

MATHEMATICS AND BIOLOGY
MATH-UA 255 and BIOL-UA 255
Syllabus

Professors Daniel Tranchina

Fall 2020

Required Textbook

Hoppensteadt, F. and Peskin, C.S. (2002), Modeling and Simulation in the Life Sciences, 2nd ed., Springer. Available online (pdf) through NYU Library Springer Link

Prerequisites

Calculus I and Introductory Biology

Week 1

The Heart and Circulation

- 1.1 Plan of the Circulation 5
- 1.2 Volume, Flow, and Pressure 7
- 1.3 Resistance and Compliance Vessels . . . 8
- 1.4 The Heart as a Pair of Pumps . . . 10
- 1.5 Mathematical Model of the Uncontrolled Circulation . . . 14

Week 2

The Heart and Circulation

- 1.5 Mathematical Model of the Uncontrolled Circulation . . . 14
- 1.6 Balancing the Two Sides of the Heart and the Two Circulations 18
- 1.7 The Need for External Circulatory Control Mechanisms 20
- 1.8 Neural Control: The Baroreceptor Loop. . . . 21

Week 3

The Heart and Circulation

- 1.9 Autoregulation 25
- 1.10 Changes in the Circulation Occurring at Birth 28
- 1.11 Dynamics of the Arterial Pulse 33

Week 4

Gas Exchange in the Lungs

- 2.1 The Ideal Gas Law and the Solubility of Gases 76
- 2.2 The Equations of Gas Transport in One Alveolus 78
- 2.3 Gas Transport in the Lung 82
- 2.4 Optimal Gas Transport 83

Week 5

Gas Exchange in the Lungs

- 2.4 Optimal Gas Transport 83
- 2.5 Mean Alveolar and Arterial Partial Pressures 85
- 2.6 Transport of O₂ 87

Week 6

Control of Cell Volume and Electrical Properties of Cell Membranes

- 3.1 Osmotic Pressure and the Work of Concentration . . . 109
- 3.2 A Simple Model of Cell Volume Control 113
- 3.3 The Movement of Ions Across Cell Membranes . . 115

Week 7

Control of Cell Volume and Electrical Properties of Cell Membranes

- 3.4 The Interaction of Electrical and Osmotic Effects . . . 118
- 3.5 The Hodgkin-Huxley Equations for the Nerve Action Potential 124

Week 8

Control of Cell Volume and Electrical Properties of Cell Membranes

- 3.5 The Hodgkin-Huxley Equations for the Nerve Action Potential 124

Week 9

The Renal Countercurrent Mechanism

- 4.1 The Nephron. 147
- 4.2 Dynamics of Na⁺ and H₂O: Transport along the Renal Tubules 150
- 4.3 The Loop of Henle 152

Week 10

The Renal Countercurrent Mechanism

- 4.3 The Loop of Henle 152
- 4.4 The Juxtaglomerular Apparatus and the Renin-Angiotensin System 155
- 4.5 The Distal Tubule and Collecting Duct: Concentrating and Diluting Modes 157

Week 11

The Renal Countercurrent Mechanism

- 4.5 The Distal Tubule and Collecting Duct: Concentrating and Diluting Modes 157
- 4.6 Remarks on the Significance of the Juxtaglomerular Apparatus 158

Week 12

Muscle Mechanics

- 5.1 The Force-Velocity Curve 171
- 5.2 Crossbridge Dynamics 173

Thanksgiving

Week 13

Muscle Mechanics

5.2 Crossbridge Dynamics 173

Week 14

Epidemiology

Epidemics (Lecture notes to be distributed)

Endemics (Lecture notes to be distributed)

Week 15

Epidemiology

Endemics (continued)

Discussion of final exam questions

Closing remarks

Course Grades

Course grades are based on graded homework assignments, midterm and final examinations.

Each accounts for one-third of the overall grade.

Office Hours

Zoom sessions, TBA

Appointments are welcome.