T.C.
MARMARA ÜNİVERSİTESİ - FEN BİLİMLERİ ENSTİTÜSÜ
LİSANSÜSTÜ DERS ÖNERİ FORMU

DERSİN ADI	Türkçe	**Yaşam Bilimleri için Matematiksel Modelleme**
	İngilizce	**Mathematical Modelling for the Life Sciences**
Yarıyılı : Güz	Saat /Hafta (Teorik – Uygulama) : 3 / Hafta 3+0	
Dersin Dili : **İngilizce**	Program :	

Gerekçe: Evolution equations arising in the modelling of life science problems is a fascinating subject area. It is at the very heart of the understanding of many important problems arising in biology, medicine, ecology, physics and mechanics. The goal of this course is to convince the audience of this and to show the important role of applying mathematics to real world situations, and explain, in particular, experimental findings.

I hope that this course will create additional interest in life-science problems among young researchers. Moreover, we aim to show how modelling real world situations (life science problems) has a crucial impact on mathematics, creating new challenging situations for mathematics itself. In particular, we will consider the following issues.

Dersin içeriği:

Contents: 1. Mitochondria swelling in vitro, in vivo and in silico

In this study we will consider new mathematical models of mitochondria swelling scenarios which take into account, in particular, nonlocal diffusion , delay as well as spatial effects. Our aim in this study is to qualitatively understand the underlying biological mechanism of swelling scenario via mathematical modelling on the basis of effects mentioned above. From the mathematical view points these new models under considerations are coupled of ODE-PDE(partial differential equations) sytems. ODE parts describes the evolution in time of three subpopulations of mitochondria(observed in experimens) and PDE part describes calcium evolution obeying nonlinear nonlocal nonstandard reaction-diffusion equations with delay that takes into account nonlocal positive feedback with delay (time dependent accelerating effect also observed in experiments). We will consider these new classes of ODE-PDE systems in bounded domain, that play role of the test tube or whole cell depending on imposing boundary condition. It is worth to note, sofar biologically is not clarified yet, whether the mitochondria located around the nucleus less sensitive to calcium signal than the mitochondria located around of the cell membrane. Furthermore we will interested in to understand both partial and complete mitochondria swelling scenarios (observed in experimental studies) depending on location on different mitochondrial group with respect to each other. Biophysicists conjecture that, for example, in the partial swelling scenario, the remaining calcium concentration is not highly enough to trigger also swelling in the other groups, which in fact can depends also the distance between them and the delay of initiation of swelling scenario triggered by the level of calcium concentrations. We hope that mathematical models considered in this study can help to understand the swelling of mitochondria for the biologically and especially pharmologically relevant cases.

We aim to prove both the well-posedness of the models under considerations and completely describe the long-time dynamics of solutions in terms of the data of the models, which is very rare phenomena for a such class degenerate parabolic type systems(ODE-PDE coupling). We eager to explain experimentally observed partial and complete swelling scenario in dependence of boundary conditions. We believe that mathematical models considered in this study can help to understand the swelling of mitochondria for the biologically and especially pharmologically relevant cases.

2. High-intensity focused ultrasound and non-invasive treatment

The treatment methods associated with high-intensity focused ultrasound, or HIFU, have received increasing interest in recent years. HIFU allows for a non-invasive,non-ionizing treatment by thermally ablating tissue at a target location while minimally interacting with other tissue. This therapy has the potential to have a dramatic impact on the treatment of a variety of conditions and it's potential for the treatment of cancerous (and benign) tumours is only just starting to be exploited. The most obvious benefit of this novel treatment modality is its ability to destroy undesirable tissue without the risks associated with established therapies such as chemotherapy,surgery or ionizing radiation. In addition, HIFU can be used to enhance drug delivery, typically through the induction of stably cavitating bubbles or through sonoporation, which increases the cell membrane permeability to create a (transient and dynamic) physical route for impermeable agents (such as chemotherapeutic drugs) to enter certain tissue regions. In cardiology and neurology, HIFU also has the, as yet untapped potential, to be used to destroy clots in key blood vessels. Furthermore, it could be used to treat essential tremors and other neurological conditions through targeted lesions in specific areas of the brain. HIFU can also be used palliatively by killing o nerve endings in affected regions of the human body.

From a mathematical point of view, the governing equations that model HIFU interaction with soft tissue or blood are of coupled hyperbolic/parabolic type, and although a number of researchers have solved these numerically, a rigorous establishment of existence (and possibly uniqueness) has yet to be carried out.

3. Bioclogging

Biofilm growth in porous media (e.g. soils) changes the hydraulic conductivity of the medium (bioclogging) which in turn changes substrate transport and thus the living conditions (food supply) for the bacteria. This naturally occurring nonlinear phenomenon is used by engineers to devise microbially based technologies for groundwater protection and soil remediation. We derived bioclogging models that accounts for spatial expansion of the bacterial population in the soil. In contrast to previous existing models, we allowed the bacteria to move into neighboring sites if locally almost all of the available pore space is occupied and the environmental conditions are such that further growth of the bacterial population is sustained. This is described by a density-dependent, double degenerate diffusion-equation that is coupled with the Darcy equations and a transport-reaction equation for growth limiting substrates. We conducted computational simulations of the governing differential equation system, which illustrates some qualitative properties of the mathematical models, namely to show that bioclogging can induce preferred flow paths in the porous medium where, living conditions on more favourable for the microbs.

4. Multicomponent biofilm models

We are interested in the disinfection process in spatially structured irregular biofilm morphologies, such as mushroom type cluster-and-channel architectures that are observed in microscopy studies. Note there are the variety of the processes that can affect the response of biofilms to antibiotics. The role of the following mechanisms on disinfection processes will be adressed:

4.1. Diffusion Résistance
4.2. Persister cells
4.3. Hydrodynamic environment
4. Quorum sensing

The goal is to provide so far missing well-posedness solution theory of the corresponding density-dependent diffusion-reaction- convection multicomponent biofilm model and its spatio- temporal dynamical behaviour for the mechanisms mentioned above.

Kaynaklar:

1) Messoud Efendiyev, Evolution Equations Arising in the Modelling of Life Sciences, Birkhauser/Springer, 2013

2) Messoud Efendiyev, Mathematical Modelling of Mitochondrial Swelling, Springer, 2018.