Syllabus

Mathematical Modeling of Infectious diseases - 2009

Credit: 3 credits

Faculty: Annelies Van Rie

Teaching Assistant for computer practicum: Sarah Radke

Time: Spring 2009, Monday, 1 – 3:50 PM

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
• Application to diseases such as TB, STD, HIV, influenza, onchocerciasis.

Course format:
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:

There is no textbook for the class. Most textbooks on mathematical modeling are too mathematically oriented for the purpose of this class.
The book “Infectious Diseases of humans - Dynamics and control” by Roy Anderson and Robert May is recommended as a reference book. Unfortunately, this book is old (published in 1991) and no revised edition has been published.
All articles listed in the syllabus are required readings, meaning that the paper has to be read by all students before the class and at least one question has to be handed it at the start of the class.

For those interested, I can always suggest additional readings, both for the methods and on the applied section of the class.

For those students less familiar with infectious diseases, basic information on the specific disease to be covered in lectures can be found on the WHO and CDC websites.

**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 15 points
- Final: modeling project : max 35 points

Grades are interpreted as follows:
- 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 a recent paper selected among 4 publications on HIV. The oral presentation is prepared in small groups, the discussion is individual, written work. Grading is based on your oral presentation (5 points), written assignment (10 points) and participation in discussions of presentation of other groups (5 points).

Papers:

The selection of papers needs to be communicated to me by Feb 18

The work is to be presented on March 31, 2007, as an informal journal club (no powerpoint). Handout of model structure is permitted.

For your written assignment you will:
- Define the research question(s)
- Discuss and present the model structure of the primary paper (if possible)
- Identify potential problems with assumptions, model structure or parameter selection of the paper
- Identify strength and weaknesses of the paper
- Discuss the accessibility of the writing and model presentation for epidemiologists / public health leaders
• Discuss the relevance to public health
For the discussion of presentation of the other groups, you will prepare a minimum of two questions on each of the other papers that were selected.

Final
Model final (group work): creation and presentation of a model investigating a model question of your choice

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.

The work is to be presented on April 21, 2007.

Lecture schedule:
Jan 12 (Van Rie): Introduction
Lecture
• Introduction to the class
• Why model
• Infectious disease and mathematical modeling terminology
• Historic milestones.

Practicum.

Jan 26 (Van Rie): The classic epidemic model.
Lecture. The classic epidemic model
Practicum. A simple measles model part I. (Computer practical)

Feb 2 (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)

Feb 9: Last years’ student presentations and group discussion on final topic
Rotavirus
Yellow fever

Feb 16 (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 23 (Radke/Van Rie) Calculating Ro

**Lecture.** The properties and methods of calculating R0

**Practical:** calculating R0 (computer practicum)

March 2: Exam

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

March 16 (Van Rie) Modeling Vaccine preventable diseases and the WAIFW matrix

**Lecture.** Modeling vaccine preventable diseases and contact patterns

**Practical:** Measles eradication. (Computer practical)

March 23 (Van Rie) Population heterogeneity and Sexually Transmitted Disease modeling

**Lecture:** modeling population heterogeneity and SDTs

**Practicum:** a simple HIV model (computer practicum)

March 30 Midterm: discussion of modeling papers

April 6 (A Lloyd): Network modeling

**Lecture:** network and small community modeling

**Reading for paper discussion:** to be announced

April 13 (Van Rie) Stochastic models

**Computer Practicum.** Onchosim, a stochastic model to study onchocerciasis


April 20: (Van Rie): Modeling tuberculosis

**Paper and computer practicum:** work by Dey C.

April 27: Final: Student presentations
Suggested additional reading (not required)


Black FL, Singer B. Elaboration versus simplification in refining mathematical models of infectious disease. Annual Reviews Microbiology 1987; 41: 677-701


<table>
<thead>
<tr>
<th>Date</th>
<th>Speaker</th>
<th>Topic Lecture</th>
<th>Practicum</th>
<th>Required readings BEFORE class</th>
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<tbody>
<tr>
<td>1/12</td>
<td>Van Rie</td>
<td>Introduction</td>
<td>Hamer paper</td>
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<td>1/19</td>
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<td><strong>Martin Luther King Day – no class</strong></td>
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<tr>
<td>1/26</td>
<td>Van Rie</td>
<td>Classic epidemic model</td>
<td>Measles comp. lab I</td>
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<td>2/2</td>
<td>Van Rie</td>
<td>Classic endemic model, complications *date BD</td>
<td>Measles comp. lab II * lab on Feb 4</td>
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<tr>
<td>2/9</td>
<td>Students &amp; Westreich</td>
<td>Last year projects</td>
<td>Discussion on final topics</td>
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<tr>
<td>2/16</td>
<td>Van Rie</td>
<td>Classic model properties</td>
<td>Seroprevalence data, age of infection</td>
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<td>2/23</td>
<td>Van Rie &amp; Radke</td>
<td>The concept of and math behind R0</td>
<td>R0 computer lab</td>
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<td>3/2</td>
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<td><strong>Exam on modeling theory</strong></td>
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<td>3/9</td>
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<td><strong>Spring break, no class</strong></td>
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<td>3/16</td>
<td>Van Rie</td>
<td>Vaccine preventable diseases, WAIFW</td>
<td>Measles comp. lab III</td>
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<td>3/23</td>
<td>Van Rie</td>
<td>Population heterogeneity, STDs</td>
<td>HIV computer lab</td>
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• Using mathematical modelling to investigate the plausibility of attributing observed antenatal clinic declines to a female sex worker intervention in Karnataka state, India. Boily MC, Pickles M, Vickerman P, et al. AIDS. 2008 Suppl 5:S149-64.  
•                                                                                                 |
| 4/6    | Llyod A          | Network and small world models                                                 | Paper Discussion           | TBA                                                                                               |
| 4/20   | Van Rie          | Tuberculosis                                                                  | Paper discussion or computer lab | TBA                                                                                               |
| 4/27   |                  | **Final: student presentations**                                               |                            |                                                                                                 |