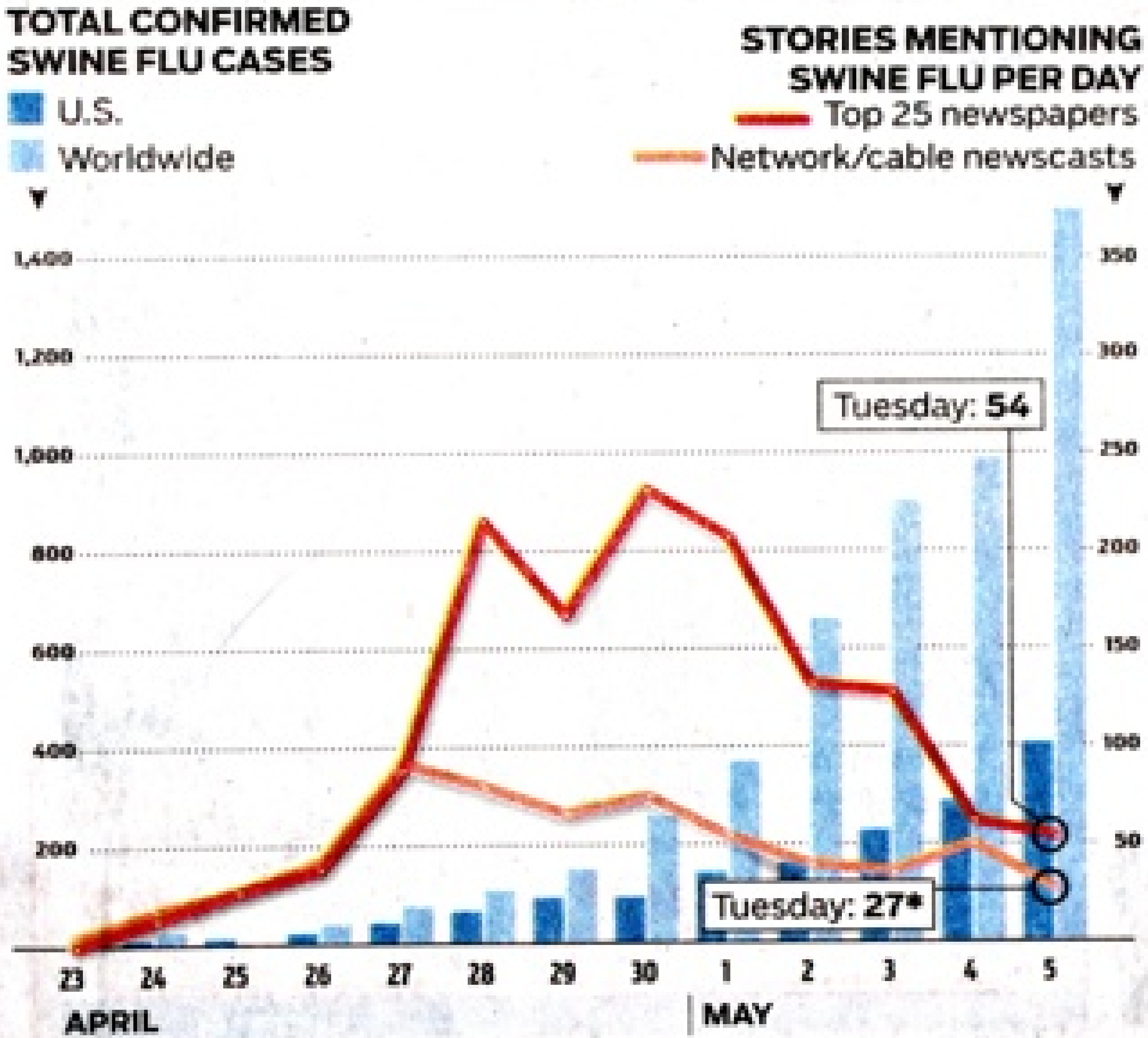
Outline

- Effects of media
- The model
- Analysis
- Optimal controls
- Adverse outcome
- Implications.

Story arc: Media and swine flu

The swine flu outbreak appears to have peaked, at least in terms of media coverage. While the number of confirmed cases continues to grow, the number of fatalities associated with the virus remains low, especially when compared to typical seasonal flu deaths.



31
Number of swine flu deaths worldwide as of Tuesday (Mexico, **29**; U.S., **2**)

55
Number of U.S. children who have died from other flus so far this season

36,000
Estimated number of Americans who die from the flu each year

NOTE: Newspapers included based on circulation and include the Chicago Tribune. Newscasts are from ABC, CBS, NBC, CNN, FOX and MSNBC. * As of 6 p.m. CDT

SOURCES: Centers for Disease Control and Prevention, World Health Organization

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The media

The media influences:

- individual behaviour
  (eg gift-chasing)
- formation and implementation of public policy
  (eg biometrics)
- perception of risk
  (eg SARS in Chinatown).

During a pandemic

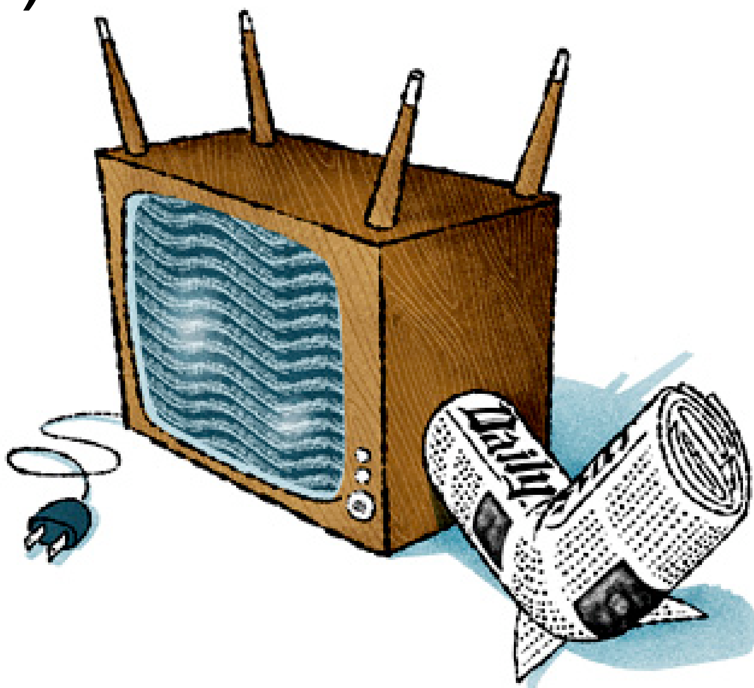
- Government information released is often restricted to only the number of infections and deaths
- Mass media are key tools in risk communication
- However, they have been criticised for making risk a spectacle.

Hypodermic theory

- The original interpretation of media effects in communication theory was the “hypodermic needle”
- It was thought that a particular media message would be directly injected into the minds of media spectators
- This suggests that media have a direct and rapid influence on everyday understanding
- However, this has been revised in recent years.

Contemporary media theories

- Media is shaped by the dominant cultural norms
- It is impossible to separate the message from the society from which it originates (eg WNV vs Chagas' Disease)
- Consumers might only partially accept a particular media message
- Or they may resist the dominant media messages altogether.



Implications for a pandemic

- Media effects may sway people into a panic
- Especially for a disease where scientific evidence is thin or nonexistent

  (eg swine flu and pig-burning)
- Conversely, media may have little effect on more familiar diseases

  (eg seasonal influenza).

