

# Modelling Infectious Diseases in Virtual Realities

The „Corrupted Blood" plague  
of World of Warcraft <sup>TM</sup> from an  
epidemiological perspective



24C3

Florian Burckhardt

MSc Epidemiology

[florian@burckhardt.de](mailto:florian@burckhardt.de)

# Me, myself and I

- 1982 Commodore 64
- 1996 MSc Biology
- 2000 MSc Epidemiology
- 2004 ❤️ ❤️ ❤️ Irene ❤️ ❤️ ❤️
- 2004+ State and Federal Public Health Institutes

# World of Warcraft

- Massively multiplayer online role playing game (MMORPG) by Blizzard Entertainment
- Launched 11/2004, 7/2007: 9 Mio players
- Players create „Avatars“ from a set of races and classes, can learn professions
- Interaction with other Avatars
- LOTS of out-of-game activity



# World of Adventure

- Avatars adventure the virtual world „Azeroth“ and progress from Level 1 to Level 60 (70, 80)
- Each new level makes Avatars more powerful: more life, talents, spells, better armoury etc.
- Powerful enemies („Bosses“) can only be defeated by several coordinated max. level Avatars („raid“)







# 09/13 2005, Azeroth: Zul'Gurub

- Release of new gaming content: Blood God „Hakkar the Soulflayer“ for high level Avatars
- During battle, Hakkar cast the spell „corrupted blood“ (CB) on random Avatars
- CB hit with severe damage once plus additional damage over time; duration 10 seconds
- CB spread from Avatar to Avatar: INFECTIOUS
- CB was never meant to leave Zul'Gurub, but:
  - Infected Avatars could teleport to cities
  - Hunters could dismiss their infected pets in Zul'Gurub and later call them back –still infected- in cities



# Media Attention

Modeling Infectious Diseases Dissemination Through Online Role-Playing Games

Author(s): Balicer, Ran D.

Issue: Volume 18(2), March 2007, pp 260-261

Publication Type: [Virtual Epidemiology]

Last Updated: Thursday, 22 September 2005, 16:18 GMT 17:18 UK

## Deadly plague hits Warcraft world

By Mark Ward  
Technology Correspondent, BBC News website

A deadly virtual plague has broken out in the online game World of Warcraft.

Although limited to only a few of the game's servers the numbers of characters that have fallen victim is thought to be in the thousands.

Originally it was thought that the deadly plague was the result of a glitch in the game.

Digital plague hits online game World of Warcraft  
by Robert Lemos, SecurityFocus 2005-09-27

virus spread by terrorists left bodies on the streets and the government was not

PRINT EMAIL COMMENT

Vulnerabilities Mailing Lists Jobs

you want to hacker

EPIDEMIOLOGY

Ads by Google

About

search:

WATCH LIVE BBC News

News Front Page World UK

England Scotland Wales Business Politics Health Education Technology Entertainment Audio

BBC NEWS

NEWS

NEWS

NEWS

However, no attempt at modelling it, yet....

## Virtual game is a 'disease model'

An outbreak of a deadly disease in a virtual world

Wednesday, Aug. 22, 2007

## World of Warcraft: A Pandemic Lab

By Laura Blue

TIME  
IN PARTNERSHIP WITH CNN

The untapped potential of virtual game world on real world epidemics

Eric T Lofgren, Nina H Fefferman

TIMES ONLINE

From The Times

August 21, 2007

How a computer game glitch could help to fight off global pandemic

ling off  
ers in an  
e.

d, wreaking  
its quarantine measures

Scientists believe the game error could offer a valuable insight

LISTEN How it reflects reality

# Mathematical Modelling of Populations

- 1798 Malthus: population grows exponentially, but food supply linearly, therefore catastrophe
- 1925/26 Lotka Volterra: Predator–Prey cycles
- 1927 Kermack-McKendrick „SIR“ disease model
- 1977 Baroyan, Rvachev, Ivannikov (Moskau): modelling of influenza epidemics in the USSR
- Post 9/11: massive interest in disease modelling
  - Bioterrorism (smallpox)
  - Pandemics (influenza, H5N1, SARS)
- Models have substantial policy impact (stockpiling, treatment priorities, cost-benefit)

