatrix}$$

$$V = \begin{bmatrix} (\gamma + \alpha) & -\mu \\ 0 & \mu \end{bmatrix}$$

$$FV^{-1} = \begin{bmatrix} \frac{\beta_H S_H^0}{\gamma + \alpha} & \frac{\beta_H S_H^0}{\gamma + \alpha} \\ 0 & \frac{\beta_P S_P^0}{\mu} \end{bmatrix}$$

$$R_0 = \max \left\{ \frac{\beta_H S_H^0}{\gamma + \alpha}, \frac{\beta_P S_P^0}{\mu} \right\}$$

Transmission Rate, β

$$\beta_H = \frac{R_0(\gamma + \alpha)}{S_H^o}$$

$$\beta_P = \alpha\beta_H$$

Chosen Values for β_H

Day 1 – 35: 0.2522e-4/1.9

Day 35 – 66: 0.01e-5

Day 66 – 100: 0.2522e-4/3

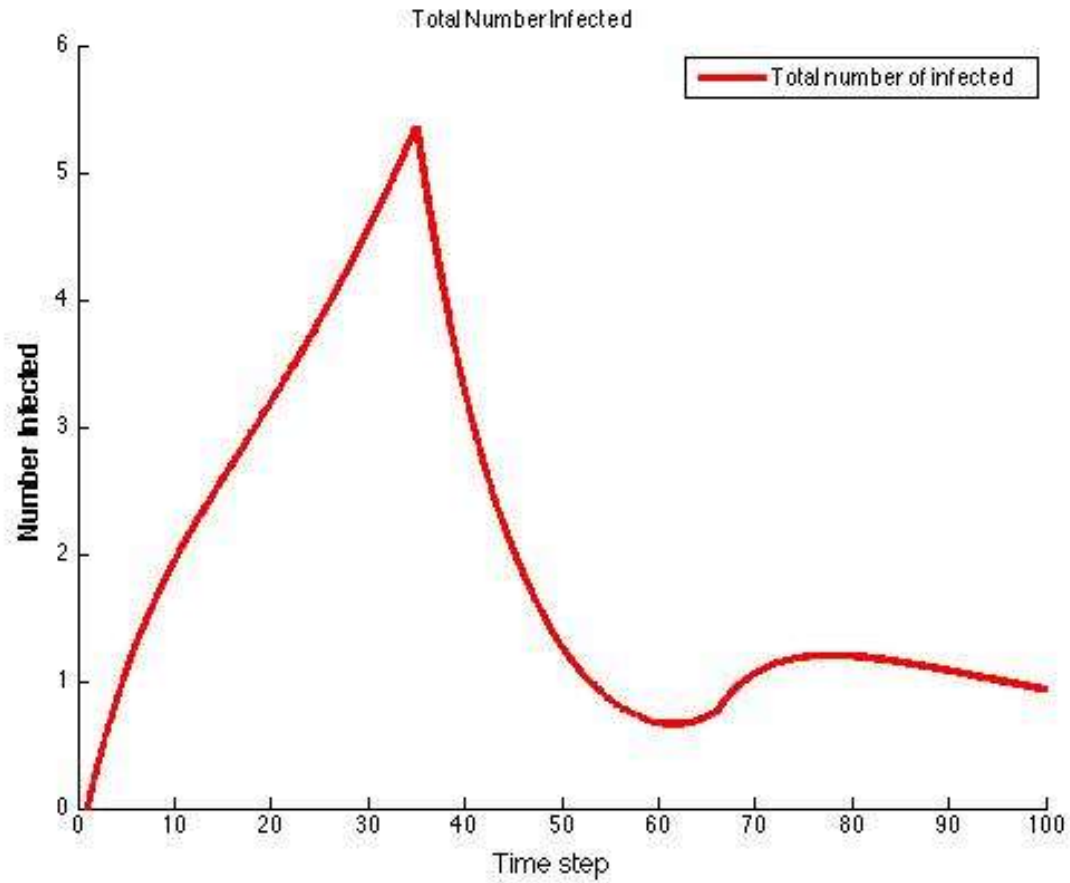
Chosen Values for β_P

Day 1 – 35 : 0.0412e-6

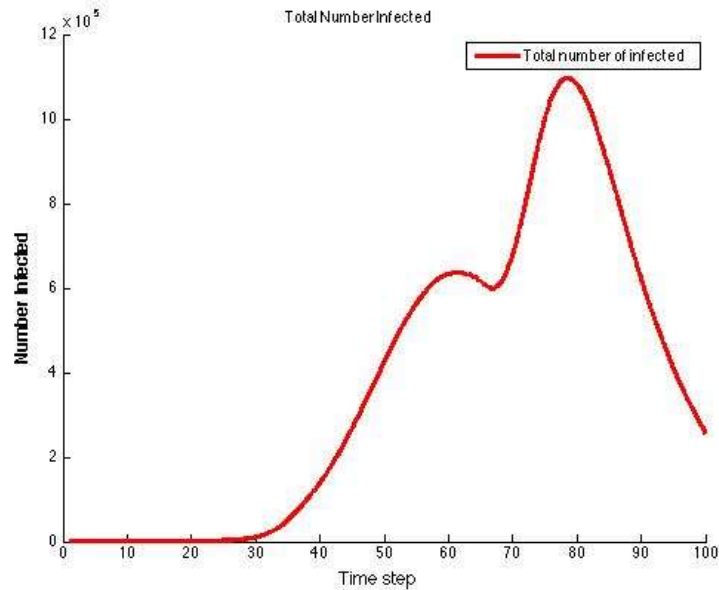
Day 35-66: 0.01e-5

Day 66-100: 0.0412e-6

Results



Sensitivity of Beta

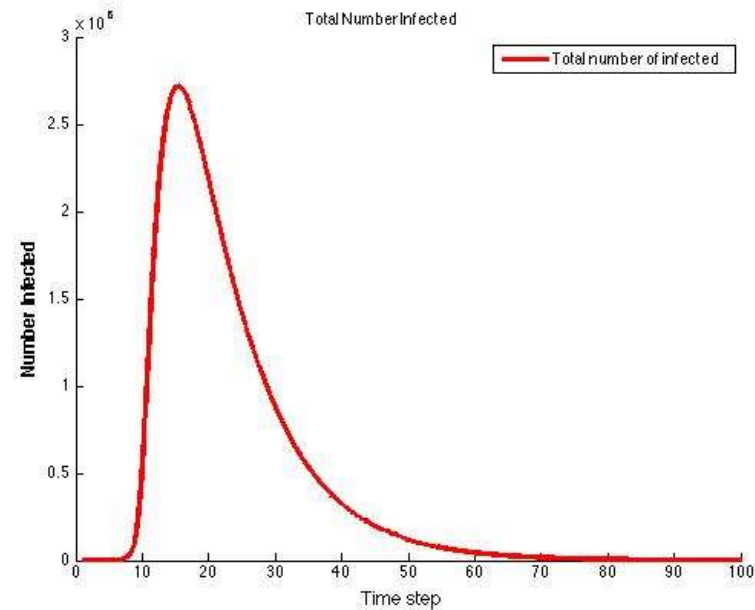


Chosen Values for β_H

Day 1 – 35: $0.2522e-5$

Day 35 – 66: $0.01e-5$

Day 66 – 100: $0.2522e-5$



Chosen Values for β_P

Day 1 – 35: $0.0412e-5/3$

Day 35 – 66: $0.01e-5$

Day 66 – 100: $0.0412e-5/1.8$

Further Investigations

- Stochastic Modeling
- Analyzing effects of isolation
- Optimizing isolation period

References

Pattern of an Epidemic [Map]. **Retrieved:** June 13, 2012, **from:**
<http://www.nature.com/nature/focus/sars/images/outbreak.jpg>

Sars Virus: Tell-Tale signs and what it does to your body. **Retrieved:** June 12, 2012, **from:**
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Anderson, R.M., Fraser, C., Ghani, A.C., Donnelly, C.A., Riley, S., Ferguson, N.M., Leung, G.M., Lam, T.H., & Hedley, A.J. (2004) Epidemiology, transmission dynamics and control of SARS: the 2002-2003 epidemic. *Philosophical Transactions of the Royal Society B*, 359, 1091-1105, doi: 10.1098/rstb.2004.1490