The left side of the slide features a decorative design consisting of several vertical stripes in shades of light red and pink, and a cluster of five solid red circles of varying sizes arranged in a descending pattern from top-left to bottom-right.

**A MATHEMATICAL MODEL OF
HIV/AIDS FOCUSING ON HIGH RISK
POPULATIONS IN YUNNAN, CHINA**

Brian Weinfurtner

Faculty Advisor: Rongsong Liu

OVERVIEW

- Background
 - A short introduction to HIV/AIDS
 - HIV/AIDS in Yunnan, China
- My research
 - Disease Modeling
 - My Model
- Future
 - Model Improvements
 - Long Term



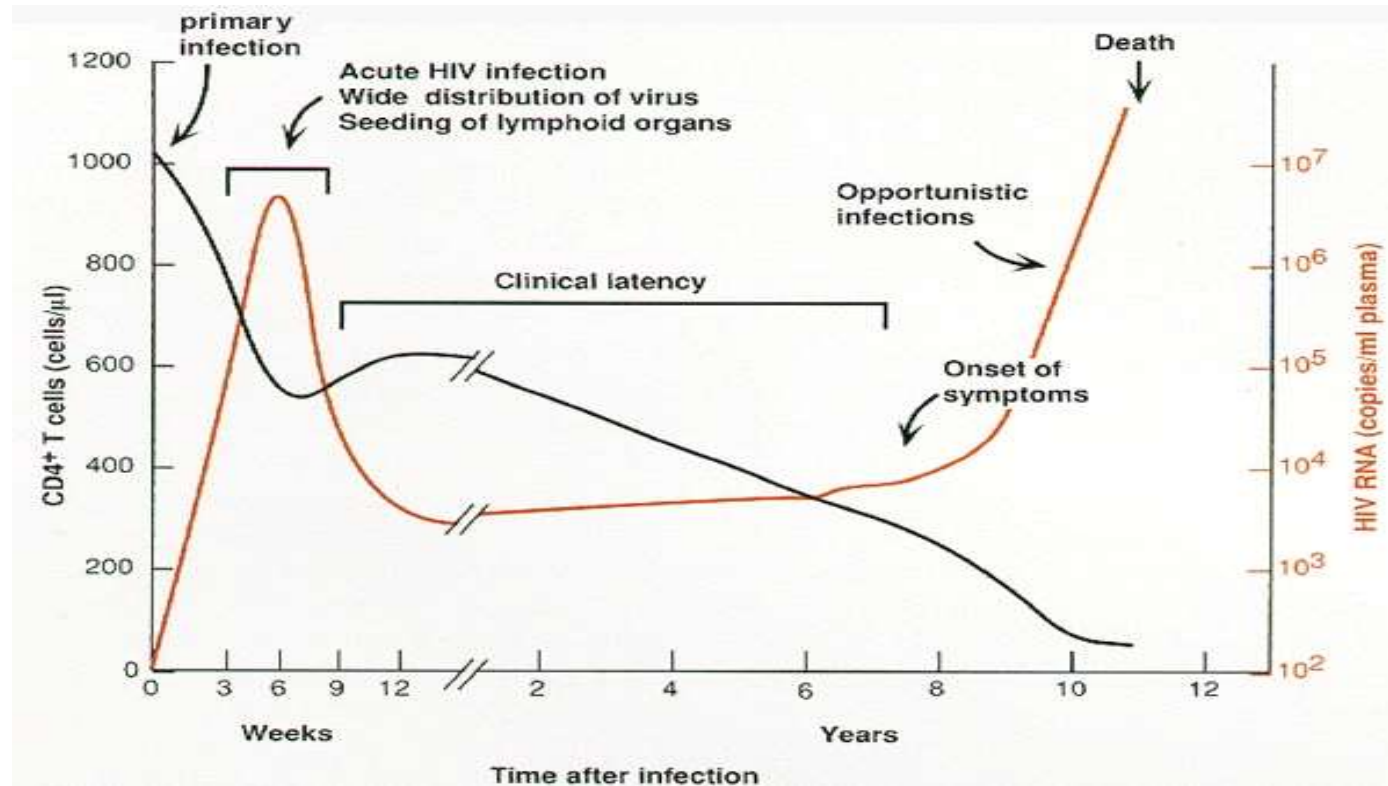


BACKGROUND

A Brief Overview of HIV/AIDS in Yunnan, China

HIV/AIDS

- HIV (**h**uman **i**mmunodeficiency **v**irus)
 - Works by attacking CD4+ T cells