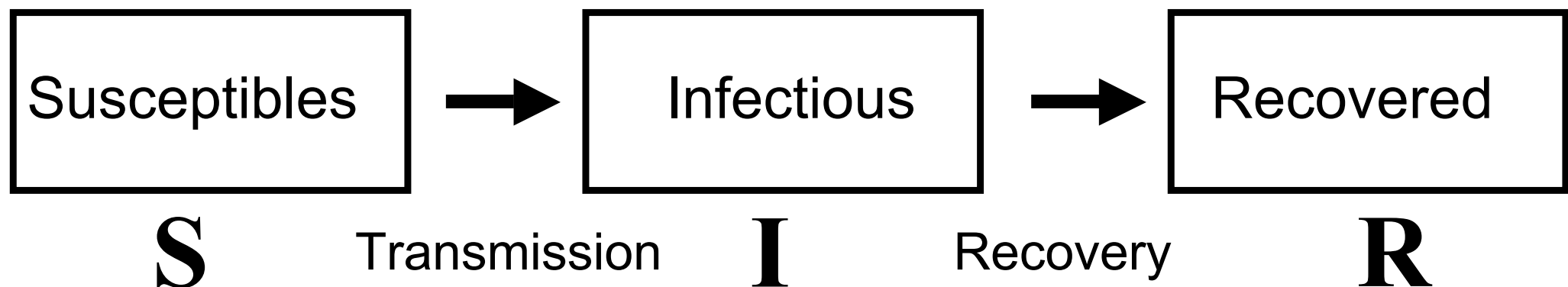


# Models: Different Flavours

- Compartmental Models (classic SIR models)
  - Deterministic
  - Stochastic
- Individual/ agent based systems (US: stochastic)
- Branching Models
- Complex models require more assumptions and parameter estimations
- „Describing complex, poorly-understood reality with a complex, poorly understood model is not progress“ J. Maynard Smith (credit: Peter White)

# Keep it SIRmple

- Susceptible (S): are healthy, but can be infected
- Infectious (I): are sick and infectious
- Recovered (R): recovered from disease and are immune to it
- Assumption: homogeneous mixing
- Challenge: estimate rates (arrows) from data

