BMA/MA 815/810 Course Syllabus

BMA/MA 815/810 – Mathematical Modeling of Infectious Diseases

Section 001/003

SPRING 2017

3 Credit Hours

Course Description

The course will focus on the simplest biological situations, namely directly transmitted infectious diseases. Discussion of more involved settings, such as indirectly transmitted diseases (e.g. malaria and other vector-borne infections) and multi-strain infectious agents (e.g. HIV and influenza) will be given, but with reduced emphasis.

The main emphasis will be on epidemiological dynamics, and the links to ecological (predator/prey) theory. The importance of evolutionary dynamics will be highlighted where appropriate.

Course Philosophy

In this course, I am hoping to interest a diverse range of people in the subject matter. As a result, I will try my best to make the course as self-contained as possible. The main thrust of the course will not delve too deeply into details of the mathematics or the minutiae of the biology, but people are free to look more closely at things that interest them.

The assessment of the course will follow a similar philosophy, and so the way in which I assess your performance will depend on your background. Your project can be tailored to suit your strengths and interests, in addition to challenging you regarding new ideas.

Above all, I am more interested in the way in which you are engaged by the subject matter and approach than by whether you can prove some result or give complex details about some specific disease.

I am also open to taking suggestions if there are specific things you want to look at during the semester...

Learning Outcomes

By the end of the course, you should be able to:

- Create an appropriate model to describe a given disease transmission setting
- Explain when and why one might use a deterministic or stochastic model formulation
- Use appropriate mathematical analyses to explore model behavior
- Use appropriate simulation techniques to explore model behavior

- Explain the assumptions underlying a given model and the implications of the assumptions
- Derive alternative models to explore whether model assumptions are justified
- Fit simple models to epidemic data
- Critically evaluate studies from the primary literature

Course Structure

Two 75 minute lectures a week.

Instructors

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Phone: 919 515-1910
Office Location: Cox Hall, room 308
Office Hours: By appointment

Course Meetings

Lecture

Days: MW
Time: 1:30pm - 2:45pm
Campus: Main
Location: Cox Hall, room 306
This meeting is required.

Course Materials

Textbooks

I shall provide notes for the majority of the course. We shall also make use of the primary literature in many cases.

Please check with me before investing in any of the following...

- Anderson and May (1991) 'Infectious Diseases of Humans: Dynamics and Control' (OUP).

  Provides an introduction to both mathematical and biological aspects of the course. We shall follow the broad outline of this book.

- Diekmann and Heesterbeek (2001) 'Mathematical Epidemiology of Infectious Diseases : Model Building, Analysis and Interpretation' (Wiley).

  A more mathematically-oriented book.

- Diekmann, Heesterbeek and Britton (2012) ‘Mathematical Tools for Understanding Infectious Disease Dynamics’ (Princeton)

- Daley and Gani (2001) 'Epidemic Modelling: An Introduction' (CUP)

  Provides examples involving statistical theory and stochastic modeling.

- Keeling and Rohani (2007) 'Modeling Infectious Diseases in Humans and Animals' (Princeton).

Expenses

None.

Materials

None.

Requisites and Restrictions

Prerequisites

I aim to make this course as self-contained as possible.

This may mean some repetition for those of you who have taken mathematical biology courses before.

What mathematical machinery will we use?
• Differential equations, with more emphasis on qualitative theory (e.g. phase plane analysis, stability analysis, bifurcations, ...) than on solving ODEs. (BMA 771 material)
• Matrix theory (eigenvalues and eigenvectors)
• Stochastic models: Markov chains, branching processes, ... (BMA 772 material)
• To a lesser extent: statistical ideas, PDEs, ...

I don't expect everyone to have an expert background in all of these topics: I'm happy for you to take some results on trust, or to work with anyone who wants to know more about the material underlying these results.

An important part of the course will be for you to get simulations of the models discussed in the course up and running. So some programming experience would be useful. I will provide sample code (usually in MATLAB), and you could probably get by just with modifying that code.

Co-requisites

None.

Restrictions

None.

General Education Program (GEP) Information

GEP Category

This course does not fulfill a General Education Program category.

GEP Co-requisites

This course does not fulfill a General Education Program co-requisite.

Transportation

This course will not require students to provide their own transportation. Non-scheduled class time for field trips or out-of-class activities is NOT required for this class.

Safety & Risk Assumptions

None.

Grading

Requirements for Credit-Only (S/U) Grading

Performance in research, seminar and independent study types of courses (6xx and 8xx) is evaluated as either "S" (Satisfactory) or "U" (Unsatisfactory), and these grades are not used in computing the grade point average. For credit only courses (S/U) the requirements necessary to obtain the grade of "S" must be clearly outlined.

We will have semi-regular homework exercises, involving both pencil and paper and computer simulation/analyses

There will also be a final project, taking the form of an extended writeup discussing a collection of papers on some topic, development of a model or model-based analysis of a dataset.