Media in a crisis

- Media reporting play a key role in
  - perception
  - management
  - and even creation of a crisis

- Non-state-controlled media thrive in a crisis (eg Wikileaks)
- However, state-controlled media are rewarded for creating an illusion of normalcy (eg embedded journalists).

An intersubjective anchorage

- Media messages are widely distributed
- Reports are retrievable
- Thus, they gain authority as an intersubjective anchorage for personal recollection
- This may make information appear “more true” the more exposure it gets from the media, regardless of the evidence

  (eg climate change).

Media and risk protection

- The evaluation of epidemics may be driven by the complex interplay between information and action
- Individuals may overprotect, which may have additional consequences for the disease
- eg, after an announcement of the 1994 outbreak of plague in Surat, India, many people fled to escape the disease, thus carrying it to other parts of the country
- Media influences behaviour, which in turn influences media.

Vaccination

- One of the most effective tools for reducing the burden of infectious diseases
- However, individuals often refuse or avoid vaccinations they perceive to be risky
- eg, rumours that the polio vaccine could cause sterility and spread HIV hampered polio eradication efforts in Nigeria
- Misplaced fears of autism in the developed world have stoked fears of vaccinations against childhood diseases.

Demographic interruption

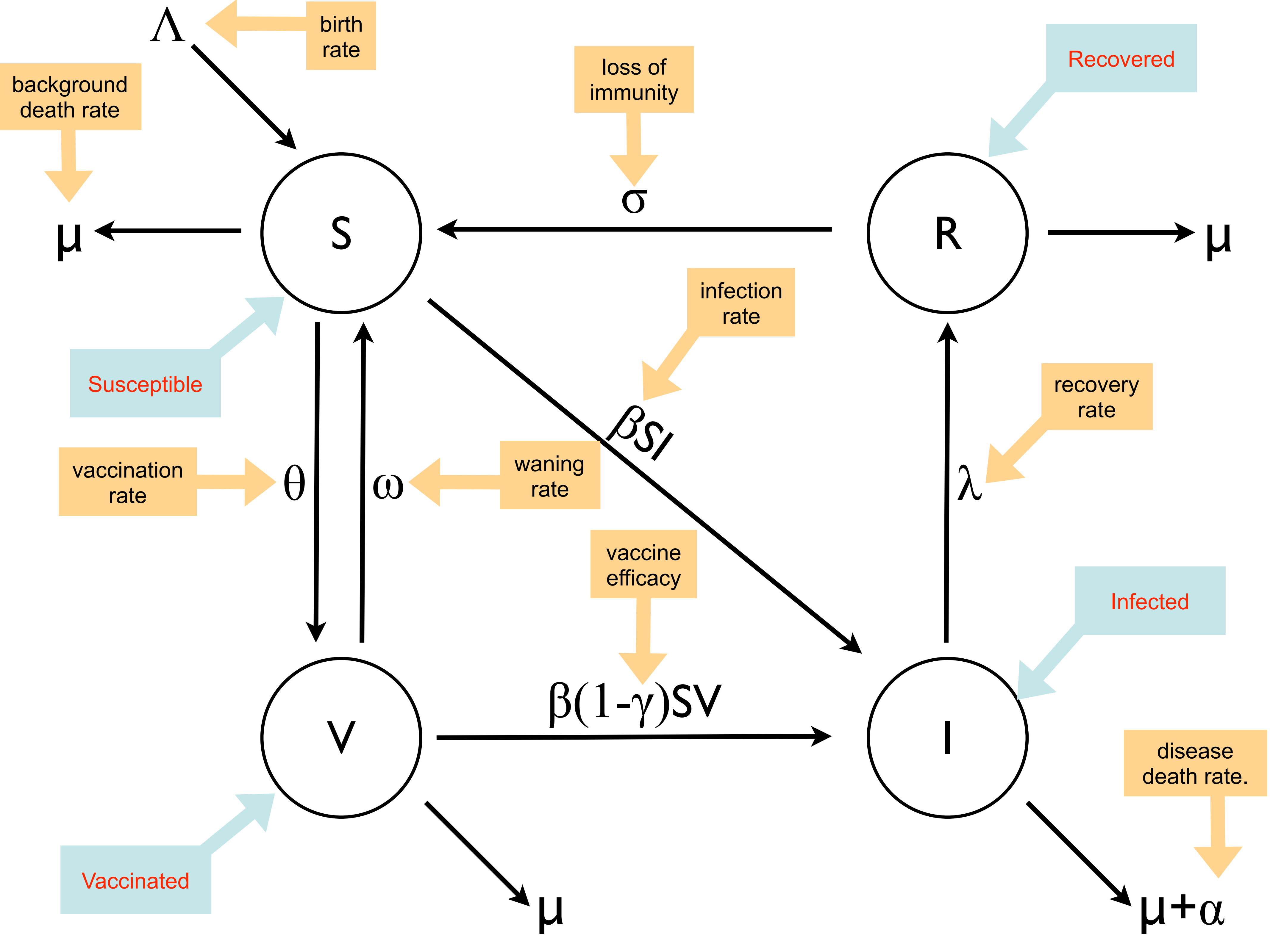
- Media exposure and attention partially mediate the effects of demographics and personal experience on risk judgements

  (eg anti-smoking campaigns)
- However, this may be especially problematic for vaccines

  (eg HPV vaccine).

The model

- We model the dynamics of influenza based on a single strain without effective cross-immunity
- We include a vaccine that confers temporary immunity
- Vaccinated individuals may still become infected but at a lower rate than susceptibles
- Media converage is included via a saturated incidence function.



Λ
birth rate
background death rate
loss of immunity
Recovered
μ
S
σ
R
μ
infection rate
Susceptible
recovery rate
βSI
vaccination rate
θ
ω
waning rate
λ
vaccine efficacy
Infected
β(1-γ)SV
V
I
disease death rate.
Vaccinated
μ
μ+α

The model equations

$$\frac{dS}{dt} = \Lambda + \omega V - (\theta + \mu)S - \left(\beta_1 - \beta_2 \frac{I}{m_I + I}\right) SI + \sigma R$$

$$\frac{dI}{dt} = \left(\beta_1 - \beta_2 \frac{I}{m_I + I}\right) SI + \left(\beta_1 - \beta_3 \frac{I}{m_I + I}\right) (1 - \gamma) VI - (\alpha + \mu + \lambda) I$$

