MATH0026 (Biomathematics)

Year:	2018–2019
Code:	MATH0026
Old code:	MATH3307 (UG)/MATHG307 (PG)
Level:	6 (UG)/7 (PG)
Normal student groups:	UG Year 3 Mathematics degrees PG MSc Mathematical Modelling
Value:	15 credits (= 7.5 ECTS credits)
Term:	1
Structure:	3 hour lectures per week
Assessment:	90% examination, 10% coursework
Normal Pre-requisites:	MATH0009 (previously MATH1302) and MATH0011 (previously MATH1402)
Lecturer:	Prof A Zaikin

Course Description and Objectives

This course introduces students to biomechanics, an increasingly important branch of applied mathematics. Its focus is in the scientific study of the normal function in living systems, or, how organisms, organ systems, organs, cells, and biomolecules carry out the chemical or physical functions that exist in a living system. It also serves to reinforce students skills in mathematical modelling, a subject of importance for all students aiming to apply mathematics to other areas.

Detailed Syllabus

The course includes 9 interconnected parts:
1. We will start with simple toy mathematical models using scaling arguments and discuss the questions: How high can an animal jump? How fast can we walk before breaking into run? What is the minimal nerve speed required to make it possible for an animal to balance? What is the simplest universal model for growth of a multicellular organism? 2. Next we will consider principles of oxygen transport and animal respiration. We will discuss the questions: Why do some living systems use diffusion for respiration and some - active pumping mechanisms? How to solve diffusion and advection equations in branching networks? Why do fishes use a counter-current flow in gills for taking the oxygen from water? 3. We will discuss basics of bird flight, balance of forces and expression for an energy required to fly. We will study conditions of stable gliding, expressions for stable glide speeds and angles, mechanics of soaring and bounding flights. 4. In this part basics of electrophysiology will be studied. We will consider the cable equation and a mathematically elegant solution for action potential propagation. 5. This part is devoted to mathematical modelling of gene expression, an increasingly important branch because of the fast development of genetic medicine and synthetic biology. We will focus on how to write differential equations to describe gene expression. Additionally, we will consider how to model a simple bi-stable genetic switch to describe mechanisms of cell differentiation or a simple genetic clock. 6. Bone mechanics is the focus of this part. We will answer the questions: why is boxing with gloves safer than without? How much do our bones shorten when you stand? Why long bones are hollow? What is a simple model for bones viscoelasticity? What is a simple model of breaking bones by bending? 7. Next we consider a simple model of neural activity in brain. We will study the FitzHugh-Nagumo model and explain why a neuron can oscillate or wait in an excitable regime for an information transmission. 8. Here we focus on blood dynamics and consider main equations of blood movement. We will answer the questions: How can viscosity of the human blood be measured? Why is ESR increased in an illness? What is the model for pulse wave? What happened to famous Arturo Toscanini in 1953 when he had a memory lapse? What are Korotkoff sounds and how can we use them to measure the blood

pressure? 9. Finally, we will consider principles of chemotaxis, and explain how bacteria can communicate and form patterns.
The emphasis of the course will be on the mathematical models, and no special knowledge of Biology is required or assumed.

The emphasis of the course will be on mathematical models, and no special knowledge of Biology is required or assumed.

April 2018 MATH0026