Pantaleo G., Graziosi C., Fauci A.S. New concepts in the immunopathogenesis of human immunodeficiency virus infection. *N. Engl. J. Med.* 1993a; 328: 327–335.

HIV/AIDS

- HIV becomes AIDS when it reaches its final stage (CD4+T cell count of <200 per mm³ of blood)
 - **Acquired ImmunoDeficiency Syndrome**
 - Rarely causes death on its own
 - Opportunistic Infections
 - Tuberculosis
 - Hepatitis
 - Pneumonia
 - CMV
- High Risk Populations
 - Injecting Drug Users
 - Sex Workers
 - MSM



HIV/AIDS IN CHINA

- 700,000 People in China living with HIV
 - With death toll of 39,000 due to AIDS
- Yunnan, China has a high density
 - Estimated to have 50,000 people living with HIV
 - Potential Causes
 - High Number of Migratory Workers
 - Large Scale Poverty
 - Borders with Laos, Vietnam, and Myanmar
 - Part of the “Golden Triangle”



GOLDEN TRIANGLE



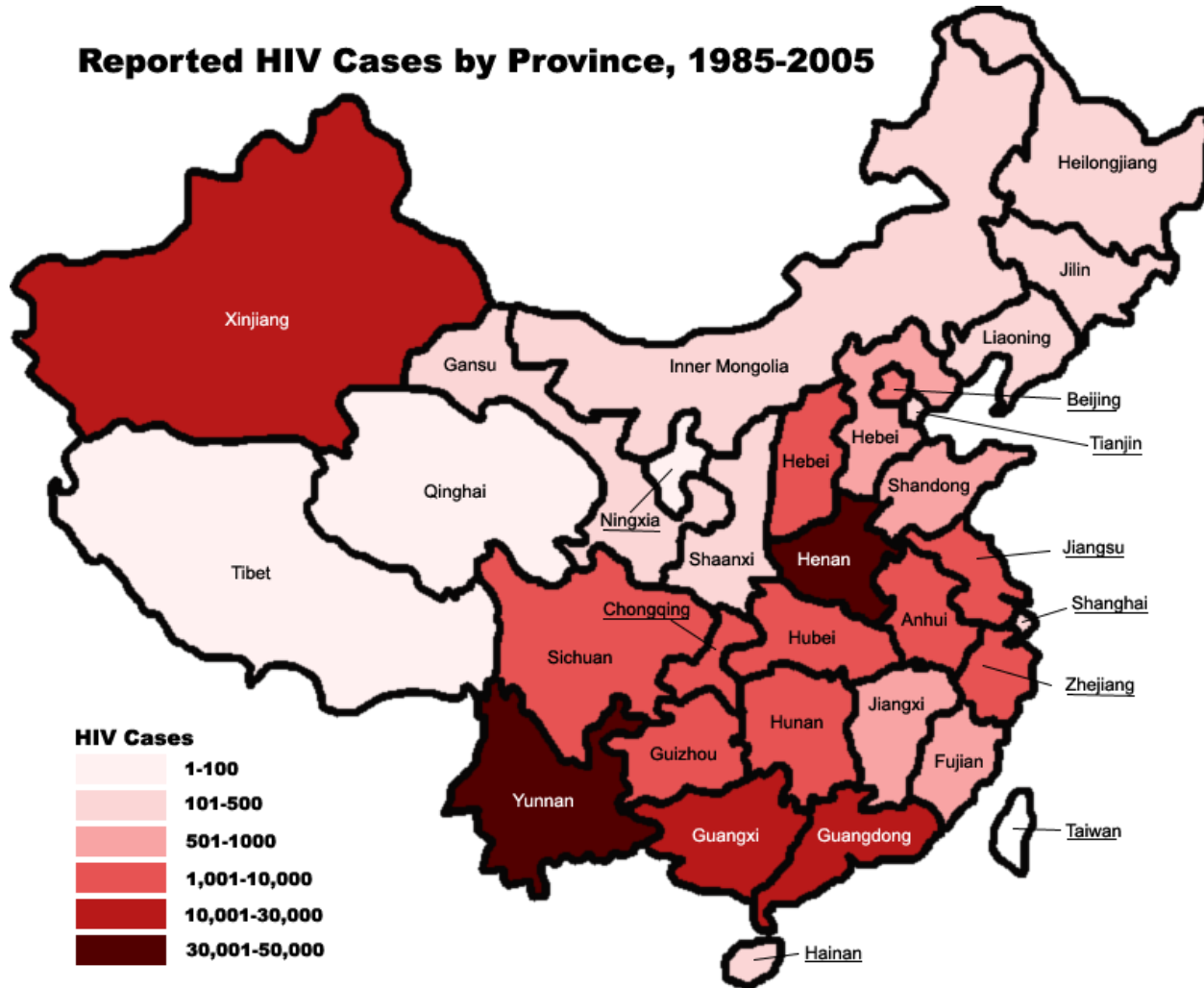
<http://news.bbc.co.uk/2/hi/asia-pacific/1768035.stm>