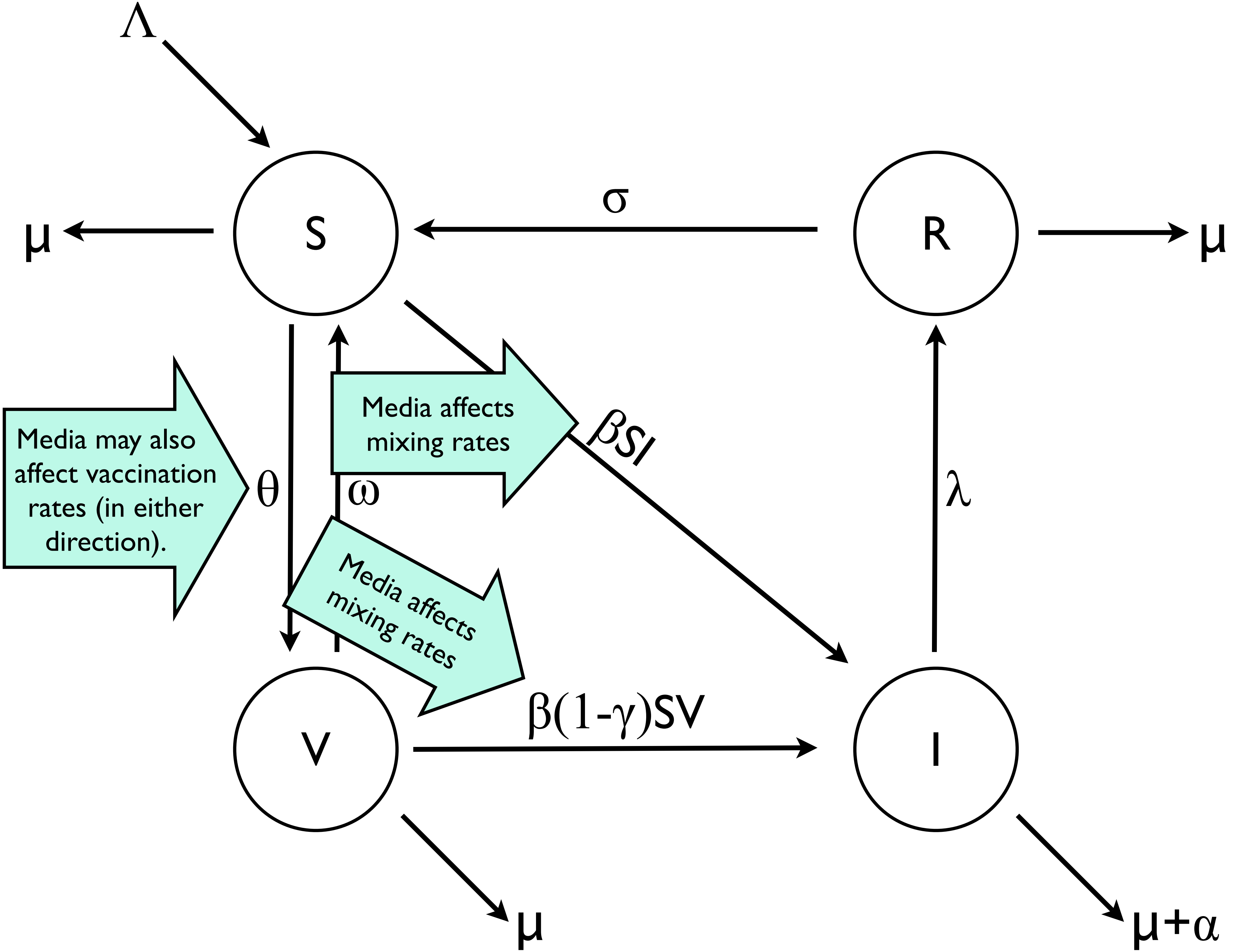
$$\frac{dV}{dt} = \theta S - (\mu + \omega)V - \left(\beta_1 - \beta_3 \frac{I}{m_I + I}\right) (1 - \gamma) VI$$

$$\frac{dR}{dt} = \lambda I - (\mu + \sigma) R$$

Media affects mixing rates

- m_I is the media half-saturation constant
- β_i are the relative transmissibilities.

Λ=birth rate μ=background death rate θ=vaccination rate
α=disease death rate ω=waning rate σ=loss of immunity
γ=vaccine efficacy λ=recovery rate



Λ
S
μ
σ
R
μ
Media may also affect vaccination rates (in either direction).
θ
ω
Media affects mixing rates
βSI
λ
Media affects mixing rates
β(1-γ)SV
V
I
μ
μ+α

Media effects

- Susceptible and vaccinated people mix less with infecteds due to media
- As many people become infected, effects of media are reduced
- ie message reaches a maximum number of people due to information saturation
- This also reflects the fact that the media are less interested in a story once it’s established in society.

Equilibria

The model has two equilibria:

- the disease-free equilibrium

$$(\bar{S},\bar{I},\bar{V},\bar{R}) = \left(\frac{\Lambda(\mu+\omega)}{\mu(\theta+\mu+\omega)}, 0, \frac{\Lambda\theta}{\mu(\theta+\mu+\omega)}, 0\right)$$

- and an endemic equilibrium

$$(\hat{S},\hat{I},\hat{V},\hat{R})$$

  which only exists for some parameter values.

S=susceptible I=infected V=vaccinated R=recovered Λ=birth rate μ=background death rate θ=vaccination rate ω=waning rate

Stability

- Using the next-generation method, we can calculate

$$R_0 = \frac{\beta_1 \Lambda(\mu + \omega) + \beta_1 (1 - \gamma)\theta \Lambda}{\mu(\alpha + \lambda + \mu)(\theta + \mu + \omega)}$$

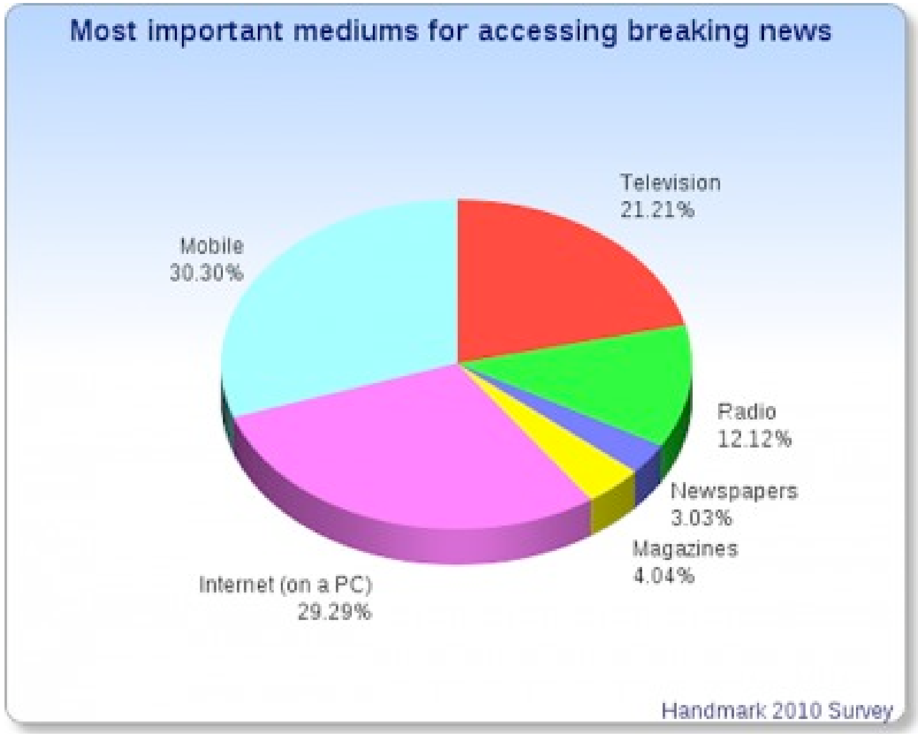
- We can prove:
  - If $R_0<1$, the disease-free equilibrium is globally stable
  - If $R_0>1$ the DFE is unstable.

Λ=birth rate μ=background death rate θ=vaccination rate
α=disease death rate ω=waning rate γ=vaccine efficacy
λ=recovery rate β_1=infection rate (susceptibles)

Optimal control

We introduce two controls, each representing a possible method of influenza control:

- u_v is the control variable for vaccination (affecting the vaccination uptake)
- u_m is the control variable for media coverage (affecting the media half-saturation constant).



