

MA800 Mathematical biology

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Course description

This course targets students majoring in both computational and biological sciences, broadly defined to include mathematical, computer science, bio-medical and environmental majors. The goal of this course is to give students an understanding of the biological-mathematical interface, and how mathematics contributes to the study of biological phenomena. Biological systems have a very high level of complexity and practically every phenomenon is the result of complex interactions between various levels of organization. To apply modeling (both mathematical and experimental models), we always simplify the natural system by making both implicit and explicit assumptions, and this course teaches students to see the hidden assumptions and understand their role in the results of model applications.

The course introduces general mathematical methods in biology, such as scaling, approximations of stochastic and individual-based biological models by differential equations, and linearization and stability analysis, using both classic and recent examples. The course covers fundamental and applied models operating at different organization levels, from processes inside individual cells to those that form ecosystems. Specific examples include: dynamics of infectious diseases (flu epidemics and AIDS), natural resource management (fisheries), forest dynamics, interacting species (resource competition, predator-prey, and host-parasite models), spatial models, enzyme kinetics, chemostat theory, and bioremediation. In this course biology students learn to formulate their specific questions in a mathematical way, while mathematics students learn what constitutes biologically relevant questions, and how to accept the high level of uncertainty that exists in biological research. A substantial part of the course will use analytical methods in concert with computer simulations, using the Mathematica software.

Syllabus

- Lecture 1.** Introduction: biological systems as complex adaptive systems. Discrete and continuous single species models.
- Lecture 2.** Age- and size- structured populations. Natural resource management, fisheries.
- Lecture 3.** Enzyme kinetics.
- Lecture 4.** Microbiological models: biodegradation and chemostat theory.
- Lecture 5.** Multi-species communities I. Competition models, coexistence.
- Lecture 6.** Multi-species communities II. Predator-prey models. Optimal foraging.
- Lecture 7.** Multi-species communities III. Host-parasite dynamics.
- Lecture 8.** Infectious diseases I. SIR models.
- Lecture 9.** Infectious diseases II. Flu epidemics, AIDS.
- Lecture 10.** Spatially-distributed models I. Conservation equation.
- Lecture 11.** Forest modeling.
- Lecture 12.** Spatially-distributed models II. Random walk and diffusion. Fick's laws.
- Lecture 13.** Spatially-distributed models III. Diffusion in biological settings.
- Lecture 14.** Fitting models to data. Optimal experimental designs.