MATH 392 – Seminar: Modeling HIV and the Immune System

Spring 2014
MWF 2:00 - 2:50 PM, Swords 321

Syllabus (1/21/14)

Instructor: Prof. David Damiano, 341 Swords, 793-2476/3374
e-mail: *ddamiano@holycross.edu* or *dbd@mathcs.holycross.edu*

Office Hours: MW 11 AM to Noon, WR 1:00 - 2:00 PM, and by appointment.

Course Home Page: `http://math.holycross.edu/~dbd/math363/math363.html`

Course Materials: (Required) *Virus Dynamics: Mathematical Principals of Immunology and Virology*, Martin A. Nowak and Robert M. May. Publisher: Oxford University Press, 2000. (Available on-line through Amazon.com. Used copies will be fine.)
(ii) There will be additional reading from Janeway's *Immunobiology*, which is available on-line through the National Institutes of Health (NIH) at:
`http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=imm.TOC&depth=2`
(search for Janeway on this page)

Prerequisites: MATH 242 and MATH 244 or permission of the instructor. (MATH 244 may be taken simultaneously.)

Intended Audience: This course is designed for upper division mathematics majors with a knowledge of mathematics through the department's intermediate level courses and an interest in applications of mathematics to biology, specifically immunology. This course fulfills the department's Applied breadth area requirement. This course also fulfills the requirement for a "project" course that must be satisfied by classes starting with the class of 2016.

Mathematical Biology and Virus Dynamics: Mathematical biology and the uses of mathematics in biology–which are not identical–have grown dramatically in the second half of the 20th century and on into the 21st century. The most well-known of these uses might be the mathematical analysis of genomic data, which has spawned a new area of research called bio-informatics. This course concerns two other important application of mathematics to biology, the spread of infectious diseases and the study of the workings of the human immune system in the presence of a pathogen. We will begin by looking at the spread of infectious diseases. This is something of a warmup for the discussion of the immune system, which is hugely complicated.

Although the ideas may be applied more generally, for example to the Hepatitis C Virus (HCV), our focus when studying the immune system will be on the Human Immunodeficiency Virus (HIV), the virus which causes Acquired Immune Deficiency Syndrome (AIDS). Of course, because of the widespread and continuing tragic impact of the AIDS epidemic, the study of HIV has received a great deal of attention in the scientific community. This has been necessary because solving the riddle of HIV has proven to be particularly difficult. Much is known about the virus and how it effects the immune system, but there is still no "cure" for AIDS. Or, more properly, current therapies, while capable of dramatically reducing a patient's viral load, cannot eradicate the virus from a patient's system. A patient on Highly Active Anti-Retroviral Therapy (HAART) can expect to be on HIV medication for life.

Our primary mathematical tools will be systems of ordinary differential equations. The sizes of human populations when considering the spread of an infectious disease and the sizes of different immune cell populations and HIV populations will be represented by time-dependent variables. The differential equations in question will be expressions for the time rates of changes, that is, the time derivatives of population variables expressed in terms of the population variables. These systems of equations are called models. In an ideal world, we would be able to solve these equations. In the real world, we don't even know values for the coefficients of the equations! However, one hopes to be able to gather enough data to use statistical techniques to estimate some of the coefficients. The number and relations between the different compartments will depend on the features of the immune system–virus interaction that we want to model.

Topics: Mathematical topics include: first order differential equations including symbolic and numerical methods of solution; systems of first order ordinary differential equations and their properties; basics of mathematical models; descriptive statistics, linear and non-linear least squares, maximum likelihood estimates, and (possibly) mixed methods for the determination of model parameters. Infectious disease topics include various models based on Susceptible-Infected-Recovered (SIR) models. Immunology topics include: innate and acquired immune system; T cell populations and phenotypes; lymph system; HIV and the viral life cycle; and the immune response to HIV. Immunological models include: models of immune cell populations in the absence of virus; models of the acute and chronic phase of HIV infection; models of infection after the onset of therapy; and models of the cytotoxic T-cell response. Laboratory topics include (all involving Matlab): computational and graphics basics; numerical solutions to first order equations and systems; and linear and non-linear least squares computations.

Class Format: Two thirds or so of the classes will be lectures. The remaining classes will be devoted to student presentations, computer labs, and guest lectures.

Assignments, hour exam and final project: There will be regular assignments including traditional mathematical homework, short oral presentations on aspects of immunology, computer labs, and a final project. Readings will come from the textbook, reserve books, and on-line sources, including research articles.

There will be a 90 minute exam (held at night) that focuses on mathematical aspects of the course. This is tentatively scheduled for the week of March 17 (day and time to be arranged).

In lieu of a final exam there will be a final project. These will be three-person team projects on a simulation and analysis of some aspect of virus dynamics of your choice. The topics may be chosen from topics suggested by our text book or other topics from the literature. The project will have several components: (i) identification of a topic (ii) a search of the literature (iii) identification of a model (iv) a model driven simulation in Matlab using current best values for parameters (v) an analysis of the simulation(s) (vi) write-up of the literature search, the model, the simulation and the analysis and (vii) an oral presentation of roughly 40 minutes in length. The last four days of the semester will be devoted to the oral presentations. The written reports will be due on the last day of reading period.

Grading: There are several components to the course grade.

Homework	30%
Computer Labs	15%
Short Oral Presentations	15%
Mid-term Exam	15%
Final Project	25%
Total	100%

Academic Honesty: The Department of Mathematics and Computer Science adheres to the College's policy on Academic Honesty, which may be found on-line in the College Catalogue. In addition, the department has formulated the attached statement intended to amplify the policy as to how it might apply in mathematics and computer science.