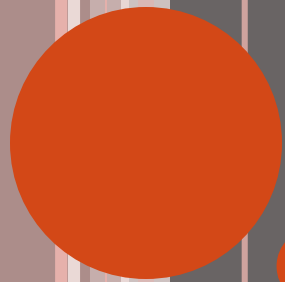
- South East Asia accounts for 424 tons of opium (UNODC)
- The area now produces 5% of the world's opiates (UNODC)
 - down from over 70% some 30 years ago
- “With high levels of poverty, the recent rapid increase in the price of raw opium and an absence of effective law enforcement, there is a high risk of a return to opium poppy cultivation in these communities of Southeast Asia”



HIV THROUGHOUT CHINA

Reported HIV Cases by Province, 1985-2005





MY RESEARCH

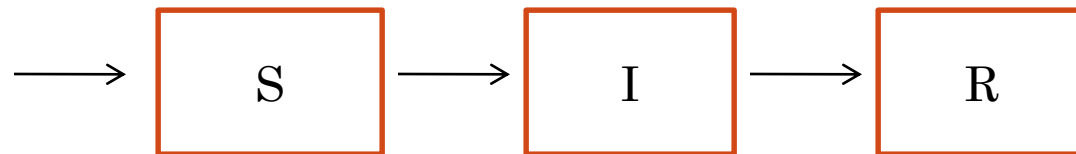
PRE-EXISTING LITERATURE

- *Compartmental Models for Epidemics*
 - Fred Brauer
- *Drugs, sex and HIV: a mathematical model for New York City*
 - S.M. Blower, D. Hartel, H.Dowlatabadi, R.M. Anderson
- *Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission*
 - P. van den Driessche, James Watmough