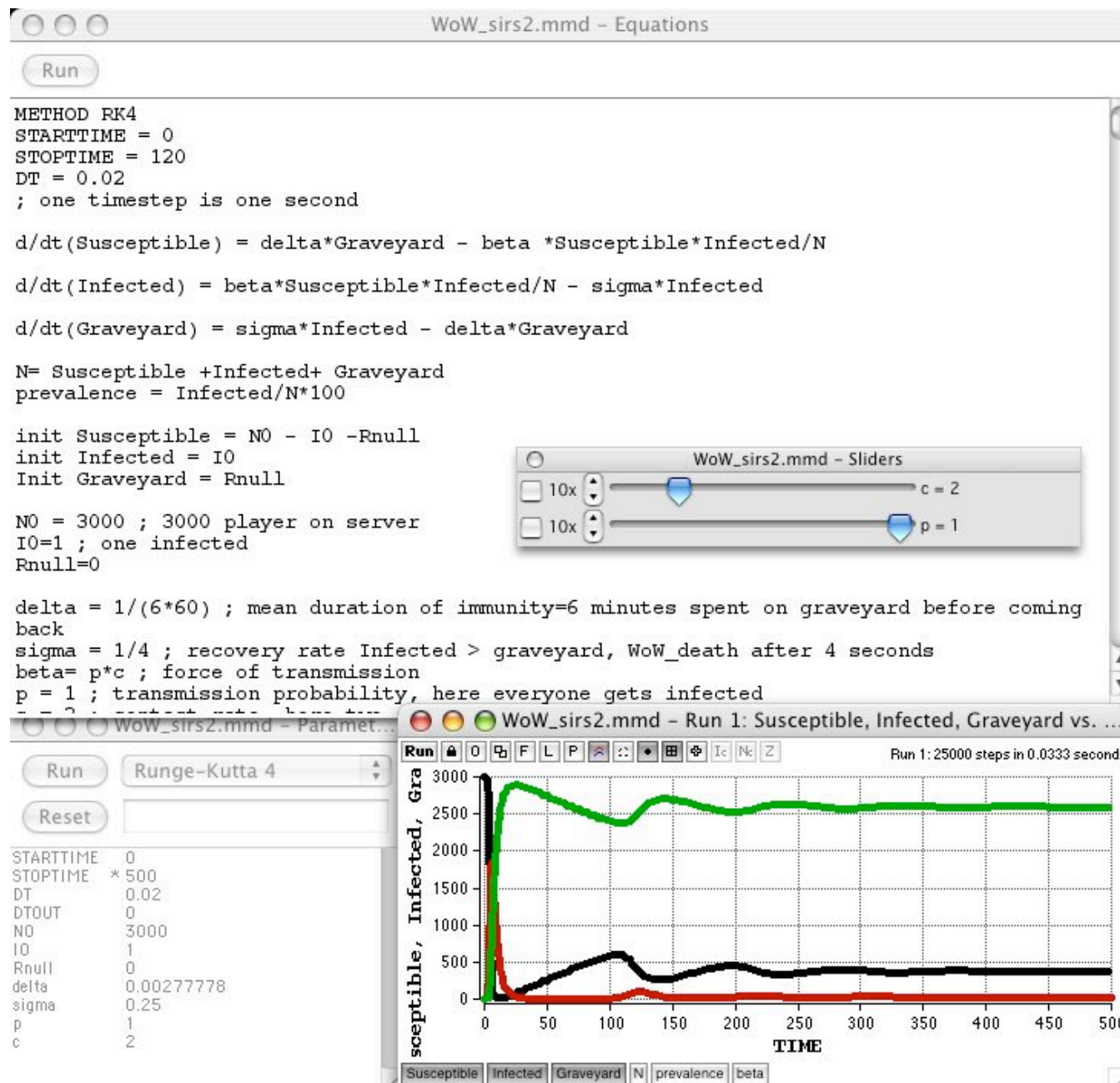


# Transmission Rate Formula P. White



- Rate of contacting others (people/time):  $c$
- Rate of contacting infectious:  $c \times \frac{I}{N}$  ( $N=S+I+R$ )  
( $I/N$  is proportion of infected in population)
- Rate of transmission from infecteds:  $p \times c \times \frac{I}{N}$   
(„force of infection“,  $p$  is transmission probability)
- Total transmission rate in population:  $S \times p \times c \times \frac{I}{N}$
- $S$ ,  $I$  change with time, product  $S \times I$  is non-linear

