University of Fribourg
Faculty of Science and Medicine - Department of Mathematics

NEW CONTRIBUTIONS IN SYSTEMS BIOLOGY:
MULTISTABILITY OF CHEMICAL REACTION NETWORKS
MODELLING OF BACTERIAL CHEMOTAXIS
INVESTIGATION IN BACTERIAL INTERACTIONS

XAVIER RICHARD

This doctoral thesis is dedicated to several problems in applied mathematics and more precisely in systems biology, a multidisciplinary field that studies complex biological systems using mathematics through theoretical and numerical models. More specifically, this work focuses on the study of bacterial behavior by presenting new mathematical approaches for understanding and interpreting experimental data.

The first part focuses on multistability of chemical reaction networks. A program to test the possible multistability of a chemical reaction network is presented. A new analytical method to study these systems is applied to reactions corresponding to the double positive and double negative feedback loop. This method is then used to describe the self positive feedback loop. This loop is numerically added to the genome of the mobile genetic element ICE*clc* present in some types of bacteria to explain its bistability output.
The second part studies the concept of chemotaxis, and in particular, the movement of bacteria in the presence of a chemoattractant. A brand-new model of bacterial chemotaxis, based on the concept of random walk biased by the Gibbs measure, modeled using the Metropolis algorithm, is presented. This model is then applied to experimental data and compared to the classic model of Keller and Segel.
The last part of this thesis focuses on the study of two types of bacteria, *Pseudomonas putida* and *Pseudomonas veronii*, when they compete for the same nutrient source. A statistical analysis of the experimental data is first presented. These data are then compared to simulations performed with the Godot game engine.

Jury:
Prof. Dr. Christian Mazza (thesis supervisor)
Prof. Dr. Jan Roelof van der Meer (external co-examiner)
Prof. Dr. Ioan Manolescu (internal co-examiner)
Prof. Dr. Ruth Kellerhals (president of the jury)