THE SIR INFECTIOUS DISEASE MODEL

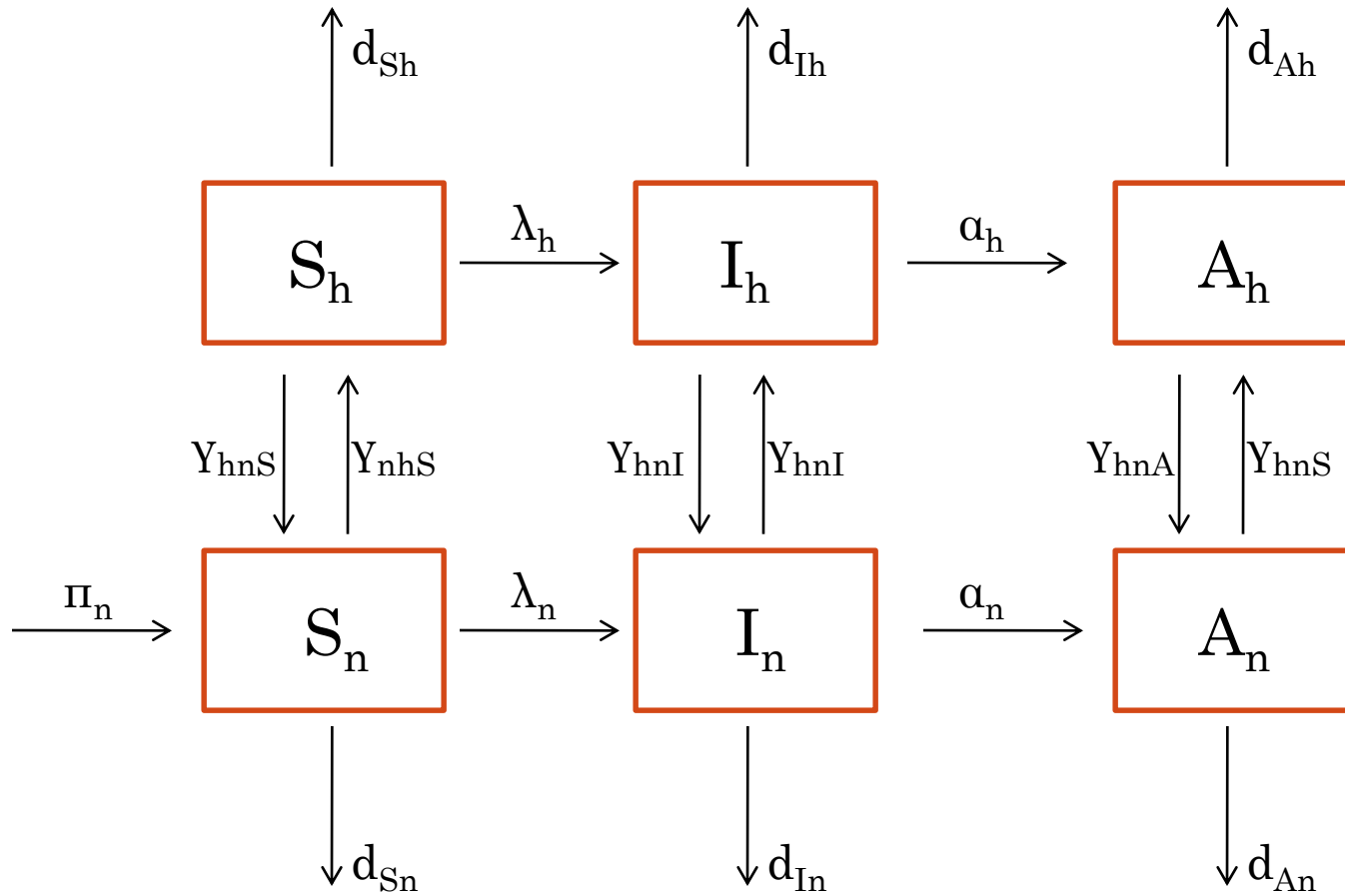
- Compartmental Model, with each compartment representing a homogenous portion of the whole population



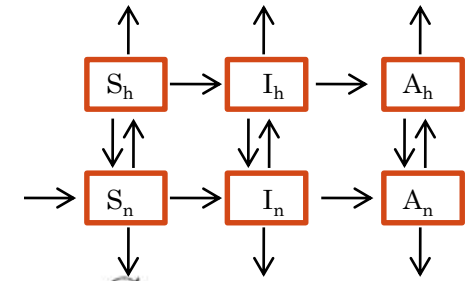
- S = Susceptible
 - Portions of the population that are at risk of obtaining the disease
- I = Infected
 - Portions of the population currently infected with the disease
- R = Recovered
 - Population that has previously had the disease, and has recovered. They are either immune or go back to the S compartment



