BMA / MA / ST 772: Biomathematics II
Spring 2019
MW 3:00 – 4:15 • 1218 SAS Hall
Course homepage: www.stat.ncsu.edu/people/gross/courses/bma772/
Moodle (for gradebook only): wolfware.ncsu.edu

Instructor: Kevin Gross (kevin_gross@ncsu.edu), 251 David Clark Labs
Office Hours: TBD

Course Text: The required course text is *An Introduction to Stochastic Processes with Applications in Biology*, by Linda J.S. Allen, 2nd edition.

Pre-requisites: BMA 771 and “elementary probability theory” are listed as pre-requisites. Although we do build on ideas from 771, it is not essential to have taken this course. Fluency with probability basics is essential. Use the pre-test given on the first day of class to determine if you need to refresh your memory on any important topics in probability. Students who need to review probability basics may wish to consult the first three chapters of Sheldon M. Ross’s *Introduction to Probability Models*, available online as an e-book from NCSU’s library.

Student learning objectives:

1. Students will construct and analyze discrete- and continuous-time Markov models. Model construction will entail formalizing interesting problems arising in the analysis of biological systems into the context of a mathematical model. Students will be able to obtain analytical results when such results are available.
2. Students will build intuition about the behavior of stochastic models by implementing and simulating models on a computer and studying output. Students will learn how simulation studies can complement formal mathematical analysis.
3. Students will understand how classic stochastic models shed light on biological phenomena such as molecular diffusion, sequence evolution, disease progression, and genetic drift. Students will learn to construct variations of classic models to pose new biological questions.
4. Students will engage and study recently published applications of stochastic models to biology in the academic literature.

Course organization and scope:

1. Discrete-time Markov chains (6 weeks)

Theory: Notation and formalism; Chapman-Kolmogorov equation; equivalence classes; transience, null recurrence, and positive recurrence; periodicity; short- and long-run behavior; convergence; single- and multi-type branching processes.

Application: Random-walk models of molecular motion; Wright-Fisher models of genetic drift; branching process models of disease progression and epidemic spread; Hidden Markov models.

2. Poisson processes (1 week)

Theory: Exponential distributions, waiting times, properties of independent exponential random variables.

Application: Foraging theory.

3. Birth-death processes and continuous-time Markov chains (6 weeks)

Theory: Notation and formalism; embedded Markov chain; forward and backward Kolmogorov equations, short-run behavior via matrix exponentiation; limit theorems and long-run behavior; simulation.

Application: Ehrenfest urn models of diffusion across a membrane; Jukes-Cantor and Kimura models of molecular sequence evolution; population dynamics; protein sliding.

4. Diffusion processes (2 weeks)

Theory: Wiener process with and without drift; Ornstein-Uhlenbeck process; Brownian increment and stochastic differential equation representation; diffusion approximations of birth-death processes.

Application: Brownian motion; diffusion approximations of Wright-Fisher models.

Grading: The final grade will be a weighted average of the homework (50%), and the two midterms (25% each). Letter grades will be assigned on a curve. +/- grading will be used. A+'s will not be awarded.

Homework: Two types of homework sets will be distributed. Pencil-and-paper problem sets will be distributed but will **not** be collected or graded. Solutions will be distributed as well. Computer simulations and more involved projects will be collected and graded. Collaboration on graded assignments is not permitted; you must work individually. Homework assignments will be announced and distributed in class, and will also be posted on the course website. Late homework assignments will not be accepted. Graded homework will be assigned approximately every other week.

Computing: Computer simulations form an integral component of this course. I will provide instruction in R, but you may use another computing language or package if you wish. For assignments that involve computing, you will need to turn in both your code and some output.

Exams: There will be one mid-term and a final. The midterm will be scheduled for either an evening or extended lecture period during the last week of February. The final will be Monday, Apr 29 from 1:00 – 4:00p (or some subset thereof). Exams will be **closed book**. You may bring one page of notes (8.5 x 11, hand-written, one side only) to each midterm Exams will not be designed to test for speed specifically, although a modest degree of fluency will be needed to perform well. The best way to prepare for exams is to study ungraded homework problems.

Attendance and absentee policy: Attendance is expected at all class sessions, and is required for exams. If you know in advance that you will not be able to attend an exam, please let me know as soon as possible.

Feedback: Feedback about any aspect of the course is always welcome and appreciated. Students will have the opportunity to evaluate the course anonymously at the conclusion of the semester.

Academic integrity: This class adheres to the University policy on academic integrity found in the Code of Student Conduct. It is the understanding and expectation of the instructor that the student's signature on any test or assignment means that the student neither gave nor received unauthorized aid.

Copyrights and use of course materials: Course materials, including class notes, labs and lectures, are intended for the sole use of students currently enrolled in BMA772. Reproduction and dissemination of course materials for purposes other than those that pertain directly to BMA772 is prohibited without the prior consent of the instructor. Audio recording of lectures is permitted, but audio recordings may be used only by students enrolled in BMA772 and may not be disseminated. Video recordings or photographs of lecture are strictly prohibited.

Statement for students with disabilities: Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653, on the web at dso.dasa.ncsu.edu. 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. 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/equalop/. 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.

Supporting fellow students in distress: As members of the NCSU community, we each share a personal responsibility to express concern for one another and to ensure that this classroom and the campus as a whole remains a safe environment for learning. Occasionally, you may come across a fellow classmate whose personal behavior concerns or worries you. When this is the case, you are encouraged to report this behavior to the NC State Students of Concern website: http://studentsofconcern.dasa.ncsu.edu/. Although you can report anonymously, it is preferred that you share your contact information so they can follow-up with you personally.