Syllabus

EPID 754: Mathematical Modeling of Infectious diseases

Credit: 3 credits

Faculty: Annelies Van Rie

Teaching Assistant: Daniel Westreich (for computer practicum only)

Time: Spring 2006, Monday, 1 – 3:50 PM

Location: Lectures will take place in McGavran Greenberg Room 2304 ; practical sessions will either take place in Room 2304 or in Room 2308 (computer lab).

Purpose of the course: This course addresses the key concepts of mathematical modeling of infectious diseases, as well as its applications to the study of specific infectious diseases. The course will focus on the role epidemiologists play in mathematical modeling, and help students discover how mathematical models help us understand the spread of infectious pathogens through dynamic populations. In addition to developing a firm understanding of the basics of mathematical modeling theory, students will explore existing mathematical models in practical computer lab sessions. Students will learn to determine the key parameters involved in the spread of pathogens, and the impact of changes in these parameters, discuss the public health and social ramifications that each model and its results carry, and discuss how they are related to cure, prevention or policy-making at large. Through discussions of published papers, students will learn how to critically evaluate a modeling paper and how to communicate modeling results to readers of scientific journals as well as policy makers.

Course objectives:
At the successful completion of the course, the student will:

- Have knowledge and understanding of the terminology, concepts and methods of mathematical modeling of infectious diseases.
- Be knowledgeable of the main areas in infectious diseases where mathematical modeling has contributed to our understanding
- Have better analytic skills to study the epidemiology of infectious disease on a population level.
- Be able to understand and critically read a mathematical modeling paper in all its aspects (methods, results, discussion).

Major content areas:

- Methodology: classic epidemic and endemic model, static and dynamic aspects of eradication and control, heterogeneity
- Applications: TB, STD, HIV, malaria, smallpox, onchocerciasis.

Course format:
There are 13 three-hour classes. In general, the first half of each 3-hour session will be lecture format, while the other half will be used for computer practical or paper discussion.

Reading materials:
Texts that will be used in class will be made available at the start of the semester. Texts marked as “references” and are supplementary reading. The content of these texts will not be evaluated in the exam.
All publications marked as “readings” need to be read prior to class. They will be discussed in class, either in paper discussion or as part of the computer practical.
For those students less familiar with infectious diseases, basic information on the specific disease to be covered in lectures. More information can always be found on the WHO and CDC websites. For those unfamiliar with a specific disease that will be the topic of one of the lectures, it is a good idea to read up on the basic epidemiology prior to class.
There is no required textbook. The book “Infectious Diseases of humans - Dynamics and control” by Roy Anderson and Robert May is highly recommended as a reference book.

Course grading:
Course grading is based on the following:

- Test (modeling theory) : max 30 points
- Mid-term exam (critical review of modeling paper): max 20 points
- Performance in computer practical/paper discussion: max 10 points
- Final: choose between modeling project (max 40 points) or paper discussion (max 20 points)

Possible grades are
Fail: grade less than 50 points
Low pass: grade 50 to 59 points
Pass: grade 60 to 79 points
Honors: grade 80 or above

Midterm

The midterm is based on a presentation of one (primary paper) and discussion of 2 (primary and secondary paper) selected among 6 publications on smallpox. The oral presentation is prepared in small groups, the discussion is individual, written work. Grading is based on the written discussion.

- Kaplan EH, Craft DL, Wein LM. Emergency response to a smallpox attack: the case for mass vaccination. PNAS 2002;99:10935-10940
- Bozette SA, Boer R, Bhatnagar V et al. A model for smallpox vaccination policy. NEJM 2003;348:416-425 (plus online supplement)
- Halloran MF, Longini IM, Nizam A, Yang Y. Containing bioterrorist smallpox. Science 2002; 298:1428-1432.
- Meltzer MI, Damon I, LeDuc JW, Miller JD. Modelling potential responses to smallpox as a bioterrorrist weapon. Emerg Infect Dis 2001;7: 959-969.
- Kretzschmar M, van den Hof S, Wallinga J, van Wijngaarden J. Ring vaccination and smallpox control. Emerging infectious diseases 2004; 10:832-841
- S Del Valle, Hethcote H, Heyman JM, Castillo-Chavez C. Effects of behavioral change in a smallpox attack model. Math Biosciences 2005; 195:228-251.

You will:

- Define the research questions of the primary and secondary paper
- Discuss and present the model structure of the primary paper (if possible)

- Identify potential problems with assumptions, model structure or parameter selection of the primary paper
- Identify strength and weaknesses of the primary paper compared to the secondary paper
- Discuss the accessibility of the writing and model presentation for epidemiologists / public health leaders
- Discuss the relevance to public health of the two papers

The selection of papers needs to be communicated to me by March 6

The work is to be presented on March 26, 2007

Final

Model final (group work): creation and presentation of a model to address the consequences of increasing urbanization on the dynamics of an infectious disease (you can choose a disease of interest) in developing world (you can choose a country of interest):
You will

- Establishing the research question
- Address the public health relevance of the research question
- Construct a model structure to address the research question
- Collect data to define parameters
- Write the key mathematical formulas for the model.

Paper discussion final (individual work): discussion of modeling paper of choice.