# Simulation: Berkely Madonna

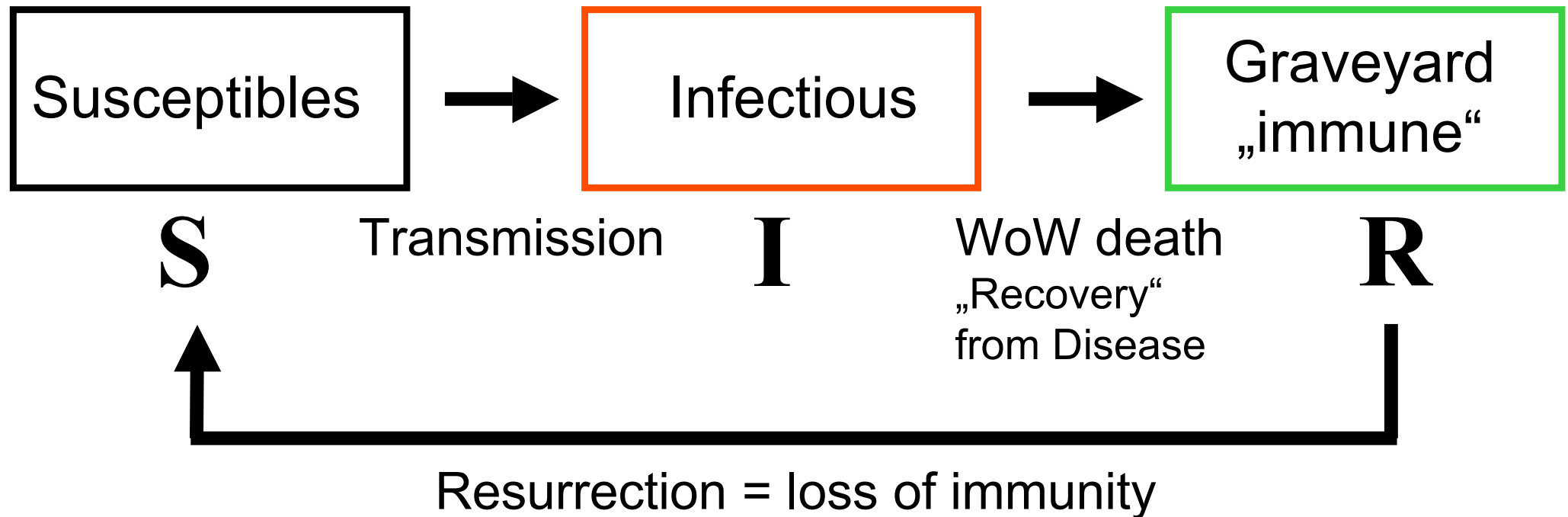




# Disease Parameters

	Measles	Syphilis	Norovirus „projectile vomiting“	Corrupted Blood
Incubation period	10 days	1-3 weeks	10 hours	0 sec
Duration of infectiousness	8 days	(1 year)	2-4 days	10 sec
Transmission probability $p$	95%	30%	high	100%
Immunity	yes, lifelong	weak	only against subtype	no
Mode of transmission	Droplet (airborne)	Sexually !condoms protect!	fecal-oral, droplet, fomite	magic (droplet like)

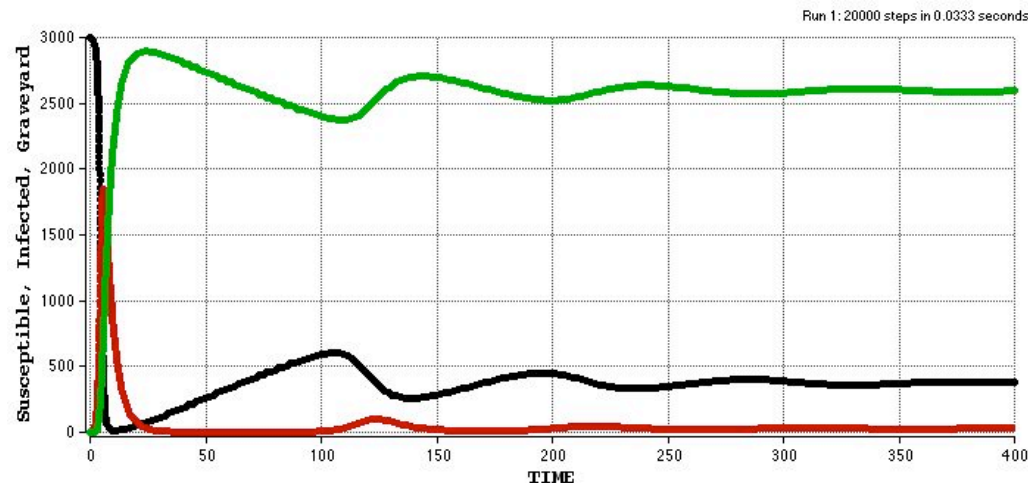
# Low/Mid Level Avatar: SIRS



- WoW: death is not permanent
- Graveyard compartment: confers CB immunity
- After resurrection, Avatars are susceptible again
- SIRS Model (or rather SIGS Model)