Objective functional

- A control scheme is optimal if it maximises the objective functional

$$J(u_v(t), u_m(t)) = \int_{t0}^{tf} [S(t) + V(t) - B_1 I(t) - B_2(u_v^2(t) + u_m^2(t))]dt$$

Benefit of uninfected populations

Weight constraint for infected populations

Weight constraint for control

- B_1 and B_2 can represent the amount of money expended over a finite period, or the perceived risk.

S=susceptible I=infected V=vaccinated
u_v=vaccine control u_m=media control

Adjoint equations

- Given optimal controls u_v and u_m, there exist adjoint variables λ_i (i=1,2,3,4) satisfying

$$\frac{d\lambda_1}{dt} = -1 + (\lambda_1 - \lambda_2)(\beta_1 - \beta_2 \frac{I}{(1-u_m)m_I + I})I + (\lambda_1 - \lambda_3)(1-u_v)\theta + \lambda_1 \mu$$

$$\begin{aligned}\frac{d\lambda_2}{dt} &= B_1 + (\lambda_1 - \lambda_2)\left[\left(\beta_1 - \beta_2 \frac{I}{(1-u_m)m_I + I}\right)S - \beta_2 \frac{(1-u_m)m_I}{((1-u_m)m_I + I)^2} IS\right] \\ &+ (\lambda_3 - \lambda_2)\left[\left(\beta_1 - \beta_3 \frac{I}{(1-u_m)m_I + I}\right)(1-\gamma)V - \beta_3 \frac{(1-u_m)m_I}{((1-u_m)m_I + I)^2}(1-\gamma)VI\right] \\ &+ \lambda_2(\alpha + \mu + \lambda) - \lambda_4 \lambda\end{aligned}$$

$$\frac{d\lambda_3}{dt} = -1 + (\lambda_3 - \lambda_2)(\beta_1 - \beta_3 \frac{I}{(1-u_m)m_I + I})(1-\gamma)I + \lambda_3 \mu + (\lambda_3 - \lambda_1)\omega$$

$$\frac{d\lambda_4}{dt} = (\lambda_4 - \lambda_1)\sigma + \lambda_4 \mu.$$

S=susceptible I=infected V=vaccinated μ=background death rate θ=vaccination rate ω=waning rate σ=loss of immunity γ=vaccine efficacy λ=recovery rate γ=vaccine efficacy m_I=media half-saturation constant B_1=weight constraint (infection) B_2=weight constraint (controls) β_2=transmissibility reduction due to media (susceptibles) β_3=transmissibility reduction due to media (vaccinated)

Optimal controls

- We can calculate the optimal controls explicitly:

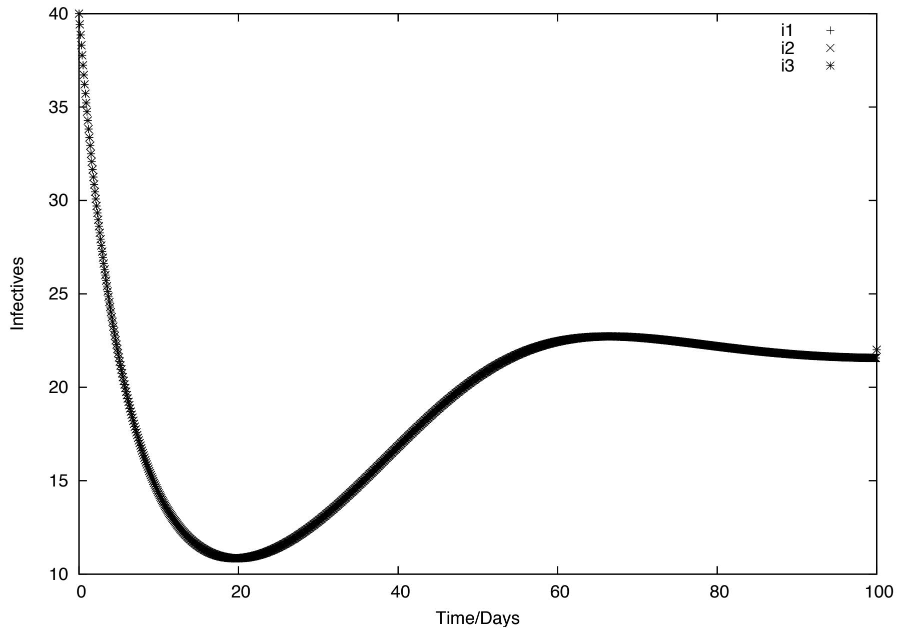
$$u_v^*(t) = \min\left\{\max\left\{a_{11}, \frac{(\lambda_1 - \lambda_3)\theta S}{2B_2}\right\}, b_{11}\right\}$$

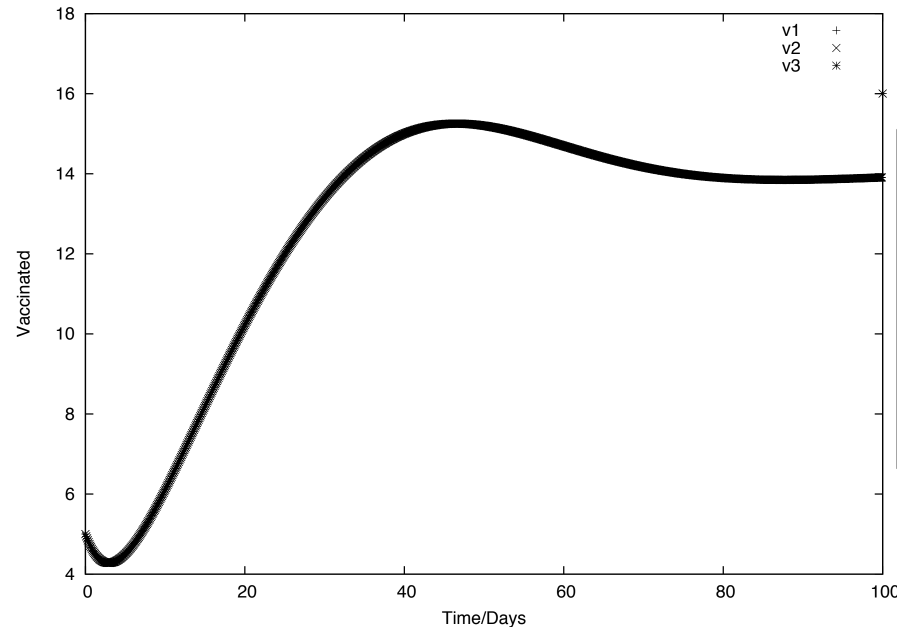
$$u_m^*(t) = \min\left\{\max\left\{a_{22}, \frac{(\lambda_1 - \lambda_2)\beta_2 m_I S I^2}{2B_2((1-u_m)m_I + I)^2} + \frac{(\lambda_2 - \lambda_3)\beta_3 m_I (1-\gamma) V I^2}{2B_2((1-u_m)m_I + I)^2}\right\}, b_{22}\right\}$$

  - a_{11} and b_{11} are lower and upper bounds for u_v
  - a_{22} and b_{22} are lower and upper bounds for u_m
- The optimal controls are unique if t_f is small.

