UNIVERSITY OF SASKATCHEWAN

Department of Biology

Version: 4 Jan 2018

## COURSE SYLLABUS

| | | | |
|---|---|---|---|
| COURSE TITLE: | **Mathematical Modeling in Biology** | | |
| COURSE CODE: | BIOL 3** | TERM: | Spring 2019 |
| COURSE CREDITS: | 3.0 | DELIVERY: | Lecture & Practicum (Lab) |
| CLASS SECTION:<br>LECTURE LOCATION:<br>LECTURE TIME:<br>WEBSITE: | 01<br>Biol 125<br>10:30-11:20 am MWF<br>via PAWS/Blackboard | START DATE:<br>LAB LOCATION:<br>LAB TIME: | Jan 4, 2019<br>Biol 212<br>T 1:30-3:20 pm |

## Course Description

Mathematical modeling is the art of mathematically analyzing a real-world problem and, applied to biology, informs both experimental design and outcomes. It is fast becoming a critical component of any biologist's toolbox. This course, relying only on concepts from introductory calculus, will explore and develop a number of mathematical modeling tools in the context of biology, develop mathematical intuition into biological problems, and introduce a sophisticated mathematical software package to enable analysis.

Prerequisite(s): BIOL 120 or BIOL 121, one of MATH 110, MATH 123, or MATH 125, and 45 hours of University credit.

## Course Themes

This course will be taught using the following themes:

1. Many biological processes can be well understood by mathematical models;
2. Mathematical models reduce experimental load and enable improved experimental analysis;
3. Communicating, understanding, and utilizing mathematics are critical for modern biologists

## Learning Outcomes

On successful completion of this course, students will have demonstrated their ability to

1. To engage effectively and efficiently in problem solving, as an individual and in cooperative situations.
2. Understand and connect concepts of mathematics with biological problems
3. Communicate mathematics clearly, in writing and orally.
4. Develop creative thinking.
5. Use the tools developed in the course, including
    a. The modeling process in general
    b. Models involving proportion and geometric similarity.
    c. Graphical and analytical model-fitting; least squares.

d. Optimization problems
e. Ordinary differential equations.
f. Autonomous systems of differential equations.
g. A flexible computational package

Note: The University of Saskatchewan Learning Charter is intended to define aspirations about the learning experience that the University aims to provide, and the roles to be played in realizing these aspirations by students, instructors and the institution. A copy of the Learning Charter can be found at:http://www.usask.ca/university_secretary/LearningCharter.pdf More information on University policies on course delivery, examinations and assessment of student learning can be found at:http://policies.usask.ca/policies/academic-affairs/academic-courses.php

## Detailed Course Schedule

| Week/ Dates | Major Lecture Topics | Laboratory Activity |
|---|---|---|
| **Week 1** | Introduction to the course.<br><br>The argument for modeling in biology<br><br>Discrete time series models: single population growth in yeast; disease spread; digoxin blood concentration<br><br>Readings: Textbook Chapter 1.1-1.3<br>Blackboard material ("Can a biologist fix a radio") | Lab #1<br>Introduction to a computational package |
| **Week 2** | Discrete time series models: population dynamics: rabbits, foxes and weather.<br><br>Readings: Textbook Chapter 1.1-1.3<br>Blackboard | Lab #2<br>Discrete models |
| **Week 3** | Proportionality and linear modeling: can unicorns fly and other important questions<br><br>Readings: Textbook Chapter 2<br>Blackboard | Lab #3<br>Proportionality and linear models |
| **Week 4** | Proportionality and linear modeling: allometry, LSD, and blood flow<br><br>Readings: Blackboard material ("The Tale of Tusko") | Lab #4<br>Allometry<br><br>Learning Assessment (10%)<br>Project 1 Due |

| | | |
|---|---|---|
| **Week 5** | Model fitting. (Graphical and linear least squares)<br><br>Readings: Textbook Chapter 3<br>Blackboard material | Lab #5<br>Graphical and least squares model fitting |
| **Week 6** | Phenomenological Modeling: higher order polynomial models; harvesting and yeast culture | Lab #6<br>Phenomenological modeling<br><br>Learning Assessment (10%)<br>Project 2 Due |
| **Week 7** | Making models from thin air: dimensional analysis<br><br>Readings: Textbook Chapter 14;<br>Blackboard material | Lab #7<br>Dimensional analysis |
| **Week 8** | Making models from thin air: more dimensional analysis<br><br>Readings: Blackboard material | Lab #8<br>Dimensional analysis: experiment and analysis |
| **Week 9** | Introduction to differential equations<br><br>Readings: Textbook Chapter 11.0, 11.5;<br>Blackboard material<br><br>Learning Assessment (10%)<br>Mid-Term Examination (up to and including Dimensional Analysis) | Lab #9<br>Numerical ODE solving<br><br>Learning Assessment (10%)<br>Project 3 Due |
| **Week 10** | Continuous single population growth; birth of a growth model…(One dimensional ODE)<br><br>Readings: Textbook Chapter 11;<br>Blackboard material | Lab #10<br>Optimal caffeination modeling with ODE |
| **Week 11** | Continuous population dynamics: rabbits, foxes, and how to build in other interesting effects (Two and Three dimensional ODE systems)<br><br>Readings: Textbook Chapters 12.1-12.5;<br>Blackboard material | Lab #11<br>Population dynamics ODE systems<br><br>Learning Assessment (10%)<br>Project 4 Due |
| **Week 12** | Discrete optimization: simplex and experimental optimization | Lab #12<br>Simplex Optimization |

