Nonlinear Dynamics in Life Sciences
Dynamique nonlinéaire dans les sciences de la vie
(Org: **Jaques Bélair** (Montréal), **Pascal Chossat** (CIRM-Marseille), **Fahima Nekka** (Montréal) and/et **Jianhong Wu** (York))

JULIEN ARINO, University of Manitoba
Resistance to the pathogens in the vectors of a vector-host disease

I will present a model for the spread of refractoriness to a pathogen among the vectors of a vector-host disease. It is assumed that vectors can transmit refractoriness to their offspring through a non-Mendelian mechanism. The interaction of resistant and non-resistant vectors is studied, and a coexistence equilibrium is shown to exist in the absence of disease. The consequence in terms of disease dynamics is the considered.

ALAIN ARNEODO, Université de Lyon, Laboratoire Joliot Curie and Laboratoire de Physique, Ecole Normale Supérieure de Lyon, France
Low frequency rhythms in human DNA sequences: from genome-wide sequence analysis to the detection of replication origins in higher eukaryotes

We explore the large-scale compositional heterogeneity of human autosomal chromosomes through the optics of the wavelet transform (WT) microscope. We show that the GC content displays relaxational nonlinear oscillations with two main frequencies corresponding to 100 kb and 400 kb which are well recognized characteristic sizes of chromatin loops and loop domains involved in the hierarchical folding of the chromatin fiber. These frequencies are also remarkably similar to the size of mammalian replicons. When further investigating deviations from intrastrand equimolarities between A and T and between G and C, we corroborate the existence of these two fundamental frequencies as the footprints of the replication and/or transcription mutation bias and we show that the observed nonlinear oscillations enlighten a remarkable cooperative organization of gene location and orientation. When further investigating the intergenic and transcribed regions flanking experimentally identified human replication origins and the corresponding mouse and dog homologous regions, we reveal that for 7 of 9 of these known origins, the (TA + GC) skew displays rather sharp upward jumps, with a linear decreasing profile in between two successive jumps. We present a model of replication with well positioned replication origins and random terminations that accounts for the observed characteristic serrated skew profiles. We further use the singularity tracking ability of the WT to develop a methodology to detect the origins of replication. We report the discovery of 1024 putative origins of replications in the human genome. The statistical analysis of the distribution of sense and anti-sense genes around these origins strongly suggests that the origins of replication play a fundamental role in the organization of mammmalian genomes. Taken together, these analyses show that replication and gene expression are likely to be regulated by the structure and dynamics of the chromatin fiber.

HENRI BERESTYCKI, Ecole des hautes études en sciences sociales, 54 boulevard Raspail, 75006 Paris, France
Travelling waves with forced speed

This talk is concerned with reaction-diffusion equations for population dynamics of the KPP type in inhomogeneous media. Specifically, the reaction term involves a bounded "favourable zone" which is travelling with a forced speed. We first studied such a model in a joint work with O. Diekman, K. Nagelkerke and P. Zegeling, in dimension 1 to describe the dynamics of a biological population facing a climate shift. In this context, global warming is interpreted as a Northward shift of the favorable zone for a given species. The goal is to understand whether a given species is able to keep pace with the climate change and how the latter affects the population size and distribution. For the extensions to higher dimensions and more general geometries, I report on joint works with Luca Rossi. First, we establish necessary and sufficient conditions to characterize the existence of travelling waves with the same speed in all of space or in cylinder like domains. This allows one to derive

the asymptotic behavior of solutions of the evolution equation in various geometrical settings. Then, we describe problems which involve two different forcing speeds or periodic time dependence. There, one is led to pulsating travelling fronts and the dynamics is related to principal periodic eigenvalues of parabolic operators. Lastly, I will also mention different properties when the Allee effect is taken into account for which the geometry plays an important role.

SUE ANN CAMPBELL, University of Waterloo
Phase Models with Time Delay

Coupled oscillators are ubiquitous in nature and engineering, and have been a focus of intense mathematical study for over 300 years, since Huygens noticed that two pendulum clocks hung on the same wall would begin to run in perfect synchrony. Major questions still remain unanswered, however. In this talk we will consider coupled oscillators consisting of a network of neurons with time delayed connections. We show how this may be reduced to a phase model network and how the time delay enters into the reduced model. For the case of two neurons, we show how the time delay may affect the stability of the periodic solution leading to stability switching between synchronous and antiphase solutions as the delay is increased. Results for oscillators with different characteristics are compared.

This is joint work with Andrew Smith and Ilya Kobelevskiy.

TROY DAY, Queen's

FREE DISCUSSION,

OLIVIER FAUGERAS, INRIA Sophia Antipolis

BASTIEN FERNANDEZ, CNRS Aix-Marseille Université
Athermal dynamics of strongly coupled stochastic three-state oscillators

We study the collective behavior of a globally coupled ensemble of cyclic stochastic three-state systems with transition rates from state $i-1$ to state i proportional to the number of systems already in state i. While the mean field theory predicts only decaying oscillations in this system, direct numerical simulations indicate that the mean field exhibits stochastic oscillations even in the limit of large number of oscillators. We characterize the regularity of oscillations by the coherence parameter which has a well-defined maximum at the coupling constant of order 1. In contrast, the order parameter characterizing the level of synchrony among oscillators, increases monotonously with the coupling strength. We derive the exact solution of the full master equation for the stationary probability distribution and find the analytical expression for the order parameter.

RÉGIS FERRIÈRE, ENS Paris

JUN LI, University of Montreal
Description and evaluation of pharmacokinetic processes and therapeutic responses: an interdisciplinary challenge for mathematics

For each patient, the pharmacokinetic profile is a key element to understand the therapeutic response that a dosing regimen is likely to generate. For a long time, the pharmacokinetic process has been empirically assessed by a simple-statistical way. The introduction of Population PK/PD methods aimed to shorten this drawback. However, refinement of sources of variability on drug response has always been the central problem in PK/PD studies. In this talk we try to update some pharmacokinetic principles by reconsidering the PK process within a random context. Moreover, we will discuss how to extend this research to investigate the corresponding therapeutic responses.

This work is in collaboration with Fahima Nekka and Denis Gohore Bi. It is supported by MITACS and NSERC.

ANDRE LONGTIN, Université d'Ottawa, Departement de Physique
Multiscale dynamics of sensory processing

The senses must process a vast amount of environmental information and package it in a form that is accessible to a variety of target neurons. Main challenges for deciphering the principles of this coding and decoding are the presence of multiple scales of time and space and the influence of plasticity. One advantage of working at the sensory periphery is that one has a better intuition as to significance of the signals being processed at each stage, which can guide the analysis. This talk will present dynamical models for select combinations of space and time, inspired from experiments in electrosensory processing (a mix of the senses of touch and hearing). We will show two parallel schemes that enable the animal to simultaneously process high and low frequencies. One relies on "envelope" coding, and the other on synchronous afferent spikes—both nonlinear phenomena. We will also discuss how spatial correlations of stimuli interact with feedback in the sensory pathway to modulate oscillation strength.

ELISABETH PÉCOU, Nice Sophia-Antipolis

HUAIPING ZHU, York

XINGFU ZOU, University of Western Ontario
Dynamics in a modified mathematical model for malaria

The classic malaria model is modified to include the lifecycle of the protozoan parasites within the mosquito vectors. Using some tools/theory from dynamical systems, the new model is analysed and the dynamical behaviors of the model are determined under some conditions.

This is a joint work with Y. Xiao.