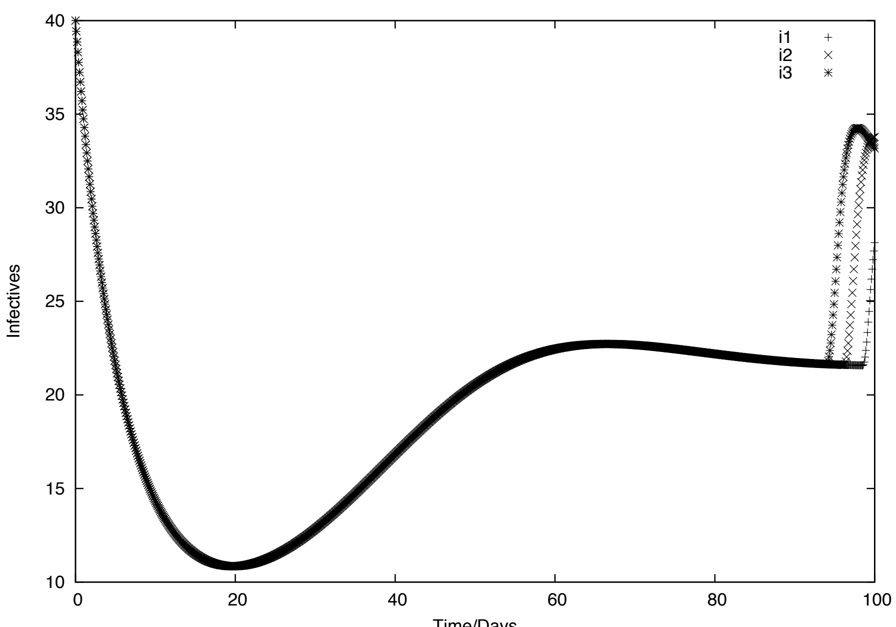
S=susceptible I=infected V=vaccinated γ=vaccine efficacy m_I=media half-saturation constant B_1=weight constraint (infection) B_2=weight constraint (controls) β_2=transmissibility reduction due to media (susceptibles) β_3=transmissibility reduction due to media (vaccinated) λ_i=adjoint variables for the controls

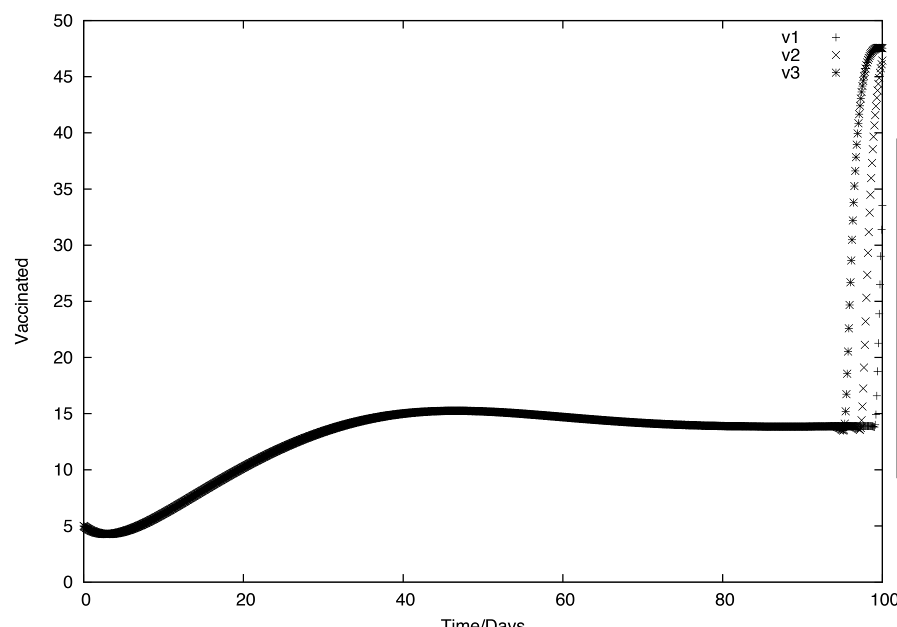
Media has beneficial effect on vaccine





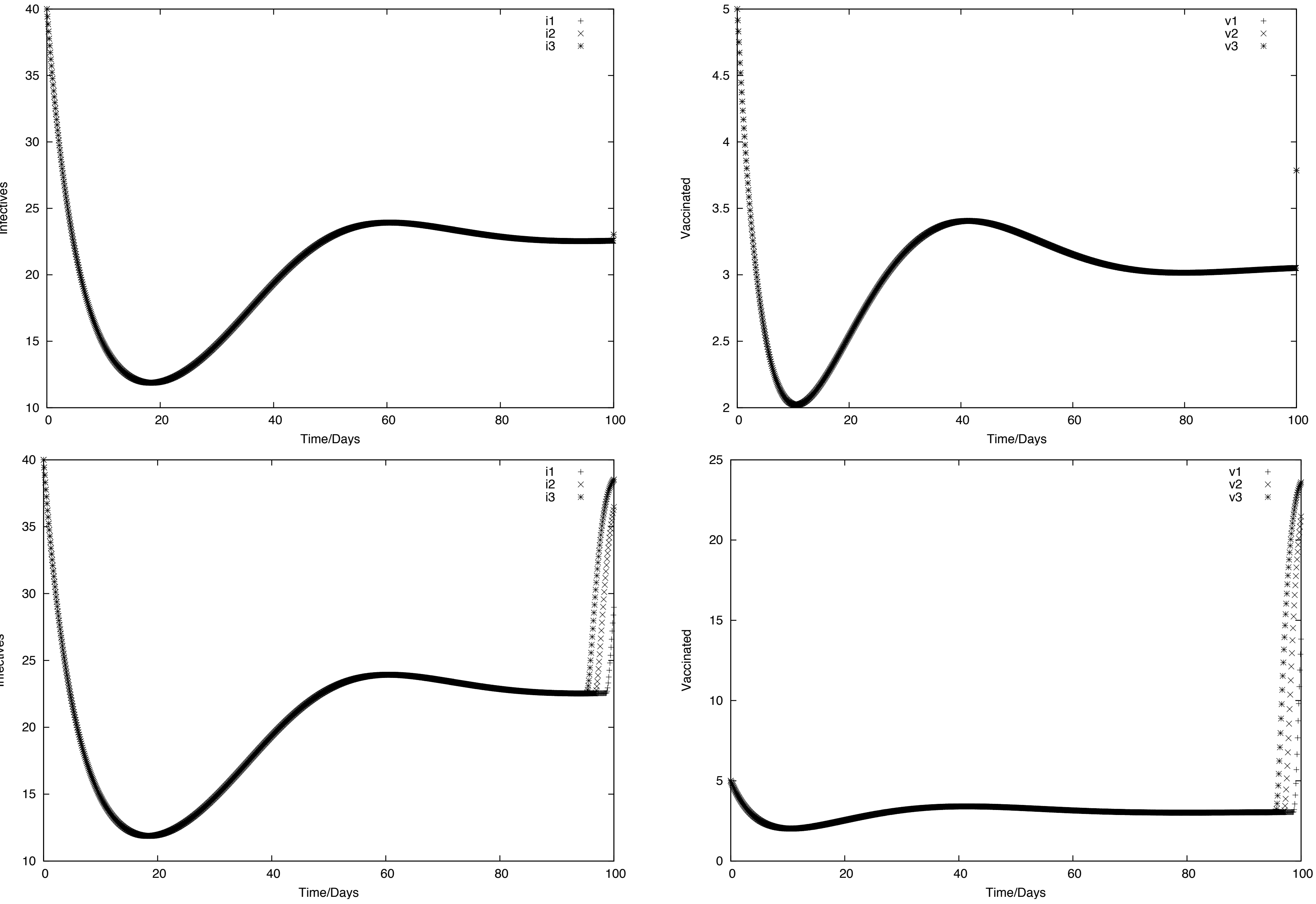
Costs of infection high, control low





Costs of control high, infection low

Media has negative effect on vaccine



Costs of infection high, control low

Costs of control high, infection low

Adverse outcome due to media?

