

## Mathematics in medicine and physiology (MATH 3900)

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**Instructor: Alla Borisjuk**

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The goals of the class are (i) to introduce the students to a range of modern mathematical tools (from dynamical systems, stochastic processes and partial differential equations); (ii) to teach the students the skill of building tractable mathematical models of biological processes; (iii) to show how to combine the mathematical knowledge, the numerical simulations (in Matlab) and biological intuition to derive new insights into the functioning of living systems.

Mathematical topics will include introduction to linear algebra, complex numbers, geometric dynamical systems, bifurcation theory, probability, Markov chain, partial differential equations

Biological topics will include modeling heart and circulation, kidneys, circadian clocks, brain rhythms, HIV, antibiotic resistance in bacteria, regulation of gene expression, biological pattern formation

**Class time:** TBA, **Required computer lab:** Friday 11:50 or 12:55

**Prerequisites:** 2250

**Text:** Hoppensteadt, Peskin. Modeling and simulation in medicine and the life sciences, Springer, 2<sup>nd</sup> edition

+ Lecture notes based on supplementary material will be provided as necessary.

**4 credit hours** (3 lecture hours + a computer lab a week)

**Website:** [www.math.utah.edu/~borisyuk/3900.html](http://www.math.utah.edu/~borisyuk/3900.html)

**Homework:** Included with weekly lab assignments, contains both mathematical exercises and simulations in Matlab.

**Tests:** In class midterm after part II, take-home final exam.

**Grade:** labs (40%) + midterm (30%) + final (30%)

### List of topics:

- I. Introduction to mathematical models, review of ideas from calculus and ODEs
  - Heart and circulation (ch. 1)
  - Gas exchange in lungs (ch. 2) or Kidneys (ch. 4)

~ 3 weeks. Labs: 1.12, 2.7 or 4.8 (+ exercises)

- II. Dynamical systems: geometric analysis, phase planes. Introduction to bifurcation theory. Phase oscillators, phase response curves (Supplementary material, Strogatz).

- Circadian clocks (ch. 6.1-6.2 + Supplementary material, Winfree)
- Rhythms in hippocampus or Deep brain stimulation (6.3 or Suppl. Material, Taas)
- Epidemics (Supplementary material, deVries et al.)
- HIV modeling (Supplementary material, Perelson)

~ 5 weeks. Labs: exercises ch. 6, Strogatz, deVries

III. Probability, random processes, Markov chains.

- Natural selection (8.1.1)
- Plasmids (antibiotic resistance in bacteria) (8.2.1-8.2.2)
- Regulation of gene expression (8.2.3)
- Infection spread in a small population (9.1)

~ 4 weeks. Labs: Exercises ch. 8, 9

IV. Introduction to partial differential equations

- Reaction-diffusion equation, patterns (Supplementary material, deVries et al., Murray)

~ 2 weeks. Labs: ch. 10