# SIRS Model (low/mid Lv Avatar)

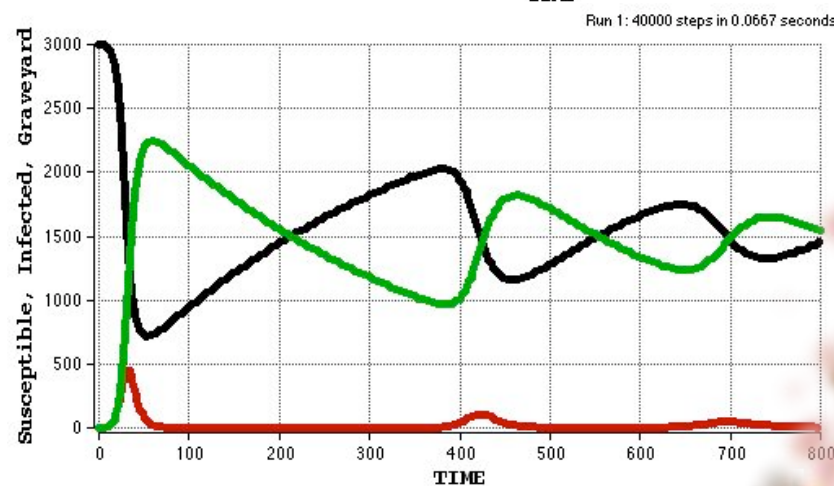
**A**



3000 Players  
1 Infected at start  
2 contacts per second  
85% on graveyard  
>>> Infection persist

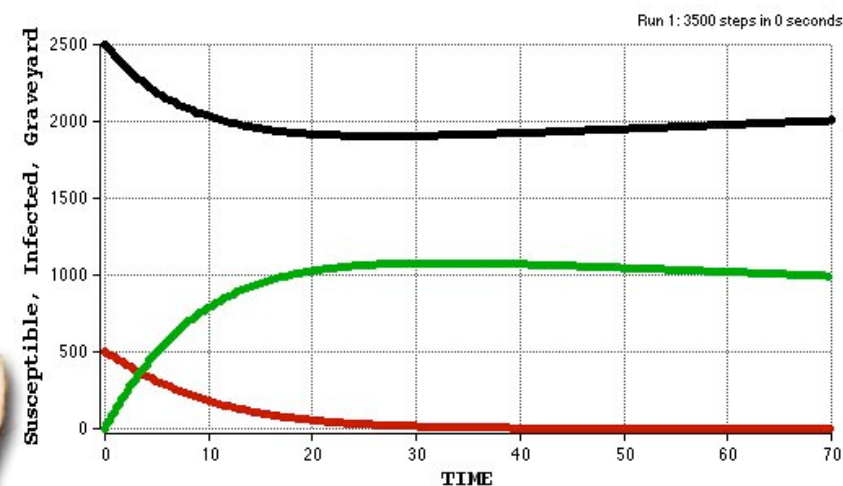
**Susceptible**  
**Infected**  
**gRaveyard**