- To illustrate a potentially adverse outcome, consider a simplified model
- Suppose, initially, the media and the general population are unaware of the disease
- Thus, nobody gets vaccinated, allowing the disease to spread initially
- New infected individuals arrive at fixed times
- We will ignore recovery in this simple model.

Media awareness threshold

- Suppose there are a critical number of infected individuals whereupon people become aware of the disease, via the media
- Above this threshold, susceptibles do not mix with infecteds
- However, vaccinated individuals mix significantly with infecteds
- Even though they may still potentially contract the virus.

Simplified model - lower region

- For $I<I_{crit}$, the model is

$$\frac{dS}{dt} = \Lambda + \omega V - \mu S \qquad t \neq t_k$$
$$\frac{dI}{dt} = -(\alpha + \mu + \lambda) I \qquad t \neq t_k$$
$$\frac{dV}{dt} = -(\mu + \omega) V \qquad t \neq t_k$$
$$\Delta I = I^i \qquad t = t_k$$

- t_k are (fixed) arrival times of new infecteds
- This approximates low-level mixing
- If arrival times are not fixed, the results are broadly unchanged.

S=susceptible I=infected V=vaccinated Λ=birth rate μ=background death rate α=disease death rate ω=waning rate λ=recovery rate I_{crit}=vaccination panic threshold

Simplified model - upper region

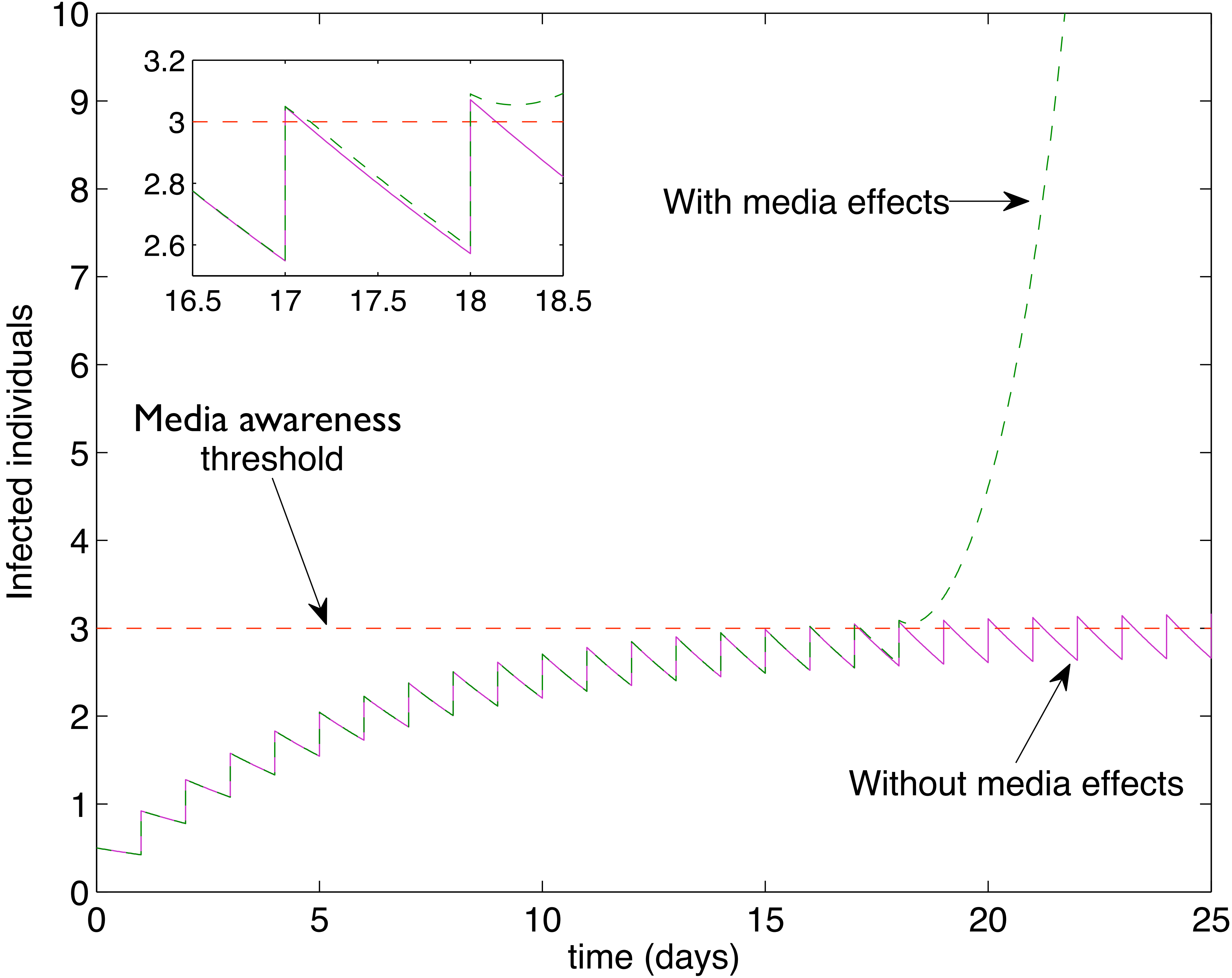
- For $I > I_{crit}$, the model is

$$\frac{dS}{dt} = \Lambda + \omega V - (\theta + \mu)S$$
$$\frac{dI}{dt} = \beta_5(1-\gamma)VI - (\alpha + \mu + \lambda)I$$
$$\frac{dV}{dt} = \theta S - (\mu + \omega)V - \beta_5(1-\gamma)VI$$

- No mixing of susceptibles and infecteds
- The vaccinated mix with infecteds, allowing them to be infected

  (at low rates).

S=susceptible I=infected V=vaccinated Λ=birth rate μ=background death rate θ=vaccination rate α=disease death rate ω=waning rate γ=vaccine efficacy λ=recovery rate I_{crit}=vaccination panic threshold



Infected individuals
time (days)
With media effects
Without media effects
Media awareness
threshold
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
3.2
3
2.8
2.6
16.5
17
17.5
18
18.5

Lower region

- If $I<I_{crit}$, we can prove that

$$I^+ \rightarrow \frac{I^i}{1-e^{-(\alpha+\mu+\lambda)\tau}} \equiv m^+$$

where $\tau = t_{k+1} - t_k$

- If $m^+>I_{crit}$, then the system will eventually switch from the lower region to the upper region.