| | | |
|---|---|---|
| | Readings: Textbook Chapter 7.1-7.4;<br>Blackboard material | |
| **Week 13** | Discrete optimization: Numerical optimization<br><br>Readings: Textbook Chapter 7.5,7.6;<br>Blackboard material | Learning Assessment (10%)<br>Project 5 Due |
| | Learning Assessment (30%)<br>Comprehensive Final Examination during regular exam period. | |

## Course Overview & Structure:

This course consists of 3 hours of face-to-face lecture per week and a 2-hour lab in each of 12 weeks. Generally speaking, the laboratory exercises are designed to illustrate specific aspects relating to the actual computational implementation of the modeling concepts covered and serve as guided training in the basics of computer programming, data analysis, and figure making. The lectures generally motivate the theory, present the theory, and then present a real-world example of the topic being discussed. The course is built cumulatively so that modeling and computational skills learned in the first portions of the course are used throughout the remainder of the course. These skills are foundational and encountered on a day-to-day basis in modeling of biological systems, but, importantly, a course objective is to familiarize students with the language of modeling and computational biology to facilitate efficient collaboration should more complicated issues arise.

Attendance at the laboratories is required. These practical sessions provide learning activities that are essential to the achievement of the learning outcomes of the course. New content is covered in these laboratories and more skills and competencies will be acquired. Students will be responsible for some advanced reading prior to attending each laboratory session and for seeking new knowledge during the lab period. This can be from the textbook or online sources; computers are critical for this during the lab period. Students will use a computational software package to complete tasks and explore concepts, as well as search for information online. Overall, the laboratory exercises will allow students to develop their skills at translating real world problems into mathematical language, and mathematical language into software to obtain computational results. Students will work in small groups and will develop teamwork and problem-solving skills by learning from each other.

Central to the course are five projects. These projects are due throughout the semester, and cover a number of topics through a guided project handout sheet. Students are asked to work independently to analyze the project as a real-world problem, use the analytic and computational tools presented in the course to that point to come up with a solution, analyze and justify their solution, and present conclusions and further discussion. This project will be submitted as an appropriately formatted research paper, and will be evaluated with an eye towards both the correct use of skills learned in the course so far, and the analysis and discussion of the results. Prompts will be guided at first but open-ended enough to allow individual freedom to investigate any interesting phenomena discovered.

Students must arrive on time for laboratories. A student who arrives late may be penalized by a 10% deduction on the learning assessment for that lab period, and in serious cases, may even be excluded from the laboratory session by the instructor. In that case, the student will receive a grade of zero for that lab activity.

## Instructors:

**Contact Information:**

Office:CSRB 320.2 Phone: (306)966-4404  email: james.benson@usask.ca

**Office Hours:** Generally speaking, the instructors above will be available in their offices on a drop-in basis. However, please note that all instructors have other commitments that may take them away from their office. Specific appointments can be set by email or over the phone. Email responses to specific questions about course material are at the discretion of each instructor.

**Instructor Profiles & Other Information:**

## Required & Supplementary Resources

**Textbook**: FR Giordano, WP Fox, and SB Horton 2013. A first course in mathematical modeling. Brooks/Cole Cengage Learning.

Additional required readings will be posted on Blackboard at the discretion of the instructor.

**Laboratory Manual**: this will be available as a download from Blackboard.

## Grading Scheme

Overall, assessment is designed to ensure students have attained the learning outcomes for the course.

| Assessment Item | Weighting | Relevant Learning Outcomes | Due Date and Time |
|---|---|---|---|
| Mid-Term Exam | 10% of the final course grade | 1, 2, 3, 4, 5 | Refer to Course Timetable |
| Final Exam | 30% of the final course grade | 1, 2, 3, 4,5 | Refer to Course Timetable |
| Projects | 50% of the final course grade as follows:<br>10% for each project | 1, 2, 3, 4, 5 | Refer to Course Timetable |
| Laboratory Exercises | 10% of the final course grade | 1, 2, 3, 4, 5 | Refer to Course Timetable |

## Learning Assessment Details

**Mid-Term Examination:**

This individual closed book examination is designed to assess students' knowledge and understanding of the core concepts covered in the first half of the course. The exam will consist of free response questions. Please refer to your course timetable for the examination date and time.

