# EN 250. First lecture. Introduction to Quantitative Biology.

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# EN 250. Overview

*The objectives of the course include:* Create links across disciplinary boundaries, drawing math, engineering and biology together. Interest engineers in biology and give them a biological knowledge base uniquely appropriate to engineers. Provide both engineers and scientists with a series of applications of mathematics to natural systems that will stimulate and motivate students in the more detailed study of math to come later in their curriculum.

# EN 250. Project and grading

EN250 is a project-based course. Grading will be based on student projects. Projects can be done individually or in small groups. Each project will focus on one mathematical model used in biology, biomedical or environmental sciences. Students are expected to prepare a presentation introducing this selected model including 2 major components, 1 - general (history and applications), 2 - mathematical (mathematical properties, parameter identification from data, and/or computer simulations).
An example of the presentation outline:

- history of the model development
- applications of the model
- mathematical properties of the model (including some analytical properties and computer simulations)
- how to fit the model to data.

Additional example of the guidelines focused on sigmoidal growth model is attached after the syllabus.
There will be a midterm and final project presentations. The midterm presentation can be mostly focused on the model history and applications and the final presentation should be comprehensive and include original computer simulations or mathematical examination of the model.

# EN 250. Quantitative Biology Toolbox

Basic elements of modeling:

- Development of quantitative models
- Analytical investigation of models and computer simulations
- Parameterization, verification and practical application of models

Applied mathematics and statistics:

- Calculus (MA115, MA116, MA227)
- Differential Equations, ODEs and PDEs (MA221, MA227, MA360, MA361)
- Linear Algebra (MA232)
- Numerical Methods (MA346)
- Probability and stochastic modeling (MA222, MA331)

Selected topics in statistics:

- Descriptive statistics
- Hypothesis testing
- Regression analysis
- Optimal design of experiments

# Model classifications (general)

Different principles of model classification:

- Theoretical vs predictive models
- Mechanistical vs empirical models
  Example: Monod model vs Gompertz model for microbial growth
- Deterministic vs stochastic models
  Example: Deterministic Matrix Models vs Markov Chains
- Continuous vs discrete models
  Example: Von Foerster-MacKendric equation vs Leslie Matrices
- Analytically tractable vs computer simulation models
  Example: Macroscopic equations for forest growth (PPA model) vs Individual-Based Forest Simulator (LES model)
- Spatially heterogeneous vs spatially homogeneous model
  (spatial vs pointed models)
  Example: KISS model vs logistic growth model

# Model classifications (biological)

Classification of biological models:

- One temporal (spatial) scale vs multiple scales
  Example: Predator-Prey model vs Spruce Budworm Model
- One population vs interacting species and community models
  Example: Logistic model vs Predator-Prey model
- Different types of biological interactions
  Example: competition vs cooperation vs neutral models
- Structured vs unstructured population models
  Example: Von Foerster equation vs Logistic model

# Tentative course outline

Conservation laws : modeling of living organisms and element cycles

Dynamics of a single population

1. Empirical models for unstructured homogeneous populations (exponential, and sigmoidal growth models)
2. Mechanistic models for unstructured populations (resource limitation, the Monod model)
3. Discrete and continuous models for unstructured populations.
4. Age- and size- structured discrete and continuous models (Leslie matrices, Euler equations, von Foerster model)
5. Modeling of infectious diseases

Multispecies models

1. Predator-Prey models and optimal foraging
2. Competition models and coexistence
3. Host-parasite dynamics.

Interactions in space and time: spatially distributed models

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# Today presentations

1. Introduction to Mathematica. (please download the program from storage01, we will use it broadly during this semester)

# Thank you