μ=*background death rate* α=*disease death rate*
λ=*recovery rate* I_{crit}=*vaccination panic threshold*

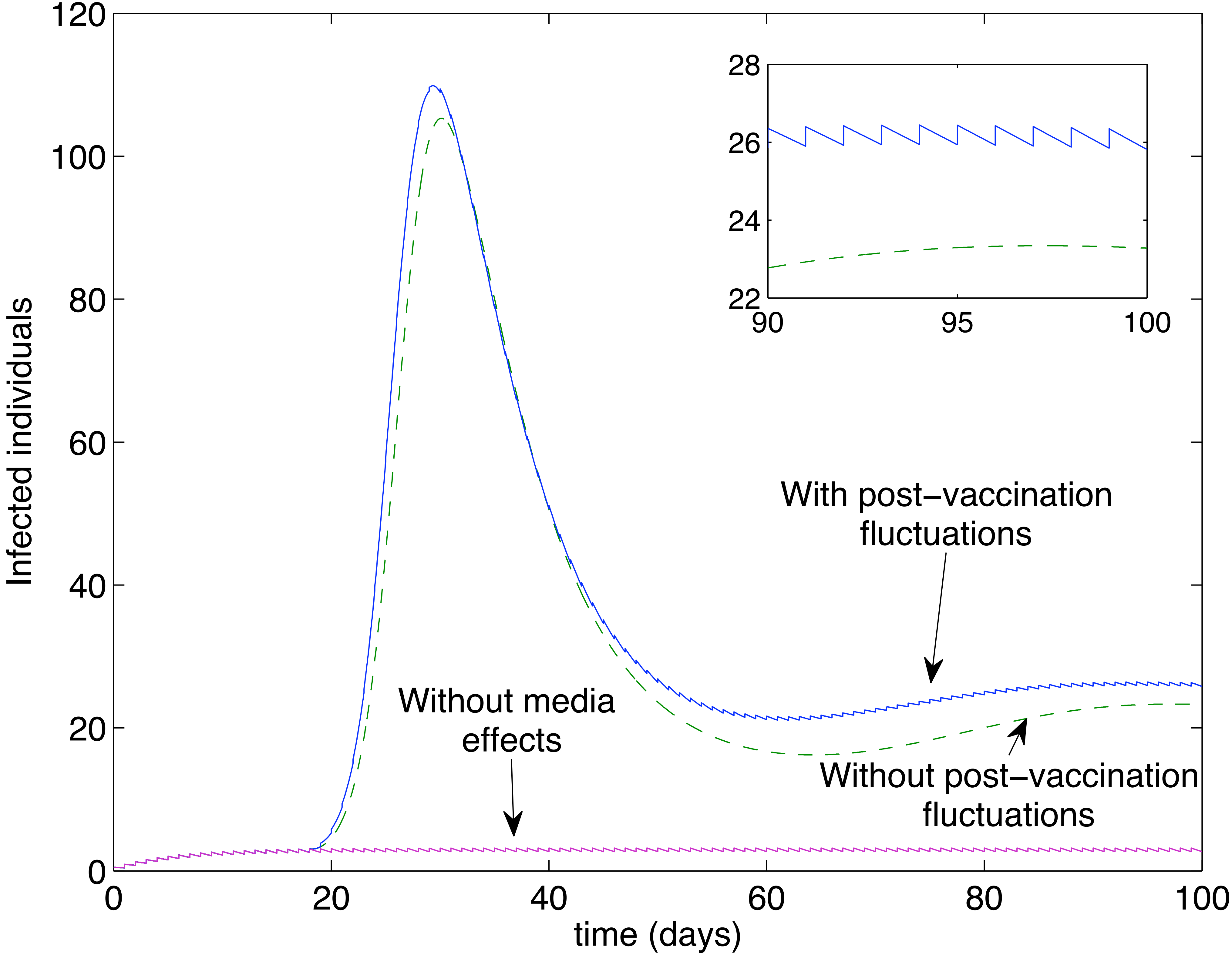
Upper region

- If $I>I_{crit}$,there is an endemic equilibrium (S^*,I^*,V^*)
- This equilibrium is stable if $I^*>I_{crit}$
- ie once trajectories enter the upper region, they will stabilise there
- If $I^*>m^+$, then the outcome will be worse than without media effects
- Thus, even in this extremely simplified model, the media may make things significantly worse.

S=susceptible I=infected V=vaccinated m^+=non-media equilibrium I_{crit}=vaccination panic threshold

Low-level mixing of susceptibles

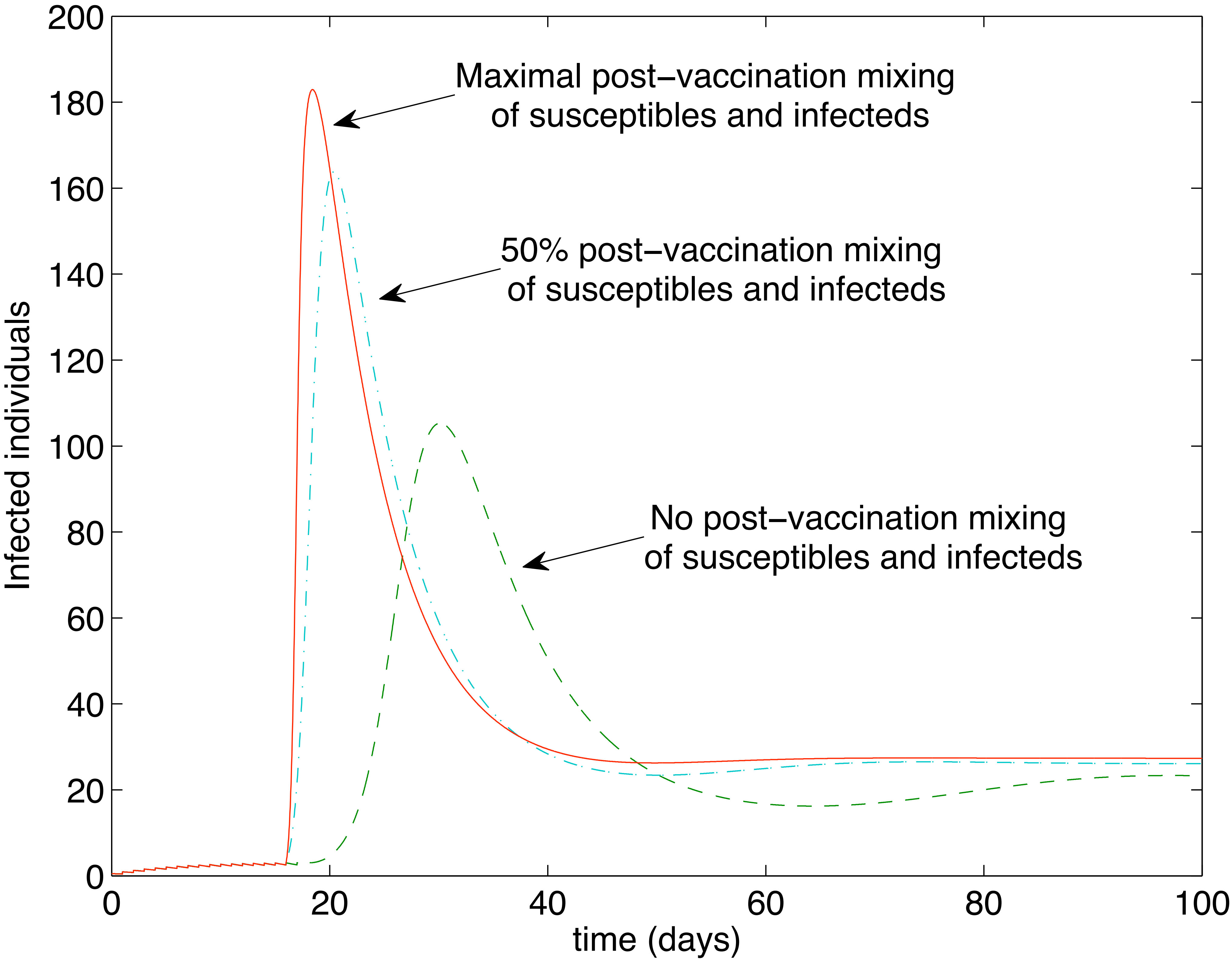
- Low-level mixing may apply to the upper region as well
- Including these will increase the long-term number of infecteds
- It will also increase the peak of the epidemic wave.



