COURSE OUTLINE

Timetable: Tuesday, 3-4pm (weeks 3-6) and Wednesday, 9-11am (weeks 3-12)
Location: AGR 829, Carslaw Building
Lecturer: Martin Wechselberger (Room 628, Carslaw Building)
Consultation: Thursday, 1-2pm; otherwise has to be arranged via e-mail (wm@maths.usyd.edu.au)

Motivation:
Physiological rhythms are central for life. Prominent examples are the beating of the heart, the activity of neurons, or the release of hormones regulating growth and metabolism. All these rhythms have in common that they evolve on at least two different time scales, i.e. there exists a quasi steady state of the system on a slow time scale (e.g. the resting state of the heart) interspersed by a dramatic change of the system on a fast time scale (e.g. the heartbeat itself). Mathematical models of such systems are called slow/fast systems or multiple time-scales problems.

In this unit we introduce a mathematical technique suitable for analysing such multiple scales problems called geometric singular perturbation theory. The method is based on dynamical systems techniques such as bifurcation theory and invariant manifold theory. We will develop the basic mathematical tools of this theory to analyse physiological problems.

The classes of physiological problems we study are biochemical reactions and electrical signalling in excitable cells. We analyse the famous Hodgkin-Huxley model of the space clamped squid giant axon describing action potentials, the main neuronal signals. Another problem of interest is electrical signalling in pancreatic cells which leads e.g. to secretion of insulin due to bursting electrical activity.

Background:
The basic theory of differential equations and stability analysis (e.g. introduced in third year course MATH3963). Knowledge and use of computational software (e.g. Matlab, XPPAUT) is desired.

<table>
<thead>
<tr>
<th>Mathematical Topics:</th>
<th>Bioscientific Topics:</th>
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<tbody>
<tr>
<td>dynamical systems theory:</td>
<td>cell signalling:</td>
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<tr>
<td>bifurcation theory</td>
<td>neurons, pancreatic cells, etc.</td>
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<tr>
<td>invariant manifold theory</td>
<td>physiological models:</td>
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<tr>
<td>geometric singular perturbation theory</td>
<td>Hodgkin-Huxley, FitzHugh-Nagumo, etc.</td>
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Assessment: Assignments = 50%; Examination = 50%

There will be four assignments to be handed out approximately in week 4 (due in week 5), week 5 (due in week 6), week 6 (due in week 7) and week 9 (due in week 10). Unfortunately, late assignments cannot be accepted. The use of computer software (e.g. XPPAUT) will be necessary for the assignments.

References:
No single textbook is required for the course. The following references cover the different subjects of this course. You may also like to browse through other books in the SciTech Library (there is a lot of material available related to the course).

- J. Guckenheimer, P. Holmes, *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields*, Springer.