**B**

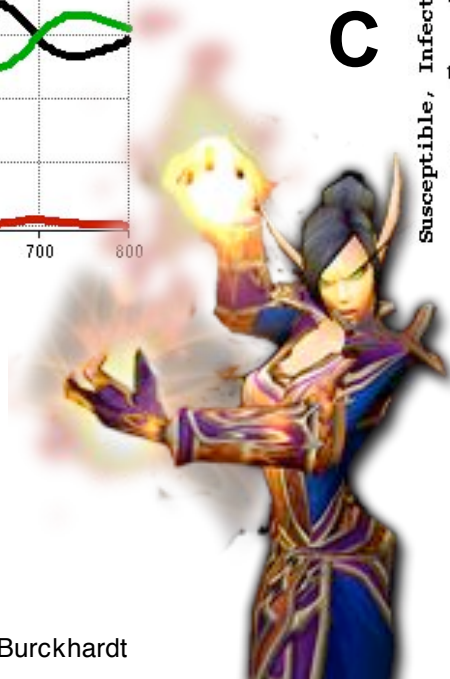


1 Infected at start  
1 contact every 2 seconds  
50% on Graveyard  
>>> Infection persists

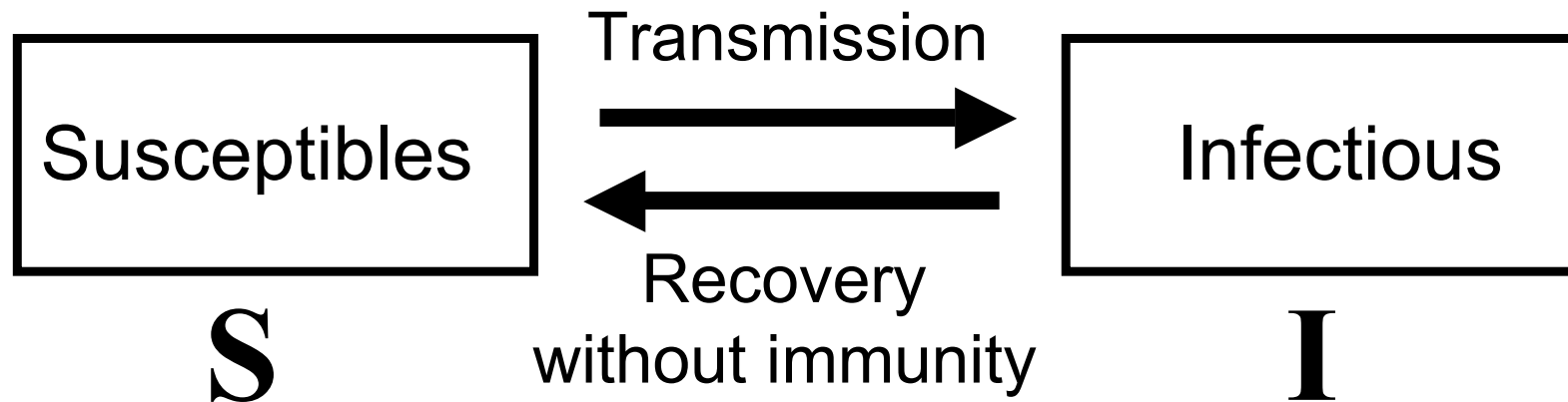
**C**



**500 Infected at start**  
1 contact every 5 seconds  
after 6mins 0% on Graveyard  
>>> Infection dies out



# High Level Avatar: SIS



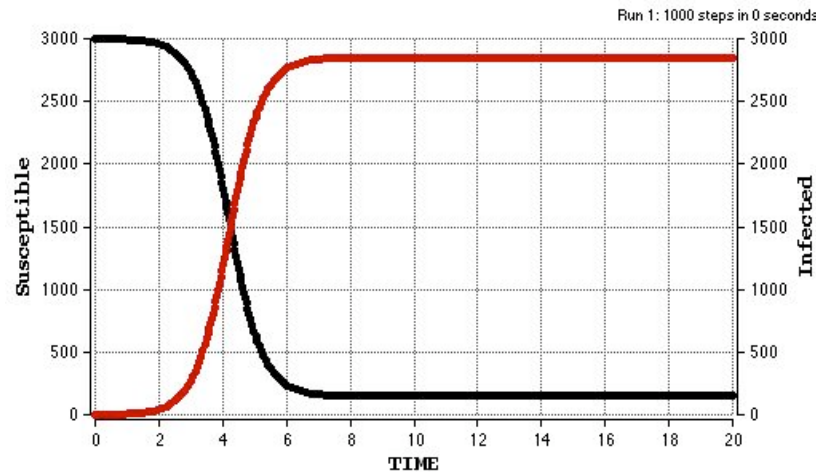
- Level 50+ Avatars are strong enough to survive „natural“ course of infection without dying first
- However, no immunity; can become reinfected
- SIS model, „classic“ sexually transmitted diseases model: syphilis, gonorrhea, chlamydia