**Final Examination:**

This individual 3 hours closed book cumulative examination is designed to assess a student's knowledge and understanding of the core concepts covered throughout the entire course. The exam will consist of free response questions. Consult the Final Exam Schedule when it is released for the examination date and time. Students who miss the final exam for a valid reason must contact the College of Arts & Science and apply for a deferred final exam. Deferred exams may utilize a different format than the regular exam. Students are encouraged to review all University examination policies and procedures:http://policies.usask.ca/policies/academic-affairs/academic-courses.php

**Project reports:**

Projects will be submitted as an appropriately formatted research paper, with title, introduction, methods/model development, results, discussion, conclusion, and reference sections. They will be evaluated with an eye towards both the correct use of skills learned in the course so far and the analysis and discussion of the results. In particular, 50% of the grade will be assessed on the correctness of mathematical analysis, 25% of the grade will be assessed on the creativity and thoroughness of the discussion and analysis, and 25% of the grade will be assessed on clarity, detail, and formatting of the exposition.

***Laboratory Exercises:***

*A major part of laboratory sessions will be the completion of assigned laboratory exercises. These will include both individual and group work that grows out of the explored topic covered that day, and will be submitted by the end of the laboratory period. Completed work will depend on the use of the computational tools developed in the course. The exercise worksheets will be assessed on completeness (33%), clarity (33%), and correctness (33%).*

## University of Saskatchewan Grading System

Students in BIOL are reminded that the University has established a grading system to be used in all of its courses. Information on literal descriptors for grading at the University of Saskatchewan (reproduced below) can be found at: https://students.usask.ca/academics/grading/grading-system.php

**Exceptional (90-100)** A superior performance with consistent evidence of

- a comprehensive, incisive grasp of the subject matter;
- an ability to make insightful critical evaluation of the material given;
- an exceptional capacity for original, creative and/or logical thinking;
- an excellent ability to organize, to analyze, to synthesize, to integrate ideas, and to express thoughts fluently.

**Excellent (80-90)** An excellent performance with strong evidence of

- a comprehensive grasp of the subject matter;
- an ability to make sound critical evaluation of the material given;
- a very good capacity for original, creative and/or logical thinking;
- an excellent ability to organize, to analyze, to synthesize, to integrate ideas, and to express thoughts fluently.

**Good (70-79)** A good performance with evidence of

- a substantial knowledge of the subject matter;
- a good understanding of the relevant issues and a good familiarity with the relevant literature and techniques;
- some capacity for original, creative and/or logical thinking;
- a good ability to organize, to analyze and to examine the subject material in a critical and constructive manner.

**Satisfactory (60-69)** A generally satisfactory and intellectually adequate performance with evidence of

- an acceptable basic grasp of the subject material;
- a fair understanding of the relevant issues;
- a general familiarity with the relevant literature and techniques;
- an ability to develop solutions to moderately difficult problems related to the subject material;
- a moderate ability to examine the material in a critical and analytical manner.

**Minimal Pass (50-59)** A barely acceptable performance with evidence of

- a familiarity with the subject material;
- some evidence that analytical skills have been developed;
- some understanding of relevant issues;
- some familiarity with the relevant literature and techniques;
- attempts to solve moderately difficult problems related to the subject material and to examine the material in a critical and analytical manner which are only partially successful.

**Failure <50**An unacceptable performance

## Integrity Defined (from the Office of the University Secretary)

The University of Saskatchewan is committed to the highest standards of academic integrity and honesty. Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the Student Conduct & Appeals section of the University Secretary Website and avoid any behavior that could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University. For more information on what academic integrity means for students see the Student Conduct & Appeals section of the University Secretary Website at: http://www.usask.ca/secretariat/index.php All students should also read and be familiar with the Regulations on Academic Student Misconduct as well as the Standard of Student Conduct in Non-Academic Matters and Procedures for Resolution of Complaints and Appeals available on the University Secretary Website.

## Examinations through Access and Equity Services (AES)

Students who have disabilities (learning, medical, physical, or mental health) are strongly encouraged to register with Access and Equity Services (AES) if they have not already done so. Students who suspect they may have disabilities should contact AES for advice and referrals. In order to access AES programs and supports, students must follow AES policy and procedures.

For more information, check [https://students.usask.ca/health/centres/access-equity-services.php](https://students.usask.ca/health/centres/access-equity-services.php) or contact AES at 966-7273 or aes@usask.ca.

Students registered with AES may request alternative arrangements for examinations. Students must arrange such accommodations through AES by the stated deadlines. Accommodation for the final exam must be made through regular AES procedures. Students who are in need of accommodation for the lab exams must present the appropriate letter from AES to the course professor. Students who require extra time or a quiet room must be prepared to make themselves available to write the lab exam on the morning prior to the regularly scheduled lab period.