You will:

- Define the research question addressed by the author
- Address the public health relevance of the research question
- Identifying potential problems with assumptions, model structure or parameter selection
- Identify the strengths and weaknesses of the paper
- Address if and how this paper informed public health decision makers

The work is to be presented on April 24, 2007.

Lecture schedule:

Jan 22 (Van Rie): Introduction

Lecture

- Introduction to the class
- Why model
- Infectious disease epidemiology terminology
- Mathematical modeling terminology
- Historic milestones.

Practicum.

Discussion and analysis of the text: Epidemic disease in England – The evidence of variability and of persistency of type. The Lancet 1906, I, 733-739.

Reference.

LA Pirofski, A Casadevall. The meaning of microbial exposure, infection, colonization and disease in clinical practice. The Lancet Infectious Disease 2002; 2:628-635.

Jan 29 (Van Rie): The classic epidemic model.

Lecture. The classic epidemic model

Practicum. A simple measles model part I. (Computer practical)

Reference.

HW Hethcote. The mathematics of Infectious Diseases. Society for Industrial and applied mathematics 2000; 42: p 599-635. (Note: reading for class is page 599-612)
Koopman J. Modelling Infection transmission. Ann. Reviews Public Health 2004,25:303-26.
Black FL, Singer B. Elaboration versus simplification in refining mathematical models of infectious disease. Annual Reviews Microbiology 1987; 41: 677-701

Feb 5 (Van Rie) The classic endemic model and complications to the classic models

Lecture: The classic epidemic model and complications to classic models

Practicum. A simple measles model part II. (Computer practical)

Reference. HW Hethcote. The mathematics of Infectious Diseases. Society for Industrial and applied mathematics 2000; 42: p 599-635. (Note: The reading for class is page 612-635)

Feb 12 (Van Rie) Properties of the classic models

Lecture:

- Properties of the classic models
- Sustained oscillations
- Analysis of seroprevalence data and their application

Practical. Analysis of seroprevalence data and calculation of average age of infection.

Feb 19 (Van Rie) Modeling Vaccine preventable diseases and the WAIFW matrix

Lecture. Modeling vaccine preventable diseases and contact patterns

Practical: Measles eradication. (Computer practical)

Reference Schere A, McLean A. Mathematical models of vaccination. British Medical Bulletin 2002; 62:187-199

Feb 26: exam

- **Part 1: theoretical exam**
- **Part 2: design compartments for an infectious disease model**

March 5 (A Lloyd): Network modeling

Lecture: network and small community modeling

Reading for paper discussion: to be announced

Reference: Lloyd, A.L. & Valeika, S. (2006). Network Models in Epidemiology: An Overview. In: *Complex Population Dynamics: Nonlinear Modeling in Ecology, Epidemiology and Genetics*, B. Blasius, J. Kurths and L. Stone (eds.), World Scientific.

March 12: Spring break, no class

March 19 (Van Rie) Population heterogeneity and Sexually Transmitted Disease modeling

Lecture: modeling population heterogeneity and SDTs

Readings for paper discussion
Rapatski B, Suppe F, Yorke JA. HIV epidemics driven by late disease stage transmission. J Acquir Immune Defic Syndr 2005; 38:241-253.
Koopman JS, Simon CP. Response to Rapatski. J Acquir Immune Defic Syndr 2006; 41:677.
Rapatski B, Suppe F, Yorke JA. Reconciling infectivity estimates for HIV-1. J Acquir Immune Defic Syndr 2006; 43:253-256.
Baggaley RF, Ferguson NM, Garnett GP. The epidemiological impact of antiretroviral use predicted by mathematical models: a review. Emerging themes in Epidemiology 2005; 2:9
Desai K, Boily MC, Garnett G, Masse BR, Moses S, Bailey RC. The role of sexually transmitted infection sin male circumcision effectiveness against HIV – insights from clinical trial simulation. Emerging themes in Epidemiology 2006; 3:19

Reference
Garnett GP. An introduction to mathematical models in sexually transmitted disease epidemiology. Sex Transm Inf 2002; 78:7-12.

March 26 Midterm: smallpox modeling

April 2 (Van Rie) Modeling tuberculosis

Reading for paper discussion. Dey C, Garnett GP, Sleeman K, Williams BC. Prospects for worldwide TB control under the WHO strategy. The Lancet 1998;352:1866-1891. (plus online supplement)

Computer Practicum. A model illustrating the effects of the HIV epidemic on tuberculosis. (Paper discussion and computer practical)

April 9 (Steve Meshnick) Modeling vector borne diseases

Computer practicum. The Ross-McDonald model for malaria

Readings . To be announced

April 16 (Van Rie) Stochastic models

Computer Practicum. Onchosim, a stochastic model to study onchocerciasis

Reading for computer practicum. Plaisier AP, van Oortmarssen GJ, Habbema JD, Remme J, Alley ES. ONCHOSIM: a model and computer simulation program for the transmission and control of onchocerciasis. Comput Methods Programs Biomed 1990 Jan;31(1):43-56

Reference. Winnen M. Plaisier AP, Alley ES, Nagelkerke NJD, van Oortmarssen G, Boatin BA, Habbema JDF. Can ivermectin mass treatments eliminate onchocerciasis in Africa? Bull WHO 2002; 80:384-390.

April 24: Final: Student presentations