THE FLOWCHART



SYSTEM OF EQUATIONS



$$S'_n = \pi_n + \gamma_{hns}S_h - \lambda_n - d_{sn}S_n - \gamma_{nhs}S_n$$

$$S'_h = \gamma_{nhs}S_n - \lambda_h - d_{sh}S_h - \gamma_{hns}S_h$$

$$I'_n = \lambda_n + \gamma_{hni}I_h - \alpha_n I_n - d_{in}I_n - \gamma_{nhi}I_n$$

$$I'_h = \lambda_h + \gamma_{nhi}I_n - \alpha_h I_h - d_{ih}I_h - \gamma_{hni}I_h$$

$$A'_n = \alpha_n I_n + \gamma_{hna}A_h - d_{an}A_n - \gamma_{nha}A_n,$$

$$A'_h = \alpha_h I_h + \gamma_{nha}A_n - d_{ah}A_h - \gamma_{hna}A_h$$

$$\lambda_n = \frac{\beta_{nhi}S_n I_h}{N_h} + \frac{\beta_{nha}S_n A_h}{N_h} + \frac{\beta_{nni}S_n I_n}{N_n} + \frac{\beta_{nna}S_n A_n}{N_n}$$

with,

$$\lambda_h = \frac{\beta_{hhi}S_h I_h}{N_h} + \frac{\beta_{hha}S_h A_h}{N_h} + \frac{\beta_{hni}S_h I_n}{N_n} + \frac{\beta_{hna}S_h A_n}{N_n}.$$



THE REPRODUCTION NUMBER

- R_0 is “the expected number of secondary cases produced, in a completely susceptible population, by a typical infective individual” (van den Driessche)

$$\mathcal{R}_0 = \rho(FV^{-1})$$

- Where F is the Jacobian matrix of vector of \mathcal{F}
 - With, \mathcal{F} (the rate of new infections)

$$\mathcal{F} = \begin{pmatrix} \lambda_n \\ \lambda_h \\ 0 \\ 0 \end{pmatrix}$$

- Where V is the Jacobian matrix of vector of \mathcal{V}
 - With, \mathcal{V} (the rate of transfer of individuals by all other means)

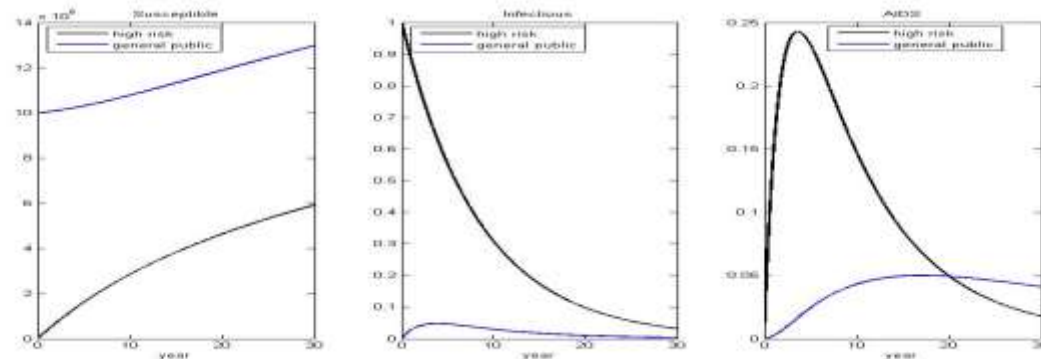
$$\mathcal{V} = \begin{pmatrix} -\gamma_{hni}I_h + \alpha_n I_n + d_{in}I_n + \gamma_{nhi}I_n \\ -\gamma_{nhi}I_n + \alpha_h I_h + d_{ih}I_h + \gamma_{hni}I_h \\ -\alpha_n I_n - \gamma_{hna}A_h + d_{an}A_n + \gamma_{nha}A_n \\ -\alpha_h I_h - \gamma_{nha}A_n + d_{ah}A_h + \gamma_{hna}A_h \end{pmatrix}$$