Requirements for Auditors (AU)

Information about and requirements for auditing a course can be found at http://policies.ncsu.edu/regulation/reg-02-20-04.

Policies on Incomplete Grades

If an extended deadline is not authorized by the Graduate School, an unfinished incomplete grade will automatically change to an F after either (a) the end of the next regular semester in which the student is enrolled (not including summer sessions), or (b) by the end of 12 months if the student is not enrolled, whichever is shorter. Incompletes that change to F will count as an attempted course on transcripts. The burden of fulfilling an incomplete grade is the responsibility of the student. The university policy on incomplete grades is located at http://policies.ncsu.edu/regulation/reg-02-50-03. Additional information relative to incomplete grades for graduate students can be found in the Graduate Administrative Handbook in Section 3.18.F at http://www.fis.ncsu.edu/grad_publicns/handbook/

Late Assignments

Late assignments will be accepted at the discretion of the instructor. Please give advance warning if an assignment is likely to be completed after the deadline.

Attendance Policy

For complete attendance and excused absence policies, please see http://policies.ncsu.edu/regulation/reg-02-20-03

Attendance Policy

Attendance is optional but highly recommended.

Absences Policy

None.

Makeup Work Policy

None.

Additional Excuses Policy

None.

Academic Integrity

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Students are required to comply with the university policy on academic integrity found in the Code of Student Conduct found at http://policies.ncsu.edu/policy/pol-11-35-01

Academic Honesty

See http://policies.ncsu.edu/policy/pol-11-35-01 for a detailed explanation of academic honesty.

Honor Pledge

Your signature on any test or assignment indicates "I have neither given nor received unauthorized aid on this test or assignment."

Electronically-Hosted Course Components

Students may be required to disclose personally identifiable information to other students in the course, via electronic tools like email or web-postings, where relevant to the course. Examples include online discussions of class topics, and posting of student coursework. All students are expected to respect the privacy of each other by not sharing or using such information outside the course.

Accommodations for Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, student must register with the Disability Services Office (http://www.ncsu.edu/dso), 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation at http://policies.ncsu.edu/regulation/reg-02-20-01.

Non-Discrimination Policy

NC State University provides equality of opportunity in education and employment for all students and employees. Accordingly, NC State affirms its commitment to maintain a work environment for all employees and an academic environment for all students that is free from all forms of discrimination. Discrimination based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation is a violation of state and federal law and/or NC State University policy and will not be tolerated. Harassment of any person (either in the form of quid pro quo or creation of a hostile environment) based on race, color, religion, creed, sex, national origin, age, disability, veteran status, or sexual orientation also is a violation

of state and federal law and/or NC State University policy and will not be tolerated. Retaliation against any person who complains about discrimination is also prohibited. NC State's policies and regulations covering discrimination, harassment, and retaliation may be accessed at http://policies.ncsu.edu/policy/pol-04-25-05 or http://www.ncsu.edu/equal_op/. Any person who feels that he or she has been the subject of prohibited discrimination, harassment, or retaliation should contact the Office for Equal Opportunity (OEO) at 919-515-3148.

Course Schedule

NOTE: The course schedule is subject to change.

Section 1. Introduction: Background and Motivation

Background: examples of problems and issues

What is modeling? Types of models, questions that we ask of models, modeling philosophies and limitations of models

Simple models for infection and transmission processes

Section 2. Epidemic Behavior

Models for epidemics. Threshold behavior, the basic reproductive number, invasion and outbreak sizes.

Section 3. Endemic Infections

Models for endemic infections: equilibria and stability analysis. Epidemiological properties and implications for disease control: herd immunity and vaccination thresholds.

Section 4. More Complicated Transmission Processes

More complicated transmission processes: backwards bifurcations. Appropriate definition of the basic reproductive number. Seasonality in transmission and its dynamical implications.

Section 5. Heterogeneous transmission

Multi-group epidemiological models. Implications for disease control. Optimal vaccination policies must account for heterogeneities

Section 6. Stochastic Models

Invasion and endemnicity conditions reconsidered in the light of stochasticity.

Stochastic invasion theorems, final epidemic size distributions.

Importance of population size; limitations of deterministic approaches.

Bartlett's work on the dynamics of childhood diseases.

Section 7. Other Topics

We will cover some of the following:

Evolutionary issues E.g. information gained from phylogenetic trees for diseases such as HIV.

Spatial issues

Network models

Within-host models e.g. HIV dynamics, drug treatment.

Emergence of drug resistance. Antibiotic resistance, HIV.

Vector-borne diseases

Section 8. Case Studies

Included in the above…

Real world examples where modeling and statistical approaches have had a major impact. Also discuss when modeling approaches have been less successful, and why.

Decision making regarding vaccination policies, e.g. differences in rubella vaccination policy between UK and US.

UK veterinary infections: BSE/CJD, foot and mouth disease. (Examples where modelers' input has informed government policy in real time.)

HIV drug treatment dynamics.