
Epidemiology - Infectious Diseases
Épidémiologie - Maladies infectieuses
(Org: **Julien Arino** (Manitoba) and/et **Robert Smith?** (Ottawa))

JULIEN ARINO, University of Manitoba

On the direction of bifurcations in metapopulations

I will discuss some work with a student (Iman Soliman) concerning bifurcations in metapopulation models for the spread of infectious diseases. This work arises from considerations on a model for the spread of tuberculosis, which I will briefly describe. The underlying mathematical issue here is the possibility of extending knowledge of the bifurcation behaviour at the level of a single population to that at the level of ensembles of populations.

LYDIA BOUROUBA, Massachusetts Institute of Technology

Contact and transmission

Despite major efforts aimed at the mathematical modelling and mitigation of infectious diseases, the fundamental mechanisms of contact and transmission remain poorly understood even for the most common infectious diseases. However, the nature of the contacts between infected and non-infected members of a population are critical in shaping the larger-scale outcome of an epidemic. I will discuss recent works in which a combined theoretical and experimental approach is aiming at shedding light on the nature of contact and mechanisms of transmission of infectious pathogens.

CAMERON BROWNE, University of Ottawa

Within-host virus model with age-structure in the infected cell compartment

Age-since-infection structure is added to the infected cell compartment of a standard within-host virus model in order to account for heterogeneity in the infected cell life cycle. We provide a global analysis of the model. The analysis is complicated by the fact that the underlying state space for the model is infinite dimensional. We formulate the model as a Volterra integro-differential equation coupled with an ODE and study the nonlinear semigroup generated by the family of solutions. The basic reproduction number, R_0 , is calculated. When $R_0 < 1$, the infection-free equilibrium is globally asymptotically stable. The semigroup is found to be asymptotically smooth, which allows us to establish uniform persistence when $R_0 > 1$. A Lyapunov functional is then utilized in order to prove global stability of the unique positive equilibrium in the case of $R_0 > 1$. As an application of the model, we provide insight into recent experimental results pertaining to the CD8⁺ immune response in HIV infected individuals.

SHANNON COLLINSON, York University

Mass media effects on influenza infection

Media reports affect social behaviour during epidemics and pandemics. Changes in social behaviour, in turn, affect key epidemic measurements such as peak magnitude, time to peak, and the beginning and end of an epidemic. The extent of this effect has not been realized. We have developed mathematical models of various scenarios to be considered during epidemic influenza based on a Susceptible-Exposed-Infected-Recovered (SEIR) model including the effects of mass media and vaccination. We have derived stochastic differential equation models for each of the different scenarios. We developed an agent based Monte Carlo (ABMC) simulation to determine the variability in these key epidemic measurements, so as to provide some insight in to the effects of mass media on epidemic data.

This is joint work with Jane Heffernan of York University.

ELSA HANSEN, Harvard School of Public Health
The mathematics of in vitro culture for Plasmodium

There are many different species of malaria that are known to infect humans. Establishing a continuous in vitro culture system for these parasites in human blood is important because it allows human malaria infection to be studied in a controlled setting. Although there exists a robust culturing system for *Plasmodium falciparum*, there are important *Plasmodium* species that can still not be cultured in vitro in human blood. In this talk I will show how a mathematical model can be used to explain patterns in data from culture experiments and also identify properties of specific *Plasmodium* species that can be exploited in order to develop a continuous culture system.

JANE HEFFERNAN, York University
Vaccination programs against sexually transmitted diseases

A main goal of a vaccination program is to interrupt pathogen transmission so as to eradicate the disease from the population in the future, and/or to decrease mortality and morbidity due to the disease in the short term. For sexually transmitted diseases (STD) the determination of an optimal vaccination program to achieve these goals is not straightforward. First, heterogeneity in transmission exist between genders and by age. Also, gender differences in demographics exist, and vertical transmission to the neonate can occur, affecting future generations. Finally, the existence of pathogens closely related to the STD in question (i.e. herpes - HSV-1 vs. HSV-2) may induce immunity in individuals that render a vaccine ineffective. In this talk, we will present some models of sexually transmitted infections (including age structure and gender) to evaluate the cost-efficacy of vaccination programs for different sexes in the context of STD control, with special application to a potential genital herpes vaccination program. We find that the stability of the system and the ultimate eradication of the disease depend explicitly on the reproduction number. In general, the models show that a female-only vaccination program provides a greater reduction in disease prevalence in the population.