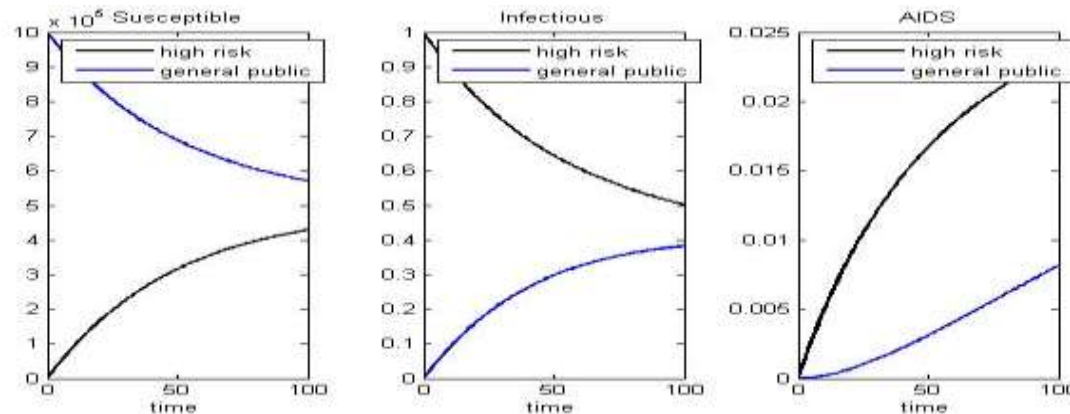
THE REPRODUCTION NUMBER CONTINUED

- Due to the complexity of our system we found it numerically (altering our β until we found appropriate graphs)

- $R_0 < 1$



- $R_0 > 1$

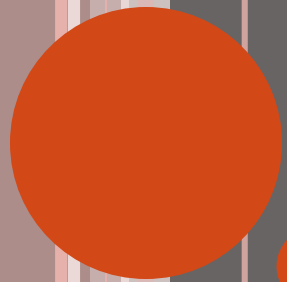


DATA

Year	1986	1987	1988	1989	1990	1991	1992	1993	1994
AIDS	0	0	0	0	2	2	2	19	38
HIV/AIDS	0	1	0	149	429	606	776	977	1393
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
AIDS	70	98	160	238	335	448	599	654	907
HIV/AIDS	2026	3554	5086	5971	7598	8946	10449	12452	14905
Year	2004	2005	2006	2007	2008				
AIDS	1223	2200	3935	7630	9752				
HIV/AIDS	28391	40157	48951	57325	63322				