# SIS Model (high Lv Avatar)

**A**



**Susceptible**

**Infected**

3000 Players

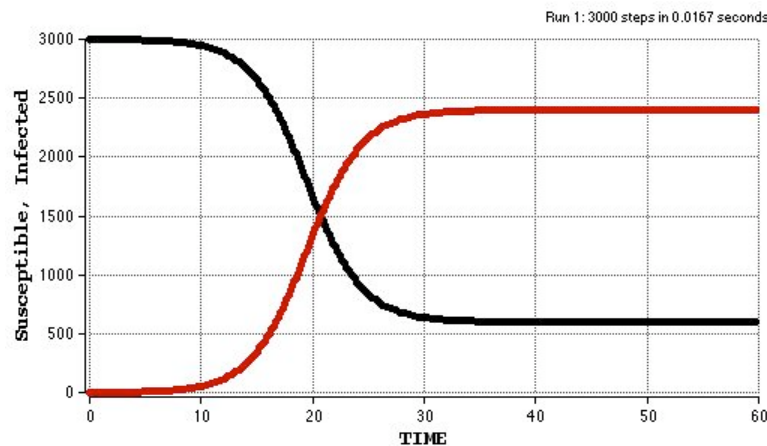
1 Infected at start

2 contacts per second

95% stay infected

>>> Infection persist

**B**



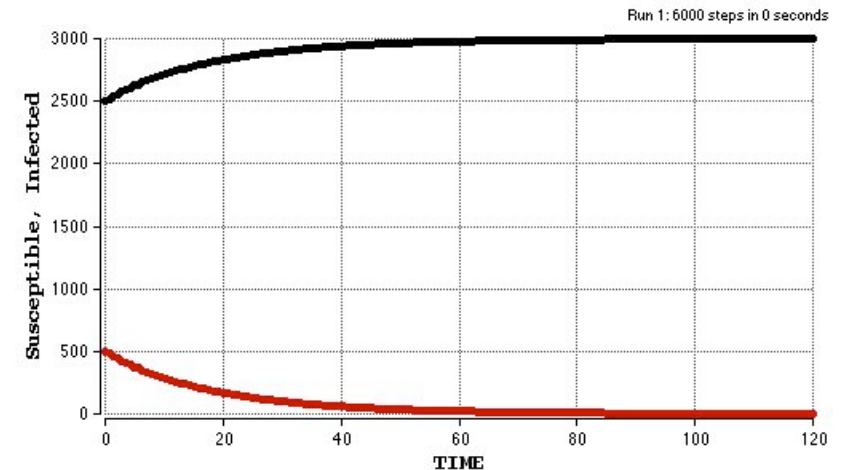
1 Infected at start

1 contact every 2 seconds

80% Infected

>>> Infection persists

**C**



**500 Infected at start**

1 contact every 20 seconds

after 2 min 0% infected

>>> Infection dies out



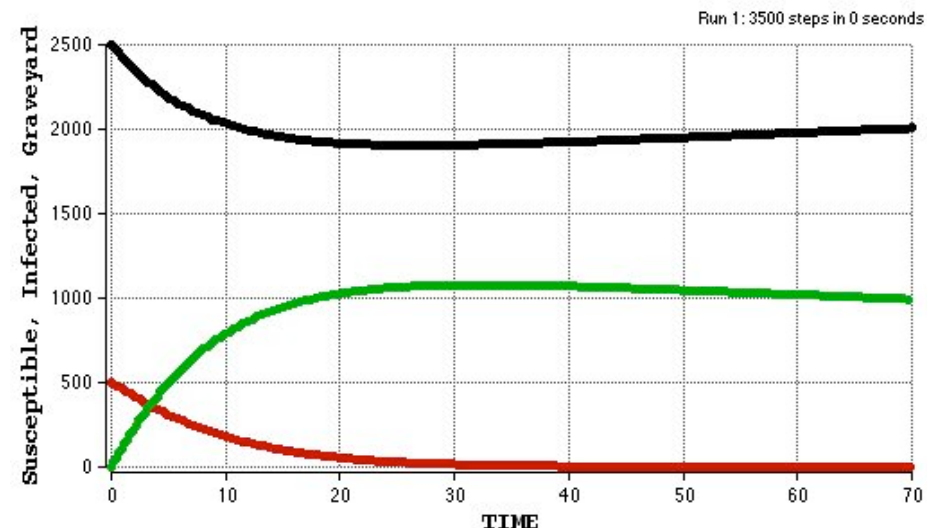
# Basic Reproductive Number $R_0$

- $R_0$  („R naught“):
  - average number of secondary infections from one single infected in a totally susceptible population
  - „how many people does one infectious person infect if everybody is susceptible ?“
- $R_0 = D \times c \times p$ 
  - D: mean duration of infectiousness
  - c: contact rate
  - p: transmission probability
- $R_0$  (CB SIS) = 10 x c x 1 (length of spell, 10s)
- $R_0$  (CB SIRS) = 4 x c x 1 (die after 4s)