NATHAN MCCLURE, Queen's University
Slowing evolution is a more effective means of managing antimicrobial resistance than enhancing drug development

The evolution of drug resistance is a serious impediment to the successful control of many microbial diseases. In principle there are two ways in which this problem might be addressed – (i) enhancing the rate at which new drugs are brought to market, and (ii) slowing the rate at which resistance to currently used drugs evolves. We present a modeling approach based on queueing theory that explores how interventions aimed at these two facets of the problem affect the ability of the entire drug supply system to provide service. Analytical and simulation-based results show that, all else equal, slowing the evolution of drug resistance is more effective at ensuring the adequate availability of effective drugs than is enhancing the rate at which new drugs are brought to market. This lends support to the idea that evolution management is not only a significant component of the solution to the problem of drug resistance, but it is in fact perhaps the most important component.

CARLEY ROGERS, University of Ottawa
Improving HPV vaccination programs across Canada

The human papillomavirus (HPV) infection can develop into several types of cancers including cervical, anal, head and neck. To combat this negative impact on the health of Canadians a country wide vaccination program was launched in 2007. However, vaccinations are under provincial mandates allowing for each province or territory to develop their own programs. Across the country these programs differ by 1) the age the vaccine is given to the girls, 2) the number of doses provided and 3) the proportion of the population that is vaccinated every year. These differences could determine the success or failure of a program. We develop an ODE model to determine the effect of each provincial program on the epidemic as well as suggest ways to improve strategies to further reduce the impact of HPV on the health of Canadians.

ROBERT SMITH?, The University of Ottawa

Controlling Malaria with Indoor Residual Spraying in Spatially Heterogeneous Environments

Indoor residual spraying – spraying insecticide inside houses to kill mosquitoes – has been one of the most effective methods of disease control ever devised, being responsible for the near-eradication of malaria from the world in the third quarter of the twentieth century and saving tens of millions of lives. However, with malaria resurgence currently underway, it has received relatively little attention, been applied only in select physical locations and not always at regular intervals. We extend a time-dependent model of malaria spraying to include spatial heterogeneity and address the following research questions: 1. What are the effects of spraying in different geographical areas? 2. How do the results depend upon the regularity of spraying? 3. Can we alter our control strategies to account for asymmetric phenomena such as wind? We use impulsive partial differential equation models to derive thresholds for malaria control when spraying occurs uniformly, within an interior disc or under asymmetric advection effects. Spatial heterogeneity results in an increase in the necessary frequency of spraying, but control is still achievable.

ROBERT SMITH?, The University of Ottawa

A mathematical model of Bieber Fever: the most infectious disease of our time?

Recently, an outbreak of Bieber Fever has blossomed into a full pandemic, primarily among our youth. This disease is highly infectious between individuals and is also subject to external media pressure, further strengthening the infection. Symptoms include time-wasting, excessive purchasing of useless merchandise and uncontrollable crying and/or screaming. We develop a mathematical model to describe the spread of Bieber Fever, whereby individuals can be susceptible, Bieber-infected or bored of Bieber. We analyse the model in both the presence and the absence of media, and show that it has a basic reproductive ratio of 24, making it perhaps the most infectious disease of our time. In the absence of media, Bieber Fever can still propagate. However, when media effects are included, Bieber Fever can reach extraordinary heights. Even an outbreak of Bieber Fever that would otherwise burn out (driven by fans becoming bored within two weeks) can still be sustained if media events are staggered. Negative media can reign in oversaturation, but continuous negative media (the Lindsay Lohan effect) is the only way to end Bieber Fever. It follows that tabloid journalism may be our last, best hope against this fast-moving and highly infectious disease. Otherwise, our nation's children may be in a great deal of trouble.

HUAIPING ZHU, York University

Bifurcations and Complex Dynamics of an SIR Model with the Impact of Hospital Resources

In this talk, I will present an SIR model with a standard incidence rate and nonlinear recovery rate, formulated to consider the impact of available resource of the public health system especially the number of hospital beds. For the three dimensional model with total population regulated by both demographics and diseases incidence, we prove that the model can undergo backward bifurcation, saddle-node bifurcation, Hopf bifurcations and Bogdanov-Takens bifurcation of codimension 3. I shall also present and explain the bifurcation diagrams and give epidemiological interpretation of the complex dynamical behaviors of endemics due to the variation of the number of hospital beds. This study suggests that maintaining enough number of hospital beds is crucial for control of emerging and reemerging infectious diseases.