Infected individuals
time (days)
0
20
40
60
80
100
120
With post–vaccination fluctuations
Without post–vaccination fluctuations
Without media effects
28
26
24
22
90
95
100

High-level mixing of susceptibles

- What if susceptibles mix with infecteds in more significant numbers?
- If these effects are included in the upper region, then the wave peak occurs earlier
- The long-term number of infecteds will also increase.

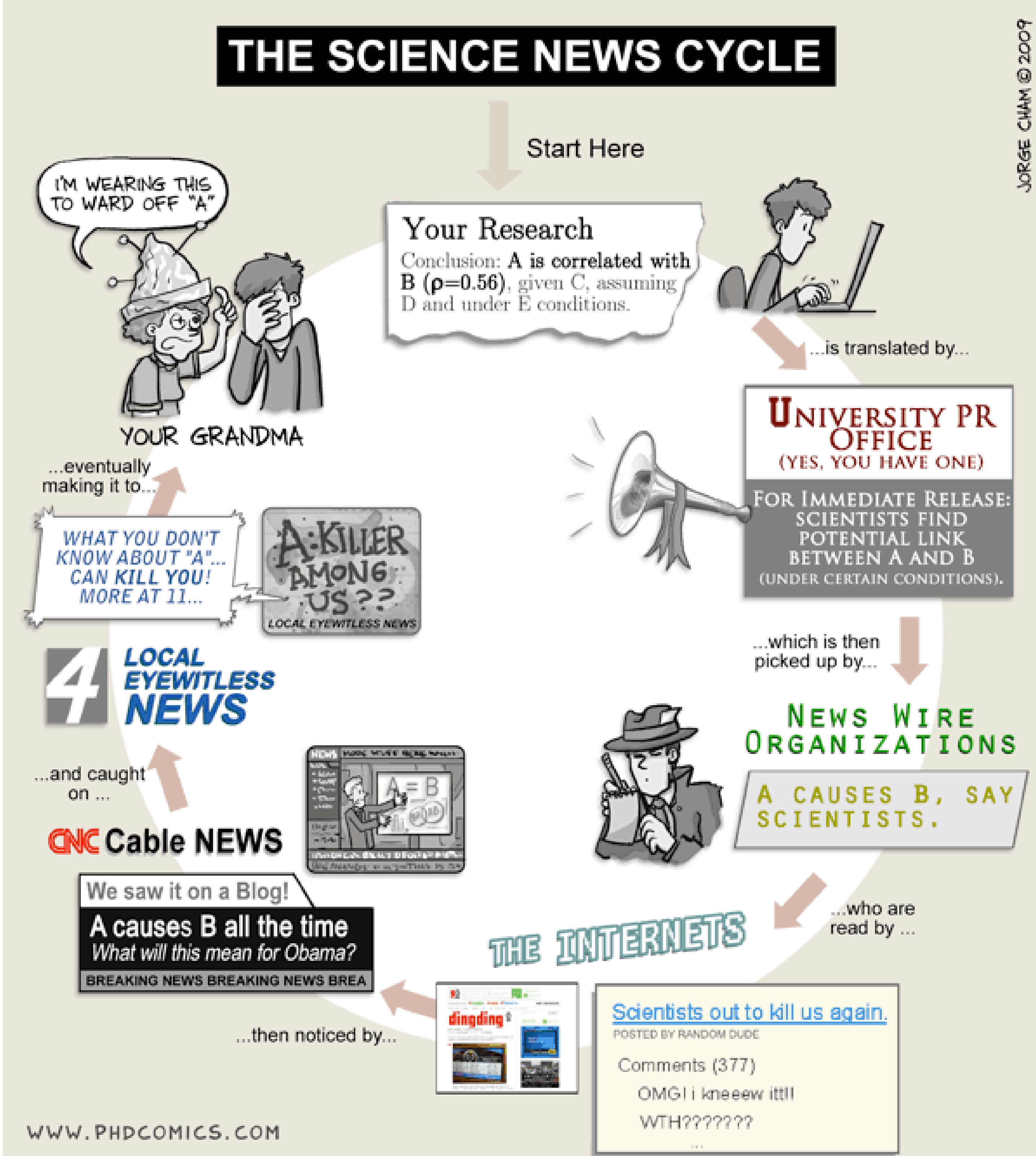


Maximal post−vaccination mixing
of susceptibles and infecteds
50% post−vaccination mixing
of susceptibles and infecteds
No post−vaccination mixing
of susceptibles and infecteds
Infected individuals
time (days)
0
20
40
60
80
100
120
140
160
180
200

Adverse outcome

- Thus, a small series of outbreaks that would equilibrate at some maximal level $m^+ > I_{crit}$ may, as a result of the media, instead equilibrate at a much larger value $I^* > m^+$
- The driving factor here is overconfidence in an imperfect vaccine
- ie vaccinated people mix significantly more with infecteds than susceptibles do
- This may happen if people feel invulnerable, due to media simplifications around vaccines.

m^+=non-media equilibrium I_{crit}=vaccination panic threshold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Start Here
Your Research
Conclusion: A is correlated with B (ρ=0.56), given C, assuming D and under E conditions.
...is translated by...
UNIVERSITY PR OFFICE
(YES, YOU HAVE ONE)
FOR IMMEDIATE RELEASE: SCIENTISTS FIND POTENTIAL LINK BETWEEN A AND B (UNDER CERTAIN CONDITIONS).
...which is then picked up by...
NEWS WIRE ORGANIZATIONS
A CAUSES B, SAY SCIENTISTS.
...who are read by ...
THE INTERNETS
Scientists out to kill us again.
POSTED BY RANDOM DUDE
Comments (377)
OMG! i kneeew it!!!
WTH???????
...
dingding
...then noticed by...
We saw it on a Blog!
A causes B all the time
What will this mean for Obama?
BREAKING NEWS BREAKING NEWS BREA
CNC Cable NEWS
A = B
...and caught on ...
4 LOCAL EYEWITLESS NEWS
WHAT YOU DON'T KNOW ABOUT "A"... CAN KILL YOU! MORE AT 11...
A: KILLER AMONG US??
LOCAL EYEWITLESS NEWS
...eventually making it to...
I'M WEARING THIS TO WARD OFF "A"
YOUR GRANDMA
WWW.PHDCOMICS.COM

Recommendations

- As scientists, we could all benefit from media training
- Messages need to be straightforward
- Plain language is crucial
- Speak in quoteable phrases, not paragraphs
- If you can't explain it...

...you didn't do it.

Summary

- Media simplifications can lead to overconfidence in the idea of a vaccine as a cure-all
- The result is a vaccinating panic and a net increase in the number of long-term infected
- Thus, media coverage of an emerging epidemic can have dire consequences
- It can also implicitly reinforce an imperfect solution as the only answer.

Limitations

- More comprehensive modelling is needed to fully understand the complex interplay between media and human behaviour
- This will require interdisciplinary research across traditional boundaries of
  - social
  - natural
  - medical sciences
  - mathematics

- eg people may ignore the media, de-linking the vaccination rate from the control.

Conclusions

- The media are responsible for treating risk as spectacle, panic in the face of fear and oversimplifications in the absence of data
- While the media may encourage more people to get vaccinated, they may also trigger a vaccinating panic
- Or promote overconfidence in the ability of a vaccine to fully protect against the disease
- When the next pandemic arrives, the outcome is likely to be significantly worse as a result of the media.