Engineering Tripos Part IIA, 3G2: Mathematical Physiology, 2020-21

Module Leader
Dr A J Kabla [1]

Lecturers
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Lab Leader
Dr A Kabla [1]

Timing and Structure
Lent term. 16 lectures.

Aims
The aims of the course are to:

- introduce students to the key physiological functions that are necessary for a living organism,
- develop an interdisciplinary analytical approach to quantitatively describe these functions,
- provide an overview of the modelling techniques that are commonly used to understand and predict physiological processes.

Objectives
As specific objectives, by the end of the course students should be able to:

- identify the key physiological processes at play at all relevant scales, from molecules to organisms,
- apply physical, mechanical and chemical principles in the context of physiological processes,
- critically discuss the validity of underlying assumptions and check their validity,
- use mathematical and computational tools to determine and interpret model solutions.

Content
A wide variety of topics are touched upon, from biochemistry and cellular function to neural activity and respiration. In all cases, the emphasis is on finding the simplest mathematical model that describes the observations and allows us to identify the relevant physiological parameters. The models often take the form of a simple functional relationship between two variables, or a set of coupled differential equations. The course tries to show where the equations come from and lead to: what assumptions are needed and what simple and robust conclusions can be drawn.

Physical and chemical principles (4L A Kabla)

- Molecular transport, diffusion, osmotic pressure
- Chemical reactions, law of mass action, kinetics
• Enzyme catalysis, Michaelis-Menten model, cooperativity.
• Gases, partial pressures and solubility

Electrophysiology (5L M Lengyel)

• Biophysical bases of cellular electrogensis and basic ingredients of the equivalent circuit model.
• Action potential generation in neurons: Hodgkin-Huxley model.
• Phase plane analysis, reduced models, extension to bursting and pacemaking activity
• Signal propagation along dendritic and axonal projections, and across chemical and electrical synapses.

Blood Physiology (3L A Kabla)

• Blood physiology, composition
• Gas storage in red blood cells
• Blood rheology, Cason equation, flow in capillaries

Physiological transport systems (4L A Kabla)

• Circulatory system, heart, cardiac output, arterial pulse
• Vessel compliance, pulsatile flow profile
• Blood flow in capillary beds, filtration
• Respiratory system, gas exchange in the lungs, ventilation-perfusion

Coursework

Physiology of speech production.

Learning objectives:

At the end of this activity, students will be able to:

• describe how phonation occurs in humans and how vocal folds exploit a steady flow of air from the lungs to generate steady oscillations;
• model the movement of the vocal folds, from stating hypotheses to calculating numerical solutions;
• use standard numerical packages to solve non-linear ordinary differential equations.
• critically discuss the different dynamic regimes observed in the model and their significance.

Practical information:

• Sessions will take place in the EIETL, around week 3.
• This activity involves preliminary work (about 1h).

Full Technical Report:

Students will have the option to produce a Full Technical Report (FTR).

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].
UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [3] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the ‘Accreditation of Higher Education Programmes’ (AHEP) document [4] which sets out the standard for degree accreditation.

The Output Standards Matrices [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
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