# What if...

- $R_0$ : „how many people does one infectious person infect (if everybody is susceptible) ?“
- IF  $R_0 < 1$  THEN epidemic fades out
  - $R_0 \text{ (CB SIRS)} = 4 \times c \times 1 < 1$
  - $c < 1/4$

**Susceptible**  
**Infected**  
**gRaveyard**



**500 Infected at start**

1 contact every 5 seconds,  $c=1/5$   
 after 6mins 0% on Graveyard


>>> Infection dies out

# InteR<sub>0</sub>ventions

- $R_0 = D \times c \times p$ 
  - D: mean duration of infectiousness
  - c: contact rate
  - p: transmission probability
- Quarantine: reduce c
- Treatment: reduce D, p
- Airborne infections: face masks can reduce p
- Relax at home: reduce c, maybe D
- WoW:
  - social distancing, stay out of cities (or on Orgrimmar's rooftops)
  - „Healing“ made things worse by increasing D, ( $R_0$ )
  - Reload w0rld (VR only...?)



# $R_0$ of some diseases

Disease	$R_0$
Measles	15-20
Foot and Mouth Disease (FMD), UK Feb 2001	Initially 8.4; animal movement restrictions: reduced to 1.3
Influenza	<3
Smallpox	3-4
HIV	2-12 (! condoms: $R_0 \ll 1$ !)
Corrupted Blood (SIS) 	$D \times c \times p = 10_{\text{sec}} \times c \times 1$ 50 (city: 5 contacts per second) 1 (countryside: one every 20s)

# Is WoW an Epidemic Simulator ?

Yes	No
Largest human-agent based system	Does not model human risk behaviour, no permanent death
Huge complexity, lots of fine tuning possible	Not representative: players do not reflect general population
Intense social interaction	Lack of external validity
Human decision and behavioural choices vs. computer simulations	No disease surveillance implemented
Multiple servers allow parallel observations	Ethical approval to allow Avatar to take part in a medical trial ?
Geographical distribution of gameservers allows study of culture-dependent behaviour	

# Ideas for better virtual Epidemics I:

## Transmission Matrix

<i>infects</i> ➔	Human	Orc	Undead	Tauren
Human	+++	+	-	+
Orc	++	+++	-	++
Undead	+++	+++	+++	+++
Tauren	++	++	-	+++

- Account for interspecies transmission
- Undead spread disease anyway...



# Ideas for better virtual Epidemics II

- Reintroduce infectiousness in WoW
- Add immunity, waning immunity (!biowarfare!)
- Add vaccination
- Add incubation period
- Race specific diseases
  - Tauren: FMD, mad cow disease
  - Orcs: orchitis
  - Humans: measles
  - Elves: otitis externa (moldy ears)
- Collect & share data!





# Links & References

- Short course on epidemiology of infectious diseases  
<http://www.imperial.ac.uk/cpd/epidemiology/>
- The untapped potential of virtual game worlds to shed light on real world epidemics, Lofgren ET, Fefferman NH, *Lancet Infect Dis* 2007; 7:625-29
- <http://www.berkeleymadonna.com/>
- Corrupted Blood, Wikipedia, accessed 16.11.2007, [http://en.wikipedia.org/wiki/Corrupted\\_Blood](http://en.wikipedia.org/wiki/Corrupted_Blood)
- Bapf
- <http://www.burckhardt.de/docs.html>
- All images taken for educational purposes only, © Blizzard Entertainment



# Onyxia says: Game On !!

Thanx to

Bapf

Peter White

Christophe Fraser

Blizzard Entertainment