From: Modeling HIV/AIDS in Yunnan, T. Zhang

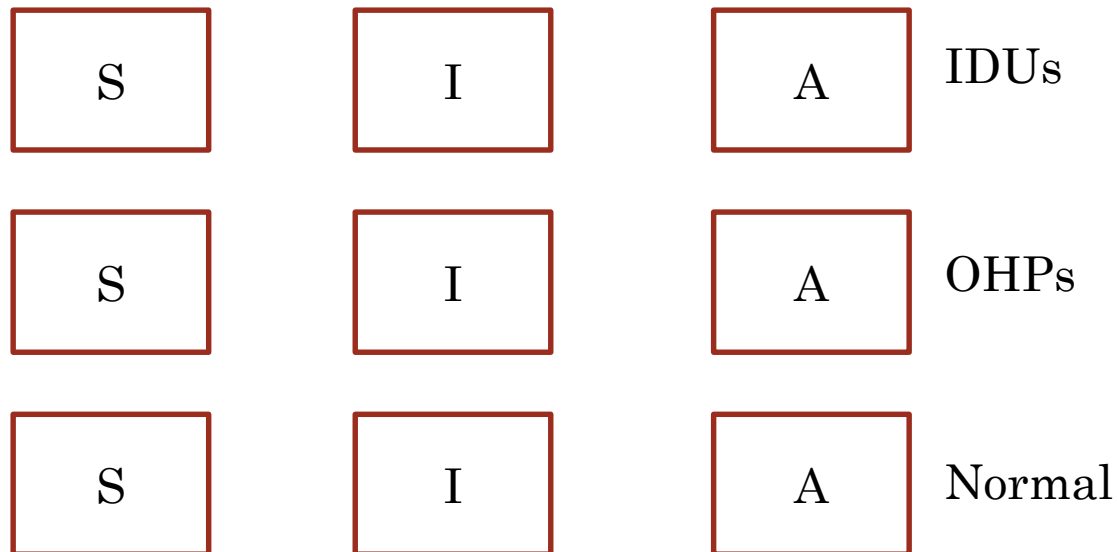




THE FUTURE

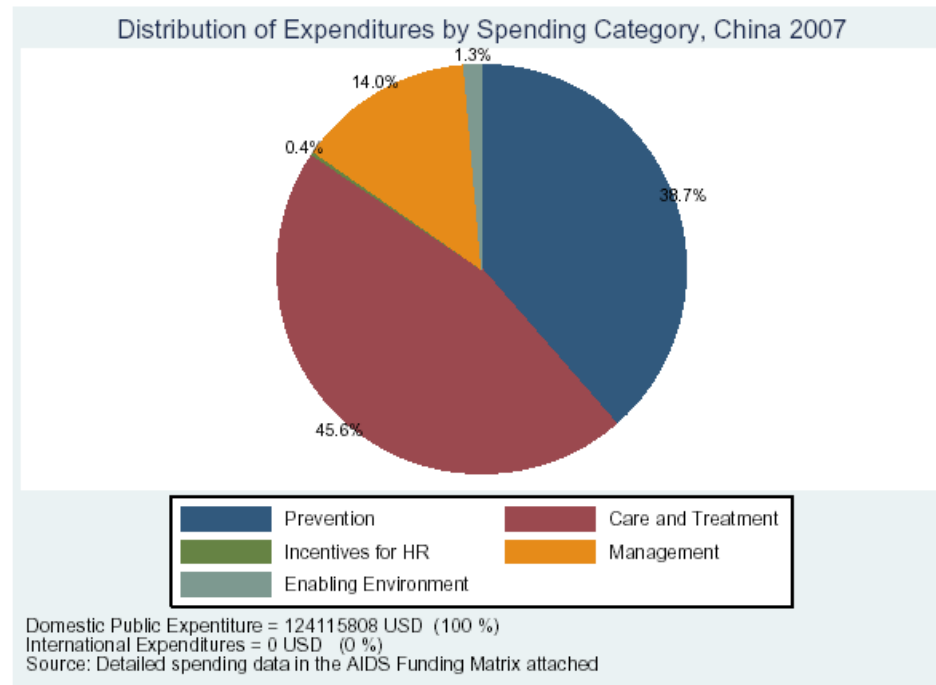
MODEL IMPROVEMENTS

- Further separation of our compartments to better fit our data
 - Injecting Drug Users (IDUs)
 - Other High Risk Populations (OHPs)
 - General Population (normal)



LONG TERM

- Come up with a recommendation of how to allocate funds to provide the most impact



From UNAIDS.org



REFERENCES (WEB)

- <http://www.unaids.org/en/CountryResponses/Countries/China.asp>
- <http://www.china-aids.org/HIV-prevalence-map4.png>
- www.cdc.gov
- www.who.int
- <http://www.unodc.org/eastasiaandpacific/en/2009/02/opium-poppy-cultivation-in-sea/story.html>
- <http://www.unodc.org/unodc/en/frontpage/drug-trafficking-in-the-golden-triangle.html>



REFERENCES (JOURNALS)

- *Compartmental Models for Epidemics*
 - Fred Brauer
- *Drugs, sex and HIV: a mathematical model for New York City*
 - S.M. Blower, D. Hartel, H.Dowlatabadi, R.M. Anderson
- *Reproduction numbers and sub-threshold endemic equilibria for compartmental models of disease transmission*
 - P. van den Driessche, James Watmough
- *New concepts in the immunopathogenesis of human immunodeficiency virus infection*
 - Pantaleo G., Graziosi C., Fauci A.S.

