# Mathematical Models in Life and Social Sciences
MA 432 spring 2019

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**Text:** "Modeling and Simulation in Medicine and the Life Sciences". Frank C Hoppensteadt and Charles S. Peskin, second edition 2004, Springer Verlag. (Optional)
"Mathematical Models in Biology". Leah Edlestein-Keshet, Classics in Applied Mathematics, SIAM. (Optional)

**Course web site:** http://www4.ncsu.edu/~msolufse

**Course time and location:**
Tuesday and Thursday 11.45–1.0pm
SAS Hall 2229

**Office hours:** By appointment via email.

**Midterm test date (tentative):** Thursday Mar 7th
**Final exam (project presentations):**

**Objectives:** The aim for this course is to provide fundamental skills to build and analyze mathematical models that can be applied to areas within biological (primarily) and social sciences. Building a mathematical model requires formulation of the problem including important relations necessary to answer relevant questions. The next step involves identification of the mathematical and statistical tools that are necessary to describe and analyze the model. The objective of this course is to introduce skills necessary for modeling including analysis of problem, model design, identification of the model type (focus will be on models that can be solved using ODEs), discussion of solution and analysis methods. For the latter focus will be on understanding how sensitivity analysis and parameter estimation can be used as part of this process. Techniques will be build using an examples approach, where we during the semester will discuss a number of classical model types used to study biological and social science questions. To understand the importance of modeling for analysis of data a more comprehensive example from the cardiovascular system will be introduced. For this example, we will collect our own data and analyze these using a model developed in the class. Evaluation for this course will consist of a midterm in class exam and a final project. For the latter you will work in teams and be expected to formulate a model to answer a question of your choice, set up, solve, and analyze equations. For this project you will have to present intermediate and final results in class and write a report in the form of a scientific journal publication. This course should serve both to give you an appreciation of the use of mathematics in modeling and to enhance the interest for deeper studies of some of the mathematical topics involved.

**Format:** The course will use a combination of lectures taken from the textbook "Modeling and Simulation in Medicine and Life Sciences" and student projects. During the semester we will work on smaller homework modeling tasks and a final project due during the last week of classes.

**Evaluation criteria:** The course will be graded based on a mid-term exam 20%, a final group project 40%, and homework 40%. The final project requires a mid- and a final report as well as two presentations (a midway and a final presentation). For the final presentation, each student will receive a question that has to be answered during the presentation – the answer to this question will be graded individually. The final presentation will run during the last week of classes and during the exam-period. In addition, you will receive numerous homework problems that will account for 40% of the grade and a midterm exam that will account for 20% of your final grade.

**Homework:** Unless discussed in class, homework assignments must be typed. An un-typed homework will result in a deduction of 10% of the grade for that homework. Homework handed in late will be deducted 5% per day it is late. I expect that all equations are typed using an equation editor in word or latex. Equations should be numbered and all symbols should be explained. If literature is cited, complete citation record should be added at the end of the homework. For group homework – all students in a given group will receive the same grade.

**Topics covered:**

1. About modeling

2. Model development and analysis
   a. Model diagram
   b. Systems of differential equations
   c. Qualitative analysis (phase plane analysis)
   d. Quantitative analysis (numerical solution of model equations)
   e. Sensitivity analysis
   f. Subset selection
   g. Parameter estimation

3. Population and disease dynamics
   a. Exponential and logistic growth models
   b. Predator prey models
   c. SIR models
   d. ….

4. Within-host models
   a. Cardiovascular models
   b. Immune system models
   c. Neural models
   d. …

**Project:** The work for your project should be documented in a report written as a scientific paper including an abstract, an introduction, a methods section, a result section, a discussion, and a conclusion. These reports should contain the following information:

- A precise description of the questions that have to be answered by the model.
- A description in words of the system that has to be modeled. A diagram that explains the model dynamics should illustrate this description. You have to write how your system is limited and what considerations you have made to reach the limited system.
- Data has to be presented and discussed. What is shown, how are they recorded, and how can they be used in the modeling process.
- Description of the mathematical representation of the system. That is the equations representing the model, including an explanation of what all symbols mean and what units they have.
- The model parameters have to be defined, and you have to consider what possibilities you have to estimate the value of the parameters, experimentally, and/or theoretically.
- If computer programs is used it should be documented. An explanation describing how and why you have chosen specific numerical approach should be included. Your report should include a printout of your code.
- Mathematical analysis. What have you done to solve your problem analytically, and how are the equations reduced before they were solved computationally.
- Numerical analysis of the model. For example, make a sensitivity analysis showing how changes in parameters and initial data affect the model predictions, or if the project includes differential equations you may be able to show if the solution is stable and converged. The results from your model analysis have to be documented using graphs and/or tables. All figures have to be explained by clear figure legends.
- Analysis and discussion of the results seen in relation to the problem you had specified.